Tamilnadu Water Supply and Drainage Board

Hogenakkal Water Supply and Fluorosis Mitigation Project

Package - I

Name of work: Operation and Maintenance of Intake works, Raw Water Pumping Station at Hogenakkal, 160 MLD Water Treatment Plant at Yanaipallam in Bevanur Reserve Forest area, Booster Pumping Station at Kanavai in Bevanur Reserve Forest area, 240 Lakh litre capacity Master Balancing Reservoir at Madam (near Pennagaram), 1500 mm diameter Raw Water and Treated Water Transmission main from Intake at Hogenakkal to Master Balancing Reservoir (MBR) at Madam for providing water supply to Dharmapuri and Krishnagiri Districts through pipeline networks and appurtenances under Packages-II, III, IV & V and SCADA works in Package-I and SCADA interconnectivity work at 74 Locations in Packages-II, III,IV & V and Under Ground Sewerage Scheme (UGSS) to Hogenakkal village with collection System, Pumping station and 0.35 MLD FBBR type STP at Hogenakkal and allied works under Package-I of Hogenakkal Water Supply and Fluorosis Mitigation Project for a period from 01.10.2019 to 31.03.2024

Specifications for Mechanical, Electrical and Instrumentation

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PART C – PLANT MATERIALS & WORKMANSHIP

C1.0 MECHANICAL & ELECTRICAL DESIGN REQUIREMENTS

C1.1 Introduction

This part of the Specification sets out the minimum standards of materials, workmanship and design to be used by the Contractor and reference to any specific material or equipment does not necessarily imply that such material or equipment is included in the Works.

All component parts of the Works shall, unless otherwise specified, comply with the provisions of this Chapter or be subject to the approval of the Engineer.

C1.2 Standard specifications

Except where otherwise specified all materials and workmanship shall comply with the current national standards of the country of manufacture provided that these standards are not less stringent than the equivalent specified British Standards or Codes of Practice or that they comply with the requirements of the International Standards Organisation (ISO) or the International Electrotechnical Commission (IEC) as appropriate.

The Contractor may be asked to make copies of relevant standards available to the Engineer or the Engineer's Representative, together with, if necessary, English translations. He shall provide these as requested for prior assessment and for use during inspection and testing.

Reference is made in this section to the Standards listed below.

ISO 10816-1:1995	Mechanical vibration. Evaluation of machine vibration by measurements on non-rotating parts. General guidelines.
BS EN 352-1:2002	Hearing protectors. Safety requirements and testing. Ear-muffs.
BS EN 681-1:1996	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Vulcanized rubber.
BS EN 681-2:2000	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers.
BS EN 729-1:1995	Quality requirements for welding. Fusion welding of metallic materials. Guidelines for selection and use.
BS EN 971-1:1996	Paints and varnishes. Terms and definitions for coating materials. General terms.
BS EN 1092-1:2002	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges.
BS EN 1515-1:2000	Flanges and their joints. Bolting. Selection of bolting.
BS EN 1561:1997	Founding. Grey cast irons.
BS EN 1563:1997	Founding. Spheroidal graphite cast iron.
BS EN 1982:1999	Copper and copper alloys. Ingots and castings.
BS EN 10029:1991	Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above.

BS EN 10051:1992	Specification for continuously hot-rolled uncoated plate, sheet and strip of non-alloy and alloy steels. Tolerances on dimensions and shape.
BS EN 10297-1:2003	Seamless circular steel tubes for mechanical and general engineering purposes. Technical delivery conditions. Non-alloy and alloy steel tubes.
BS EN 12540:2000	Corrosion protection of metals. Electro deposited coatings of nickel, nickel plus chromium, copper plus nickel and copper plus nickel plus chromium.
BS 1486	Lubricating nipples.
BS 1710:1984	Specification for identification of pipelines and services.
BS 3100:1991	Specification for steel castings for general engineering purposes.
BS 3643-1&2:1981	ISO metric screw threads.
BS 3692:2001	ISO metric precision hexagon bolts, screws and nuts. Specification.
BS 4190:2001	ISO metric black hexagon bolts, screws and nuts. Specification.
BS 4395-1&2:1969	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering.
BS 4800:1989	Schedule of paint colours for building purposes.
BS 4871-3:1985	Specification for approval testing of welders working to approved welding procedures. Arc welding of tube to tube-plate joints in metallic materials.
BS 4872-1:1982	Specification for approval testing of welders when welding procedure approval is not required. Fusion welding of steel.
BS 4872-2:1976	Specification for approval testing of welders when welding procedure approval is not required. TIG or MIG welding of aluminium and its alloys.
BS 4921:1988	Specification for sherardized coatings on iron or steel.
BS 4933:1973	Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts.
BS 5252:1976	Framework for colour co-ordination for building purposes.
BS 5493:1977	Code of practice for protective coating of iron and steel structures against corrosion.
BS 5499-5:2002	Graphical symbols and signs. Safety signs, including fire safety signs. Signs with specific safety meanings.
BS 7079	Preparation of steel substrates before application of paints and related products. All parts thereof.
BS 7668:1994	Specification for weldable structural steels. Hot finished structural hollow sections in weather resistant steels.

C1.3 Plant design and life

The Works as a whole shall be new, of sound workmanship and robustly designed for a long, reliable operating life and shall be capable of continuous operation for prolonged periods in the climatic and working conditions prevailing at the Site, with the minimum of maintenance. The design shall take account of temperature changes, the stability of paint finish for high temperatures, the rating of engines, electrical machinery, thermal-overload services, cooling systems and the choice of lubricants for possible high and prolonged operating temperatures. The Contractor shall be called upon to demonstrate this for any component part, either by service records or evidence of similar equipment already installed elsewhere or relevant type tests.

The Plant shall be designed to provide protection against damage by the entry of vermin and dust, and to minimise fire risk and consequent fire damage. It shall be protected against damage due to dampness and condensation. Plant shall operate without undue vibration, and parts shall be designed to withstand the maximum stresses under the most severe conditions of service. Materials shall have a high resistance to change in their properties due to the passage of time or any cause which may have a detrimental effect upon the performance or life of the Works.

All manually-controlled Plant located outside a building shall be tamperproof. This is in addition to any requirements of the Specification for securing Plant under operational conditions.

All component parts of the Plant shall be manufactured to be interchangeable with the component parts of similar Plant.

The Plant shall be designed to have a high resistance to change in its operating characteristics due to passage of time or any other which may affect the performance or life of the Works. The Contractor may be called upon to demonstrate this for any component part either by service records of similar equipment, or by the records of extensive type tests.

Materials shall be selected taking into consideration their location and duty. For Plant in contact with water, the risk of electrolytic reaction between differing materials of construction and to the effects of corrosion and erosion shall be taken into account.

The plant shall be designed to provide easy access for replacement of component parts which are subject to wear, without the need to replace whole units. Except for consumable items requiring frequent replacement, no part subject to wear shall have a life from new to replacement or repair of less than five years. Where major dismantling is unavoidable to replace a part, the life shall not be less than ten years.

C1.4 Substances and products

Substances and products used in the Works which may be in contact with water which is to be supplied for drinking, washing or cooking shall not contain any matter which could impart taste, odour, colour or toxicity to the water or otherwise be objectionable on health grounds.

All substances and products so used shall meet the requirements of Regulation 25 of the Water Supply (Water Quality) Regulations 1989 or the Water Supply (Water Quality) (Scotland) Regulations 1990 or other equivalent body as applicable.

C1.5 Workmanship

Workmanship and the general finish of plant installations shall be of first-class commercial quality and in accordance with the best workshop practice, and shall be performed by persons skilled in their respective trades.

Pipework, fittings, cables, cable trays and the like shall be fitted in a neat, straight and symmetrical manner so as to present a pleasing appearance.

Indicating gauges fitted to machine assemblies or control panels shall generally be of similar style and grouped together.

External welds and flame cuts shall be finished smoothly by grinding.

Chequer plate coverings shall be fixed squarely in their frames with their patterns properly aligned. Handrailings shall be free from burrs.

C1.6 Welding

Where welds may be highly stressed, the Contractor shall supply to the Engineer before welding starts detailed drawings of all weld preparations and procedures proposed. No welding shall be carried out before the Engineer has approved the procedures. No alteration shall be made to any previously-approved procedures without prior approval of the Engineer. Welders shall be qualified in accordance with the requirements of the appropriate section of BS 4871-3:1985, BS 4872-1:1982 and BS 4872-2:1976.

C1.7 Castings

The structure of castings shall be homogeneous and free from non-metallic inclusions and other defects. Surfaces of castings which are not machined shall be carefully fettled to remove all foundry irregularities.

Minor defects which do not exceed 10mm in depth or 10% of the total metal thickness (whichever is less) and which will not ultimately affect the strength and serviceability of the casting may be repaired by approved welding techniques. The Engineer shall be notified of larger defects and no repair welding of such defects shall be done without his prior approval.

If the removal of metal for repair should reduce the stress-resisting cross-section of the casting by more than 25%, or to such an extent that the computed stress in the remaining metal exceeds the allowable stress by more than 25%, then the casting will be rejected.

Castings repaired by welding for major defects shall be stress-relieved after such welding, or as otherwise instructed by the Engineer.

Non-destructive tests may be required for any casting containing defects whose effect cannot otherwise be established, or to determine that repair welds have been properly made.

Unless otherwise specified, castings shall be produced to the following standards or equal:

• grey-iron	BS EN 1561:1997	Grade 220
• carbon steel	BS 3100:1991	Steel alloy
• stainless steel	BS 3100:1991	Steel 316C16
• copper & copper alloy	BS EN 1982:1999	Group A grade LG2 Group B grade CT1, AB2 Group C grade G1

C1.8 Forgings

Major stress-bearing forgings shall be made to a standard specification which shall be submitted to the Engineer for approval before work begins. They shall be subject to internal examination and non-destructive tests for the detection of flaws and shall be heat-treated for the relief of residual stress. The name of the maker and particulars of the heat treatment proposed for each major forging shall be submitted to the Engineer.

C1.9 Non-metallic materials

The use of organic materials shall be avoided as far as possible but where these have to be used they shall be treated to make them fire resistant and non-flame propagating.

Fabrics, cork, paper and similar materials which are not subsequently to be protected by impregnation, shall be treated with a fungicide. Sleeving and fabrics treated with linseed oil varnish are not acceptable.

The use of wood shall be avoided as far as possible. If used, woodwork shall be thoroughly seasoned teak or similar hardwood which is resistant to fungal decay and other blemishes. All woodwork shall be treated to protect it against damage by any cause. All joints in woodwork shall be dovetailed or tongued and pinned. Metal fittings on wood shall be non-ferrous. Adhesives shall be impervious to moisture and fungus growth. Only synthetic resin cement shall be used for joining wood.

C1.10 Nuts, bolts, studs and washers

Nuts and bolts for pressure fittings shall be of high-quality steel, machined on the shank and under the head and nut. Bolts shall be dimensioned, so that, only one to three threads shall show through the nut when in the fully-tightened condition.

Fitted bolts shall be a light driving fit in the reamed holes they occupy. These shall have the screwed portion of a diameter that will not be damaged in driving and shall be marked in a conspicuous position to ensure correct assembly at site.

Washers, locking devices and anti-vibration fittings shall be provided where necessary to ensure that no bending stress is caused in the bolt.

When there is a risk of corrosion, bolts and studs shall be designed so that the maximum stress in the bolt does not exceed half the yield stress of the material.

All bolts, nuts and screws which are subject to frequent adjustment or removal in the course of maintenance and repair shall be made of nickel-bearing stainless steel or brass.

Bolts, nuts, screws and washers which may be submerged in a corrosive liquid shall be stainless steel.

The Contractor shall supply all holding-down, alignment and levelling bolts complete with anchorages, nuts, washers and packings required to attach the Plant to its foundation. The Contractor shall also supply all bedplates, frames and other structural parts necessary to spread the loads transmitted by the Plant to concrete foundations without exceeding the design stresses.

Isometric black hexagonal bolts, nuts and screws shall comply with BS 4190:2001 strength grade 4.6.

Isometric precision hexagonal bolts, nuts and screws shall comply with BS 3692:2001 strength grade 8.8.

High-strength friction-grip bolts, nuts and washers shall comply with BS 4395-1&2:1969.

Black cup and countersunk head bolts and screws with nuts shall comply with BS 4933:1973.

Stainless steel nuts, screws, washers and bolts shall be manufactured from Grade 316S31 steel complying with BS 10250-4:2000 or BS 1515-1:2000.

Bolting for pipes and fittings shall comply with the relevant provisions of BS EN 1515-1:2000 except that spheroidal graphite iron bolts for use with ductile iron pipes and fittings shall be manufactured from metal complying with the provisions of BS EN 1563:1997 for grade 500/7.

C1.11 Threads

All threads shall be of preferred metric sizes with the standard coarse form of medium fit to BS 3643-1&2:1982 except for special applications, for which the metric fine thread or other thread forms may be utilised, subject to the approval of the Engineer.

C1.12 Guards for moving parts

All moving parts shall be protected by safety guards.

Guards shall be rigid, securely fixed and designed to allow normal operation, running maintenance and routine inspection on equipment without the need to remove the guard. Where this is impractical, guards shall be designed for easy fixing, dismantling and re-assembly.

C1.13 Safeguarding of plant

The Contractor shall ensure that the whole of the Works as installed is safe for use by the operating and maintenance staff, and by any other persons having access thereto. Guards, electrical safety devices, thermal insulation, noise-suppression devices, written notices, safety colours and the like shall be provided where necessary during erection and permanently.

Plant layout shall provide easy and safe access to all operating devices, free from hazardous obstructions.

Nothing in this Specification shall remove the Contractor's obligation from drawing the attention of the Engineer to any feature of the Works which is not consistent with safety, or prevent him making proposals for incorporating equipment or designs which would increase the safety of the Plant.

C1.14 Rating plates, name plates and labels

The Contractor shall ensure that each main and auxiliary item of Plant and equipment shall have permanently attached to it in a conspicuous position a nameplate and rating plate. Upon these shall be engraved the manufacturer's name, type and serial number of plant, details of the loading and duty at which the item of Plant has been designed to operate, and such diagrams as are deemed necessary. All indicating and operating devices shall have securely attached to them or marked upon them designations of their function and proper use. Provision shall be made to incorporate descriptive numbering codes as indicated on the layout drawings.

All valves shall have an identification plate bearing the valve number and a short description of valve function.

On major items of plant and valves, details of proposed plates, labels and inscriptions shall be provided by the Contractor for approval by the Engineer.

Nameplates, rating plates and labels shall be of a non-flame-propagating material, either non-hygroscopic or transparent plastic, with engraved lettering of a contrasting colour. Fixing shall be by means of non-corrodible screws.

Warning labels shall be provided where necessary to warn of dangerous circumstances or substances. Inscriptions or graphic symbols shall be black on a yellow background and to internationally recognised standards.

Instruction labels shall be provided where safety procedures (such as the wearing of protective clothing) are essential to protect personnel from hazardous or potentially-hazardous conditions. These labels shall have inscriptions or graphic symbols in white on a blue background.

C1.15 Lubrication

(a) General:

Plant shall be lubricated, as necessary to ensure smooth operation, heat removal and freedom from undue wear. Lubricated items shall be designed so that they do not require more than weekly lubrication, unless otherwise approved by the Engineer.

All grease nipples, oil cups and dip sticks shall be readily accessible, being piped where necessary to a convenient position.

The Contractor shall supply the first fill of oil and grease for Plant and maintenance equipment. The Contractor shall also provide the Employer with enough consumables for all equipment for two months of normal operation from the date of the Taking-Over Certificate.

A complete schedule of recommended oils and other lubricants shall be provided by the Contractor as part of the operating and maintenance manuals. The number of different types of lubricants shall be kept to a minimum. For grease-lubricated ball and roller bearings, a lithium-based grease is preferred.

(b) Oil lubrication:

Gear boxes and oil baths shall be provided with adequately filling and draining plugs and oil level indication.

Roller chain drives shall have oil-bath lubrication.

Drain points shall be positioned so that an adequately sized container can be placed beneath them. Where a large quantity of oil is involved or drainage to a container difficult, a drain valve and plug shall be provided at the point of discharge.

Bearings equipped with forced-feed oil lubrication shall be automatically charged prior to machinery starting up, and pressure monitored during operation with automatic shutdown of machinery and alarm on low oil pressure.

All points where oil leakage may occur shall be suitably trapped to prevent oil contamination of water. Oil filling and drain points shall be arranged to avoid the risk of contamination of water by accidental spillage.

Access, without the use of portable ladders, to lubrication systems shall permit maintenance, draining and re-filling, without contamination of the charged lubricant.

The design of breathers shall take into account the conditions at the vent point, and include measures to prevent contamination of the lubricant.

(c) Grease lubrication:

Grease application shall be by steel lubrication nipples manufactured in accordance with BS 1486.

Anti-friction bearings requiring infrequent charging shall be fitted with hydraulic type nipples.

Plain bearings requiring frequent charging shall be fitted with button-head pattern nipples.

A separate nipple shall be provided to serve each lubrication point. Where a number of nipples supply remote lubricating points they shall be grouped together on a conveniently placed battery plate, with spacing in accordance with the recommendations of BS 1486-1:1959, Tables 9 and 10.

The Contractor shall provide a grease gun for each size and type of nipple installed. Where different types of grease are involved, separate grease guns shall be provided for each type. They shall be suitably labelled and, if possible, be of different styles to prevent incorrect greasing.

C1.16 Gaskets and joint rings

Joint rings shall be manufactured to conform to BS EN 681-1:1996 and BS EN 681-2:2000. They shall be of chloroprene rubber or other approved synthetic material suitable for temperatures up to 80°C or greater, to suit the application.

Joints shall be made in accordance with manufacturer’s instructions or as specified herein.

Each rubber ring or gasket shall be stored in the dark, free from the deleterious effects of heat or cold, and kept flat so as to prevent any part of the rubber being in tension.

Only lubricants recommended by the manufacturer shall be used for rubber rings and these lubricants shall not contain any constituent soluble in the fluid conveyed. They shall be suitable for the climatic conditions at the Site and shall contain an approved bactericide.

Graphite grease or similar shall be applied to the threads of bolts before joints are made.

C1.17 Electroplating, galvanising and sherardizing

Parts to be galvanised, other than nuts, bolts and fasteners, shall be hot-dip galvanised to BS EN 729-1:1995, and associated parts thereof, to give a minimum average coating of 610g/m² of area covered and a zinc thickness of not less than 85 microns.

Where specified, nuts, bolts and fasteners to be galvanised shall be hot-dip galvanised to BS EN 729-1:1995 to give a minimum average coating of 305g/m² and a zinc thickness of not less than 43 microns. Where hot-dip galvanising is not practicable, nuts, bolts and fasteners shall be sherardized. Sherardizing shall be in accordance with BS 4921:1988, the thickness of zinc coating shall be not less than 30 microns.

Where chromium plating is used, it shall comply with the requirements of BS EN 12540:2000 including the following provisions:

- no blistering of any surfaces will be accepted;
- where the base metal is steel, plating shall be applied in accordance with Table 2;
- for all base metals, the service condition number 2 shall be used.

C1.18 Noise

Except as provided for below, the noise emitted by any single item of Plant shall not exceed a sound pressure level of 85dB(A) when measured at a distance of 1m from the reference surface of that item in any direction and under the environmental conditions appropriate to the test requirements of ISO 3746 ‘Acoustic determination of sound power levels of noise services - survey methods’ or the equivalent ANSI S12 36 - 1990 (R1997).

The Contractor shall be responsible for all noise tests on site. Sound pressure levels shall be measured in dB(A) using a calibrated sound meter with its response speed set to ‘slow’.

For major items of Plant, the Contractor shall provide certificates from the manufacturer covering noise-level tests on the items or type test certificates for similar items of Plant.

If any item of Plant does not comply with the above requirement, the Contractor shall reduce the sound pressure level by providing improved or additional silencers or fitting sound-insulating materials until the requirement is met.

Plant such as compressors, diesel generators, gas turbines, blowers and the like, where reduction in noise to below 85dB(A) at 1m is impractical, will be installed in separate rooms constructed in or containing sound-absorbing material, generally as shown in the drawings. The noise level shall not exceed 75dB(A) when measured 1m from the outside of the room or structure. The Contractor shall provide hazard warning notices at the entrance to the room indicating that ear defenders must be worn. The Contractor shall provide a minimum of three pairs of ear defenders to BS EN 352-1:2002 which shall be stored in a dust-proof locker.

Diesel-engine exhausts shall incorporate acoustic splitter-type louvres to reduce noise level to below 80dB(A) at 1m distance.

The background noise level at any point along the boundary of the site, arising from operation of plant shall not exceed 65dB(A).

No item shall have a sound level exceeding 85dB(A) at 1m distance unless that item and its actual sound pressure level is included in the Schedules of leading particulars, which form part of the Contract and is approved.

C1.19 Vibration

All rotating elements shall be dynamically balanced so that the level of vibration at any point on any Plant item when operating at Site, either singly or with other Plant, and at any speed throughout the operating range, shall be within the limits of Class IV, grade B, as defined in ISO 10816-1:1995.

Pipework, valves and other connected equipment, or forming part of the operating system, shall be provided with adequate supports, brackets and fixtures, as necessary, to restrict any induced vibration to a minimum, under any operating condition.

Vibration measurements shall be taken on site by the Contractor at various points on each complete machine as defined above.

Measurements shall also be taken on connecting plant. If any item is found to be vibrating beyond the level considered by the Engineer to be a reasonable minimum, the Contractor shall reduce the vibrations to the required level.

C1.20 Access steelwork

The Contractor shall provide adequate access to all Plant items to which access is necessary for routine maintenance and operation.

The principal ladders, platforms, covers and handrails to be supplied and fixed under this Contract are shown in the drawings.

Any small areas of chequer plating or other covering needed to cover gaps between items of Plant and the surrounding structure, and any access ladders, platforms and handrails that must be attached to items of Plant to facilitate operation, inspection or maintenance, shall be supplied and erected by the Contractor.

Handrails shall consist of double ball forged steel standards with tubular rails, hot-dip galvanised in accordance with BS EN 729-1:1995.

Chequer plating shall be of 'Durbar' or other non-lip pattern, not less than 4.5mm thick (exclusive of pattern) and hot-dip galvanised after fabrication in accordance with BS EN 729-1:1995.

Diamond type pattern chequer plate shall not be used. Open-type or solid-type chequer plate flooring shall be used as appropriate for the location, taking into account ease of cleaning, precautions against slipping and areas below walkways.

C1.21 Handrailing

Handrailing shall be double rail 1100mm high and 900mm high on stairs measured vertically from the nose of the tread.

Standards shall be 38mm diameter solid forged steel to BS 7668:1994 and BS EN 10029:1991 Grade 43A with 60mm diameter solid forged steel balls at handrail locating points drilled to give 1.5mm clearance to handrails. Each ball shall incorporate a concealed grub-screw with Allen-type head to secure the rail. Standards shall have a minimum base width of 65mm, drilled for M16 fixing bolts and be set at maximum 1800mm centres.

Handrails shall be 33.7mm OD × 3.2mm thick tubular steel to BS EN 10297-1:2003. Joints shall be arranged to coincide with the spacing of standards where possible, otherwise they shall have butt joints with a tubular steel ferrule, plug welded or fixed with a 5mm diameter countersunk head pin.

Removable sections of handrail shall have half-lap joints secured with a countersunk head pin.

Chains across openings shall be 10mm × 3 links per 100mm galvanised mild steel. The hooks and retaining eyes shall be securely fixed to the balls of the standards.

All components for handrailing shall be hot-dip galvanised after manufacture in accordance with BS 729-1:1995.

C1.22 Machinery, lifting and dismantling

Machinery bedplate design, packing and fixing shall minimise distortion and vibration. Aligned machinery shall be mounted on either bed or sole plates, permitting removal and reinstatement without a requirement to re-grout. Bedplates shall incorporate fine adjustment of the vertical and horizontal alignment between driver and driven Plant.

All machinery shall be fitted with lifting facilities. Large structures shall be provided with jacking points.

For Plant subject to frequent dismantling, tapped holes or other provision shall be made in all main castings, for the insertion of jacking screws or the fixing of drawing gear. Bolts or studs shall be used in preference to set screws.

C1.23 Seals

(a) General

The Contractor shall select a seal, compatible with his Plant and best suited for the worst conditions likely to be met when the Plant is in operation.

All seal materials shall be compatible with the fluid (including gases) being handled. For potable water, seal materials shall be subject to approval.

(b) Soft-packed glands

Shafts shall be provided with renewable gland sleeves. Glands subject to abrasive liquids or negative pressures shall include lantern rings and a clean water continuous flushing system.

Gland adjustment nuts shall be readily accessible.

Gland drain pipework, shall be provided, discharging to the nearest sump or drainage channel.

(c) Mechanical seals

Mechanical seals which are subject to abrasive or corrosive fluids (including gases) or negative pressures shall be provided with a clean water gland flushing system. A back-to-back sealing arrangement with a flushing/cooling system will be accepted as satisfying the requirements of this clause.

C1.24 Bearings

The Contractor shall select the most appropriate type of bearing for the Plant being supplied.

Single journal plain bearings shall be phosphor bronze or synthetic lubrication impregnated bushes with carbon or stainless steel journals respectively. Synthetic bearings shall be used only where bearing condition can be inspected readily.

Plain-type bearings shall be self-lubricating either by grease, forced oil or impregnation.

Ball and roller type bearings shall be adequately lubricated by oil or grease and sealed to prevent leakage of lubricant along the shaft. The dismantling of bearings shall be simple and free from risk of damage.

Bearings fitted to gearboxes shall have a minimum design life of 100 000 hours at maximum loading.

C1.25 Gearboxes

Gearboxes shall have a life of 100 000 hours, be selected in accordance with American Gearbox Manufacturers' Association recommendation for horsepower and service factor application. They shall employ a standard reduction ratio.

Gearboxes which have to be angle-mounted shall have a rating, choice of bearings, seals and lubrication system designed for such mounting.

Dependence on splash lubrication alone is not acceptable but it may be used in conjunction with a forced-feed method to reach all bearings and gears.

C1.26 Safety signs

All signs providing health and safety information or instructions shall comply with BS 5499-5:2002 and equivalent local standards.

Signs shall be of durable quality and shall comprise a substrate of 22 gauge aluminium, pre-drilled for fixing and with radiused corners free of burrs or sharp edges. Symbols and lettering shall be screen printed.

C1.27 Corrosion and erosion

Unless otherwise specified, the Contractor shall make proper provision for the prevention of corrosion and erosion in any part of the Plant. Provision shall include the use of suitable materials, choice of operating speeds, design of components and type of protective coatings and finishes.

C1.28 Precautions against damp

Special precautions shall be taken to prevent corrosion due to humidity, rainfall and moisture.

All wall-mounted equipment shall be fitted with spacers to provide a minimum gap of 5mm. All holes in equipment shall be effectively sealed against the ingress of water. All items exposed to the weather or water shall be free of water traps; where necessary, drain holes shall be provided to prevent the accumulation of water.

All fixings, fastenings and spacers which may be submerged in a corrosive liquid shall be galvanised or sherardized, unless otherwise specified.

All electrical equipment which is not sealed against free movement of air shall be protected from condensation with anti-condensation heaters. In general, heaters shall be thermostatically-controlled and switched off when enough heat is generated by operation of the Plant.

C2.0 PAINTING AND PROTECTION

C2.1 Scope

Protective coatings shall comply with BS 5493:1977 'Code of practice for the protective coating of iron and steel against corrosion' except as otherwise specified. For coatings designed to BS 5493:1977 exterior conditions shall be assumed to be 'polluted inland' conditions and the interiors of buildings shall be assumed to be 'frequently damp or wet' except for control rooms. The thickness of coatings stated in this section of the specification is the minimum allowable thickness as defined in Clause 19 of BS 5493:1977. Where the paints that are available do not provide dry-film thickness as specified, additional coatings shall be applied. Protective coatings for surfaces of tanks and other plant in contact with chemicals or otherwise in conditions not foreseen in this section of the specification or in BS 5493:1977 shall be suitable for those conditions. They shall be the subject of design submissions supported by evidence proving satisfactory experience of the proposals elsewhere.

Where dissimilar metals are in contact, the Contractor shall provide insulation to prevent electrochemical corrosion.

C2.2 General

The protective coating system shall have a minimum 10-year life to first maintenance. A five-year minimum performance warranty shall be given in respect of the paint as applied.

All coatings applied to any part of the plant in contact with water to be used for drinking, washing or cooking shall be non-toxic, non-carcinogenic, shall not impart taste, odour, colour or turbidity to the water or foster microbial growth and shall be approved in the same manner as substances and products in clause C1.4.

No manufacturer's name-plate identification, vented filler plugs in gearboxes or grease nipples shall be painted over.

To avoid the possibility of the presence of carcinogenic poly-aromatic hydrocarbons all bituminous paints and coatings shall be manufactured from petroleum or asphaltic bitumen and not from coal tar bitumen.

Lead based paints shall not be used.

All machined, polished or bright surfaces shall be given suitable protection against corrosion, damage and deterioration.

The Contractor shall ensure that, before despatch from the manufacturer's works and after completion of erection, all plant has received suitable preparation followed by the protection system listed in tables A and B attached.

The Contractor shall liaise closely with the plant manufacturer who shall provide full facilities for him to inspect and check the preparation and painting during all stages. The Contractor shall report on his inspections to the Engineer.

All paint materials shall be stored and applied strictly in accordance with manufacturers' instructions.

Paint shall not be applied under adverse conditions. Air temperatures shall be above 5°C and relative humidity less than 55% or as otherwise specified by the paint manufacturer.

The Contractor shall ensure that, for the materials specified, application conditions are in accordance with the specification and manufacturer's instructions. Paint shall be applied only to surfaces that have been cleaned and prepared in accordance with these instructions.

Where local climatic conditions make the specified requirements difficult to achieve, the Contractor shall provide temporary protection during painting.

The dry paint-film thickness shall be measured by Elcometer or other approved method.

Galvanising shall comply with Clause C1.17. All manufacturing processes shall be complete prior to galvanising with all erection markings clearly legible afterwards. Surfaces shall be adequately degreased before the application of any coating, pre-treated with a brush application of etch primer or T wash.

Steel subject to hydrogen embrittlement through galvanising shall not be used.

All iron and steelwork to be painted shall be blast cleaned to all parts of BS 7079 Second Quality to achieve a surface profile with a minimum amplitude of 0.025mm and a maximum of 0.100mm.

Following blast cleaning, steel surfaces shall bezinc metal sprayed where specified.

Aluminium structures and fittings shall need not be painted.

C2.3 Coating systems

Tables A and B identify the coating systems to be used and minimum coating thicknesses.

C2.4 Fusion-bonded epoxy powder coatings

All fabricated steel pipework and other Plant where specified, shall have a lining and coating, not less than 250 microns thick, of 100% solids, thermosetting fusion-bonded, dry power epoxy coating.

All grit and dust shall be removed and coating shall be started before formation of visible oxidation of the surface. The metal shall be pre-heated to a temperature recommended by the manufacturer and the epoxy powder applied by immersion in a fluidised bed, after which excess powder shall be removed. The powder shall be allowed to flow out completely before curing.

The thickness of the coating, including any repaired areas, shall be checked with a calibrated tester. Spark testing, for pinholes, voids, contamination, cracks and damaged areas, shall use a high-voltage spark generator.

Repairs due to coating imperfections or damage shall be done using a brush-applied compatible two-pack liquid epoxy compound.

The area to be repaired shall be cleaned to remove dirt, grease, scale and damaged coating, which shall be feathered. Pinhole surface preparation is not required other than removal of detrimental contaminants which could impair the adhesion of the repair material.

The surface coating shall be applied by an approved applicator.

GRP covers and guards shall be pigmented to give the finished colour without painting.

C2.5 Coating system for electrical enclosures

Enclosures shall be given protective coating at the place of manufacture and before installation of any electrical fittings.

Electrical panels, including switchboards, control panels and instrument panels, installed within buildings shall be prepared as follows:-

(i) Thoroughly clean surfaces to remove rust, scale, dirt, loose paint and the like and degrease by the use of solvents which are compatible with the paint finish to be applied. If rust-proof steel has not been used in the construction, the surfaces shall be treated with a passivating agent such as phosphoric acid.
(ii) Internal surfaces shall have a minimum of three coats of paint of which the first shall be an approved priming coat. The final coat shall be an opaque gloss white enamel.
(iii) External surfaces shall have a minimum of five coats of paint of which the first shall be an approved priming coat, the second and third a suitable undercoat, all of which shall be rubbed smooth when dry before application of the next coat. The colour of undercoat paints shall be different from priming and finishing coats.
(iv) The final coats shall be of stove enamel paint to a finish and colour as specified in Table C. The dry-film thickness shall be not less than 100 microns.

Electrical panels which are to be installed in exposed positions or in damp conditions shall receive a surface preparation containing zinc prior to application of the primer undercoat and finishing coats.

A 500 ml tin of matching touch-up paint shall be supplied with each panel.

C2.6 Defects

Defects are defined in BS EN 971-1:1996 ‘Glossary of paint terms’.

The Contractor shall ensure that all coatings are free from defects and adequate in all respects for the purpose intended.

The painting system shall be deemed to have failed if:-

(a) after painting, damage has been caused by handling, impact, abrasion or welding;
(b) any portion of the paint film separates from any other or the parent metal;
(c) after painting the total dry-film thickness is less than that specified.

Failure shall not include:-

(a) loss of gloss;
(b) variation of shade, not affecting the anti-corrosive properties of the system.

C2.7 Colour coding

Unless otherwise specified, colour coding for plant, equipment and pipework shall be as given in tables C to H. Steel pipes shall be painted and hoses and thermoplastic pipes shall be colour banded in accordance with BS1710. When using colour bands on thermoplastic pipes the Contractor shall ensure that the adhesives used on colour bands do not contain agents which will cause deterioration of the pipes. Colour bands shall be applied on straight lengths of pipes at no more than 3m spacing. Bands shall be applied, at all junctions, both sides of valves, Plant, fittings and wall penetrations.

Finishing coats shall be applied as specified in the colour schedule in accordance with the requirements of BS 1710:1984, BS 4800:1989, BS 5252:1976 and BS 5499-5:2002.

Pipeline contents shall be identified by name and the direction of flow by arrows.

Where two or more pipes in a duct or gallery convey the same fluids, each pipe shall display a separate number, with contents named at each point of entry or outlet.

Table A: Required coating systems and minimum coating thicknesses for plant and equipment

	Applied prior to delivery and erection					**Applied following installation**
	Substrate	**Pre-treatment**	**First coat**	**Second coat**	**Third coat**	**Finishing coat**
ABOVE WATER LEVEL: Machinery & steelwork not in contact with sewage, sludge or water to be used for drinking, washing or cooking	Steel (galvanised)	Etch prime or T wash	Zinc phosphate CR alkyd primer undercoat (0.050mm)	High-build chlorinated rubber paint (0.075mm)		High-build chlorinated rubber paint (0.075mm)
	Steel zinc sprayed (0.070mm)	Etch prime				
	Steel, cast iron, ductile iron	Blast clean BS 7079 2nd quality	Zinc phosphate CR alkyd blast primer (0.050mm)	Zinc phosphate CR alkyd primer (0.050mm)	High-build chlorinated rubber (0.075mm)	
BELOW WATER LEVEL: Machinery and steelwork in contact with water to be used for drinking, washing or cooking	Steel (galvanised)	Etch prime or T wash	Epoxy primer high-build (0.125mm)	Epoxy high-build (0.050mm)	Epoxy high-build (0.075mm)	
	Steel, cast iron, ductile iron, zinc sprayed (0.070mm)	Etch prime				
Pipework	Steel	As specified elsewhere				
Switchboard shells, frames and backplates	Steel	As specified elsewhere				

TABLE B: REQUIRED HEAT-RESISTANT COATING SYSTEMS FOR STEELWORK

<table>
<tr><th>Working temperature</th><th>A1: Surface treatment</th><th>First coat</th><th>Second coat</th><th>Third coat</th></tr>
<tr><td rowspan="2">50°C to 175°C</td><td rowspan="2">Blast clean BS 7079 second quality</td><td>Polyvinyl Butyral (0.025mm)</td><td rowspan="2">Aluminium heat-resistant @ 200°C (0.025mm)</td><td rowspan="2">Aluminium heat-resistant @ 200°C (0.025mm)</td></tr>
<tr><td>Zinc chromate primer (0.012mm–0.015mm)</td></tr>
<tr><td rowspan="2">175°C to 500°C</td><td>Blast clean BS 7079 second quality</td><td>Aluminium pigmented silicone heat-resistant (0.025mm)</td><td>Aluminium pigmented silicone heat-resistant (0.025mm)</td><td></td></tr>
<tr><td colspan="4">NB A minimum temperature of 350°C within a short time after application is required</td></tr>
</table>

TABLE C: COLOUR CODING FOR PLANT AND EQUIPMENT

<table>
<tr><th colspan="2" rowspan="2">Equipment</th><th colspan="2">Colour finish</th><th rowspan="2">BS 4800

shade number</th></tr>
<tr><th>Drinking water</th><th>Waste water</th></tr>
<tr><td rowspan="11">Above water level:

Machinery and steelwork not in contact with sewage, sludge or potable water or specified as requiring identification as table D below</td><td rowspan="2">Pumps and machinery</td><td>Green</td><td>—</td><td>12–D–45</td></tr>
<tr><td>—</td><td>Saxe blue</td><td>18–C–39</td></tr>
<tr><td>Dry-well motors</td><td>Tangerine</td><td>Tangerine</td><td>06–E–51</td></tr>
<tr><td>Guards</td><td>Flame</td><td>Flame</td><td>04–E–53</td></tr>
<tr><td>Gearboxes</td><td>Saxe Blue</td><td>Saxe blue</td><td>18–C–39</td></tr>
<tr><td>Compressors & blowers</td><td>Blue</td><td>Blue</td><td>24–E–51</td></tr>
<tr><td>Lifting gantries</td><td>Gorse</td><td>Gorse</td><td>08–E–51</td></tr>
<tr><td rowspan="2">Valves & pipework above FFL</td><td>Green</td><td>—</td><td>12–D–45</td></tr>
<tr><td>—</td><td>Pale grey</td><td>00–A–05</td></tr>
<tr><td>Pipework below FFL</td><td>Black</td><td>Black</td><td>00–E–53</td></tr>
<tr style="display:none"></tr>
<tr><td colspan="2">Below water level: Machinery and steelwork (including pumps, penstocks, pipework and the like)</td><td>Black</td><td>Black</td><td>00–E–53</td></tr>
<tr><td colspan="2">Switchboard shells</td><td>Light grey semi-gloss</td><td>Light grey semi-gloss</td><td>18–B–17</td></tr>
<tr><td colspan="2">Switchboard supporting frames</td><td>Black semi-gloss</td><td>Black semi-gloss</td><td>00–E–53</td></tr>
</table>

Switchboard internal equipment mounting plates	White semi-gloss	White semi-gloss	00–E–55
Control and instrument panels - external	Light grey semi-gloss	Light grey semi-gloss	18–B–17
Control and instrument panels - internal	White gloss	White gloss	00–E–55
GRP covers (pigmented)	Spruce	Spruce	14–C–39

TABLE D: IDENTIFICATION COLOURS FOR PIPES
All pipes are to be identified in accordance with BS 1710

	Basic identification colour	**BS 4800 shade no.**	**Colour code indication**	**BS 4800 shade no.**
Drinking water	Green	12–D–45	Auxiliary blue	18–E–53
Steam	Silver grey	10–A–03	—	—
Mineral, vegetable and animal oils combustible liquids	Brown	06–C–39	Green	14–E–53
Diesel fuel	Brown	06–C–39	White	00–E–55
Gases in either gaseous or liquid defined condition (except air)	Yellow ochre	08–C–35	Refer to Tables E to J	
Acid and alkalis	Violet	22–C–37	Refer to Tables E to J	
Air	Blue	20–E–51	—	—
Other liquids	Black	00–E–53	Refer to Tables E to J	
Electrical services such as conduits & trunkings	Tangerine	06–E–51	—	—

TABLE E: IDENTIFICATION COLOURS FOR PIPES - CHLORINE

Steel pipework carrying chlorine shall be painted in the following colours to BS 381C:

Chlorine pipework : golden yellow, no. 356

uPVC pipework carrying chlorine or sulphur dioxide gas or solution shall be banded with vinyl laminated identification tape to enable individual lines to be identified throughout their length. The banding shall conform to BS 1710 to indicate the fluid conveyed and shall have flow direction arrows, lettering and codings as described below:

(a) Lettering

Duty	Lettering	Colour	Height
Gas	"CHLORINE" or	Black	5mm
Solution	"Cl_2" or "SO_2"	White	10mm
Motive Water	Not applicable	-	-
Waste Water	"DRAIN"	White	5mm
Relief Vent	"VENT"	Black	5mm

(b) Banding

Duty	Coded Bands
Gas	yellow ochre - danger marker - yellow ochre
Solution	violet - danger marker - violet
Motive Water	green - blue - green
Waste Water	black
Relief vent	yellow ochre - danger marker - yellow ochre

Individual bands shall be 50 mm wide. Bands for gas and solution lines shall incorporate danger warning markers (black/yellow diagonal stripes) 50 mm wide giving a composite width of 150 mm.

Colours stated above refer to BS 4800 shades as follows:

Colour	Code
Yellow ochre	08 C 35
Violet	22 C 37
Green	12 D 45
Blue (auxiliary)	18 E 53
Yellow	08 E 51
White	00 E 55
Black	00 E 53

TABLE F: IDENTIFICATION COLOURS FOR PIPES - HYDRATED LIME

Steel pipework carrying hydrated lime slurry shall be painted black, colour code 00E53 with banding.

Pipework conveying hydrated lime slurry shall be banded with vinyl laminated identification tape to enable individual lines to be identified throughout their length. The banding shall conform to BS 1710 to indicate the fluid conveyed and shall have flow direction arrows, lettering and codings as described below.

(a) Lettering

Duty	Lettering	Colour	Height
Slurry	"LIME"	White	10mm
Service Water	Not applicable	-	-
Waste Water	"DRAIN"	White	5mm

(b) Banding

Duty	Coded Bands
Slurry	violet - danger marker - violet
Service water	green - blue - green
Waste water	black

Individual bands shall be 50mm wide.

Bands for slurry lines shall incorporate danger warning markers (black/yellow diagonal stripes) 50mm wide giving a composite width of 150mm.

Colours stated above refer to BS 4800 shades as follows:

Colour	Code
Violet	22C37
Green	12D45
Blue (auxiliary)	18E53
Yellow	08E51
White	00E55
Black	00E53

TABLE G: IDENTIFICATION COLOURS FOR PIPES – ALUMINUM SULPHATE

Pipeline shall be banded with vinyl laminated identification tape to enable individual lines to be identified throughout their length. The banding shall conform to BS1710 to indicate the fluid conveyed and shall have flow direction arrows, lettering and codings as described below:-

(a) Lettering

Duty	Lettering	Colour	Height
Aluminium sulphate	"ALUM"	White	10mm
Dilution water	Not applicable	-	-
Wastewater	"DRAIN"	White	5mm

(b) Banding

Duty	Coded Bands
Aluminium sulphate	Violet - danger marker - violet
Dilution water	Green or Green - blue - green (if drinking quality)
Wastewater	Black

Danger markers shall consist of black/yellow diagonal stripes 50mm wide.
The overall width of individual or composite bands shall be 150mm.
Colours stated above refer to BS4800 shades as follows:-

Colour	Code
Violet	22C37
Green	12D45
Blue (auxiliary)	18E53
Yellow	08E51
Black	00E53
White	00E55

TABLE H: IDENTIFICATION COLOURS FOR PIPES - MISCELLANEOUS

Sample lines:

Pipework conveying sample water shall be banded with vinyl laminated identification tape to enable individual lines to be identified throughout their length. The banding shall conform to BS 1710 to indicate the fluid conveyed and shall have flow direction arrows, lettering and codings as described below.

(a) Lettering

Duty	Lettering	Colour	Height
Sample	"SAMPLE XXX"	Black	5 mm
Wastewater	"DRAIN"	White	5 mm

Note that the approved sample designation for each line is to be substituted for "XXX".

(b) Banding

Duty	Coded Bands
Sample	Green (150 mm wide)
Wastewater	Black (50 mm wide)

Colours stated above refer to BS 4800 shades as follows:

Colour	Code
Green	12D45
White	00E55
Black	00E53

Air pipework:

Pipework conveying air shall be identified throughout its length in accordance with BS1710.

For steel pipework, the finish colour of the protective coating system generally shall be the basic identification colour, blue 2O-E-51 to BS4800. Where this is precluded by use of high temperature paint finishes and/or the application of thermal insulation and cladding, then banding shall be applied in appropriate materials. The banding shall be 150 mm wide and in the same basic identification colour.

For non-steel pipework such as instrument air supply branches, identification shall be by means of banding generally as above except that the width of banding shall be limited to 50 mm.

PART D - MECHANICAL STANDARD SPECIFICATION

D1.0 PUMPING PLANT

D1.1 Definitions

For this Specification the following definitions shall apply:-

(a) Design duty: The total head to be developed and the quantity of fluid to be discharged when the pump is running at rated speed;

(b) Static head: The difference between free water surface level on the suction side of the pump and the delivery level;

(c) External friction head: The head required to overcome friction external to the Works (Frictional loss in the transmission main) and the velocity head at the outlet of the pumping main;

(d) Station losses: The friction losses in valves and pipes within pump room;

(e) Internal losses: The frictional losses in the pump suspension main and head bend up to the delivery flange of vertical wet well pumps

(f) Total head: The sum of (b), (c), (d) and (e);

(g) Design duty head: The sum of (b) and (c);

(h) NPSHa : Net positive suction head available at site

(i) NPSHr: Net positive suction head required by the pump

(g) LWL: Low Water Level at free water surface level on the suction side of the pump.

(h) HWL: High Water Level at free water surface level on the suction side of the pump (during flooding)

'Pumpset' where used in this Specification and the schedules including the price schedules, shall mean the complete assembly of pump, motor, driving arrangement, and supporting headpiece or baseplate as appropriate.

Note:
All materials and workmanship shall comply with latest edition of the applicable standards and codes.

D1.2 Pump design and layout

D1.2.1 General

The head/quantity characteristics of pumps shall be stable at all rates of flow between closed valve and fully-open valve, and the characteristics shall be steep enough for satisfactory operation in parallel under all conditions specified.

Pump efficiency shall be well maintained over the whole of the specified duty range.
For vertical-shaft suspended pumps, the pump efficiencies quoted shall take into account shaft and rising main losses up to and including the pump discharge bend and pump coupling.

Lubrication arrangements shall be designed to avoid any contamination of the pumped fluid, except for raw-water pumps with shaft bearings lubricated by filtered raw water.

Pumps and associated pipework shall be arranged so that air can be completely removed during priming, using air-release valves at high points, and complete drainage is provided from low points by drain valves.

Pump suction and discharge flanges shall each be provided with 2 opposed plugged tappings for fitting pressure gauges and the like. The tappings shall be fitted with suitable metallic plugs for transport.

Arrangements for the easy handling of all pumping machinery shall be provided, by using lifting lugs or eyes as appropriate.

D1.2.2 Driving arrangements

Unless otherwise specified, pumps shall be driven by electric motors and be directly coupled. Motors shall provide a power margin of not less than 10% above the maximum power absorbed by the pump in any possible operating condition.

D1.2.3 Seals, glands and sleeves

If pumps are fitted with packed glands, the shafts shall be fitted with replaceable sleeves where they pass through the gland. Packing shall be readily replaceable and adjustable. If packed glands are used, effective means shall be provided for collection of the gland leakage water which shall be piped into the drainage system.

Pumps may be fitted with mechanical seals in place of packed glands only if the seals have a proven record of satisfactory running when fitted to the pump design in question, and with prior approval. Mechanical seals shall be readily adjustable and replaceable

Flushing facilities shall be provided for mechanical seals or packed glands if the pumped fluid may include abrasive material.

D1.2.4 Raw water pumps

Pumps for raw water shall be designed to avoid possible choking by weeds or any other material and shall be capable of passing 50 mm-diameter solids.

D1.2.5 Bearings

Pump bearings shall have a design running life of not less than 75 000 hours. Bearings shall be designed for loadings 20% in excess of calculated maximum loading and shall be suitable for reverse rotation at 150% of rated speed or the maximum reverse speed the pump can reach in installed conditions when driven backwards by reverse flow if this is greater.

Bearing cooling arrangements shall use closed circuits. Open discharge of cooling water into the pumping station drainage system is not permissible. The coolant flow shall be easily visible and local indication of bearing metal temperature shall be provided. Excessive metal temperatures shall result in safe shutdown of the pump.

D1.2.6 Balancing

Rotating assemblies shall be statically and dynamically balanced in accordance with ISO 1940–1. They shall be designed so that the first critical speed of the pump and its drive is at least 50% higher than the maximum operating speed. Ifrotating assemblies are small and out-of-balance forces are negligible, the Engineer may waive this requirement. For each pump, the manufacturer shall state whether or not balancing has been completed.

D1.2.7 NPSH

The NPSH requirements of pumps, based on the 2% output drop criterion, shall be at least 1m less than the NPSH available at every working condition at site maximum ambient temperature.

D1.2.8 Velocities in pump branches

Unless otherwise specified, the water velocity in the suction branches of a pump shall not exceed 1.5m/s and in the discharge branch shall not exceed 2.5m/s when the pump is operating within its specified working range. There shall be no discernible noise due to hydraulic turbulence or cavitation within the pump or its associated pipework and valves.

If discharge branch velocities exceed 2.5m/s in the working range, the use of profiled taper pipes will be allowed. Taper pipes shall be designed to reduce velocity progressively to not greater than 2.0m/s, using profiled internal contours which contain no steps or angles from which turbulence or cavitation can be generated. The taper pipes shall be considered as part of the pump and be included in performance calculations and tests.

D1.2.9 Priming

Unless otherwise approved, pumps shall be set at levels which ensure they are primed automatically at the lowest inlet water level which is possible in normal operation.

D1.2.10 Baseplates

If pump and motor are mounted on a combined bedplate, the bedplate shall be a substantial fabricated-steel construction or of cast iron. Holes for holding-down bolts shall be included, and all packing for levelling, and all holding-down bolts and the like shall be provided. Steel dowels shall be fitted after final alignment of pump and motor to facilitate dismantling and reassembly.

D1.2.11 Pump performance

Pump performance guarantees shall relate to the flow rate, the total head and the efficiency of the pump when tested at the manufacturer's works. Verification of factory test results shall form part of the Site Tests on Completion.

Pumps shall operate at design duty within the acceptance tolerances for flow and total head laid down in ISO 3555.

Unless otherwise specified, at the time of tender the Contractor shall supply the performance curves for the pumps he is providing. The curves shall show total head, pump efficiency, power absorbed by the pump, and NPSHr plotted against flowrate for the full operating range required. The curves shall be extended to show shut valve conditions, and to show performance at flowrates at least 20% in excess of the maximum flowrate expected in normal operation at site conditions.

Where appropriate, curves shall also be included to show the variations in station losses and internal plant losses plotted against flowrate, to enable the complete pump performance curves to be shown.

If the Purchaser's estimated system curves for head against flow have been provided, the Contractor's pump curves shall be superimposed on the system curves to show conveniently the expected performance in site conditions.

Power consumption for tender adjudication and discounted cash flow will be calculated as shown below:

If the parameters A, B & C are given in the Particular Specification, the sum of weighted power consumptions of the pump when operating at separate points in the duty range shall be used, calculated as shown below.

If the parameters A, B, and C are not given, continuous operation at the design duty will be assumed.

$$\left(\frac{kWi}{kWo}\right)_m = A\times\left(\frac{kWi}{kWo}\right)_{ha} + B\times\left(\frac{kWi}{kWo}\right)_{hb} + C\times\left(\frac{kWi}{kWo}\right)_{hc}$$

where	kWi	=	kW power input at the motor terminals
	kWo	=	kW gained by the water pumped
	m	=	signifies the weighted power consumption
	hb	=	pump design duty (which shall be guaranteed)
	ha , hc	=	pump operating points at the limits of working range specified
	A, B, C	=	percentages, reflecting the percentage of time the pump will operate at these points.

D1.3 End-suction pumps

Pumps shall be horizontally-mounted complete with drive motor on a common baseplate. The coupling shall be of the spacer type to facilitate removal of the pump rotating element and bearing housing without dismantling the pump casing, adjoining pipework or motor.

The dimensions of the pump shall be metric conforming to BS 5257 or its equivalent. Flanges shall conform to BS 4504.

The velocity at the entrance to the pump impeller shall not exceed 3.5m/s.

Impellers shall be provided with means to prevent abrasive matter reaching the glands, and with fully-shrouded impellers to prevent the trapping of matter between the impeller vanes and the casing.
Pump speed shall not exceed 1,500 rpm unless otherwise specified.

D1.4 Concentric casing mixed flow and axial flow pumps

D1.4.1 General

Suspended concentric casing pumps shall be to one of the following arrangements. The particular arrangement shall be as specified.

- The pump including shafting and suspension main supported by the motor stool with the discharge bend above motor floor level;
- The pump including shafting and suspension main supported by the motor stool with the discharge bend below motor floor level;
- The pump including shafting and suspension main supported by the discharge bend, and the motor supported at a higher level with the drive transmitted through an extension shaft fitted with universal couplings in matching pairs.

The requirements for the component parts shall be as follows:-

D1.4.2 Casings

Pump casings for mixed and axial flow pumps shall be designed to produce a concentric discharge from the casing around the pump shaft and through the suspension main.

Mixed flow pump casings shall be formed in two parts consisting of a bellmouth and main casing containing a diffuser of the guide-vane type. A central hub supported by the diffuser vanes shall provide the housing for the pump bearings. The bellmouth shall be provided with guide vanes when this is advantageous in promoting axial flow into the impeller. When the impeller is an unshrouded type the main casing shall be sub-divided into two sections, an impeller section and a diffuser section, the impeller section being renewable when blade clearance becomes excessive. For shrouded impellers, replaceable wear rings shall be fitted in the main casing at the impeller entry.

Axial-flow pump casings shall also be formed in two parts consisting of a suction bellmouth and a main guide-vane casing. A central hub housing the pump bearings shall be supported by discharge guide vanes in the pump casing.

D1.4.3 Impellers

Mixed-flow impellers of the shrouded type shall normally be fitted with wearing rings at the impeller to provide hydraulic balancing. The rings shall be renewable.

If the impellers are of the unshrouded type, means shall be provided for axial adjustment of the impeller at the pump thrust bearing. Impellers shall be keyed and positively secured to the pump shaft by fasteners fitted with locking devices.

Surfaces shall be machined or finished smooth all over.

D1.4.4 Shafts

Shafts shall be in sections to suit the bearing centres and shall be accurately machined all over. The design of the shaft and the positioning of the bearings shall ensure that the running speed is well below the first critical speed. Renewable shaft sleeves shall be securely fitted to the shaft where it passes through the bearings and stuffing box.

The couplings for the intermediate and pump shafts shall provide a positive non-slip drive between motor and pump. Shaft nuts for locking the couplings shall be guarded to prevent unscrewing from shaft rotation in either direction.

D1.4.5 Bearings

Thrust bearings shall be located within the motor support stool or the pump support pedestal, and shall be designed to withstand the hydraulic thrust and support the weight of the combined rotating assembly of pump shaft, impeller, and intermediate shafting.

For small and medium capacity pumps with moderate thrust loading, bearings shall be grease-lubricated combined ball or roller thrust and journal bearings. For large capacity pumps with high thrust loading, an oil-lubricated Michell combined thrust and journal bearing shall be fitted. The bearing shall be of the self-contained type with a cooling-water jacket incorporated in the bearing housing.

Intermediate shafting radial-support bearings shall be carried on spiders spigotted into the flanges of the suspension main sections. Normally, bearings shall be water lubricated using filtered water obtained from the pump discharge. Where specified, the shaft and bearing shall be enclosed in a tunnel tube supplied with filtered water. The arrangements for supplying filtered water shall ensure:

a) that filters used are duplex type so that one filter can be cleaned while the second remains in service;

b) that if required by the bearing design, a filtered water supply is provided to each bearing before the shaft can begin to rotate.

The lengths of tunnel tubing shall correspond to the lengths of suspension main and shall be designed to fit positively against gaskets incorporated in the bearing spiders.

D1.5 Multi-stage high-pressure pumps

Pumps shall be horizontally-mounted multi-stage centrifugal type, complete with motor on a common baseplate. Pump speed shall not exceed 3,000rpm.

Pump shaft bearings shall be oil lubricated The design shall ensure that axial loads are hydraulically balanced as far as possible. If required, axial hydraulic loads shall be balanced by an oil-lubricated thrust bearing. Lubrication arrangements shall be designed so that there is no contamination of the pumped fluid.

Dimensions shall be metric, conforming to API 610 or its equivalent. Inlet flanges shall conform to BS 4504 and delivery flanges shall conform to BS 1560: Part 2.

The velocity at the entrance to the pump impeller shall not exceed 3.5m/s.

D1.6 Vertical turbine (VT) pumps

Pumps shall be vertical and shaft-driven by vertical-shaft motors. Impellers shall be of the mixed or axial-flow multi-stage type, driven at a maximum speed of 1500 rpm unless otherwise specified.

Vertical-shaft driving motors shall be mounted on the discharge head above the discharge bend. Unless otherwise specified or approved, they shall be of the hollow-shaft type, fitted with an axially-adjustable thrust bearing designed to carry the combined weight of pump and motor rotating parts, the drive shaft with couplings, and hydraulic loadings.

Impellers and guide vanes shall be either surface-coated cast iron or cast bronze unless otherwise specified. Support bearings shall be provided between each impeller stage. The impeller shaft shall be corrosion-resistive low-alloy steel, designed for low stress and long life.

The drive-shaft couplings shall be designed to preserve true shaft alignment in all operating conditions, and shall be close to bearings. Coupling design shall provide for accurate assembly and re-assembly within the limits of the permissible end-float of the shaft.

The drive shaft and couplings shall be designed to withstand the maximum accelerating torque of the motor, with a factor of safety of at least two.

When required, the Contractor shall provide his design calculations to demonstrate that the shaft size chosen meets the requirement for safety factor given in the paragraph above.

Unless otherwise specified or approved, the drive arrangement shall incorporate an approved ratchet arrangement to ensure that if the pumps are driven in reverse for any reason, the motor is uncoupled from the pump.

Unless otherwise specified, the discharge pipework shall include an automatic air inlet/release valve, designed to vent the pipework on pump start and to allow air ingress when the pump stops. The valve shall be sized to ensure that accumulated air shall not be passed to the delivery pipework on starting.

If draining the column pipe on pump stopping could result in reverse rotation of the pump, means shall be incorporated to ensure that the pump cannot be restarted before reverse rotation stops.

D1.6.1 Discharge head and mounting plate

The discharge head shall be a composite fabrication or casting. The supporting-plate assembly shall consist of a steel baseplate, strong enough to carry the weight of the complete pumping unit without significant deflection. The assembly shall provide the motor mounting arrangement and support the pump.

If required, the supporting plate shall be supplied with a flanged sleeve to facilitate mounting, with a puddle flange for building in.

The following shall be included:

- supporting plate with holding down bolts or studs;
- bedplate ring with levelling screws and plates;
- lifting lugs
- fixings for motor and coupling;

- provision for insertion of cables and level-recording equipment if required;
- provision for access to service the shaft seal.

The discharge-head shaft seal shall be selected for long life with minimum maintenance, and may be of the mechanical or packed-gland type. Packed glands shall have an intermediate lantern ring, supplied with filtered water. The pressure limit of mechanical seals shall be at least 50% greater than the pump closed-valve delivery pressure. Provision shall be made to return to the pump well any water leaking past the head seal.

D1.6.2 Water-lubricated line-shaft bearings:

Bearings shall be spaced at the intervals needed to ensure vibrationless running at all possible pump operating speeds, with a maximum distance of 2.5m apart. Guide bearings shall be of resilient synthetic rubber, mounted in spider bearing-retaining assemblies.

Transmission shafts shall be of forged steel, with ground finish. The shaft sections shall be connected by mild-steel couplings and shall have machined left-hand or right-hand threads, depending on the direction of rotation of the pump, to tighten during pump operation. Shaft sections shall be in lengths chosen to be the same as the guide-bearing spacing. The butting faces of each section shall be machined square to the axis of the shaft.

Means shall be provided to supply filtered water to each bearing. The arrangements for supplying filtered water shall ensure:

a) that filters used are duplex type so that one filter can be cleaned while the second remains in service;
b) that if required by the bearing design, a filtered water supply is provided to each bearing before the shaft begins to rotate.
c) that if the installed arrangement makes any reverse rotation possible on pump stopping, if required by the bearing design a filtered water supply is provided to each bearing until reverse rotation stops.

D1.6.3 Pump column pipe

Column pipe shall be steel, coated internally and externally with an epoxy bituminous solution or other approved protective coating.

The column pipe shall comprise a number of flanged sections, designed to suit the installation requirements. The sections shall be connected by welded-on flanges.
The butting flange faces of the riser pipe shall be machined square to the axis of the pipe.

The column pipe shall be provided with a long-radius flanged discharge bend at the top end. The bend shall incorporate the shaft sealing arrangement.

D1.7 Double-entry split-casing pumps

Pumps shall be horizontally mounted and directly coupled to their motors. Pump and motor shall be mounted on a combined fabricated steel baseplate.
Pump casings shall be split along the axis of the shaft to allow the removal of the impeller and shaft assembly without dismantling the pipework. Half casings shall be dowelled to ensure alignment. Jacking screws shall be provided to facilitate dismantling.

Bearings shall be of the ball or roller type to BS 292 or BS 3134 as appropriate, or shall comprise phosphor bronze or white metal bearings, complete with means of lubrication and seals. Bearings shall be mounted outboard.

Where shafts are susceptible to wear at bearings and glands, renewable sleeves shall be fitted. Wear rings and bushes shall be fitted to the casing and impeller at the points of running clearance.

Unless otherwise specified, pump shafts shall be forged steel with ground finish, and impellers shall be zinc-free bronze. Pump casings shall be close-grained cast iron.

Provision shall be made for periodic lubrication of bearings without removal of any parts.

Glands may be fitted with suitable mechanical seals or conventional soft packing.

Flushing facilities shall be provided for packed glands and means shall be provided for collection of the gland-leakage water which shall be piped into a separate drainage system.
Rotating assemblies shall be statically and dynamically balanced and shall be designed so that the first critical speed of the pump and its drive is at least 50% greater than the maximum operating speed.

Pump shall not exceed 1450rpm without approval.

D1.8 Submersible sump drainage pumps

Sump pumps shall be of the open-impeller centrifugal-type, vertically-mounted and close coupled to their fully-submersible electric motors.

Sump pumps of 1.5kW and under shall incorporate an integral level detector, control and motor starter and shall be powered only with a suitably-fused three-phase or single-phase low-voltage supply and with supply isolation at the supply point.

Sump pumps over 1.5kW shall be controlled and started from the supply point. Control shall be by means of adjustable float level switches mounted near the pump.

Pumps shall be supplied with all necessary pipework to discharge to surface drainage. Each pump shall be provided with delivery reflux and isolating valves, and suitable lifting gear for lowering and lifting the pump from the sump.

Pumps weighing 40kg or more shall be lowered into the sump on guide rails and be located to their respective discharge pipework with an angle flange connection and self-locating clamps.
Pump impellers shall be designed to pass solids of the sizes which pass through the inlet ports of the pump and shall be capable of pumping solids of up to 50mm diameter.

D1.9 Progressive-cavity pumps

Pumps shall be of the type in which a pumping action is generated by a helical rotor rotating eccentrically within a resilient stator in the form of a double internal helix. The eccentric motion of the rotor as it travels through the pump shall maintain a constant seal across the stator, to give a uniform positive displacement.

Pumps shall be arranged generally with a single shaft seal at the suction end. Mechanical seals shall be used. If a flexible shaft is used to accommodate the eccentric motion, a corrosion-resistant shroud shall be fitted to prevent fibre build-up on the shaft. Enlarged inspection access holes shall be fitted to the suction chambers of all pumps for periodic removal of accumulated debris.

The shaft bearings shall be positively isolated from the fluid being pumped.

The rotor material shall be selected for corrosion and abrasion resistance for the fluid being pumped, and for prolonged service life. Hard chrome or other approved coatings shall be not less than 250 micron thickness and shall be diffused into the base material. The rotor shall generally be single-stage and shall incorporate not less than 360° of twist, but for high-head applications, it may be necessary to use more than a single-stage.

The stator shall be of a resilient material selected for chemical and abrasion resistance for the fluid being pumped.
Pump speed shall suit the application. Where variable delivery output is needed, the pump shall be provided with a variable-speed drive. The size and speed range of the pump shall ensure that the highest expected duty point shall lie within the available speed range.

Pumps shall normally be driven by a fixed-speed electric motor through reduction gearing and the combined drive shall be continuously rated. Pump and motor shall preferably be mounted in-line on a common base plate. Alternatively, the drive motor may be mounted above the pump to minimise floor area, and shall be connected by external V-belts and pulleys. V-belt drives shall have full guards which shall allow the belts to be observed without removal of the guard. Facilities shall be provided for ready adjustment of belt tension.

Rigid, securely fixed coupling guards shall be provided, designed so that removal is not necessary during normal operation, routine maintenance and routine inspections.
Motor enclosures shall be provided with protection to IP55. Motor anti-condensation heaters shall be provided and shall be suitable for use on a 220V single-phase, 50Hz supply.

Bearings shall have a B10 design life of not less than 100 000 running hours and shall be designed for loadings 20% in excess of calculated maximum loading.

Pumps shall be fitted with individual dry-running protection to initiate pump trip. Dry-running protection by ‘under-current’ monitoring or ‘pipeline-intrusive’ devices shall not be used.

Pumps shall be fitted with an over-pressure sensing device to detect high pressure in the delivery pipework immediately downstream of the pump. The device shall initiate pump trip over an adjustable range of 50% to 300% above normal operating pressure. Means shall be provided to prevent trip due to short time pressure transients.

D1.10 Vacuum self-priming pumps

Vacuum self-priming pumps shall be end-suction centrifugal pumps horizontally-mounted with their drives on a common baseplate. Pumps shall have automatic front and back priming, using a vacuum pump and priming tank incorporating a float valve to stop water entering the vacuum pump. Pumps shall be capable of handling solids and operating under ‘snore’ conditions.

Impellers shall be of the open-blade high-efficiency type, fully shrouded to prevent the trapping of matter between impeller vanes and casing. They shall pass up to 50mm solids. The pump wear plate shall be adjustable and replaceable. The pump shall be able to operate between 1,500rpm and 2,500rpm.

As a minimum, the pump component parts shall be manufactured from the following materials:-

Pump volute casing:	Cast iron
Shaft seal cover:	Cast iron (BS 1452)
Suction cover:	Cast iron (BS 1452)
Bearing housing:	Cast iron (BS 1452)

Wear plate:	Nodular iron (BS 2789)
Wear ring:	Stainless steel
Shaft:	Steel (BS 970)
Non-return valve box:	Cast iron (BS 1452)
Non return valve:	Oil-resistant polyurethane
Priming tank:	Cast aluminium (BS 1490)
Vacuum pressure seal:	Cast iron packing (BS 1490) with rubber 'O' ring.

The dimensions of the pump shall be metric conforming to BS 5257 or its equivalent. The discharge line shall have a non-return valve. The suction and discharge hose connections shall be quick-release couplings, sized so that the maximum suction or discharge velocity is not greater than 3m/s. Rotating assemblies shall be statically and dynamically balanced with the first critical speed of the pump and drive at least 30% greater than the maximum operating speed.

Glands may be fitted with suitable mechanical seals or conventional soft packing. The gland arrangements shall be designed for ease of adjustment and removal of the packing and seal. When soft-packed glands are used, shafts shall be sleeved in the area of the gland, and flushing facilities and drainage ports shall be provided

D1.11 Vacuum priming pumps

D1.11.1 General

Pumps shall be sized for the air extraction rate and the vacuum needed to prime the main pumps they serve. Unless otherwise specified, priming shall take no longer than 5 minutes with the lowest possible inlet water level.

Vacuum pumps shall be of the horizontally-mounted, water-ring rotary type, with no contacting parts except for bearings and shaft seals. They shall be directly coupled to horizontal-shaft caged induction motors, and mounted with the motor on a combined cast or fabricated-steel baseplate.

Pump maximum speed shall not exceed 1,500 rpm, and pumps shall operate within permissible vibration levels and with the minimum of noise.

Materials for pump components shall be chosen for long life in the specified service conditions with minimum maintenance. Design life shall be not less than 30,000 operating hours.

D1.11.2 Casings

Pump casings shall be provided with feed-water tappings at the top part of the casing to provide sealing water. The tappings shall be individually valved, and connected to the delivery manifold of the main pumps they serve. If required to ensure an initial supply of sealing water on starting, a suitable header tank shall be provided, which shall be filled through a ball valve from the delivery manifold of the main pumps, and connected to the feed-water tapping of each vacuum pump.

D1.11.3 Rotors

Pump rotors shall be of the water-ring type, and shall be suitable for operation in a mixture of air and water.

D1.11.4 Pump shafts

Pump shafts shall be designed to minimise deflection. Deflector plates shall be provided to prevent water seepage to the bearing housings.

D1.11.5 Bearings

Pump bearings shall be designed for a minimum service life of 30,000 hours. Bearings shall be heavy duty, single or double-row anti-friction type, designed to support the rotating parts and to withstand any axial loads.

D2.0 PIPEWORK

D2.1 Pipework within structures

The term pipework shall include all necessary supports, saddles, slings, fixing bolts and foundation bolts required to support the pipes and associated equipment.

Pipework layout within pumping stations shall be agreed with the pump manufacturer.

Pipes and fittings over 100mm diameter and within buildings shall be steel.

Pipework shall be laid out and designed to facilitate the erection, painting in situ and dismantling of any section for maintenance and to give a constant and uniform flow of working fluid with a minimum of head loss. Where steel pipework is used, the number of flanges shall be kept to a minimum and the size of each length of pipework shall be determined by the ease of handling, installation and general appearance of the completed pipe system. Positions of flanges shall take account of any concrete pipe supports or thrust blocks needed.

Flexible joints shall be provided where needed to facilitate removal of Plant or to allow for differential settlement of the building. Wherever practical, flexible joints shall be provided with tie-bolts or other approved means to transfer thrust or tension axially along the pipework.

Where steel and cast flanges are to be bolted together, the steel flange shall be machined over its full face after welding to the pipe is completed. Flanges shall be finished truly square with the pipe axis. Wherever possible, standard fittings shall be used in preference to special fittings.

Facilities shall be provided for draining the pipe system and releasing air. The drained fluid shall be piped into the appropriate drainage system and the time for drainage shall not exceed 30 minutes.

Valves, strainers and other devices mounted in the pipework shall be supported independently of the pipes to which they connect.

Flanges shall be drilled in accordance with the appropriate pressure rating.

Where a pipe passes through a wall, a retaining wall, or is subject to end thrust, it shall incorporate a puddle flange. Puddle flanges shall be undrilled.

Unless otherwise approved, steel pipework in pumping stations shall be internally and externally coated with an approved two-component solvent-free, spray-applied epoxy coating.

D2.2 High-pressure pipes and fittings (over 24 bar)

High-pressure pipework shall be of seamless or welded steel, complying with API

Specification 52 for line pipe.

Pipes and fittings shall be specified by nominal diameters.

The process of manufacture shall be as stated by the Contractor in the Form of Tender. Test and test certificates will be required for the pipework supplied under this Contract in accordance with Clauses 3.3 and 3.5 of API Specification 5L including ladle and check analyses of the steel. The pipework manufacturer shall perform fracture toughness tests in accordance with API Specification 5L and shall provide test certificates to show the pipe is suitable for use under the operating conditions specified at temperatures between –5°C and 40°C.

Steel specials for butt-welding shall comply with BS 1640: Part 3 or ANSI B16.9. All specials shall have the same strength and be compatible in all other respects with the line pipe with which they are to be used.

Carbon steel pipes shall be in accordance with BS 3601. Carbon steel fittings shall comply with BS 1965 Part 1

Pipework and fittings shall be completely fabricated and corrosion-protected at the maker's works.

Welding shall be in accordance with BS 2633 Class 1 arc welding. All welding and fabrication operatives shall be coded and tested by an independent inspection authority. The work shall be done manually by welders qualified for all-position welding to BS 2633 and the Contractor shall submit to the Engineer details of all welders whom he proposes to employ. The Engineer's approval for any welder will be given only after the welder has satisfied the requirements of the welder tests prescribed by BS 4871: Part 1. The welder shall perform the relevant tests, and test certificates shall be provided by the Contractor for examination by the Engineer. The Engineer reserves the right to visit the premises where fabrication is taking place, to examine procedures, to inspect fittings, and to spot check where relevant all certification of materials and operatives employed on work being done for the Engineer.

The internal and external surfaces of the pipe shall be smooth, clean and free from grooving and other defects which might impair its functional properties. The ends of the pipe shall be cleanly cut square with the axis and free from deformity. The pipe shall be homogeneous throughout and uniform in colour, opacity, density and other physical properties. The pipe shall be delivered in the longest lengths possible to keep site jointing to a minimum.

D2.3 Dismantling joints, flexible couplings and flange adaptors

Where dismantling joints, flexible couplings or flange adaptors are used these shall be of the Viking-Johnson type except where otherwise specified or approved.

Pressure ratings shall match the pressure rating of the pipework in which they are installed, and materials used and methods of protection shall not be inferior to those used for the pipework.

Where needed, joints and couplings shall be provided with tie bolts to restrain the maximum axial thrust arising when in service.

Detachable flexible couplings shall be suitable for the angular deflections specified below without leakage. Flange adaptors shall be suitable for half the angular deflection stated.

Nominal pipe diameter (mm)	**Angular deflection** (degrees)
Up to 600	5
601 to 750	4
751 to 900	3
901 to 1200	3
1201 to 1800	2
1801 upwards	1

Flexible couplings for each size of pipe shall also be capable of withstanding the shear force applied by the weight of a 4m length of pipe of that diameter full of water suspended between two couplings.

Detachable flexible couplings shall be provided with central registers or location plugs only where specified or detailed in the Drawings.

Flange adaptors shall have flanges as specified for flanged joints.

Bolts, nuts and washers shall comply with the requirements for bolts, nuts and washers for flanges.

The metal components of flexible couplings and flange adaptors shall be protected by thermoplastic polyamide or fusion-bonded epoxy coatings unless otherwise specified or detailed in the Drawings.

D3.0 VALVES

D3.1 General

Valves shall be suitable for use with the fluid being conveyed at the temperatures and pressures required for the application. Unless otherwise approved, pressure designation shall not be less than PN 10.

Valves shall have integral flanges drilled as specified in BS 4504 where applicable. Flanges to other standards shall be used only if approved and provided that any differences do not affect mating dimensions. Back faces of flanges shall be machined.

Sluice valves and butterfly valves shall be suitable for flow in either direction.

Sluice valves shall comply with BS 5150 or 5163 as appropriate

Butterfly valves shall comply with BS 5155 / AWWA-C-504/1980. Reflux/check valves shall conform to BS 5153

Valves shall be suitable for frequent operation, and for infrequent operation after long periods of standing either open or closed.

Rubber used in valves shall be ethylene propylene rubber (EPDM or EPM) or styrene butadiene rubber (SBR). It shall comply with the requirements of Appendix B of BS 5155, be suitable for making a long term flexible seals, and be resistant to anything causing deterioration of the flexible seal.

D3.2 Gate valves (Sluice valves)

Gate valves shall comply with BS 5150 and be of the solid wedge-gate type with non-rising stems. Valves less than 250mm diameter may be of the resilient-seated type unless otherwise specified.

Gate valves up to and including 1000mm nominal diameter shall conform to the requirements of BS 5150 for copper-alloy faced or resilient-seated valves with solid or split wedge, except that gate valves up to and including 600mm nominal diameter may conform to BS 5163.

Gate valves larger than 1000mm nominal diameter shall comply with the materials and other relevant provisions of BS 5150.

Valve spindles shall be of the internal non-rising type. The valve spindle seal shall be replaceable with the valve fully open and the main under pressure.

Valves used with potable water shall not use any brasses which contain more than 5% zinc.

Valves 450mm and over shall be fitted with integral by-passes and gate jacking screws.

Valves below 80mm NB shall comply with BS 5154.

D3.3 High-pressure gate valves (over 24 bar)

Gate valves shall be wedge type complying with BS 1414, Class 900. The pressure/temperature rating shall be in accordance with Table PE-1 of BS 1560: Part 2.

The wedge shall be plain solid-wedge type, made from the materials listed in Table PE-1 of BS 1560: Part 2.

Trim material (except the stem) shall be bronze to BS EN 1982: LG2 as listed in Table 2 of BS 1414.

The stem shall be stainless steel 18-8 Ti as listed in Table 2 of BS 1414.

Flanged ends shall be Class 900 raised-face type, complying with ANSI B16.25 or Table PE-1 of BS 1560: Part 2.

Butt-welded ends shall be in accordance with Clause 8.7 of BS 1414.

Operation shall be by handwheel or square head and tee key as shown in the Drawings.

One body tapping shall be provided in the bottom of the valve in accordance with Clause 8.9 of BS 1414 for drainage. Tappings shall be provided with a plug.

A valved by-pass shall be provided in accordance with Clause 17.2 of BS 1414. The materials of the by-pass shall be at least of the same standard as those specified for the main valve.

D3.4 Reflux /Check valves

Reflux/check valves shall be designed for rapid closing without slamming no later than the moment forward flow stops. The valve size and design shall be chosen to give the best performance possible, taking account of the system where the valve is installed. The effect of any surge vessel in the system as well as the static and dynamic heads shall be included in the assessment.

If self-closing without slamming cannot be achieved, external mechanisms may be used to control the closure rate. Details of mechanisms shall be subject to approval.

Valves shall preferably be fitted with resilient faces or seats.

Check valves used in raw water systems shall not be installed vertically, or positioned so that water-borne solids can settle against the valve flap when the flap is closed.

D3.5 Butterfly valves

Unless otherwise specified, valve body and disc shall be of close-grained grey cast iron. and valves shall be mounted with shafts horizontal.

Valves shall be fitted with indicators to show the position of the disc, clearly marked with 'open' and 'closed' positions.

Valves shall not contain any brasses containing more than 5% zinc. Gunmetal to BS 1400 Grade LG2, aluminium bronze, or nickel components may be used for internal components.

Resilient-seated valves shall have nitrile rubber seals. For valves of 900mm and above, retaining rings shall be provided to enable the sealing ring to be replaced without the need to remove the valve body from the pipework.

Metal-seated valves of 900mm and above, shall be have seat clearances adjustable to obtain as near a watertight condition as possible, without the need to remove the valve body from the pipework.

D3.6 Pressure and flow control valves

D3.6.1 General

Pressure-control valves and flow-control valves shall be designed for the operating conditions specified.

Valves shall be capable of controlling the required flow or pressure within plus and minus 5 percent of the set value. The rate of response of opening and closing of the main valves shall be controllable at the valve. External indication of the position of the valve element shall be provided.

Hydraulic control systems shall include isolating valves to allow maintenance or replacement without interrupting the supply.

D3.6.2 Altitude valves

Altitude valves shall be designed for installation at the base of ground-level or elevated storage tanks, as shown on the Drawings, to prevent overfilling.

The main valve shall be controlled by a slave ball cock mounted in the tank at top water level and connected to the valve operating mechanism by small-bore pipework. The level of the ball shall be readily adjustable so that the main valve closes fully when the water level reaches maximum.

D3.6.3 Flow-control valves

Flow-control valves shall be designed to prevent the flow downstream rising above that specified or shown on the Drawings for the particular application, regardless of the operating pressures in the system upstream or downstream of the valve.

D3.6.4 Pressure-sustaining valves

Pressure-sustaining valves shall be designed to maintain the pressure in the pipeline immediately upstream of the valve to a preset minimum value, irrespective of the flow and pressure downstream of the valve.

The set pressure shall be adjustable. A pressure gauge shall be provided to indicate upstream pressure over the operating range of the valve.

D3.6.5 Pressure-relief valves

Pressure-relief valves shall be designed to prevent the pressure in the pipeline upstream of the valve rising above a preset level. The valve shall remain closed at lower pressures.

The pressure at which the valve opens shall be adjustable. A pressure gauge shall be provided to indicate upstream pressure over the operating range of the valve.

Safety valves shall comply with BS 6759: Part 1. They shall be designed to open at the specified pressure and re-close and prevent further release of fluid after normal pressure has been restored. The pressure / temperature rating shall be in accordance with Table PE−1 in BS 1560: Part 2.

Shell material shall be from the materials listed in Table PE−1 BS 1560: Part 2.

Flanged ends shall be Class 900, raised-face type complying with ANSI B16.25 or Table PE−1 or BS 1560: Part 2. Butt-welded ends shall be in accordance with Section 8 of BS 1868.

D3.6.6 Pressure-reducing valves

Valves shall be capable of maintaining a constant downstream pressure from a higher upstream pressure and they shall be drop-tight under no-flow conditions.

A pressure gauge shall be provided to indicate downstream pressure over the operating range of the valve.

Valve operation shall be controlled by the interaction of the inlet pressure, outlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valve.

The pilot valve or relay system shall be actuated by a diaphragm connected to the outlet pressure on its underside and a constant pressure on its upper side, derived either from weights or from a spring.

Valves shall be flanged and drilled to BS 4504 for the operating pressure required.
Materials for valves shall be as follows:—

Component	Material
Body and cover	Cast iron
Internal valve	Gunmetal with bronze liner, cups and facing rings in leather
Relay valve	Bronze with stainless steel shaft and nylon valve face
Diaphragm	Reinforced synthetic rubber
Loading spring, If employed	Spring steel
Cylinder & weights, If employed	Cast iron
Lever	Steel with gunmetal pins and links
Connecting pipework to cylinder	Copper
Cylinder	Mild steel epoxy lined with internal working parts gunmetal bushed

D3.6.7 Automatic air-relief valves

Air valves shall be provided as specified or shown on the Drawings, to achieve the following:-

(a) To exhaust air automatically during filling, the air being released fast enough to prevent back pressure restricting water inflow.

(b) To ventilate pipework automatically during emptying, the air inflow being fast enough to prevent the development of any significant negative pressure.

(c) To release air automatically during normal working.

Conditions (a) and (b) shall be met by using an orifice capable of handling large volumes of air at a high-flow rate in either direction. Condition (c) shall be met by using a small orifice capable of discharging small volumes of air as they accumulate.

Valves shall have approved screens to prevent the ingress of foreign matter.

Air valves shall be of one of the following types;-

(a) Double valves shall combine both large and small orifices in one valve. The large orifice shall be sealed by a float and the valve shall be designed to avoid premature closing of the valve by the discharging air. The small orifice shall be sealed by a float at all pressures above atmospheric, except when air accumulates in the valve body.

(b) Single large orifice type for automatic ventilation or exhaust of pipework.

(c) Single small orifice type for automatic release of air under normal working pressure.

Large orifice air valves, including those incorporated in double air valves, shall be constructed so that the air flow holds the valve open during discharge of air at all flows possible in service. When coupled to their respective isolating valves, they shall be capable of admitting or exhausting the required quantities of free air without the pressure differential across the combined air valve and isolating valve exceeding 0.5 bar.

Small orifice air valves, including those incorporated in double air valves, shall be capable of discharging not less than 0.5 m^3/min of free air when the pressure in the pipeline is at the maximum working pressure.

Balls or floats shall be of ABS, vulcanite, rubber-covered metal, stainless steel, or other approved materials, and shall operate automatically at all pressures up to the test pressure. Orifices shall be bronze or stainless steel.

Air valves shall be designed so that each float seats against its orifice or causes the orifice to be closed without leakage at all pressures between 0.2 bar g. and the specified test pressure. Balls and seats shall be designed to minimise adhesion of the ball to the seat. They shall be of a type proven to be suitable for the specified duties.

Each air valve shall be provided with an isolating valve, which shall be an integral lever-operated isolating ball valve.

Each small orifice or double air valve shall be fitted with a test cock in the valve body for verification that the small orifice air valve is operating properly.

Body ends shall be flanged with raised faces and drilled to BS 4504 for the nominal pressure specified.

The materials for valves shall be not inferior to the following:

- body cover and cowl: cast iron;
- small orifice: cast iron with gunmetal seat;
- small orifice ball: rubber-covered or other approved;
- large orifice: cast iron with rubber seat;
- large ball: Vulcanite covered or other approved.

D3.6.8 Ball float valves

Ball float valves shall be designed for installation on the inlet to a storage tank and shall automatically shut off when the water reaches a predetermined level. They shall be of the single beat type with balancing piston, resilient seatings, and direct float and lever operation.

Ball float valves shall be suitable for long-term operation when partly open.

D3.6.9 Plug valves

Plug valves shall conform where applicable to BS5158/IS 10459.

Plug valves shall be of the non-lubricated type, resilient rubber covered and be designed for low operating torque.

Valves shall be of quarter turn operation from fully open to fully closed. In the fully open position, flow shall pass straight through the valve.

Plug valves shall not be used for throttling.

Plugs shall be spring loaded to compensate for wear, ensure tight closure and provide easy operation.

An indicator shall be provided on the end of the valve stem to confirm the plug position.

D3.6.10 Diaphragm valves

Diaphragm valves shall conform where applicable to BS5156.

For steel or ductile iron pipework the body shall be cast iron. When used with abrasive materials, the body shall be suitably lined.

Where used for abrasive material, the diaphragm material shall be selected for maximum resistance to abrasion.

For slurry or sludge applications, valves shall be of the straight-through type.

D3.6.11 Ball valves

Ball valves shall conform where applicable to BS5159.

Multi-piece bodies shall be used where work on the ball and seats when installed may be needed. If valves need removal for servicing, one-piece bodies may be used.

Seat materials shall be chosen for long life, with erosion and corrosion resistance.

Ball supports shall be of the floating ball or trunnion type. If line pressure is too low to ensure a positive leak-free seal, built-in seat loading devices, or specially shaped seatings shall be used to ensure sealing.

D3.6.12 Float-controlled valves (delayed-action type)

Float-controlled valves for regulating flow into a reservoir or tank shall be angle type, mounted at the end of the supply line and discharging downwards.

Valves shall be controlled by the action of the float on a pilot valve, with sensitive response to small forces. Valves shall close drop-tight.

Floats shall be mounted within a stilling tank, as shown in the Drawings.

The stilling tank shall fill through a siphon pipe and empty through a subsidiary ball cock, so that the tank cannot begin to fill until the water in the reservoir reaches top level. The tank then fills completely and the valve moves from fully-open to fully-closed in one continuous stroke. Similarly, valve opening shall not start until low-water level is reached.

Valves shall be suitable for closing against the maximum possible operating head.

D3.7 Penstocks (Sluice gates) and headstocks

D3.7.1 General

Penstocks shall be of cast iron or plastic construction as specified and suitable for either on-seating or off-seating as specified. Apertures may be rectangular or circular.

On-seating penstocks shall be drop tight at their operating seating pressure, unless otherwise approved.

The leakage rate for off-seating penstocks shall be stated by the Contractor and will be subject to approval.

D3.7.2 Penstocks — cast iron

Penstocks shall be cast iron complying with BS 1452 not less than Grade 12 and to the dimensions specified.

Penstocks shall be flat-backed for wall mounting or be provided with short spigots for building into an opening, Penstock apertures shall be rectangular or circular.

Seating surfaces shall be gunmetal to BS 1400 LG2, or bronze to BS 2874, hand-scraped and securely fixed to frame or door.

Penstocks shall be suitable for either on-seating or off-seating pressures as required by the application, and shall be drop-tight at their operating seating pressures.

Rising or non-rising shafts shall be provided, as specified.

Rising shafts shall be mild steel, connected to the door and working through a gunmetal nut rotated by the operating gear. Rising-shaft penstocks shall be provided with head and foot brackets, or foot brackets only as required.

Non-rising shaftsshall rotate in a gunmetal nut in the door, and shall be of manganese bronze or phosphor bronze. For long shafts, only the screwed portion need be of manganese bronze or phosphor bronze.

Extension shafts shall be provided with sockets which engage the penstock shafts. A securing bolt, locked in position, shall unite the 2 shafts.

Guide brackets shall be provided wherever necessary.

Operating handwheels shall be big enough diameter to enable the required duty to be achieved.

Hand-operated weir penstocks shall be lockable in any position.

D3.7.3 Penstocks — plastic

Plastic penstocks shall be suitable for wall mounting or building in, and shall have circular or rectangular apertures.
Frames shall be of epoxy-coated mild steel or continuously-welded stainless steel grade 316 S16. They shall be suitably reinforced and include corner gussets. All fasteners shall be stainless steel grade 304 S16.

Frames shall be fitted with plastic seals molecularly incompatible with the gate material, and have a coefficient of friction of less than 0.1. Provision shall be made for easy, on-site adjustment of the seals by means of easily-replaceable stainless steel fasteners. Where a flush invert is required, the seal shall be an integral part of the lower frame member and manufactured from a resilient material having a Shore hardness of 80A.

Gates shall be manufactured from suitably-reinforced composite materials, which are non-toxic, ultraviolet-stabilised and comply with Class 1 fire resistance. The material shall have a linear coefficient of expansion not more than 0.000016 per degree Celsius. The bottom of the gate shall be angled to provide a knife-edge seal.

Penstocks shall be suitable for either on-seating or off-seating pressures and shall be drop-tight at their operating seating pressures.

Either rising or non-rising shafts shall be provided. They shall be mild steel or stainless steel grade 303 S21 or 316 S16. The shaft nut shall be machine cut from solid plastic material or gunmetal.

D3.7.4 Headstocks

Where remote operation of penstocks, gate or butterfly valves is required they shall generally be as shown on the Drawings, using headstocks or headstocks with operating shaft extensions.
Headstocks for direct connection to valves or penstocks shall be for use with non-rising stem valves. They shall be cast iron and fitted with position indicators. Stem bearings shall be gunmetal bushed.

If operational conditions require, handwheels shall operate through bevel gears.

If the installation requires, extensions shall be provided between penstock or valve and headstock. Extension lengths shall be adjustable during assembly on Site. Universal couplings shall be fitted next to the valve and the headstock, and the two couplings shall be arranged to give linear transmission of rotational movement between headstock and penstock shaft.

D3.8 Valve Operation

D3.8.1 Shafts and caps for tee-key operated valves

Operating and extension shafts for valves operated by tee key shall be capped.

Extension shafts shall be circular section. For valves installed in chambers, extension shafts shall be provided with split bearings, rigidly held on brackets spaced no more than 1,500 mm apart. For buried valves, the shaft shall be supported inside a protecting tube held on a purpose-made support, which shall be fixed to the top of the valve and provided with a shaft guide.

Bearings and shafts shall be suitably protected against corrosion.

Extension shaft couplings shall be provided with locking arrangements.

D3.8.2 Manual operating mechanisms

Manual closing of valves shall be by the clockwise rotation of a tee key or handwheel.

Tee-key operated valves shall be provided with detachable cast iron shaft caps, with keys to match the cap. One key shall be supplied for every five valves installed, with a minimum requirement of two keys in any one size.

Handwheels shall be shaped to give a safe grip without sharp projections, clearly marked with the direction of opening and closing and shall be fitted with integral locking devices. A padlock and chain will not be acceptable for locking.

Manually-operated valves and penstocks shall be capable of being opened and closed by one person, when the specified maximum unbalanced pressure is applied to the valve or penstock. Under this condition the total force required at the rim of the handwheel or at the tee key to open the valve or penstock from the closed position shall not exceed 30 kg (15 kg each hand). Where necessary, gearing and bearings shall be provided and the handwheel sized to fulfil this requirement.

Gearboxes shall be totally enclosed oil bath lubricated. Thrust bearings shall be provided so that the gearcase may be opened for inspection or be dismantled without releasing the stem thrust or taking the valve or penstock out of service. Oil and grease lubricated gearing, bearings and glands shall be protected against the ingress of dust and moisture.

Operating mechanisms shall be of the weatherproof type and those parts subject to submergence shall have a degree of protection IP68 to BS 5490 at a depth of submergence of 5 m. Where practicable, operating mechanisms shall be fitted with mechanical position indicators clearly visible from the operating position.

Headstocks of the non-rising shaft type shall each have an index pointer working over a graduated, open-to-closed position indicator fixed to the side of the pillar.

D3.8.3 Solenoid-operated valves

Solenoid-operated valves shall be of the direct acting type, full bore and balanced. They shall not depend upon pressure differential for their operation.

Valve bodies shall be of cast iron or stainless steel as specified with screwed or flanged ends. Sealing shall be by `O' rings.

Solenoids shall have direct current coils and an integral rectifier for use on a 220 V A.C. supply unless otherwise specified. The coils shall be encapsulated in epoxy resin.

Limit switches with voltage-free changeover contacts shall be provided for remote signalling of open and closed positions.

Enclosures shall have a minimum degree of protection IPW 67 to BS 5490.

A manual mechanical override shall be fitted.

D3.8.4 Pneumatic actuators – on/off type

Pneumatic actuators of the double or single acting type, with or without spring closing, shall be provided as specified. Cylinders shall provide satisfactory operation using dry, oil-free air at 5.5 bar g pressure and shall be factory tested for pressure retaining integrity at 16.5 bar g.

The valve actuator mechanism shall be totally enclosed. The cylinder shall be rigidly secured to the mechanism housing and shall not pivot, rotate, or swing during operation. The piston rod shall be enclosed in the housing and shall not be exposed to view.

Pneumatic actuations shall be fitted with a local valve-position indicator and handwheel-operated manual override. If pneumatic actuators are used on fail-close valves, means shall be provided for automatic closing on supply air failure.

A 4-port solenoid valve shall be provided to control the operation of double-acting actuators and a 2–port solenoid valve shall be provided for single acting actuators. Each solenoid valve shall be heavy-duty, single 24 V dc coil, two-position type, rated for a differential operating-air pressure of 8.5 bar g, with manual override facility.

In general the solenoid valves shall comply with the Specification for solenoid-operated valves.

Pneumatic actuators in areas specified in the instrumentation, control and automation section of this specification as being fieldbus system areas shall be able to be connected to the chosen fieldbus system. If there are no pneumatic actuators available that meet this requirement, use of conventional i/o wiring for the actuator involved shall be subject to approval.

The air connections on each cylinder shall be equipped with an adjustable flow-control valve. The flow-control valves and connecting piping shall be arranged to control the flow rate of exhaust air from the cylinder and to allow independent adjustment and control of valve opening and closing speeds.

Control valves shall be sized so that the time required for the piston to complete its stroke is adjustable between 30 and 120 seconds, with an air supply pressure of 5.5 bar g. Flow-control valves shall be brass or stainless steel.

Actuators shall be designed to eliminate any risk of contact between the actuator lubricant and the fluid conveyed.

D3.8.5 Pneumatic actuators – modulating type

Pneumatic actuators of the double or single acting type with or without spring closing shall be provided as specified.

Actuators shall provide satisfactory operation using dry, oil-free air at 5.5 bar g pressure and shall be factory tested for pressure-retaining integrity at 16.5 bar g.
The actuator shall be rigidly secured to the mechanism housing and shall not pivot, rotate, or swing during operation. The actuator shaft shall be enclosed in the mechanism housing and shall not be exposed to view.

Pneumatic actuators shall be fitted with a local valve-position indicator and handwheel-operated manual override. If pneumatic actuators are used on fail-close valves, means shall be provided for automatic closing on supply air failure. Otherwise, actuators shall be provided with the appropriate fail safe devices.

Actuators for modulating valves shall have the following accessories:

- An electronic or digital positioner which can accept 4-20 mA input signal and position the valve accordingly.

- An electronic position transmitter to provide 4-20 mA feed back of the valve position.

- Air sets in the supply and signal air lines.
- Pressure gauges of appropriate ranges in the supply and signal air lines.
- Limit switches to indicate fully open and fully closed positions.

Pneumatic actuators in areas specified in the instrumentation, control and automation section of this specification as being fieldbus system areas shall be able to be connected to the chosen fieldbus system. If there are no pneumatic actuators available that meet this requirement, use of conventional i/o wiring for the actuator involved shall be subject to approval.

The air connections on each actuator shall be equipped with adjustable flow-control valves. The flow-control valves and connecting piping shall be arranged to allow control of the flow rate of exhaust air from the actuator and to allow independent adjustment and control of valve opening and closing speeds. Control valves shall be sized so that the time required for the cycle time is adjustable between 30 and 120 seconds, with an air supply pressure of 5.5 bar g. Flow control valves shall be manufactured from brass or stainless steel.

The actuator shall be designed to eliminate any risk of contact between the actuator lubricant and the fluid conveyed.

D3.8.6 Electric actuators

Electric actuators shall operate valves and penstocks at opening and closing rates that will not impose unacceptable surge pressures on the pipework.

Actuators shall be rated at not less than 20 percent in excess of the power required to operate the valve or penstock under maximum working conditions.

Actuator enclosures shall have a minimum protection IPW 67 to BS EN 60529.

Actuator electric motors shall comply with BS 4999. For non-modulating type actuators, the motor short-time rating (STR) shall allow the successive full travel operation of the travel from open to closed and vice versa but shall be not less than 15 minutes. For modulating type actuators the motor shall have a duty-type rating (DTR) to meet the varying cyclic load requirements of the valve.

Electric motors shall be provided with built-in thermal protection complying with BS 4999: Part 111.

Actuators shall be complete with:

(a) An alternative system for manual handwheel and reduction gear operation which shall be lockable.

(b) An interlock, to prevent engagement of the handwheel whilst the actuator is being power driven and to disengage the manual drive positively when the power drive is started.

(c) Reversing type motor starter complete with isolating switch.

(d) Local and remote control selector switch when specified, which shall be lockable.

(e) Open, stop and close push-buttons.

(f) Potentiometer for remote valve position indication when remote control is specified.

(g) Torque switches for mechanical disengagement of the drive at the extremes of valve operation to limit excess torque.

(h) Supply failure and remote control available monitoring relays. The supply failure relay shall operate under single phasing and phase reversal conditions.

(i) Auxiliary and interposing relays as necessary.

(j) Voltage-free changeover type contacts for the remote indication of:

-Motor tripped on overload

-Fully open

-Fully closed

-Operating

-Supply failed

-Remote control available

The rating of volt-free contacts shall be not less than 15 A at 240V a.c. and 2 A at 50V d.c. unless otherwise specified. The contacts shall be suitable for inductive load switching.

(k) Anti-condensation heater

Separate or segregated terminal boxes shall be provided for the connection motor, heater and control cables.

D3.9 Valve packaging and installation

D3.9.1 Marking and packing

Each valve shall be indelibly marked with the diameter and pressure rating and shall carry a unique reference number to enable each item to be clearly identified with works fabrication records, works test certificates, delivery notes and the like.

Wherever possible, the identification marks shall be painted on the outside of the item but where there is not enough smooth surface area for the identification marks they shall be put on rust-proofed metal tags secured to the item with galvanised wire or chain (not through flange holes).

Valves shall be packed in the `closed' position except that uncrated resilient seat gate valves for transport to tropical areas shall be in the `open' position.

D3.9.2 Valve handling

The Contractor shall provide all equipment needed to handle and install valves and associated equipment without damage. The equipment shall include lifting beams, reinforced canvas slings, protective padding, cradles and the like. Unprotected wire rope or chain slings shall not be used for handling.

Temporary packing, coverings or crates provided for protection in transit shall not be removed (except for inspections, after which they shall be replaced) until immediately before installation.

D3.9.3 Valve installation

Valves shall be installed and commissioned in accordance with the manufacturer's instructions. After installation, valves shall be cleaned, and gates, discs, seats and other moving parts closely inspected, foreign matter removed, and the valves checked for ease of operation. Moving parts shall be lightly greased or otherwise treated in accordance with the manufacturer's recommendations.

Unless otherwise specified or directed by the Engineer, butterfly valves shall be enclosed in chambers, installed with the shaft horizontal, and supported as detailed on the Drawings. They shall be installed so that when the valve is opening the lower portion of the disc moves in the direction of the main or normal flow.

Unless shown otherwise on the Drawings, gate valves shall be installed with their shafts vertical.

Gate valves without external gearing, and not otherwise required to be in a chamber, may be buried. The buried part of the valve shall be protected as specified. Unless otherwise specified, backfilling shall be to just below the top of the valve or shaft shroud, and a surface box shall be provided.

Jointing, sleeving, external wrapping, anchor and thrust blocks, valve chambers, valve marker posts and the cleaning and disinfection of valves shall be executed as specified for the associated pipeline.

D4.0 COMPRESSORS AND SURGE VESSELS

D4.1 Compressors for surge vessels

The term 'compressed-air unit' shall include drive motor, base frame and all directly associated valves, switches and pipework required to form a fully-automatic unit supplying compressed air, continuously or intermittently as required, and at the specified rate and pressure.

Compressors shall be rated for continuous operation at full duty.

Cylinder heads shall be readily removable for inspection. Each cylinder shall be constructed to provide easy replacement and maximum cooling.

All necessary fittings shall be provided including:

- air-line check valve;
- delivery-pipe isolating valve;
- air filters.

Medium-duty air-compressor units, of which there shall be at least one duty and one standby, shall each comprise:

- reciprocating air compressor;
- induction drive motor;
- air receiver and filter;
- silencer;
- oil lubricator;
- oil-eliminating filter;
- air delivery line, including check valve, isolating valve, moisture trap and pressure regulator.

Compressors shall be tested in accordance with BS 1571.

Inlet and outlet pressure gauges shall be provided on the air receiver, and each gauge shall incorporate low and high pressure micro-switches with changeover contacts. A pressure-relief valve shall be fitted near the pressure gauge, rated to pass at least 200% of the compressor rated flow at 150% of the working pressure.

D4.2 Surge vessels

Vessels shall be cylindrical steel pressure vessels, designed, constructed and tested to BS 5500. Each vessel shall include:

(a) saddle supports and legs complete with holding-down bolts;

(b) drilled-and-tapped or flanged facings for the following fittings which shall be provided:

- pressure-relief air valve rated for not less than 150% working pressure and to pass 200% maximum air flow into vessel
- adequate access for inspection of the inside of the vessel;
- calibrated level sight glass of the reflective type covering the full range of water level in the vessel and having top and bottom shut-off cocks and hinged safety glass, and pressure/level calibrations carried on a substantial engraved plate;
- air vent and inlet valves;
- 150mm diameter pressure gauge and isolating cock;
- lifting lugs to enable handling of the vessel on Site without damage;
- flanged inlet and outlet branches;
- drain valve;
- high and low water level float switch with stilling tube and changeover-contact micro-switches rated for 220V/420V ac for both high and low level settings.
- all necessary pipes, fittings, brackets, fixings and the like required to mount system onto the pumping main.

Unless otherwise specified, surge vessels shall be of the diaphragm type, containing a removable liner of neoprene or similar material and an expansion cage. The liner and expansion cage shall be designed to accept a charge of air to given pressures for given volumes as stated in the detailed specification for surge protection equipment.

In accordance with BS 5500, an inspection and regulating authority shall be selected and appointed by the Contractor for the surge equipment.
The name and address of the Authority and extent and details of inspection to be done shall be submitted for approval before manufacture commences.

D5.0 CRANES

D5.1 Electric overhead travelling cranes

General requirements

Cranes shall be designed and constructed in accordance with BS 2573 and shall comply with the requirements of BS 466: Class 2 medium-duty operation.

The term ‘crane’ shall be deemed to include gantry rails, platform with handrails for maintenance use, down-shop conductors, end stops, holding-down bolts and all other items required for complete installation.

Cranes shall be prominently marked with their SWL on both sides of the crane bridge girders.

Crane hooks shall be fitted with safety catches and the hook block shall incorporate fully-guarded rope sheaves.

The maintenance platform shall be designed to provide safe access to the crane machinery and all high-level lighting and roof-mounted ventilation plant. Access to the platform shall be by fixed stairway from a convenient point in the pump hall.

Enough slings, ropes, shackles, lifting beams and the like shall be supplied to handle all the plant to be served by the crane. They shall be labelled or marked with the safe working load (SWL) and the purpose for which they are intended.

The crane, and all other lifting equipment supplied shall be tested by the manufacturer at his works. The tests shall be at 125% of safe working load, and test certificates shall be submitted by the Contractor.

Site tests shall be done by the Contractor who shall supply the necessary materials for the test loads. The test loads shall be removed from Site by the Contractor after successful tests have been completed.

Electrical requirements

All movements shall be electrically powered and be suitable for operating with the hook fully loaded. Motors shall be of the quick-reversing type with electro-mechanical brakes suitable for the duties specified. Limit switches shall be incorporated to prevent excess travel, or over-hoisting and over-lowering of the crane hook. Facilities shall be provided for the accurate location of the hook by means of ‘inching’ all the motions.

Crane operation shall be from ground floor level by bridge-mounted pendant push-button controls. Controls shall be mechanically and electrically interlocked to prevent inadvertent operation of opposing motions. The pendant shall be supported independently of the electric cable and shall be arranged for extending for operation when necessary.

Down-shop conductors shall be of the fully-insulated shrouded busbar type. The current collectors shall have renewable contact pieces. Festoon cables may be used for cross travel.
A crane isolator, lockable in the ‘off’ position and incorporating a warning lamp, illuminated when the supply is ‘on’, shall be provided at the bottom of the access ladder. A second isolator shall be provided at the control cubicle located on the crane platform.

The Contractor shall supply all necessary contactors, control cubicles and protection equipment necessary to operate the crane and provide adequate electrical protection against overload, phase and earth fault and fail-safe protection if the power supply fails.

All electrical equipment shall be fully tropicalised. Motors and switchgear shall be provided with anti-condensation heaters, which shall be energised when the crane is at rest, and suitable warning notices shall be provided.

D5.2 Hand-operated overhead cranes

Cranes shall be designed and manufactured in accordance with BS 2573 and shall comply with the requirements of BS 466 Class 2 medium duty.

The crane details and ancillary equipment provided shall conform with applicable parts of the General Requirements specified above for electrically-operated overhead cranes, except that the crane shall be manually-operated in all motions by conveniently-mounted endless chains, arranged for operation by one man.

D6.0 COMPRESSED AIR PLANT

D6.1 General

Compressed air plant shall include at least one duty and one standby compressor set which shall be electrically driven by cage induction motors.

Air shall be filtered at the compressor inlets to remove dust.

Oil lubricated compressors may be used provided that oil eliminating filters are installed on the compressor deliveries. Where oil-mist lubrication is recommended for pneumatic valve actuators, suitable lubricators shall be installed at each point of air use.

Air shall be cooled after compression using after-coolers. Air receivers shall be provided to balance supply and demand and to provide an operating reserve Air dryers shall be provided.

Noise from compressed air plant shall be limited as specified.

D6.2 Air intakes

Air intakes shall be positioned to avoid collection of contaminants including engine exhaust fumes and excessive dust, and away from any extractor fan discharge points.

Air may be admitted through an external wall or via an intake duct to the room which houses the compressors.

Louvered panels and primary filters shall be installed at the air inlet. Filters shall comprise removable panels with frame-mounted elements. The elements shall be washable, and a spare set shall be provided.

Intake ducting shall be galvanised steel and sized to minimise pressure drop and vibration. If needed to suppress low-frequency noise, a silencer of the multiple-aerofoil or beam-splitter type shall be installed within the duct, close to the inlet point.

If air is drawn by the compressors directly from the room, appropriate provision shall be made to protect equipment and pipework from ambient temperatures.

If air is drawn from outside the building, heat from the machines shall be dissipated effectively at times of high ambient temperatures. The compressor room shall be properly ventilated.

D6.3 Reciprocating compressors

Compressors shall be of the reciprocating oil-lubricated type shall be used

Each compressor shall be rated for continuous operation at twice the maximum air demand, or to recharge the receiver from empty in one hour, whichever is greater. They shall be suitable for intermittent operation and shall maintain the associated air receiver pressure between pre-set limits irrespective of actual air demand up to the maximum demand.

Cylinder heads shall be readily removable for inspection.

Each compressor shall be driven via a V-belt drive by a cage induction motor, rated to allow the compressor to operate at the safety valve setting without overloading. The compressor and motor shall be mounted on a combination baseplate, with slide rails for belt tension adjustment. A sheet-steel belt-guard shall be bolted to the base plate.

Where necessary, compressors shall have an automatic solenoid-operated unloading system to facilitate starting. This system shall be initiated by auxiliary contacts on the compressor motor starter, and shall be subject to an adjustable time delay.

Oil-lubricated machines shall have an automatic oil lubricator, fitted with indication of oil level and feed rate. The delivery side of each machine shall have an oil-eliminating filter with provision for draining into a portable container.

Each compressor shall have an inlet air filter and silencer, a pressure-relief safety valve, fusible plug, check valve and isolating valve.

Compressors shall be tested in accordance with BS1571 Part 2 .

Safety valves shall comply with BS6759 Part 2. The installation of safety valves, gauges and fusible plugs shall comply with BS1123 Part 1.

D6.4 After-coolers

Compressed air plant shall incorporate after-cooling.

Unless otherwise specified, a single after-cooler with isolating and bypass arrangement shall be provided for all applications.

After-coolers shall either be of the air-cooled type with finned-tubes and electrically driven cooling fan, or water-cooled shell-and-tube heat exchanger type. Materials in contact with cooling water shall be resistant to corrosion.

All heat exchange surfaces shall be accessible for cleaning.

Generally, the air outlet temperature shall approach the cooling medium temperature to within 10 deg. C at maximum air throughput or as otherwise specified.

D6.5 Air receivers

Air receivers shall be installed where needed to balance a variable rate of air consumption with a fixed rate of supply. The capacity shall be enough to limit the number of compressor starts to no more than 10 per hour.

Air receivers shall be of welded-steel construction to BS5169, with a corrosion allowance of 2 mm, and may be either vertically or horizontally mounted. The vessels shall have suitable supporting feet or cradles.

Fittings shall include a pressure gauge, pressure safety valve, automatic drain valve with isolating valve and separate manual drain valve. The drain connections shall discharge to an approved point.

Safety valves shall comply with BS6759 Part 2. The installation of safety valves, gauges and fusible plugs shall comply with BS1123 Part 1.

Pressure switches with volt-free contacts shall be installed on the receiver to control the associated compressors and initiate a low pressure alarm. The control relays shall normally be mounted in the same panel as the compressor motor starters. Both the cut-in and cut-out pressure settings of the standby machine(s) shall be set lower than the corresponding settings of the duty machine(s).

D6.6 Air dryers

Air dryers shall be of the automatic twin cell desiccant type designed to produce an outlet dew point better than -40 deg. C.

Dryers shall be of the wall-mounting type, with twin carbon steel adsorber vessels packed with silica gel beads.

Vessels shall each have an electric immersion heater designed for a 415 V a.c. supply, unless otherwise specified. Air inlet and outlet connections, and drying media filling and emptying pads shall be provided.

Dryers shall incorporate an automatic adsorber changeover and reactivation system comprising solenoid-operated valves and a control panel. Air for reactivation shall be taken from the dry air outlet side, and passed through the absorber to be reactivated at a rate controlled by an orifice plate.

Dryers shall be thermally insulated, and clad with aluminium sheet.

Each adsorber shall be sized for 8 hours drying duty when operating at pressures between 4.5 and 7 bar g. The reactivation cycle shall include a period of air purge with the heater deactivated, to cool the reactivated adsorber to operating temperature prior to changeover.

The control panel shall incorporate the following features:

(a) Isolating switch for 415 V a.c. supply.

(b) Circuit protection.

(c) Cycle timer.

(d) Heating timer.

(e) Heater contactors.

(f) Control relays.

(g) Control transformer.

(h) Indicator lamps for CELL No 1 DUTY, CELL No 2 DUTY, HEATER No 1 ON, HEATER No 2 ON.

(i) Indicator lamp for DRYER FAULT, volt-free contacts for remote transmission of fault, and RESET push-button.

(j) LAMP TEST push-button.

D6.7 Air pipework

Pipework up to and including 50 mm N.B. shall be in steel to BS1387, with heavy fittings in malleable iron to BS143 screwed to BS21. Threaded joints shall be made with a temperature resistant jointing compound. PTFE tape shall not be used.

Pipework over 50 mm N.B. shall be in steel with flanged joints, designed to the appropriate pressure rating.

Steel pipework shall be hot dip galvanised in accordance with Part 3 of the Specification. No other internal coating is required.

Instrument air pipework and fittings from the off-take point on the air supply main onwards shall comply with the Particular part of the Specification.

Pipework shall be arranged to minimise transmission of vibration. Where necessary, connections shall be made with anti-vibration couplings.

Where condensation is likely to accumulate, such as following compression or cooling of ambient air, or discharge of reactivation air from dryers, the accumulation of moisture shall be minimised. Appropriate traps and automatic drain valves discharging to approved points shall be installed.

Thermal insulation and cladding shall be arranged to provide access to valves and other components for maintenance.

D6.8 Air isolating valves

Air isolating valves shall be generally of the cast iron gate type to BS5150 or butterfly type to BS5155.

Air isolating valves up to 50 mm N.B. may be in copper alloy to BS5154 where compatible with the required temperature and pressure rating.

Isolating valves shall be tested in accordance with BS5146: Part 2.

D7.0 FANS

D7.1 General

Unless otherwise indicated, the requirements of this Section shall not apply to individual fans having a duty air flow rate of $0.7m^3/s$ or less.

The make and type of fan shall be subject to approval.

Fans shall be type-tested in accordance with the requirements of BS 848 and shall be selected to give the air flow rate and sound power level specified.

Fans shall be built to a fully-developed design and shall be capable of withstanding the pressures and stresses developed during continuous operation at the selected duty. Belt-driven fans shall be capable of running continuously at ten per cent in excess of the selected duty speed.

Values of the resistance to air flow of items of equipment, ductwork and the total distribution system, where indicated in the contract documents, are approximate. The Contractor shall verify these values based on the equipment offered, and provide fans capable of delivering the required air volume when operating against the actual total system resistance.

Where fans are supplied with noise attenuators, full details shall be provided.

Fan drives shall be as detailed elsewhere in this Specification.

Fans shall be installed using bolts, nuts and washers with all ‘as-cast’ bearing surfaces for bolt heads and washers counterfaced. Holding-down bolts for fans and motors shall be provided with means to prevent the bolts turning when the nuts are tightened. Anti-vibration mountings shall be as detailed elsewhere in the Specification. Fans heavier than 20kg shall be provided with eyebolts or other purpose-made lifting facilities.

Where specified, or as necessary, fans shall be fitted with variable inlet vanes which shall be matched to fan performance to give stable control. Vanes shall be interlocked to ensure movement in unison.Operation shall be manual or automatic as specified. Where manual control is specified, the operating device shall facilitate positive locking in at least five different positions.

Vane blades shall not vibrate or flutter in any possible operating condition, and the construction of the linkage system shall minimise friction and lost motion.

Unless otherwise specified, the shaft and impeller assembly of all fans shall be statically and dynamically balanced. All propeller fans shall be statically and dynamically balanced where the impeller diameter is 750mm or greater. Where indicated, limits of vibration severity shall be in accordance with BS 4675: Part 1.

Fan bearings shall be suitable for the installed attitude of the fan. They shall be grease/oil ball and/or roller type or oil-lubricated sleeve type. All bearing housings shall be precision-located and arranged so that bearings may be replaced without the need for realignment. Bearing housings shall be protected against the ingress of dust and, where fitted with greasing points, they shall be designed to prevent damage from over-greasing. For grease-lubricated systems, the bearings shall be provided initially with grease recommended by the bearing manufacturer. For oil-lubricated systems, the housings shall provide an adequate reservoir of oil and shall include a filling plug and be oil-tight and dust-proof. Systems other than total-loss types shall include an accessible drain plug. All bearing lubricators shall be located to facilitate maintenance.

D7.2 Ceiling fans

Ceiling fans shall comply with BS 4934 for safety and BS 5060 for performance.

Fans shall be speed-controlled in at least fivediscrete steps, using a separate surface-mounted controller. The controller shall use a tapped auto-transformer for speed control.

Motors shall be capacitor start/run type, with inner wound stator and rotating outer body and incorporating ball-type bearings .

Motors shall be suitable for use in a tropical environment.

D7.3 Centrifugal fans

Centrifugal fans for high-velocity high-pressure systems (defined within the HVCA Specification DW/141) shall be backward-bladed type.

Unless otherwise specified, centrifugal fans of more than 7.5kW at the fan shaft shall be of the backward-bladed type having a fan total efficiency not less than 75%.

Fan casings shall be built to allow withdrawal of the impeller after installation. Fans other than those in air-handling units shall be provided with flanged outlet connections and spigoted inlet connections unless otherwise specifed, except that, for negative pressures greater than 500Pa, inlet connections shall be flanged. A plugged drain point shall be fitted at the lowest point in fan casings. Permanent indication shall be provided showing the direction of rotation of the fan impeller. Fan casings shall be provided with removable access panels incorporating purpose-made air seals. The sizes of access panels shall facilitate cleaning and maintenance.

Impellers shall be of mild steel or aluminium alloy, of riveted, welded or other approved construction, with spiders or hubs of robust design.

D7.4 Axial-flow fans

Axial-flow fan casings shall be rigidly constructed of mild steel or aluminium alloy, stiffened and braced where necessary. Mounting feet shall be provided where necessary for bolting to a base or to supports. Inlet and outlet ducts shall terminate in flanges to facilitate removal. For in-duct mounting fans, the length of the fan casing shall be greater than the combined length of the impeller(s) and motor(s) and electrical connections to the motors shall be through an external terminal box secured to the casing.

Impellers shall be of steel, aluminium or plastics and the blades shall be secured to the hub or the blades and the hub shall be formed in one piece. The hub shall be keyed to the shaft. Blades shall be aerofoil or laminar section, capable of pitch adjustment where specified.

For axial-flow fans driven by motors external to the fan casing, the requirements for drives and guards mentioned elsewhere in this Specification shall be met. Unless otherwise indicated, a guard is not required for any part of a drive which is inside the fan casing. An access panel with purpose-made air seals shall be provided in the fan casing. The access panel shall be sized to facilitate maintenance.

Where axial-flow fans of the bifurcated type are specified, the motors shall be out of the air stream. Motors may be placed between the two halves of the casing in the external air or may be placed within the fan casing, provided that effective ventilation is given to the motors.

D7.5 Propeller fans

Propeller fans shall be ring-mounted or diaphragm-mounted as specified. Impellers shall be of steel, aluminium, or plastics. Blades shall be securelyattached to the hub, or the blades and hub shall be formed in one piece.

D7.6 In-line centrifugal and mixed-flow fans

Mixed-flow fan casings shall be rigidly constructed of mild steel, or aluminium alloy stiffened and braced where necessary. Mounting feet shall be provided where necessary for bolting to a base or supports. Inlet and outlet shall terminate in flanges to facilitate removal. Stator vanes shall be of mild steel or aluminium alloy. The design shall

facilitate access to the impeller. Where motors are mounted external to the casing, the requirements for drives and guards given elsewhere in this Specification shall be met. An access panel with purpose-made air seal shall be provided in the fan casing. The access panel shall facilitate maintenance.

D7.7 Mechanical roof-extract units

The fans used in roof extract units shall meet the appropriate requirements of the preceding clauses relating to fans generally and to particular types of fans. Cowls and bases shall be of materials which are resistant to the weather and solar radiation, and are appropriate to the location of the fan. Casings shall be formed to facilitate a weatherproof fitting to the building structure. Adequate access to electrical supply terminals and lubrication points shall be provided by means of hinged cowls or otherwise as appropriate. Back-draught dampers or fire-release dampers shall be provided where specified. Bird guards of not greater than 25mm mesh shall be provided as an integral part of the unit
.

D7.8 Protectively-coated fans and fans for corrosive or hazardous applications

Where fans are required to handle toxic, corrosive, flammable, explosive or high-temperature gases, the materials of construction shall be chosen appropriately, and all relevant safety regulations shall apply. Bearings and lubrication arrangements shall be suitable for the conditions. Protectively-coated fans shall meet the appropriate requirements of the preceding clauses relating to fans generally and to particular types of fans, and the form of protection shall be as indicated. Where a protective coating is required for use with corrosive gases the coating shall cover all parts of the complete fan, motor and casing assembly which will be affected No fan shall be installed if the protective coating has been damaged. Impellers shall be of coated steel, stainless steel, aluminium or plastics as specified.

For fans are installed in hazardous atmospheres, requirements shall be as specified.

D7.9 Air filters

Filters shall be complete with robust purpose-made holding frames which shall not distort in operation. Filters shall be arranged to facilitate access for cleaning, removal and refitting. Purpose-made seals shall be provided to minimise air leakage around filters and the effectiveness of the seals shall not be impaired by periodic removal and refitting of the filter cells.

Where a flame-proof filter medium is required, the material shall comply with the requirements of BS 476.

The design air velocity at the face of the filters shall not exceed 2.5m/s. At the design air-volume flow rate the initial (clean) resistance shall not exceed 90Pa for filters.

Enough spare filter elements shall be provided to replace the complete filter bank.

Unless otherwise indicated, filters shall be selected from the following range of preferred nominal sizes:

(a) 600mm x 600mm;
(b) 500mm x 500mm.

D8.0 MISCELLANEOUS ITEMS

D8.1 Automatic in-line strainers

In-line strainers shall be totally-encased, self-cleaning, metallic-element filters suitable for installation in and forming part of the pipework system. They shall be capable of removing all waterborne debris which may reasonably be expected to pass through a 25mm-spaced coarse bar screen.

The strainer body shall be manufactured and designed as a pressure vessel. If fabricated, it shall be designed in accordance with the relevant sections of BS 5500 except for inspection and witness of testing which shall be the responsibility of the Contractor to arrange.

As a minimum, the strainer body shall contain:

(i) Removable man-way cover allowing inspection and maintenance of the strainer elements and cleaning mechanism. The man-way cover shall be easily re-mountable and incorporate lifting eyes or similar to facilitate handling with an overhead crane.

(ii) Inlet and outlet branches rated and sized to suit the pipework system in which it is installed without necessitating a change in pipe diameter.

(iii) Air vent valve.

(iv) Drainage valves and pipework necessary to route drainage water into the building drainage system.

(v) Pressure differential switch to give adjustable settings for strainer stop/start control and high differential pressure alarm and reset.

The strainer element and associated brackets, fixings and screws shall be of a non-corrodible material equal to or better than 316 S16 (EN58J) stainless steel. The elements shall be readily removable from the strainer and designed to withstand a differential pressure equal to the maximum generated head within the pipe system.

The backwash mechanism shall be held within water-lubricated bearings which shall be arranged to prevent the ingress of sand. The mechanism shall be electrically-driven from an IP55, 415V, 3–phase motor via a suitably-rated gear box and shear pin or similar device to prevent damage occurring due to the backwash device ‘jamming’. The drive shall be arranged by means of a cam and micro switch on the main drive shaft to ‘park’ at an unperforated section of the screen in order to reduce the backwash flow when the screen-drive motor is not operating.
Where the operating head of the pipe system is not enough for backwashing, a single-entry close-coupled centrifugal pump and fully-submersible type motor shall be used. The pump shall have a suitable NPSHr characteristic, and be able to handle trash likely to pass a 25mm-spaced coarse bar screen.

D8.2 Access steelwork

Ladders, step-irons, platforms, covers and handrails to be supplied and fixed under this Contract are generally shown on the Drawings, but the Contractor shall ensure that the Works are designed for safe operation and maintenance by providing whatever safe access arrangements are needed.
Any small areas of chequer plating or similar coverings that are needed to cover gaps between items of Plant and the surrounding structure, and any access ladders, platforms and handrails that need to be attached to items of Plant to facilitate operation, inspection or maintenance, shall be supplied and erected by the Contractor.

The Contractor shall also supply and erect adequate access to all handwheels, sight glasses, gauges, lubrication points and any other items to which access is necessary for routine maintenance.

Handrails shall consist of double-ball forged-steel standards with tubular rails, hot-dip galvanised in accordance with BS 729.

Chequer plating shall be of 'Durbar' or other non-slip pattern, not less than 4.5mm thick (exclusive of pattern) and hot-dip galvanised after fabrication in accordance with BS 729.

Aluminium alloy flooring may be used instead of chequer plating. It shall comply with BS 1470 material H 30 TB.

D8.3 Handrailing

Handrailing shall be double-rail, 1100mm high. On stairways, it shall be not less than 900mm high above the stairs measured vertically from the nose of the tread.

Standards shall be 38mm diameter solid forged-steel to BS 4360 Grade 43A with 60mm diameter solid-forged steel balls at handrail locating points, drilled to give 1.5mm clearance to handrails. Each ball shall incorporate a concealed grub-screw with Allen-type head to secure the rail. Standards shall have a minimum base width of 65mm, drilled for M16 fixing bolts and be set at maximum 1800mm centres.

Handrails shall be 33.7mm external diameter, 3.2mm thick tubular steel to BS 1775 Grade 13. Joints shall be arranged to coincide with the spacing of standards where possible otherwise they shall have butt joints with a tubular steel ferrule, plug-welded or fixed with a 5mm diameter countersunk head pin.

Removable sections of handrail shall have half-lap joints secured with a countersunk head pin. Chains across openings shall be 10mm with 3 links per 100mm galvanised mild steel. The hooks and retaining eyes shall be securely fixed to the balls of the standards.

All components for handrailing shall be hot-dip galvanised after manufacture in accordance with BS 729.

D8.4 Manually-raked inclined bar screens

Screens shall have the aperture size specified, to prevent coarse debris from entering the inlets and protect the plant against mechanical damage. They shall be inclined at an angle of approximately 15 degrees from vertical to facilitate raking. Inclined length shall not exceed 2.5m

Screens shall be designed for mounting as shown on the Drawings. The design shall avoid the formation of areas of stagnation in the flow. Sealing shall be provided between the frame and the inlet channel walls.

Screens shall be designed to withstand the maximum possible pressure differential across the screen when fully blinded, without incurring any damage or overload. The working headloss across the screen at maximum flow shall not exceed 50 mm following screen cleaning. Unless otherwise specified the velocity of the flow through the screen shall not exceed 1.2 m/s.

The equipment shall be capable of operation under all duty flow variations and debris loadings, and shall be capable of withstanding the impact of large floating material and heavy objects in the flow without damage to the screen.

Screen bars shall be accurately set and secured to give the designed clearance between the bars. The bars shall extend from the sole plate, to which they shall be individually welded, to a point above maximum possible top water level, at which point they shall be individually welded to the screen top plate. Intermediate stiffening supports shall be welded to the screen bars as necessary for screens to accommodate hydraulic pressure due to depth and high flow rates through the inlet channels. The screen bars shall be individually welded to each stiffening support. Stiffening supports shall be fitted so they cannot impede raking

The sole plate shall be profiled to induce screenings and debris to be directed onto the screen bars and not to accumulate at the foot of the screen. The leading edge of the sole plate shall be level with the inlet channel invert.

The top edge of the screen shall be profiled to enable easy raking-off of screenings material.

When specified, for applications where large or heavy oversize debris may accumulate against the screen, hoisting equipment shall be provided. The screen shall then be fitted with hoist-guide pulleys, and operator access shall be provided to enable manual removal of oversize objects from the flow.

Screens shall be constructed from hot-dipped galvanised steel.

Raking shall be manual and screenings shall be transferred manually to a rakings container. The scope of supply shall include manual rakes and manually moved containers, with all accessories needed to remove the collected debris.

Rake handles shall not exceed 2.5 m long. Rake tines shall be designed to fit the screen apertures, and tines shall be of material which cannot damage the screens.

Rakings containers shall be sized so that, when fully loaded with the typical tropical organic material expected, the gross weight shall not exceed 50kg. They shall be fitted with handles to facilitate manual or mechanical handling as specified.

Where needed, means shall be provided for safe man-access to a raking platform which shall be provided along the whole width of the screens, above the screen top edge. Access shall be by ladder with handrail. Safety handrailing shall be provided along the whole length of the platform, which may be designed as partly-removable during raking. Secure anchorages at suitable intervals shall be provided for operatives safety harness, using hook-on arrangements.

D8.5 Surge analysis and report

Where specified, the Contractor shall make a surge analysis for pumping systems and report the results to the Engineer. Analysis of the performance of the pumping station and its associated delivery pipeline shall be included.

The analysis shall determine the magnitude of surge pressures in the pumping mains under normal operation and under power failure, with all possible combinations of plant operating.

On completion of the surge analysis, a report shall be drafted and 3 copies shall be submitted to the Engineer.

The report shall include the following:

(a) A short introduction, describing the scope of work done and the method used for analysis.
(b) A summary of all the results.
(c) A description of the system studied, detailing the hydraulic components and any assumptions made.
(d) The basic equations that have been used.
(e) An engineering discussion of the system design and operation, including operation before and after installation of the surge protection measures recommended.
(f) System characteristics and determination of steady flowrates for the full range of operating conditions.
(g) A detailed explanation of the engineering significance of all computer results of transient simulations.
(h) Selected pressure and flow graphs at important locations along the mains, plus an envelope of maximum and minimum pressure vs distance for each transient simulation.
(i) Detailed observations and conclusions.
(j) A brief assessment of the suitability of the following surge suppression devices:
    (i) Surge vessels
    (ii) Air valves
    (iii) Closing-speed control of non-return valves
    (iv) Feed tanks
(k) Calibration and verification of which methods of suppression would be acceptable.
(l) Final recommendation of surge suppression equipment proposed, with preliminary drawings and specifications

The surge analysis report shall be submitted to the Engineer within 3 months of the date of starting the Contract.

When the Contractor is notified of acceptance of the report, detailed specifications and installation drawings for the surge pressure control equipment shall be submitted to the Engineer within six weeks.

The surge suppression devices shall be installed with the main equipment.

When the system has been installed, the Contractor shall take measurements to verify correct performance at different operating conditions.

If the performance proves inadequate, the Contractor shall at his own cost make any modifications needed to keep system maximum and minimum pressures within acceptable limits.

D8.6 Stoplogs

Unless otherwise specified, stoplogs shall be corrosion-protected mild steel. They shall be strong enough to withstand the maximum water pressure which could be applied to them in service without distortion causing any leakage.

Stoplog slots to be provided in structures shall be fitted with channel-section inserts, built-in to the structure during construction. Materials used for the inserts shall be corrosion resistant and designed for long life in installed conditions at site. The slot inserts shall be designed to ensure effective sealing with stoplogs.

Stoplogs shall be fitted with suitably durable sealing arrangements, designed for long life when kept in the storage provided, and designed to ensure minimal leakage between adjacent stoplogs and the stoplog slot inserts when in position. The side seals, bearing against the fixed slot inserts, shall be low-friction type, to minimise the lifting force needed. Rubber seals shall not be used.

Hardened steel lifting pins or eyes, designed for use with the stoplog hoist and lifting beam, shall be incorporated with each stoplog.

D8.6.1 Stoplog lifting beam

Stoplog lifting beams shall be designed to couple and uncouple automatically in service when lifting and lowering stoplogs, and shall fit in the stoplog slots to facilitate operation.

Beams shall be of galvanised steel, with self-lubricating bronze bushes at bearing points.

Beams shall be provided with permanently attached steel-wire slings for lifting with the hoist lifting hook

D8.6.2 Stoplog hoist and monorail

Unless otherwise specified, stoplog hoists shall be manual wire-rope hoists, designed for operation using an endless chain by one man.

Stoplog hoists shall run on overhead monorails leading from each stoplog slot to the position for stoplog storage to be provided. The hoist hook shall incorporate a safety catch to facilitate safe operation.

Hoists shall be provided with enough lifting cable to enable stoplogs to be positioned at the bottom of the lowest of the stoplog slots provided.

The complete lifting system including monorail, hoist, slings, lifting beam and stoplog pins shall be strong enough to lift the weight of one stoplog and overcome the friction in the stoplog slots when the stoplog is fully loaded by water pressure up to the top of the stoplog, with a design safety factor of not less than 2

D8.6.3 Stoplog storage

Stoplog storage shall be in corrosion-protected steel racks, designed to accommodate stoplogs and lifting beam, including any spare stoplogs provided.

PART E - PROCESS STANDARD SPECIFICATION

E1.0 MIXERS AND FLOCCULATORS

E1.1 General

Chemical mixing shall use either hydraulic or mechanical energy and shall provide uniform mixing of the chemical in the main flow of water at all times over the entire range of chemical doses applied and flows through the works. A high degree of local turbulence is considered necessary for satisfactory mixing. The electrical power or headloss requirements to achieve efficient mixing shall be optimized to ensure minimum energy consumption at each mixing location.

Mixing energy shall be defined either by the 'mean velocity gradient', G, in the expression water power (W) per unit flow (m^3/s) is equal to the product of the viscosity (Pa-s), mean residence time (s) and square of the velocity gradient (s^{-1}) or any other method approved by the Engineer.

E1.2 Static Mixers

Static mixers shall be inline mixers where dosed chemicals are mixed by energy of water flow alone, employing stationary mixing elements which forces water and chemicals to mix through a progression of divisions, expansion and redistribution of the flow. They shall have no moving parts and have minimal maintenance requirements.

The mixer shall comprise fixed elements installed in a housing of diameter same as the pipe diameter and shall be provided with raised face P16 flanged end connections to BS EN 1092 part 1 or BS EN 1515 part 1, unless otherwise specified. The chemical injection pipes shall form an integral part of the mixer unit. Any section of empty pipe between the outlet of the mixer and the sampling point shall not be considered as part of the mixer.

The mixer housing shall be designed and tested in accordance with ANSI B31.3 and constructed of carbon steel to BS 4360 Grade 43A. The internals of the mixer shall be protected with a fusion bonded epoxy coating to a minimum thickness of 300 microns.

Mixing elements shall be compatible with the chemicals to be dosed at the maximum concentrations likely to be in contact with the mixer and shall be of carbon steel to BS EN 10028 Grade 154 - 360 protected with a fusion bonded epoxy coating system or stainless steel 316S14 or 304S14 to BS 3605.

The supply and location of the chemical injection point shall be the responsibility of the static mixer supplier. Each static mixer shall be provided with two injection points (one duty, one standby) for each chemical. Injection points shall be fitted with 25mm stainless steel injection boss for each injection point. Injection tubes shall be of the withdrawable under pressure type. The material of construction of the injection tubes shall be compatible with the chemical dosed at its maximum dosing solution concentration and shall be stainless steel or hastealloy C276 or fibre reinforced plastic and shall be adequately supported and designed to withstand the flow velocity at the point of application and any flow or turbulence induced vibrations. The injection tubes shall be supplied complete with cooperation cocks and non-return and isolating valves.

Each mixer unit shall have a flow direction arrow and lifting lugs.

The mixer shall be designed to achieve a 95% minimum degree of mixing or to give a coefficient of variation (Cov) not greater than 0.05 for the mixer over the range of water flows in the pipe at a head loss less than the head loss specified

Sampling point shall be located three pipe diameters downstream of the outlet end of the mixer. Facilities shall be provided for taking representative samples of the water from the pipe cross section for testing purposes. The tests shall demonstrate that 95% of all concentration measurements taken from the pipe shall be within plus or minus 10% of the mean concentration over the specified flow range in the pipe and the specified dose range.

E1.3 Flocculators

Flocculators shall be slow speed vertical shaft top entry type with four-blade gate paddles or other proven paddle arrangement subject to the approval of the Engineer.

The degree of agitation shall be defined by the `mean velocity gradient', G (sec^{-1}) in the expression water power (W) per unit flow (m^3/s) is equal to the product of viscosity (Pa.s), mean residence time (s) and square of the velocity gradient (s^{-1}). The flocculation condition shall be defined by the product of velocity gradient and mean residence time (=volume of tank ÷ flow).

The drive unit shall be suitable for 24 hour a day continuous operation. The drive unit shall consist of an electric motor and gear reduction unit with a flexible coupling provided between the motor and the gear reduction unit. When specified, the motor shall be provided with a variable speed control system to allow control of the rotational speed of the flocculator over the operating range. The speed adjustment shall be by manual operation of a `knob' or `lever' with a pointer moving against a scale calibrated in the flocculator speed units.

Lifting lugs shall be provided to permit lifting the complete drive unit. The motors shall be readily separated from the gear reduction unit. All gearing shall be helical or spiral bevel and shall be totally enclosed. Output shaft shall be enclosed in a drywell which provides positive leak proof sealing. The flocculator shaft shall be rigidly coupled to the output shaft.

The coupling to the flocculator shaft shall be readily accessible so that the gearbox may be easily removed and replaced without entry of personnel into the mixing chamber or shutdown of the flow.

Gear reduction units and motor bearings shall be oil or grease lubricated. All points where oil leakage may occur shall be suitably trapped to prevent oil contamination of water. The bearings shall have a L-10 rating of 100,000 hours.

Each flocculator shall be mounted on structural steel beam or channel supports with chequered plate access platform complete with handrailings. The opening in the platform shall be large enough to permit removal of flocculator and the shaft after the removal of the paddles.

The arrangement of the paddles, their dimensions and the tip speed shall be of a design to provide efficient flocculation of the chemically treated water.

Flocculator paddles and paddle shaft shall be constructed of stainless steel type 316. Alternatively suitably protected teak is acceptable as a material for paddles.

Flocculators shall be suitable for installation in concrete tanks. The mean residence time in the tanks and the velocity gradient shall be as specified in the Particular Requirements. The flocculation tank shall consist of one, two or three equal-size compartments in series depending on the downstream process flocculation requirements. Tanks shall be provided with baffles arranged in such a way to eliminate short-circuiting. If necessary an allowance shall be made in the residence time for short-circuiting. The number of flocculation tanks to be provided in parallel shall be dictated by the maximum tank size acceptable to the Contractor. Where tanks are provided in parallel the water flow shall be divided equally between the tanks by weirs and flocculated water shall overflow out into a common outlet channel.

The flocculators and the tanks shall be designed to achieve uniform mixing of chemically dosed water to produce flocs of characteristics suitable for the downstream solid-liquid separation process.

E2.0 CLARIFIERS

E2.1 General

Clarifiers shall be of a single design for each works. and shall be of concrete construction each with identical internal dimensions.

E2.2 Lamella clarifier

Plates shall be partly submerged with plates laid to extend above the normal water surface to enable settled water to flow out between individual plate spacings. The space below the lamella plates shall not be less than 2.5 m for sludge collection and to accommodate scrapers or hoppers. The slope of the plates shall be not less than 55º to the horizontal.

The plates shall be designed to slide down into position and it shall be possible to remove the plates singly by two men working off duckboards. Plates shall be supported on stainless steel supports. The supports shall be designed to withstand the weight of the plates when the clarifiers are empty during draining, in operation with possible additional loads due to sludge and other material deposits and additional loads during maintenance.

The plates shall be constructed in stainless steel sheets at least 0.7 mm thick. Minimum plate width shall be 1.25 m and the horizontal centre-to-centre plate spacing shall be 80 mm. The plates shall be flat sheets; corrugated sheets will not be acceptable. The plates shall be stiffened at the top and bottom as recommended by the manufacturer. The plate efficiency shall be greater than 95%.

Facilities shall be provided to allow easy and safe access into the lamella thickener below the plates for maintenance of the sludge scrapers.

The Contractor shall demonstrate that the proposed lamella clarifier design has been in satisfactory and successful operation in similar applications in at least two countries outside the proposed manufacturer's country of origin for a minimum of 5 years and the proposed manufacturer has been engaged in the design and manufacture of such systems for a minimum of 10 years. Evidence of the relevant experience shall be submitted with the tender.

E2.3 Lamella clariifer channels

Flocculated water shall be distributed evenly to all the plates. The method of distribution shall be by slotted openings in the side walls of channels running on either side of the plates along the length of the tanks, which shall introduce the flocculated water between each pair of plates near the bottom. The channels and the openings shall be hydraulically designed to equally distribute the influent to all of the plates.

The settled water shall be collected by submerged orifices, one between each pair of plates, in decanting launders.
The flocculated water distribution and clarified water collection channels in each lamella row and channel components shall be of concrete construction.

Alternative flocculated water distribution systems and settled water collection systems proven in waterworks over a minimum period of five years will be considered; design details and evidence of relevant experience shall be submitted with the tender for approval.

E2.4 Sludge Scrapers

Scraper assemblies shall each comprise a rotating radial arm[s] scraper supported by a bridge, bridge mounted centre drive unit and all associated equipment necessary to safely and efficiently remove sludge from the clarifier tank floor without re-suspension so as to not influence the quality of the clarified water. Consideration will be given to peripheral drive systems of proven design.

The sludge shall be scraped to a central hopper from which it shall be evacuated by gravity under hydrostatic head in the clarifier. The plant shall be rated for continuous operation and shall be suitable for operation in an outdoor environment.

For systems adopting a centre mounted drive unit/system, the scraper assembly shall comprise a central torque tube of adequate stiffness supported from a bearing assembly mounted on the bridge, designed to carry the rake and sub-assemblies. The bearing should carry the final gear drive ring to engage with a pinion gear on the output shaft of the motor reducer, or the motor reducer may be directly coupled to the torque tube.

The bridge and scraper assemblies shall be designed to accept without distortion any normal torsional or bending/deflection loads which may occur during erection, testing and operation Any structural movements of the bridge/scraper radial arm[s], must be limited so as not to effect the efficiency of both sludge removal and performance of the clarifier.

Underwater bearings particularly support and stuffing boxes will not be acceptable.

The scraper shall comprise either one radial arm or two diametrically opposite radial arms spanning the clarifier and bearing a series of vertical blades sweeping the settled sludge on the floor to a central hopper.
Alternatively it shall have two diametrically opposite long radial and two diametrically opposite short radial arms each bearing a series of vertical blades sweeping the settled sludge on the floor to a central hopper.
Scraper blades shall be firmly secured to the bottom of truss members and shall include angle stiffeners.
The scraper central shaft shall also be fitted with an additional single blade for scraping sludge off the sides of the central hopper.

Scraper blades shall be manufactured in steel with an epoxy finish and shall be fitted with renewable synthetic rubber wearing strips to maintain contact with the floor surface, and to cope with possible minor undulations in the floor. The renewable inserts shall be not less than 100 mm by 15 mm in cross-section and supported within 40 mm of the contact edge by stainless steel 316 backing plates using bolts, nuts and washers in stainless steel 316 bolts. Adequate provision for vertical adjustment shall be made to suit the extent of wear allowable before replacement and to ensure proper clearance above the tank floor for efficient scraping and to allow for deflection of the bridge and assembly tolerances.

The scraper shall be used by the Contractor to trowel the cement mortar screed over the base of each clarifier. The scraper blades and squeegees shall be removed and replaced by timber screeding boards for this operation. The Contractor shall clean the mechanism and replace the scraper blades and squeegees after this operation.

The drive unit shall comprise a variable or fixed speed electric motor as specified with coupling and totally enclosed reduction gear, all mounted on girders so that the shaft couplings are accessible, and the gear box easily removed and readily replaced without entry into the tank. Working access to all sides of the drive unit shall be possible.and to all items of equipment requiring periodic adjustment, inspection and maintenance.

All points where oil leakage may occur shall be suitably trapped to prevent oil contamination of water. Greasing points shall be extended as necessary to readily accessible locations.

The drive shall be capable of producing free and uniform rotation without binding, when operating with excessive accumulations of sludge on the tank floor. It shall be designed to start from rest following a sit-down condition such as start-up following restoration of power after a power failure. The drive unit shall be designed with a minimum service factor of 2 to withstand the blade loads and hydraulic drag on the scraper mechanism whilst operating under the specified performance criteria and at the maximum rotational speed recommended by the manufacturer.

Each drive unit shall be provided with a torque limiting coupling between the geared motor and the gearbox suitable for manual adjustment of the breaking torque. The coupling shall incorporate a limit switch to shut down the motor during an overload condition. An alarm shall be annunciated at the motor starter and also at any other location specified in the Particular requirements. Additionally shear pin overload protection shall be provided in each drive unit as a back-up to the torque limiting coupling device. The shear pin protection shall be designed to fail at a torque 25% in excess of the torque limiting coupling maximum setting and also at not more than 75% of the torque for which the drive and scraper structure mechanism is designed. Shear pins shall be placed in an accessible location and shall not be subjected to bending stresses. All shear pins shall be full diameter type.

Drive unit motors shall be as specified in Section 4.13 of the Specification. gear assemblies shall conform to American Gear Manufacturer's Association (AGMA) standards and shall be designed with a service factor of not less than 1.5. Gears shall be supported on anti-friction bearings and shall be oil lubricated. Oil fill, breather and level indication devices shall be provided.

All bearings on the drive unit shall be selected to give a minimum calculated B 10 design life of 100,000 hours.

For peripheral drive systems, the bridge shall be provided with wheels of polyurethane construction running on the outer wall of the clarifier. A special durable running surface such as brass shall be installed, true to line and level. Also, all guide wheels and traction wheels shall be provided with bearings adequate for the loads to be carried and for the conditions of operation.
Mechanical plant shall be designed so that it may easily be maintained and removed from the tanks.

E2.5 Clarified water removal

The clarified water in circular sedimentation tanks shall be removed in a peripheral launder located outside the clarifier. The clarified water shall enter the launder by submerged orifices.

E2.6 Clarifier access

Circular clarifiers shall be provided with access to the peripheral weir, scraper drive and flocculator drives. Where necessary platforms shall be provided to carryout maintenance work. Scraper bridge shall be provided with open mesh flooring.

Sludge blanket clarifiers shall be provided with access on top for cleaning and maintenance of clarifiers and between the clarifiers. Access shall also be provided to any plant rooms located on top of the clarifier.

Lamella clarifiers shall be provided with access to the flocculator drives and scraper drive. Access shall also be provided between each clarifier and to clarified water collection channels. The Contract shall ensure that the access provided is adequate for the removal of plates for cleaning. Facilities shall be provided for removing plates for cleaning.

All desludging valves shall be provided with access for maintenance. Access shall also be provided into sludge galleries.

All access ways shall be provided complete with hand railings.

E3.0 FILTERS

E3.1 `General

The filters shall be rapid gravity type of concrete construction, each identical in internal dimensions and designed for washing by the simultaneous application of air and water as specified.
Filter wash water shall be disinfected filtered water.

Filters shall operate on a constant rate principle. The filter inlet system shall be designed to ensure that the total inflow is divided equally between filters in service at all works throughputs.

Backwash pumps, air blowers and other filter ancillary plant shall be located within the filter block.

E3.2 Filter media

Filtration shall be through suitable filter media appropriate for the duty and shall be supported by a layer of suitably graded packing pebbles.

E3.3 Sand

Filter sand size shall be defined by its effective size and uniformity coefficient.

The effective size is defined as the size of the aperture through which 10% by weight of sand passes, and the uniformity co-efficient is defined as the ratio of the size of aperture through which 60% of the sand passes to the effective size.

Filter sand shall be a hard grained quartz or silica sand having no constituent in any way friable or liable to mechanical breakdown during handling and use.

The sand shall not contain organic matter, clay or silt.

Loss in weight on acid washing shall be less than 2% by weight. Acid washing shall be of the water-washed and dried sample, with 24 hours contact in 10% by volume hydrochloric acid.

Loss in weight on ignition at 350°C for one hour, which is a measure of the organic content, shall be less than 2% by weight.

The filter sand shall have a saturated-surface-dry specific gravity of not less than 2.40.

The loss due to attrition (friability) shall not exceed 1% by weight over 100 hours backwashing on a laboratory test basis by the method described in Appendix E3-1.

Filter sand shall be substantially free of fine and coarse material and at least 95% by weight shall be between the grading limits specified.

E3.4 Packing gravel

Filter sand shall be supported by a layer of suitable graded packing gravel. The packing layer shall be not less than 50mm depth and be such as to ensure adequate and uniform distribution of washwater and air after leaving the nozzles, with the minimum risk of mixing sand with the layers of packing media, or of fines in the sand penetrating the nozzle apertures.

Filter gravel or pebbles shall be rounded or waterworn stones which, when placed in layers in a filter above and around the nozzles, will distribute the washwater effectively.

The gravel shall be washed to remove all carbonaceous matter, clay and silt, and loss on acid washing shall be less than 4% by weight. Acid washing shall be of the water-washed and dried sample with 24 hours contact in 10% by volume of hydrochloric acid.

E3.5 Media source

The Contractor shall submit with his tender his detailed specification for the media which he proposes to use for the Works (which shall be at least to the requirements set out herein), and shall include details of his proposed methods of test and quality control (including friability) and details of the source from which he proposes to obtain his supplies.

Following award of Contract, the sources of media shall be subject to the consent of the Engineer. Upon preliminary approval of sources and within two months of the award of Contract, the Contractor shall submit to the Engineer a 10kg representative sample of each media for testing and consent.

Only when the Engineer has approved the samples, shall orders be placed. The Contractor shall thereafter not alter his sources without the prior written consent of the Engineer.

All filter sand shall be obtained from an approved single source and supplier and shall be washed, heat dried, graded and packed in bags as approved by the Engineer for delivery to or storage at Site. Hessian bags, and bags made of similar materials which may deteriorate during transit or in open storage shall not be used.

E3.6 Spare media

Spare media to replace that lost in the first 5 years of filter operation following the issue of the Maintenance Certificate, shall be provided.

Media for storage shall be dried and subjected to the quality control procedures specified for media to be placed in filters.

The spare media shall be packed in bags suitable for long storage. Bags shall be stacked on pallets of the close-boarded type as specified elsewhere for chemical storage.

E3.7 Media placing

Following installation and satisfactory testing of filter floors and when the Engineer is satisfied that the installations are complete, the Contractor will be given written permission to commence charging the filters, which shall be carried out to the procedures set out in section 23 of the AWWA (American Water Works Association) Standard for Filtering Media (AWWA B100-80) with the exception that the wash rate may be varied.

Filter media shall be carefully placed and not charged by dropping or dumping, or any other method which, in the opinion of the Engineer, will be detrimental to the media, nozzles, floors and sealants. Chutes may be employed only after 300mm of covering has been placed over the floor. After placing each layer of media it shall be thoroughly back washed to clear debris, mud and other impurities. This shall be followed by an air distribution test to check that nozzles have not been damaged during the placing of the media.

Prior to setting the filters to work, the media in each filter shall be backwashed in-situ and skimmed to remove fines so that, in the top 150mm of the media, the proportion of fines does not exceed 5% any time up to the end of the Period of Maintenance. Fines are defined as the particles which pass through an aperture 0.9 times the effective size of the media. The depth of material removed in skimming shall be replaced by an equal depth of media to the specified grading.

The Contractor shall supply and replace free of charge sand lost in the washing of filters during the periods of setting to work, site tests and the Period of Maintenance.

The Contractor shall not place the media in a filter until, in the opinion of the Engineer, the construction work is reasonably complete, and that there is no threat of extraneous construction debris contaminating the media. Where construction work in the filters is necessary after placing the media, the Contractor shall use suitable heavy duty covers to protect the media from contamination.

E3.8 Filter underdrain system

E3.8.1 General

Filter underdrain system shall include all items and materials within the filter cell, above base slab and below the gravel layer. Such items and material within each filter cell shall include the means for collecting filtered water for uniformly distributing air and backwash water, together or separately and for retaining, supporting, and sealing the filter underdrain system; all as necessary for a complete underdrain system.

Prior to commencing any work on the system, the Contractor shall submit complete details of the design, construction and the operating characteristics of the underdrain system to the Engineer for review and approval. Such submissions shall include supporting calculations with up and downwards loadings and their derivations, materials of construction, head loss data for filtration and backwash, installation details, levelling tolerances, allowable percentage of flow mal-distribution within a filter cell and any other information which in the opinion of the Engineer is necessary to assess compliance with the Specification.

The Contractor shall demonstrate that the proposed underdrain system has been in satisfactory and successful operation in similar applications for a minimum of 5 years and the proposed manufacturer has been engaged in the design and manufacture of such systems for a minimum of 10 years.

E3.8.2 System description

The system for the collection of filtrate and the distribution of air scour and washwater shall be by means of nozzles set in a reinforced concrete floor (i.e. plenum floor).The plenum floor shall be either constructed in-situ concrete or from individual floor sections.

E3.8.3 Materials

Underdrain system shall be of proven non-corrodible materials. All exposed metals shall be type 316 stainless steel. Other materials used in the construction of the reinforced concrete floor including the sealants shall be as recommended by the manufacturer subject to the approval of the Engineer.

Nozzles shall be made of polypropylene.

Items fabricated from asbestos cement shall not be used in the underdrain system.

E3.8.4 Design requirements

The underdrain system shall be designed to provide uniform draw-off of filtered water and uniform distribution of air and water over the whole area of the filter and shall comply with the following:

(i) The spacing of nozzles shall be such that local disturbance of the pebbles and/or sand layers surrounding or above the underdrain does not affect the performance of the filter.

(ii) Nozzles shall:

- Incorporate separate entrances for air and water.
- Be capable of being adjusted to exactly the desired level.
- Be capable of being replaced without damaging fixed sealing rings.
- Be "sand tight" bearing in mind the media in question which is likely to reach the nozzles.
- Be capable of being capped watertight to allow pressure testing of the underdrain system.

(iii) Nozzles shall be designed to provide efficient separate positive control of the distribution of air or washwater.

The underdrain system shall be structurally designed to withstand the following loadings:

- Net loading during backwash at the maximum back wash rates.
- Net downward loading.
- A safety factor to account for dynamic shock loadings which may occur during the starting and termination of air and water backwash.
- All loads incurred during shipment, handling and installation.
- To prevent any excessive loadings due to blockages of the filter nozzles or accidental introduction of high pressure water, the Contractor shall include a pressure relief chimney, with free discharge, in the washwater pipework system. A pressure relief valve system shall not be acceptable. The overflow from the system shall be arranged to discharge to the site overflow receptor system or to the filter inlet channel.
- Access to the plenum shall be by a 600mm diameter access manhole on the side wall of the filter. Man holes or similar sealed removable covers shall not be provided on the filter floor.

E3.8.5 Installation

The Contractor shall install the filter underdrain systems in strict accordance with approved drawings and procedures.

The Contractor shall take all necessary measures to ensure that the false floor containing nozzles and the air and water conveying system of pipes or channels connected to the plenum are free from any concrete, sand or other debris which could otherwise block or partially block the nozzles.

The underdrain system shall be laid to level, within the tolerances stated in the consented drawings and shall be confirmed by measurement following installation.

All apertures in the underdrain system shall be plugged until the nozzles are installed, to avoid the possibility of extraneous material entering the underdrain system during installation.

Media shall be placed in the filter only after all construction work in the proximity of the filter has been completed and air distribution tests have been successfully carried out. Where this is unavoidable the media shall be kept under cover using heavy duty polythene sheeting to prevent contamination of the media with construction debris.

E3.9 Air scour plant

E3.9.1 Air blowers

Air supply to the filters shall be provided by Rootes type positive displacement rotary air blowers supplying oil-free air. The blowers shall include at least one duty and one standby unit. Automatic starting of the standby on failure of the duty is not required. The selection of the duty blower shall be carried out at the motor starter. Blowers shall be sized to deliver directly the necessary flow rate of air at the pressure required by the filter.

Blower speed shall be less than 2000 rpm. Bearings shall be rated for a minimum B-10 life of 100,000 hours.

Each blower shall be driven via a Vee belt drive arrangement by a cage induction motor. The blower and motor shall be mounted on a combination baseplate with slide rails for belt tension adjustment. A sheet steel guard shall be bolted to the baseplate and the baseplate shall be provided with heavy duty anti-vibration mountings.

Each blower shall have an inlet air filter, inlet and discharge silencers, a pressure safety valve, pressure gauge, check valve and isolating valve. Due allowance shall be made for operating a pressure safety valve set at a higher pressure without overloading the blower or its driver.

Where necessary to facilitate starting of the blower (eg. at reduced voltage), an unloading arrangement shall be incorporated in the blower delivery system and shall include a motorised valve operated via auxiliary contacts on the blower motor starter.

Under no circumstances shall a blower be selected to operate at or above the continuous maximum temperature or discharge pressure specified by the blower manufacturer. A clear safety margin shall be allowed, preferably of at least 0.2 bar.

In process applications where the discharge pressure may approach the maximum permitted, the machine shall be arranged to shutdown on high discharge temperature and a suitable switch and thermometer shall be provided.

The sealing arrangement between the timing gearbox and compression chamber shall ensure that leakage of oil cannot take place during operation or shutdown.

Where necessary to facilitate starting of the blower (eg. at reduced voltage), an unloading arrangement shall be incorporated in the blower delivery system and shall include a motorised valve operated via auxiliary contacts on the blower motor starter.

Where appropriate, the blower and its accessories may be preassembled on a steel frame.

The noise from the air blower plant shall be limited as set out in the Specification. If necessary the blowers shall be provided with acoustic enclosures and the blower room shall be sound proofed.

E3.9.2 Air intake

Air intakes shall be positioned in a manner which avoids collection of contaminants such as engine exhaust fumes and excessive dust and always away from any air extractor fan discharge points.

Air may be admitted to the room which houses the blowers either through an external wall or, where this is not possible, via an intake duct.

A louvered panel or panels shall be installed at the air inlet point together with primary filters. The filters shall comprise removable panels with convoluted elements mounted in frames. The elements shall be of the washable type and a spare set shall be provided to facilitate substitution for this purpose.

Intake ducting shall be in galvanised steel and of adequate proportions to minimise pressure drop and vibration. Where necessary to suppress low frequency noise, a silencer of the multiple aerofoil or `beam splitter' type shall be installed within the duct close to the inlet point. Where air is drawn from outside the building, then heat from the machines must be dissipated effectively at times of high ambient temperatures. The room shall be properly ventilated.

E3.9.3 Air pipework

The blowers shall be connected to the pipework by stainless steel braided flanged flexible connectors not less than 250mm long.

Valves and pipework covering air shall be designed for air velocities not exceeding 30m/s. Care shall be taken in the design of the filter inlet to handle high air velocities.

Air scour pipework shall be located at such an elevation and shall ensure that water cannot siphon back to the blowers.

Provisions shall be made for the release of air from the system at the end of the air scour before the rinse commences. The necessary valve/pipework shall be provided as appropriate to the filter design proposed.

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E3.10 Backwash plant

E3.10.1 Pumps

Washwater shall be delivered direct to the filter by pumps or drawn by gravity from an elevated storage tank.

The pumps shall be of the double entry split casing or end suction centrifugal type and shall be admitted to the filters at flows recommended by the Contractor.

A minimum of two identical washwater pumps shall be provided to serve as duty and standby units.

Automatic starting of a standby unit in the event of failure of a duty unit is not required.

Selection of the duty washwater pump shall be carried out at the motor starter.

The pumps shall be self-priming with their drive motors mounted above flood-level and connected to the pump via suitably supported intermediate drive shafts.

E3.10.2 Pipework

Pipework shall be complete with all necessary stays, brackets, thrust collars and rings to facilitate erection and to prevent movement.

Washwater delivery pipework shall be designed to cope with the maximum hydraulic loadings likely, particularly with respect to supports and anchorages. The maximum velocity through washwater pipework and the filter wash inlet valve shall not exceed 3.5m/s. Care shall be taken in the design of the pipework and underdrains to handle any possible high velocities and to avoid surge, cavitation and uneven pressure within the system.

A protection device shall be provided to safeguard washwater system from the effects of water hammer.

E3.10.3 Washwater flow control

The washwater supply pipework to the filters shall be provided with a flowmeter of the magnetic type. The rate of flow shall be indicated local to the control valve.

The rate of backwash flow to the filters shall be controlled by a butterfly valve located within the filter block and downstream of the flow measuring element.

Operation of the valve shall be manual by lockable handwheel. The valve shall be provided with a position indicator.

Backwash system designs which require two wash rates, the different rates shall be achieved either by providing a suitably sized bypass to the control valve or by the use of he control valve.

The maximum velocity through the control valve shall not exceed 5 m/s.

E3.11 Filter valves and motive power systems

E3.11.1 Valves

Butterfly valves shall be used for the filters in preference to penstocks or sluice valves. The use of penstocks shall be limited to the filter inlet. Where valves are required for flow control, butterfly valves shall be used.

Valve operating mechanism including any actuator shall be accessible for removal and maintenance, and clear of any water surface.

Valves shall be sized by the Contractor to enable the filters to operate within the hydraulic limits set down in the Specification but also so that the following upper limits of velocity through valves or penstocks are not exceeded:

Filter inlet	1.0 m/s
Filtered water outlet	1.5 m/s
Washwater inlet	3.5 m/s
Waste washwater outlet	2.0 m/s
Air inlet	30.0 m/s

Each filter shall be provided with means for draining the filter completely. The drain valve shall be not less than 150 mm diameter and shall be operated by hand wheel. Discharge pipework shall be provided to direct the water to a suitable drainage system in the pipe galleries. If gravity drainage is not possible, a pump sump with duty/standby submersible pumps complete with level sensing system shall be provided.

All butterfly valves shall be made by the same manufacturer, and shall be rubber seated and double flanged. Wafer type U-section through-bolted flangeless valves for insertion and clamping between flanges shall not be used.

Where filter inlet isolation other than by valve or penstock is proposed, a manually operated gate shall be provided to isolate the flow and permit maintenance of the device.

E3.11.2 Motive power systems

Filter valves which require to be operated as part of the washing cycle shall be power operated as specified. The time taken to open or close any valve/penstock shall be less than 60 seconds.

In the event of motive power failure, filter valves, including outlet control valves, shall remain `held' in the position they were in prior to power failure.

Valves and penstocks operated during the backwash sequence shall be fitted with proximity switches; volt free contacts shall be provided for transmitting signals for remote operation and/or state lamps and initiation of valve/penstock failure alarms.

E3.11.3 Pneumatic actuators – on/off type

Pneumatic actuators shall comply with the requirements of the Mechanical Standard Specification for both modulating and non-modulating valves and penstocks.

E3.12 Filter-internal and gallery pipework

Flexible jointing shall be provided as necessary on all runs of pipework particularly at main movement joints in structures.

Pipework generally shall be of steel or ductile iron and shall be adequately supported. Pipes to be built into concrete shall have puddle or thrust flanges as appropriate.

Access shall be provided to the pipework and valves opposite each filter. In the case of a continuous pipework gallery, access shall be provided by means of ladders and platforms located at least at opposite ends or each gallery and if necessary in the middle of the gallery. In the case of non-continuous gallery, access shall be provided to each section (pit) of the gallery by means of ladders fixed to the wall of the filtered water channel opposite each filter.

Access to the filter base sections (plenum floor) shall be achievable without dismantling the main filter pipework. The clearance for access below the filter floor fittings and support beams shall be at least 600 mm.

Entrance manholes shall be provided to each compartment within the filter base; 600 mm blank flanged spigots shall lead to the floor voids (one to each filter void) and a similarly mounted but flush fitting studded steel cover, 600 mm x 500 mm, shall lead down to any central lower air/water distribution channel between the filter sections.

E3.13 Location of pipes and channels

Clarified water shall be distributed to the filters in channels which run along the end of each filter remote from the central pipe gallery. The filter washout channels shall be located beneath the filter inlet water channels.

The dimensions of the filter inlet pipes and channels shall be such that when all filters are operating at the maximum filtration rate, the difference in level between the highest and lowest water level in the inlet channel system shall not exceed 100 mm.

Filtered water shall be delivered to a filtered water channel located centrally within each pipe gallery. The filtered water channel shall be hydraulically isolated from the filter outlet/pipework. The outlet from each filter shall be taken to a concrete weir box with side entry discharge into the filtered water channel. The level of the weir shall be set at or above the top of the media level in the filter.

The filtered water channel shall be designed to carry a flow equal to the theoretical flow from all filters operating at the maximum filtration rate. The highest water level at the remotest filter shall be 100 mm below the weir/trough discharge level and the maximum velocity in the channel shall not exceed 1 m/s.
Filter gallery pipework and access platforms shall be designed to enable lifting gear to be positioned for subsequent removal of pipes, valves and penstocks for maintenance purposes.

The access platforms shall also be arranged to give easy access to pipework, valves and services located on filter front walls.
Filtered water channel drainage facilities shall be provided together with the necessary isolation to facilitate future inspection and maintenance.

Filter washwater inflow pipes may be located in the duct space between the filtered water from the duct space to drain by gravity.

The common used filter washwater channel and the washwater outlet valves/penstocks shall be sized to ensure that, at maximum discharge rates, water does not pressurise the washout channel or back-up in the filter washout bay. The minimum requirement is for conduits to be sized for a `dump' and for washing of one filter simultaneously. A ‘dump’ is defined as the discharge of the contents of a filter via the washwater outlet valve.

E3.14 Filter plant access

The top of the filters shall be provided with walkways around three sides of each bank of filters excluding the sides common with the central gallery, and between filters. Access from the top of the filters shall be connected to the central covered upper filter gallery. The sides of the upper central gallery shall be of glass panel construction above a height of 1000 mm to allow operators to observe the washing of filters from the central gallery. The filter wash control panels shall be located in the central gallery opposite each filter. Access to the filters shall be provided from two opposite ends at least at one level. It shall also be possible to access administration building and the filter plant rooms from the filters.

Stair access shall be provided from upper gallery to lower gallery from the opposite ends.

E3.15 Filter plant lifting equipment

An overhead hand-operated hoist shall be provided and installed in:

- The lower pipe galleries;
- Washwater pump basement(s) where applicable;
- Washwater pump motor room(s) where applicable;
- Air blower room(s).

Each hoist shall have adequate capacity for handling the largest items of Plant in the area commanded and shall be provided with lifting chains, hooks and slings, runways and fixings,

The hoist system in the lower galleries shall be designed to aid the placing of pipework and valves and their removal for maintenance if required. The blower room(s) hoist shall be designed for off-loading from vehicles.

E4.0 WASTE TREATMENT FACILITIES

E4.1 Submersible mixers

Submersible mixers shall be of the axial flow type with shrouded propeller and horizontal motor and propeller shafts.
The design requirements of the mixer shall be as follows:

(a) Maintain solids in a uniform suspension throughout the tank without shearing the flocculated material.
(b) Totally submerged operation to a depth 1.5 times the normal depth of submergence.
(c) Operation in sludge of at least twice the specified solids content.
(d) Capable of starting from a "sit-down" condition without the need to raise the mixer and then lower it after start-up.
(e) Suitable for continuous operation in the sludge of specified physical and chemical characteristics without undue wear and tear.
(f) Motor rates shall be not less than 20% in excess of maximum absorbed power rating.
(g) Capable of being operated at any depth and capable of angular positioning both in the horizontal and vertical planes with location stops at no greater than 30°.

Mixers shall be designed to be raised or lowered and shall be easily removed from its working position without the need to enter the tank in which it operates. Each mixer shall be provided with a guide rail and post with integral davit fixed to the wall of the tank. Davit arms shall be at a height no greater than 2.25m above local platform or hardstanding. The base of the guide rail shall be fixed to the floor of the tank.

The davit post shall be rotatable or pivoted and be provided with means for lowering the mixer on to the walkway adjacent to the tank when it is raised out of the tank. The davit shall be provided with all necessary ropes, shackles and pulleys. Pully block shall be suitable for exterior applicable without corroding. The complete lifting unit shall be rated for twice the maximum duty required.

Mixer motors shall have a built in cooling system which shall permit continuous operation at rated output both when submerged and not submerged.

Motor cable terminations shall be provided with cable sleeve and strain relief. The cabling to the motor shall be securely sheathed to prevent fouling with the propeller. The cabling shall be of the correct length allowing only a minimum of excess length.

Motor bearings shall be maintenance free.

The propeller and propeller shaft shall be in stainless steel to BS EN 10090. All installation accessories including guide rail and wire rope shall also be in stainless steel.

E4.2 Thickeners and scrapers

E4.2.1 Thickeners

Thickeners shall be continuous flow type comprising a cylindrical tank of reinforced concrete construction and a sludge scraper. The design of the thickener shall be to TR 189, ' Sludge Treatment Plant for Waterworks', Water Research Centre, UK, 1983 or any other design proven in waterworks coagulant sludge thickening for at least five years; design details and evidence of relevant experience shall be submitted with the tender for approval.

E4.2.2 Sludge Scraper

Thickening tank scrapers shall be the rake type and shall comprise of a fixed support bridge, a rotating rake spanning the full diameter carrying rake blades, bridge mounted centre drive unit, and all associated equipment necessary to safely and efficiently remove sludge from the thickener tank floor without re-suspending.

The sludge shall be scraped to a central hopper from which it shall be evacuated by gravity or pumps as specified. Plant shall be rated for continuous duty and shall be suitable for operation in an outdoor environment.

The rake assembly shall comprise a central torque tube of adequate stiffness, supported from a bearing assembly mounted on a fixed bridge of steel construction and carrying the rake and sub-assemblies. The bearing may carry on the final gear drive ring to engage with a pinion gear on the output shaft of the motor reducer, or the motor reducer may be directly coupled to the torque tube.

The assembly shall be suitable for installation in tanks of specified side water depths and floor slopes.

The rake assembly shall be fitted with two arms spanning the thickener and bearing a series of vertical blades consisting of a central spiral blade and outer blades set in echelon formation mounted at an angle to the arm, sweeping the settled sludge on the floor. It shall also be fitted with an additional single blade for scraping sludge off the sides of the central hopper.

Rake blades shall be manufactured in steel and shall be fitted with renewable synthetic rubber wearing strips (squeegees) to maintain contact with the floor surface, and to cope with possible minor undulations in the floor. The renewable inserts shall be not less than 100mm by 15mm in cross-section and supported within 40mm of the contact edge by stainless steel backing plates. Adequate provision for vertical adjustment shall be made to suit the extent of wear allowable before replacement.

The scraper shall be used by the Contractor to trowel the cement mortar screed over the base of each thickener. The scraper blades and squeegees shall be removed and replaced by timber screeding boards for this operation. The Contractor shall clean the mechanism and replace the scraper blades and squeegees after this operation.

The fixed bridge structures shall be supported on the tank walls and constructed from rolled steel beam sections that span the tanks. One half of the bridge shall be provided with galvanised mild steel walkway, handrailing and toeboards. The fixed bridge structures shall be shot blasted and zinc sprayed after manufacture and painted with an approved paint system. The walkway shall comprise open mesh flooring, 750mm wide and not less than 20mm thick, of the specified pattern with individual panels weighing not more than 50 kg. The panels shall be of adequate section to support a uniformly distributed load of 5 kN/m2. Walkway panels maximum deflection shall be 0.005 of the span or 5mm, whichever is the least.

Handrailing and flooring shall be provided between the point of access to the bridge and extend to 1500mm beyond the drive unit. In the vicinity of the drive unit it shall be widened to provide a minimum 750mm clear unobstructed flooring around both sides. Handrailing and toeboards, 150mm high and 5mm thick shall be fitted around all three sides of the walkway.

The bridge structures shall be designed to withstand self weight, weight of a superimposed load of 5 kN/m2 over the complete walkway and a wind loading of 40 m/s. Under the design loads the maximum deflection shall not exceed 1/360 of the span.

Steps shall be provided as necessary for access to the peripheral end of the bridge.

The drive unit shall comprise of a variable or fixed speed electric motor as specified with coupling and totally enclosed reduction gear, arranged so that the shaft couplings are accessible, and the gear box easily removed and readily replaced without entry into the tank. Working access to all sides of the drive unit shall be possible.

The drive shall be capable of producing free and uniform rotation without binding, when operating with excessive accumulations of thickened sludge on the tank floor. It shall be designed to start from rest following a sit-down condition such as start-up following restoration of power after a power failure. The drive unit shall be designed with a minimum service factor of 2 to withstand the blade loads and hydraulic drag on the scraper mechanism whilst operating under the specified performance criteria and at the maximum rotational speed recommended by the manufacturer.

Each drive unit shall be provided with a torque limiting coupling between the geared motor and the gearbox suitable for manual adjustment of the breaking torque. The coupling shall incorporate a limit switch to shut down the motor during an overload condition. An alarm shall be annunciated at the motor starter and also at any other location specified in the Particular requirements. Additionally shear pin overload protection shall be provided in each drive unit as a back-up to the torque limiting coupling device. The shear pin protection shall be designed to fail at a torque 25% in excess of the torque limiting coupling maximum setting and also at not more than 75% of the torque for which the drive and scraper structure mechanism is designed. Shear pins shall be placed in an accessible location and shall not be subjected to bending stresses. All shear pins shall be full diameter type.

Drive unit motors shall be as specified and gear assemblies shall conform to American Gear Manufacturer's Association (AGMA) standards and shall be designed with a service factor of not less than 1.5. Gears shall be supported on anti-friction bearings and shall be oil lubricated. Oil fill, breather and level indication devices shall be provided.

The reduction gear shall incorporate an oil dam so that the oil contained is not lost in the event of a seal failure.

All points where oil leakage may occur shall be suitably trapped to prevent oil contamination of water. Greasing points shall be extended as necessary for readily accessible locations.

All bearings on the drive unit shall be selected to give a minimum calculated B10 design life of 100,000 hours.

E4.2.3 Supernatant removal

The supernatant shall be removed in a peripheral launder located outside the thickener tank. The effluent shall enter the launder by overflowing a V-notch weir which shall be provided for peripheral channels in sections with vertical adjustment. The weir plates shall be constructed from stainless steel grade 316 or epoxy coated steel and shall have a minimum thickness of 6mm and shall be supplied complete with stainless steel 316 anchor bolts and sealing strips.

Holes for anchor bolts shall be slotted to provide vertical adjustment of not less than 30mm.

E4.3 Sludge pipework and valves

All isolating valves on the sludge pipelines shall be resilient seated sluice type, eccentric plug type or straight through diaphragm type. Sludge pump delivery pipework shall be provided with pressure relief and non-return valves.

Relief valves shall be adjustable spring loaded type capable of passing the whole of the output of the pump. Valves shall be arranged to discharge the relief individually back to the balance tank compartment in service and thickeners as appropriate. Small bore pipework shall not be used on the relief. The discharge of the relief shall be visible.

Sludge pipework shall be designed to minimise sludge settlement and blockages and shall be easy to flush and clean. Pipe tapers shall be of the flat type and where possible branches from sludge lines shall be taken from the top of the pipe.

Sludge pump suction and delivery pipework shall be provided with rodding branches and flushing connections complete with isolating valves and terminating in hose connectors.

E5.0 CHEMICAL PLANT

E5.1 General

The contractor shall design, supply and install the complete system for each chemical to be handled including the chemical storage tanks, solution/slurry preparation systems, water supply system, pumps and fittings, together with the system of administering the chemicals to the points of application. Where strainers are necessary, valves and fittings shall be provided to allow the strainers to be removed for cleaning.

The system shall be complete with dust extraction and filter equipment, chemical handling and weighing equipment, and all other accessories specified and required to provide a comprehensive chemical plant in all respects.

In the layout of the plant adequate space shall be provided for access to carry out operations and maintenance of equipment.

Particular attentions shall be paid to the layout of the chemical pipework, which shall be functional and neat in appearance. Generally, where pipework is not installed in main ducts, it shall be supported not less than 150 mm clear of the floor.

Where necessary, equipment and pipes shall be suitably protected from the effects of cold weather. Protection of equipment and pipes may also be required for other reasons such as local heating effects and/or condensation problems.

E5.2 Storage and reception

Chemical building shall be designed to receive supplies of chemicals by road transport and shall provide for unloading and transport to storage. Lorry hardstandings shall be provided for all chemical unloading areas.

Facilities shall be provided as specified for unloading chemicals delivered in individual or palletised packages.

Storage areas for chemicals delivered in packages shall be sufficiently large to provide space for storage, access corridors for personnel and mechanical handling equipment.

Following features shall be considered in the design and layout of the storage areas:

- Good access for mechanical handling equipment such as pallet trucks, trolleys etc. Adequate access corridors shall be provided and shall be sized for manoeuvring pallet trucks into position making allowances for their turning radius;
- Packages shall be placed about 25 to 50 mm away from the walls, particularly if condensation on walls is likely to occur.
- Windows shall be avoided in the store.
- Doors shall be draught proofed.
- Good access to packages shall be provided to ensure good stock rotation.
- Bags shall be stacked on pallets.
- Adequate ventilation and where applicable dust filters and extractors shall be provided.

E5.3 Chemical plant safety

The Contractor shall design the plant to a high standard of safety and shall comply with all local statutory requirements and where such local standards do not exist, those of any other relevant bodies recognised or applied locally unless otherwise specified. The Contractor's design and installation shall comply with the standards and codes of practice of his country of origin.

The chemical storage and handling plant shall conform to the relevant technical service notes and literature published by the potential chemical suppliers and plant manufacturers and any other guidelines published by reputable authorities.

The Contractor shall obtain the approval of the chemical supplier for the design of the reception and storage facilities before proceeding with installation. In the case of toxic or hazardous chemicals the Contractor shall afford the suppliers the opportunity of offering advice on safety precautions to be taken on the design layout, operation and maintenance of the plant.

Safety showers and eye baths shall be provided in the chemical solution preparation and dosing areas.

The contractor shall supply and install all necessary warning and safety signs to BS 5499.

Signs shall be manufactured from durable, non-fading, and weather resistant materials. Materials shall be of durable quality and chemical resistant for their intended environment, and suitable for both indoor and outdoor sue.

Signs shall be in stove enamelled aluminium with rounded corners and drilled fixing holes.

A suitable backing board shall be provided for mounting suppliers notices either on a clear wall just inside the access door or adjacent to plant as appropriate.

Safety signs shall use local or internationally recognised pictorial representations, such as those in BS 5378 and BS 5499.

E5.4 Chemical handling

E5.4.1 Pallet trucks

Pallet trucks shall be of the hand powered hydraulic type with wheels made of polyurethane. When loaded to its maximum safe working load the full lift from the lowered position shall not be less than 100 mm. The lowering speed shall be infinitely variable by hand lever which shall be in the neutral position whilst manoeuvring.

E5.4.2 Pallets

Pallets for transport and storage of chemicals and other specified material shall be of the close or open boarded and reversible or non-reversible types with two-way or four-way entry, as specified. In open boarded pallets a maximum spacing of 50 mm between deck boards (whether top or bottom) shall not be exceeded. Pallets dimensions shall be as specified and shall be fully compatible with the pallet trucks supplied under the Contract.

Pallets shall be constructed in accordance with BS ISO 6780. Deck boards shall have sectional dimensions not less than 25 x 125mm and shall be of European redwood or approved equal. Blocks shall be 100mm cubes and bearers shall have sectional dimensions 50 x 100mm. Blocks and bearers shall be of European Oak or approval equal. Wood shall be fully treated against fungal, insect and animal attack. The Employers name shall be burnt into pallets.

E5.5 Dosing pumps - reciprocating type

E5.5.1 General

Dosing pumps shall be mounted in a bund separate from the storage tanks and shall be fully accessible for operating and maintenance purposes without personnel having to enter the bund itself. Where appropriate, the pump bund shall be interconnected with the tank bund at an intermediate level.

The pumps shall be of the reciprocating mechanically actuated diaphragm type driven by electric motors. The pump, motor and drive arrangement shall be mounted on a robust combination baseplate. Unless otherwise specified, only one liquid end shall be driven by any motor.
Pumps shall comply with API standard 675, Positive Displacement Pumps - Controlled Volume.

E5.5.2 Pump head materials

Pump heads and diaphragms shall be manufactured from thermoplastic materials suitable for the duty conditions.

E5.5.3 Pump stroke adjustment

Variable stroke mechanisms shall be incorporated in the drive arrangement to allow infinitely variable adjustment of pump output by means of a micrometer, handwheel or similar mechanical device whilst the pump is running.

Where the pump is part of an automatic coagulation control or other process control loop, the stroke mechanism shall be fitted with a three phase bi-directional motor with torque limiter and automatic stops at both extremes of travel. A position feedback potentiometer shall be provided to facilitate control and remote indication of position. The operational range of stroke adjustment shall be not less than 6:1.

E5.5.4 Drive arrangement

The pump head shall be driven through a totally enclosed speed reduction gearbox with integral reciprocating drive device of the adjustable crank or mechanical lost motion type. The gearbox and reciprocating drive shall be oil bath lubricated. The unit shall incorporate filling and drain plugs for oil and an oil level indicator.

E5.5.5 Drive motor

Drive motors shall be of the three phase cage induction type whether for fixed speed or variable speed operation.
Where variable speed operation is specified, the speed turn-down ratio shall be not less than 5:1.

E5.5.6 Pump performance

The performance characteristics of the dosing pumps shall be adequate in terms of linearity, accuracy and reproducibility as defined in API standard 675 to achieve the stated plant performance guarantee. The deviation from flow linearity of the pump shall not exceed ±3% of the rated capacity. The steady state accuracy shall not exceed ±1% of the mean delivered flow under fixed system conditions over the entire turndown range. The flow rate repeatability expressed as a percent of the rated capacity of the pump shall not exceed ±3% of the rated capacity.

E5.6 Transfer pumps

End suction centrifugal pumps of the back pull-out type shall be used for chemical transfer duties. The pumps shall be fitted with an external PTFE bellows seal with a ceramic seat or alternatively may be of the glandless magnetic drive type. All pumps shall be protected against dry running.

Pumps shall be constructed in suitable plastic materials such as glass filled epoxy resin or high density polyethylene with external metal armouring or stainless steel or steel depending on the chemical used.
Transfer pumps shall be located in bunded areas and shall be fully accessible for operating and maintenance purposes without personnel having to enter the bund itself.

E5.7 Pipework for chemicals

E5.7.1 General

Pipework materials for chemicals shall be selected with due regard to chemical compatibility, location, environmental conditions and operating regimes.

Specific material requirements are set out for the filling pipes of storage tanks.

In the case of pipework located outdoors, particular consideration shall be given to the effects of ultra-violet rays, temperature and impact by wind-blown objects. Thermoplastic materials shall not be painted as a means of protection but shall be shielded from direct sunlight and adequately guarded against mechanical damage.

Where pressure and temperature de-rating precludes the use of thermoplastics, suitably lined reinforced plastics, rubber lined carbon steel or stainless steel shall be used. Stainless steels shall not be used for chemicals containing chlorides.

All external chemical pipework shall be laid in trenches provided with removable covers.

All pipework and hoses shall be adequately supported throughout their run. Pipes shall be fixed to walls or mounted on channel sections fixed to walls or on cantilevered supports off walls. Hanger type supports shall not be acceptable nor shall pipes be underslung from roofs or cantilevered supports or supported on the underside of pipe supports.

Pipework laid on the floor shall be supported on channel sections or similar off the floor.

Supports shall be spaced and shall be at centres not exceeding those recommended by the pipe manufacturer. Pipe supports shall be designed and installed to allow free axial movement of the pipe through the support during the process of expansion and contraction. Supports shall not be positioned in close proximity to fittings which would interfere with the natural movement of the pipes. Supports shall be sufficiently wide to offer adequate bearing surface and shall be installed so as to offer lateral restraint without restricting axial movement of the pipe.

Heavier fittings shall be supported independently of the pipe.

Measures shall be taken in the design of pipework system to ensure that expansion arising from temperature fluctuations can be accommodated without damaging the system.

Fixings of pipes shall by clips (cobra type) or clamps. Where clamps are used on plastic pipes, pipe cushioning shall be used and the pipe shall be mounted on channel sections with a plastic strip in between.

All pipe supports shall be hot dipped galvanised.

Hoses carrying chemical solutions shall be laid on horizontally mounted trays. Hoses shall be securely fixed to trays by clips or similar.

Hoses and pipes shall be laid in such a way that individual pipe/hoses can be removed without dismantling adjacent pipes/hoses. An allowance shall be made in the layout for any trace heating/lagging of pipework.

The racks or trays used to carry chemical pipes/hoses and water service pipes shall not be used for conveying electrical/instrument cable. Where electric/instrument cables are laid in the same duct with chemical/water pipes the electric/instrument cables shall be laid on uppermost trays.

Particular attention shall be paid to the layout of the chemical pipework, which shall be functional and neat in appearance.

All pipework above access ways shall be at not less than 2.5m above floor level. Pipes laid at or near floor level across access ways shall be suitable protected from damage. Joints in pipelines and fittings shall be sited away from access ways and working areas; where this is unavoidable anti-splash guards over the joints shall be provided.

Pipework at pumps shall be rigid and well supported so that strain is not placed on pumps. Suction pipes shall, where possible, be straight and short. Elbows shall be avoided in pipework as far as possible and shall be replaced by 45 degree or long sweep 90 degree fittings.

Chemical transfer pipework shall be arranged for self draining either towards the dosing pumps or dosing point. Provision shall be made for draining all pipe sections at low points and for flushing same with clean water and facilities for safe disposal of the drainage.

Pipework shall be provided with flushing connections and drains to facilitate cleaning of pipes/hoses, dosing pumps and other fittings.

It shall be possible to isolate sections of pipework and dosing pumps for flushing with minimum of interruption to dosing. All dosing pipes/hoses and associated injection/diffuser fittings shall be provided in duplicate (1 duty, 1 standby).

Chlorine solution lines shall not be laid inside buildings (not designated for chlorine). Where chlorine solution lines are laid in dosing chambers and other confined spaces which are accessible by personnel, then the Contractor shall provide a permanently installed leak detector and mechanical ventilation systems.

In pipes carrying slurries, tees and crosses shall be used in place of elbows in areas where mechanical cleaning might be required. Pipe reducers on slurry lines shall have level inverts and branches from slurry pipes shall be taken from top of pipe. Long vertical rises above the discharge valve of dosing pumps shall be avoided. Slurry pipework shall be designed and laid to eliminate settlement of particles; a minimum velocity of 0.3m/s shall be maintained at all points in the pipework over the entire range of operating conditions.

All nuts, bolts, washers and screws shall be manufactured from stainless steel as set out in the Specification.

E5.7.2 Pipework materials

Carbon steel pipework shall be specified by nominal diameters in accordance with BS EN 10220 and shall be in seamless material to BS EN 10216 or BS EN 10217 grade 360 or 430.

Carbon steel fittings shall comply with BS EN 10253 Part 1. Welding of carbon steel shall be carried out in accordance with BS2633 Class 1 arc welding. All welders shall be tested by an independent testing authority and shall satisfy the requirements of BS EN 287 Part 1. Carbon steel pipework shall be lined with natural rubber 3mm in thickness or alternative material approved by the Engineer. Where protective coatings are required they shall comply with the Specification.

Unless otherwise specified, flanges for steel pipework shall be of the weld neck type, Code 111 to BS EN 1092 or BS EN 1515 with the appropriate pressure designation but not less than PN10.

Stainless steel pipework shall be type 316S13 to BS3605 and shall be flanged. Fittings shall comply with BS1640 Part 4. All welding shall be carried out to BS 4677 and procedures shall be subject to approval in accordance with BS EN 288 Part 3. Welders shall be tested by an independent testing authority and shall satisfy the requirements of BS EN 287 Part 1.

Welder test certificates shall be provided by the Contractor for examination by the Engineer.
All welds shall be dressed.

uPVC pipework shall be `hi-impact' type to BS EN 1452 or BS3506 Class E with solvent welded joints and fittings complying with the relevant parts of BS EN 1452 . Where flanged joints are required, full face uPVC flanges and galvanised steel backing rings shall be used.

Where reinforced plastics are used, these shall comply with BS6464 and shall contain a uPVC liner as specified above for uPVC pipework. The pipework shall be fabricated and assembled such that only the liner comes into contact with the fluid. The piping system shall be designed and constructed in accordance with BS7159.

Alternative plastic materials such as polypropylene and polyvinylidene difluoride (PVDF) may be used in certain circumstances subject to approval by the Engineer.

Flanges shall conform to BS EN 1092 or BS EN 1515 PN10 minimum.

Joint rings for steel pipework shall be compressed asbestos fibre or proprietary alternative approved by the Engineer.

Joint rings for plastic pipework shall be of Viton encapsulated in PTFE.

Flexible hoses shall be reinforced rubber or equal of similar performance and quality to reinforced rubber.

E5.8 Dilution systems

E5.8.1 General

Certain chemicals shall be provided with dilution or carrier water systems as specified to assist in the conveying of the chemical to point of application and/or to improve mixing and shall be carried out downstream of the dosing pumps.

E5.8.2 System design

The dilution water system shall be designed such that it is impossible for chemicals to contaminate the drinking water supply system by back-flow or other means or to cross-contaminate other chemical dosing systems. Non-return valves shall not be considered a sufficient method of back-flow protection.

E5.8.3 System components

The system shall incorporate all isolating valves for water and the chemical, check valves and flowmeter on the water inlets.

E5.9 Valves and fittings for chemicals

E5.9.1 Isolating valves

All isolating valves shall be positioned with due regard to routine access for operational and maintenance purposes. It shall not be necessary to enter any bunded facility to operate isolating valves.

Isolating valves shall be compatible generally with the pipework systems in which they are installed.

Manual isolating valves for hydrated lime slurry shall be either ball valves of the full bore type or diaphragm valves of the straight through type.

Valve bodies shall be of cast iron whilst balls shall be stainless steel. Flexible diaphragms shall be selected for maximum resistance to abrasion. Assembly nuts and bolts shall be in stainless steel.

(a) uPVC valves

Isolating valves shall be of the diaphragm type with uPVC bodies, glass filled polypropylene topworks and PTFE diaphragms. Assembly nuts and bolts shall be stainless steel.

End fittings may be plain sockets for solvent welding or flanged as appropriate. Flanges shall be to BS EN 1092 or BS EN 1515 PN10 minimum.

These valves may not be used for isolating tank outlets and drains unless otherwise approved by the Engineer.

(b) Rubber lined valves

Isolating valves shall be of the diaphragm type to BS EN 13397 with weir bodies in grey cast iron to BS EN 1561 grade 220 (or alternative grade allowed by the design standard) having integral flanged ends, a natural rubber ebonite lining, PTFE diaphragms and topworks in standard proprietary materials. Assembly nuts and bolts shall be in stainless steel. The valves shall be flanged to BS EN 1092 or BS EN 1515 PN10 minimum.

Isolating valves for tank outlets shall be of the sealed bonnet type.

All valves shall be tested in accordance with BS EN 12266.

E5.9.2 Pressure relief valves

Pressure relief valves shall be fitted to the delivery side of all positive displacement pumps. All materials of construction shall be fully compatible with the chemical handled.

The valves shall discharge in a safe manner to a gulley or sump designed for this purpose. The discharge pipes shall not be manifolded.

The valves for lime slurry applications shall be of a non-choking type free of cavities and crevices likely to block with lime.

A means shall be provided of detecting that a relief valve is operating and of raising an alarm.

E5.9.3 Loading valves

Loading or back-pressure valves shall be fitted where necessary to the delivery side of the dosing pumps. All materials of construction shall be fully compatible with the chemical handled.

The valves lime slurry applications shall be of the tubular pinch type pressurised externally with compressed air or of an alternative approved type.

E5.9.4 Pulsation dampeners

Pulsation dampeners shall be fitted where necessary to the suction or delivery side of dosing pumps to attenuate peak pressure drops and to smooth the flow.

The dampeners shall be of the vertical air vessel type or approved alternative type.

An air supply shall be connected to the dampeners to facilitate periodic re-charging. The supply shall incorporate a filter, pressure regulator and pressure gauge.

E5.9.5 Injection fittings

Where chemical is to be dosed into an open channel, weir chamber or downstream of a hydraulic jump, it shall be applied using a distributor as specified. The submerged distributors shall be tubular with orifices drilled at even intervals to ensure uniform distribution of the coagulant. The distributors mounted above the water surface shall be pipe or channel type with orifices drilled at intervals to ensure uniform distribution. The channel type shall be used for slurries.

Where chemical is to be dosed into flow in pipelines, it shall be applied using a suitable arrangement of injection tubes designed for the specified duty flow rate.

(a) Pipelines up to 600mm in diameter

A single horizontal injection tube shall be used extending one third of the pipeline diameter into the fluid stream.

(b) Pipelines up to 1000mm in diameter

Two injection tubes shall be used mutually located at 90° with their axes at 45° to the horizontal and extending 15% of the pipeline diameter into the fluid stream.

(c) Pipelines up to 2500mm in diameter

Four injection tubes shall be used mutually located at 90° with their axes at 45° to the horizontal and extending 15% of the pipeline diameter into the fluid stream.

The nozzle velocity shall exceed 0.75 m/s or one half of the large pipe velocity whichever is greater.
Distributors and injection tubes shall be of sturdy design and adequately supported. They shall withstand the flow velocity at the point of application and any flow or turbulence induced vibrations
.
The materials of construction of the distributors and injection tubes shall be resistant to erosion and chemical attack over the full range of operating conditions.

The distributors and injection fittings shall be supplied complete with the necessary isolating valves and, where applicable, non-return valves.

When injecting chemicals into static mixers, the static mixer supplier provide the injection device as an integral part of the mixer.

E5.9.6 Dosing pump calibration vessels

Calibration vessels shall be transparent tubes of material resistant to the chemical and not discoloured by the chemical.

The effective height of the vessel shall not be less than 1.25m and the diameter shall be selected to ensure that at the maximum pumping capacity the rate of fall of level in the vessel shall not be greater than 1.0m/min. The height of the vessel shall be such that when full the liquid level in the calibration vessel shall the same as that in the stock tank. This may be achieved by providing the calibration vessel with a vent pipe.

The calibration vessel shall be provided with a drain discharging to an appropriate bunded area.

E6.0 COAGULANT PLANT E

6.1 General requirements

The coagulant plant shall be suitable for use with the chemical or selection of chemicals specified.
The Contractor shall obtain information on properties, materials of construction for handling equipment and safety information and verify availability of the form, grade and delivery lot size of the specified coagulant(s) at time of tender.

E6.2 Storage tanks

E6.2.1 Capacity, design and fabrication

The coagulant plant shall be suitable for use with the chemical or selection of chemicals specified in the Particular Requirements.

E6.2.2 Saturators

Saturators shall be designed for receipt of aluminium sulphate in block form and dissolution of same to form a saturated solution.

Saturators shall comprise reinforced concrete tanks with an acid-resistant lining. The lining shall comprise an impermeable membrane further lined with acid-resistant brick bonded with acid-resistant cement or an alternative lining system such as fibre glass approved by the Engineer.

The tanks shall be enclosed within a building and shall be arranged for manual charging.

The floor of the tank shall be further protected by pebbles approximately 14–20 mm in size to a depth of at least 300 mm to absorb initial impact and to protect the solution draw-off pipes.

Areas of the tank walls subject to impact shall be protected by hardwood facing which shall be secured with stainless steel fixings.

The tanks shall be sized for the specified duty requirements assuming $1.4m^3$ of solution will be generated from each tonne of solid aluminium sulphate.

A system of perforated pipes shall be mounted on the tank floor to effect uniform draw-off of the saturated liquor across the whole area of the tank. The pipes shall be of non-corrodible materials and secured by means of stainless steel fixings.

The following pipe connections shall be provided as a minimum on each tank. All puddle pipes and connections shall be in stainless steel type 316S13 to BS 3605:

- water inlet;
- solution outlet;
- re-circulation inlet; • overflow;
- drain;
- level gauge

The saturated solution shall be transferred to stock tanks for dilution tanks by means of pumping. Provision shall be made for using the transfer system for recirculation of solution from the saturator outlet to a high level inlet in order to assist dissolution. Two isolating valves shall be fitted to the tank outlet together with a sampling valve and an in-line strainer.

Each tank shall be provided with a level gauge equipped with low and high level alarm switches and any other switches required for operational purposes.

It shall be possible to back flush the gravel bed via the overflow to waste.

E6.2.3 Dilution and stock tanks

Dilution and stock tanks shall be designed for diluting a saturated solution of aluminium sulphate to a pre-etermined concentration as specified or to store a pre-diluted solution of aluminium sulphate.

Such tanks shall operate on a rotational batch basis with a cycle frequency as specified.

Tanks may be constructed from concrete or rubber lined mild steel or fibre reinforced polyester or alternative material as specified.

Each tank shall be equipped with a turbine type mixer constructed of stainless steel to BS 970 Part 1 or BS 1449 Part 2 grade 316S11.

The following pipe connections shall be provided:

- Water inlet;
- Solution inlet;
- Solution outlet;
- Overflow;
- Drain;
- Level gauge.

Where applicable, suitable level switches or probes and level measuring equipment shall be provided for operational and monitoring purposes.

E6.2.4 Constant head tanks

Constant head tanks shall be designed to provide a constant operating head for downstream feeders. The constant head shall be maintained by providing an inflow greater than the outflow with the excess flow being returned to feed (stock) tank.

The tanks shall be constructed in fibre reinforced polyester or alternative material approved by the Engineer. The following pipe connections shall be provided:

- Solution inlet;
- Solution return;
- Overflow;
- Drain;
- Outlet.

E7.0 HYDEATED LIME PLANT

E7.1 Slurry mixing tanks

Slurry mixing tanks shall be cover and shall be of concrete or fabricated from mild steel as specified and designed to hold the required volume of hydrated lime slurry at concentrations up to 10% w/v.
Each tank shall be provided with the following fittings:

(a) Cover fitted with manhole (750mm x 750mm) and serving as a maintenance platform.

(b) Handrailing around periphery of tank cover and access ladder from floor level.

(c) Top entry paddle mixer of the slow speed type with driving motor and speed reduction gearbox mounted on structural steel supports spanning the diameter of the tank.

The gearbox output shaft shall be coupled to the mixer shaft by means of a flexible coupling. The upper end of the mixer shaft shall have a combined journal and thrust bearing and the lower end shall have an inert non-metallic bearing.

The paddle blades shall be inclined from the vertical plane.

Unless otherwise specified, the mixer shaft and paddles shall be in stainless steel to BS 970 Part 1 or BS 1449 Part 2 grade 316S11.

Where necessary for maintenance purposes, a steel lifting beam complying with BS 2853 shall be provided for removal of the mixer and its drive assembly.

(a) Sight glass type level gauge with isolating valves and flushing connections.
(b) Conductivity type level probes for level monitoring.
(c) A bag loader which shall comprise a hinged lid to place the bag, a spike to retain the bag when the lid is in the closed position and coarse screen.
(d) Venting connection complete with filter sock.
(e) Flanged connections drilled to BS EN 1092 or BS EN 1515 PN 10 for water inlet, slurry outlet, overflow and drain. Where specified, additional connections shall be provided for slurry re-circulation. The tank design shall ensure that insoluble impurities are not passed into the outlet system.
(f) Special lime strainer for tank outlet.

E7.2 Lime saturator

Saturators shall be of steel construction. They shall have a conical bottom section with a cone angle of about 60o, terminating in a straight vertical section.

They shall be suitable for the preparation of saturated lime solution (lime water) at water temperatures of up to 30°C from lime slurry up to 10% w/v (100 g/l). The saturators shall be designed to operate at a nominal rise rate (in the straight section) of 1.0 m/h at maximum rates. The design shall allow sufficient contact time for the feed water to become saturated.

In designs where mixers are used in a draught tube in the saturator the rise rate in the straight section shall be 2.0 m/h.

The design shall allow for a saturator operating efficiency of not less than 80% and this factor shall also be taken into account in the sizing of the lime handling/slurry preparation plant and saturator dross/sludge removal/transfer and associated dewatering plant.

The saturators shall be provided with the following:

- a domed roof for saturators located in the open;
- where applicable a top entry motor driven propeller mixer of stainless steel construction arranged so that no bearings are in contact with the lime solution and of adequate power for mixing the incoming lime slurry and feed water. The mixer shall be located within a central baffle/draught tube;
- lime slurry inlet;
- a feed water inlet to bottom of the saturator or central baffle/draught tube with variable area flowmeters with flow control and isolating valves and a valved bypass. The inlet point shall be positioned to ensure even up-flow and distribution of the water through the slurry bed (avoiding streaming) as appropriate to the Contractors design. The water feed shall be on a continuous basis;
- valved sample points at normal blanket upper, middle and lower levels for slurry blanket monitoring purposes and at the bottom section of the vessel to monitor the build-up of lime dross/sludge. A valved lime water sample connection shall also be provided on each outlet pipe from the saturators;
- an adequate means for the uniform collection of lime water discharging via fully submerged orifices in a peripheral launder;
- an adequate number of vertical upstand/breather pipes to collect surface lime water and avoid dead areas;
- sludge removal line with a full-way outlet valve and guard valve;
- access stairway to the top of the outside saturators, necessary platforms and handrailing to facilitate inspection and maintenance of the saturators, and to access sampling valves.
- a supporting structure terminating in suitable bearing plates complete with all necessary anchor bolts.

The tanks shall be designed to facilitate ease of internal cleaning.

Where appropriate all pipework connections shall be side entry/exit with pipework routed in the (triangular) voids between the hopper sections. Where appropriate all pipework shall be provided with accessible rodding facilities.

E8.0 CHLORINE PLANT

E8.1 Drum handling systems

E8.1.1 Drum weight

Drum handling systems shall be designed to operate with chlorine drums, of approximate chlorine capacity 1000kg

E8.1.2 Monorail runway beam

Monorail runway beams (straight or U-type) shall conform to BS 2853 and shall extend the length of the drum store and over the unloading area. U-section of a monorail shall have a minimum radius of 2 m and the spacing between the two rails forming the U-beam shall be not less than 2 x the minimum radius.

E8.1.3 Electric travelling hoist

Electrically operated travelling hoists shall be complete with shackles, drum lifting bar and, where specified, a suspended weighing device. Travel and hoist motions shall be electrically driven.

Hoist functions shall be controlled from a single fully insulated heavy duty pendant suspended by a non-metallic cord. The pendant shall operate at a low voltage not exceeding 50 volts A.C. and shall incorporate a key-operated switch to prevent unauthorised operation. Push button controls shall be provided for dual speed and fine control of both travel and hoisting operations with separate motors for each function. An interlock shall prevent simultaneous travel and hoisting and an emergency stop shall be fitted. Linear operating speeds shall approximate the following criteria.

	High speed	Low speed
Raise/lower	5m/min	0.5m/min
Travel	10m/min	5m/min

Limit switches shall be fitted to prevent over-hoisting and over-lowering and shall be adjustable within the working range of the hook. The mechanism shall be self-resetting. End stops shall be fitted to each end of the runway beam.

The power supply to the hoist shall be delivered by a 3 phase and earth festooned cable system supported from a track mounted off the top flange of the runway beam. Where possible, this shall terminate within the store clear of the main doors and the supply continued to the hoist by means of an extensible flexible cable. The necessary junction box between these cables shall also run in the track and shall be engaged by the hoist unit on inward travel through the doorway and disengaged on reaching a mechanical stop in the track prior to outward travel of the hoist unit through the doorway. In situations where the festoon arrangement continues through the doorway, the proposed sealing arrangement for the support track at the doorway shall be subject to approval by the Engineer.

An isolating switch, lockable in the off position, shall be provided wall mounted 1400mm above floor level with the store room arranged to enable the hoist to be isolated from all power supplies.

The hoist and trolley shall comply with the operating performance of BS 466.

Hoists shall be fitted with a right and left hand spiral groove cast iron drum with a wire rope hoist arrangement with spring-loaded rope bands and guards to ensure accurate guidance and location.

Safety disc brakes shall be incorporated to hold the suspended load instantly, securely and automatically in the event of the electricity supply being cut-off for any reason.

Lifting hooks shall be safety hooks from grade 30 carbon steel to BS EN 1677 and capable of swivelling through 360 degrees.

Steel wire rope shall be of tensile grade and conform to BS EN 12385.

Bearings shall be ball or cylindrical roller type.

Drum lifting bars shall be made of structural steel to BS EN 10137 and BS EN 10029 and shackles and hooks shall conform to BS 3551 as applicable.

A permanent fixed elevated platform shall be provided at one end of the monorail beam to enable maintenance work to be carried on the hoist and trolley. The platform decking shall be non-slip chequer plate and the platform shall be provided with access ladder and handrailing.

The complete drum handling system including the suspended weigher shall be designed for a safe working load of 2800 kg and shall be tested with a load of 3500 kg.

E8.1.4 Suspended weigher

Where specified, the lifting system shall incorporate a suspended weighing device. This shall be suspended from the load hook of the hoist and shall itself have a swivel hook with safety catch to engage the centre shackle of the drum lifting bar. The device shall be of the hydrostatic load cell type with a circular scale indicator calibrated in 50kg divisions with the zero at the top of the scale. The capacity of the weigher shall not be less than 2000 kg. The pointer shall incorporate tare adjustment of up to 20% of full scale. The dial shall be not less than 300 mm in diameter.

Alternatively a digital indicator with the readout attached directly to the load cell shall be provided. The display shall be by a bright four digit 50 mm high LED display with 1 kg resolution. The display module shall be housed in an enclosure protected to IP 67.

The weigher shall have an overall accuracy better than + or – 0.5% of full scale deflection with 25% over rated capacity safety factor and shall be unaffected by temperature variation in the range -10 to +50°C.

E8.1.5 Safe working loads

All parts of the lifting system shall be stamped with the manufacturer's symbol for identification, with the manufacturer's test certificate and the date of manufacture. The system shall be certified for a safe working load of 3.20 tonnes and tested with a load of 4 tonnes.

E8.2 Liquid catchpots

Where chlorine is withdrawn as a gas from containers, the container header shall terminate at a purpose designed liquid catchpot comprising a carbon steel pressure vessel not less than 300 mm in length and 140 mm in diameter, with flanged inlet and outlet connections, flanged full way top plate, an internal dip tube on the inlet side and a wall mounting bracket. The catchpot shall be works tested hydrostatically to 52 bars g. Isolating valves shall be installed upstream and downstream of the catchpot.

E8.3 Gas pipework

Flexible tubes for connections to containers for gas withdrawal shall be copper externally plated with silver or cadmium or alternatively shall be Monel. The tubes shall be fitted with suitable screwed adaptors for making the connections to the containers.

All screwed pipework conveying chlorine under pressure shall be constructed from solid drawn steel tube to BS 1387 with heavy fittings in malleable iron to BS 143 screwed to BS 21. Threaded joints shall be made with a jointing compound compatible with chlorine or sulphur dioxide as appropriate. PTFE tape shall not be used.

All flanged pipework conveying chlorine gas under pressure shall be carbon steel hot finished seamless, cold drawn seamless or electric resistance welded to BS EN 10216 or BS EN 10217 grade 360 or 430. Flanges shall be raised face drilled to BS 1560 Class 150, double fillet welded, stress relieved and radiographed. Joint rings shall be made of chemical resistant elastomers such as Hypalon (Chlorosulphonated Polyethylene) or Viton (Co-Polymer of Vinylidene chloride and hexafluro propylene) or alternatives approved by the Engineer and shall fit within the bolt circle. Prior to installation, the joint rings shall be impregnated or smeared with graphite compound or similar compound compatible with chlorine.

All pipework for chlorine gas under vacuum or venting directly to atmosphere shall be rigid `hi-impact' uPVC to BS 3506 Class E or T with solvent welded joints and fittings complying with the relevant parts of BS EN 1452. Venting pipework shall be arranged to inhibit ingress of moisture and shall be fitted with an insect screen. Venting pipework shall not be manifolded.

Pipework shall be adequately supported throughout its length. Sleeves shall be used where pipework passes through walls. All apertures shall be properly sealed with a chlorine and sulphur dioxide resistant compound.

Pipework within buildings shall not be run in floor ducts unless otherwise approved by the Engineer.

E8.4 Gas isolating valves

Isolating valves in pipework conveying chlorine under pressure shall be interchangeable and specifically designed for chlorine service.

Valves shall be provided at each end of flexible connecting tubes to containers and shall be needle valves having 150lb class forged bodies in silver plated brass with screwed end connections and shall be of glandless design with a nickel diaphragm. The valve shall be operated by means of a handwheel.

All other isolating valves shall be sleeved plug valves having 150lb class forged bodies in carbon steel with integral end connections, tapered plug in Monel with pure PTFE sleeve and top seal arrangement with PTFE diaphragm and delta seal ring, back up metal diaphragm, floating thrust collar, electrostatic eliminator, four bolt cover and three point self-aligning plug adjustment. The valve design shall ensure that excess pressure in the plug and body cavity of the closed valve is relieved spontaneously towards the direction of high pressure. The valve shall be operated by a forged steel wrench with padlocking facility in the closed position or otherwise by power actuator as specified elsewhere.

Flanged valves shall have raised face flanges drilled to BS 1560 Class 150.

All valves shall be supplied degreased and dried for chlorine service and maintained in this condition for inclusion in the Works.

All valves shall be tested in accordance with BS 6755 Part 1 and II.

A works test certificate is required for each valve covering hydrostatic testing of the shell and seat and air testing of the seat. The gauge pressure for the air test shall be 10 bars.

E8.5 Drum changeover systems

Drum changeover systems shall automatically switch the source of chlorine from a duty set of containers to a standby set upon the pressure in the duty set falling to 1.0 bar g.

The system may comprise an integral purpose-designed assembly where applicable or separate components, in either case complete with a locally wall mounted control panel.

The changeover activating device shall be a pressure switch. A 100 mm diameter pressure gauge shall also be provided. Changeover shall be effected by means of one or more electrically operated valves.

The design shall ensure that the expired duty chlorine supply is isolated before the standby supply is brought on line.

The control panel shall incorporate the following features:

- Isolating switch;
- Indicator lamps for SUPPLY No. 1 ON and SUPPLY No. 2 ON and volt-free contacts connected to the SCADA system;
- Indicator lamp for NO RESERVE, volt-free contacts connected to the SCADA system and RESET pushbutton;
- Push button to indicate that RESERVE is available;
- LAMP TEST pushbutton;
- Manual over-ride switch.

Control circuit and valve actuator voltage shall be 110 V a.c. Unless otherwise specified on power failure, the system shall stay put.

The drum changeover system shall have a manual isolation and bypass arrangement to facilitate maintenance.

E8.6 Vacuum regulating valves

Vacuum regulating valves shall be wall mounted on a suitable backing board in the drum store, located as close as is practical downstream of the drum changeover system.

Vacuum regulating valves shall be spring loaded diaphragm operated valves, designed to reduce varying gas pressure upstream to a desired regulated vacuum downstream and to maintain this vacuum within close limits. The diaphragm shall be made of PTFE.

The vacuum regulating valve shall be fail safe and shall close fully upon loss of vacuum.

The valve shall be provided with an isolating valve upstream and a pressure relief valve downstream. The pressure relief valve shall discharge to outside the building. Vent pipes from pressure relief valves shall not be manifolded.

The regulated vacuum shall be indicated on a vacuum-pressure gauge which may be integral with the vacuum regulating valve or mounted separately.

E8.7 Gas Control Units

Chlorinators are referred to herein as gas control units. They are devices for measuring and controlling the flow rate of chlorine gas under vacuum conditions created by a water driven ejector.

Gas control units shall be wall or floor mounted as applicable otherwise and shall incorporate the following items all assembled and tested at place of manufacture:

- Variable area flow meter with linear scale calibrated in g/s or mg/s of chlorine as applicable.
- Gas flow control valve to provide precise setting of the gas flow rate over a 20:1 flow range with an accuracy of ±4% of the indicated gas flow rate.
- Vacuum differential regulating valve to maintain a constant vacuum difference between the inlet and the outlet of the flow control valve over the operating range of the gas control unit.
- Vacuum relief valve, if applicable, which shall be connected by pipework to outside the building and arranged in a similar manner to venting pipework.
- Vacuum gauge to indicate the unregulated vacuum induced by the ejector and calibrated in mbar.
- Vacuum switches, which may be integral with the gauge. One switch shall initiate a high vacuum alarm and the other shall initiate a low vacuum alarm. Both switches shall have volt-free changeover contacts.

E8.8 Ejectors

Ejectors shall be designed to induce the vacuum necessary to operate the corresponding gas control units over their working range under all downstream pressure conditions at the point of application when supplied with motive water at or above the minimum pressure.

The design flow range of motive water shall take into account the dissolution requirements of the chemical, control loop time considerations for automatic control systems and effective hydraulic design. Ejectors shall be mounted in the vertical. Noise shall be kept to an absolute minimum consistent with efficient operation but shall in no event exceed the sound pressure level stated in the Specification.

The ejector shall incorporate an integral diaphragm-operated non-return valve to prevent ingress of water to the gas system. A separate non-return valve shall also be installed in the gas line to the ejector as a security measure.

The nozzle and throat diameters shall be engraved on a plate fixed to the ejector in a visible position. Where small clearances are involved on the water side of the ejector, in-line strainers shall be installed in the motive water supply pipework to protect the ejectors from blockage. A minimum recovery length of 1.0m straight pipe length shall be provided downstream of the ejectors.

Ejectors shall be mounted separately from the gas control units either within the same room or in a remote location as specified elsewhere.

Fittings on the downstream side of the injector shall be selected to give the lowest possible `K' factor. Thus, valves shall be of the straight through type, tees shall not be used, and bends shall be swept and long radius.

E8.9 Solution pipework

All pipework for chlorine solutions within buildings and elsewhere unless otherwise specified, shall be rigid `hi-impact' uPVC to BS 3506 Class E with solvent welded joints and fittings complying with the relevant parts of BS EN 1452.

Where flanged joints are required, full face uPVC flanges and galvanised mild steel backing rings shall be used. Joint rings shall be Hypalon or Viton. Flanges shall be drilled to BS EN 1092 or BS EN 1515 PN10 minimum.

Pipework shall be supported in accordance with manufacturer's recommendations and adequate provision shall be made for thermal expansion and contraction.

E8.10 Solution isolating valves

Manual isolating valves for chlorine solutions shall be of the diaphragm type with uPVC bodies, glass filled polypropylene topworks and PTFE diaphragms. Assembly nuts and bolts shall be stainless steel.

End fittings may be plain sockets for solvent welding or flanged as appropriate.

E8.11 Injection fittings

Where chlorine is to be dosed into flow in an open channel, weir chamber, contact tank or downstream of a hydraulic jump, it shall be applied using a submerged chlorine solution distributor.

The distributor shall be either a drilled tube or a ceramic tubular diffuser, designed to ensure uniform distribution of solution at the point of application.

Where chlorine is to be dosed into flow in pipelines, it shall be applied using an injection fitting/device designed for the specified duty flowrate as follows:

(a) Pipelines up to 600 mm in diameter.

The injection tube shall extend one-third of the peline diameter into the fluid stream. In this case a withdrawable type injection fitting entering the pipe through a corporation cock shall be used.

(b) Pipelines up to 1000 mm in diameter.

The injection tube shall be perforated and shall extend right across the pipe bore and be supported with ends located in diametrically opposite flanged branches. The tube shall be drilled at predetermined centres to ensure uniform distribution across the flow profile.

(c) Pipelines up to 2500 mm in diameter.

Two perforated injection tubes shall be used, each generally as for (b) only installed mutually at right angles and with their axes at 45° to the horizontal in a plane normal to the direction of flow within the pipeline.

Alternatively, four injection nozzles, mutually located at 90° and extending 15% of the pipe diameter shall be installed. The nozzles shall be installed in diametrically opposite flanged branches and in the same plane normal to the direction of flow in the pipeline.

The nozzle velocity shall exceed 0.75m/s or one half the large pipe velocity whichever is greater. When injecting chlorine into static mixers, the static mixer supplier provide the injection device as an integral part of the mixer.

Distributors and injection fittings shall be of sturdy design and adequately supported and designed to withstand the flow velocity at the point of application and any flow or turbulence induced vibrations.

The materials of construction of the distributors, injectors and sealing shall be compatible with up to 3500mg/l chlorine at operational fluid temperatures up to 30°C. Porous ceramic material where used shall be inert and non-toxic. uPVC tube where used shall conform to BS 3506, Class E.

Chlorine solution distributors or injection fittings shall be supplied complete with the necessary non-return and isolating valves.

E8.12 Motive water supply

Pumps shall be of the multistage centrifugal type. Pumps shall be vertically mounted complete with direct coupled motor face or flange mounted on top. Suction and discharge chambers shall be in fine grained cast iron whilst intermediate chambers shall be in the same material or stainless steel.

Impellers shall be stainless steel or bronze with stainless steel shroud. Pump shafts shall be stainless steel and pump bearings shall be bronze or tungsten carbide. The shaft seals shall be of the mechanical type with polished tungsten carbide surfaces mounted on bronze or stainless steel carrier assemblies.

Facilities shall be provided for the removal of trapped air on priming and for draining the pump. The speed of the pump shall not exceed 2900 rpm.

Pipework and valves for water supply systems shall comply with the requirements for chlorine solution pipework.

Isolating valves at the off-take plant from the treated water mains shall be cast iron gate valves to BS EN 1171. Where supplies are taken from high pressure mains in excess of 10 bar or where significantly reduced pressures are required by downstream equipment, pressure regulating and relief valves shall be installed.

E8.13 Layout and design considerations

The chlorination installation shall comprise a chlorine container store and chlorinator room and where necessary annexes for housing motive water pumps, ejectors and switchboard.

The container store shall house full and empty containers with a container unloading area at one end, containers on-line, automatic changeover devices and vacuum regulators. Adequate space shall be allowed in the store for duty and standby container on-line, containers in storage and spaces for empty containers. The chlorinators, ejectors, motive water pumps and switch gear shall be housed in respective rooms.

The chlorine container store, chlorinator room and ejector room shall be provided with separate exit doors opening outwards and emergency exit doors also opening outwards fitted with pushbar operated panic bolts. Adequate exits shall be provided to ensure that the maximum distance of access route from any point in the store to the nearest exist is less than 10 metres. Interconnecting doors between any room in the chlorine building shall not be provided.

The levels of ceilings shall be sufficiently high to allow handling of drums, satisfactory maintenance and replacement of parts. All doors shall be of robust construction preferably faced with a single sheet of material to ensure that they are reasonably gas tight, and rebated into the architrave on the sides and top. Bottom gap shall be kept to a minimum. All rooms where chlorine leaks can occur shall be of substantially gas tight construction.

Adequate angle iron or channel iron protection shall be provided at all protruding corners and frames or openings to prevent damage to structures during container handling. Fire resistant construction material shall be used throughout.

No external windows shall be provided in the container store and chlorinator room, artificial illumination being employed throughout. To safeguard personnel in the event of a chlorine leak, gas-tight wire armoured toughened glass glazed panels shall be provided in internal walls so that all areas may be observed from adjacent rooms. Individual lighting fixtures shall be provided wherever feasible, with two/three-way switching to allow lights to be operated from the viewing rooms.

Air conditioning shall not be provided in the chlorine building.

The floor of the chlorine building shall be placed at such an elevation above adjacent ground level that ingress of storm water is prevented, but entrances shall not be higher than 200m above finished ground levels.

Switchboards, motor control centres and any other panels and electrical or electronic equipment shall not be housed in areas where there is a potential for chlorine gas or solution leak. Any electrical equipment required to be located in such areas such as leak detectors, changeover panels etc. shall have enclosures protected to IP 65.

All equipment and plant used in the chlorine environment shall be made of appropriate chlorine (wet/moist) resistant construction material. Where necessary they should be adequately protected against corrosion by painting or otherwise.

All pipework and cables to and from chlorine store and chlorinator room shall be taken through the wall. All threader tubes carrying cables and pipes respectively out of the chlorine store and chlorinator room shall be sealed to prevent any chlorine leaks being transmitted to other areas. Arrangement and layout of pipework shall comply with the specification for chemical pipework.

Independent ventilation systems for each area of activity where there is a potential for chlorine leak shall be provided. Air intakes shall be through louvred grills at high level and extraction shall be at low level in the room with high level discharge to outside.

Each area of activity shall be provided with leak detectors specific to the chlorine gas and capable of detecting levels down to 0.5 ml/m3. They shall be powered by UPS systems which shall be operable for up to 4 hours in the event of a power failure.

Chlorine container store and chlorinator room shall be used solely for of chlorine facilities.

The siting of other buildings with respect to the chlorine building shall be such that their ventilation intakes are at least 25m from the chlorine building.

Adequate number of breathing aids and protective clothing shall be supplied as specified.

In the siting, layout and design of the plant the contractor comply with all local statutory requirements and standards, foreign codes of practices and guidelines applied and/or recognised in the country of installation and those of the country of origin of equipment.

E9.0 WATER SAMPLING EQUIPMENT

E9.1 General requirements for sampling

E9.1.1 Sample points

Sample points shall be provided as specified where recommended by the Contractor to suit his design.

E9.1.2 Location

Sample points shall be positioned in a manner which ensures that the sample is properly representative of the fluid stream from which it is taken in terms of physical, chemical and microbiological parameters.

Special care shall be taken following chemical dosing to ensure that mixing has taken place before the sample is withdrawn.

In pipelines up to 600 mm in diameter, the limiting position of the sample point shall be where the ratios of minimum concentration to maximum concentration of the dosed chemical across the horizontal and vertical diameters of the pipeline are at least 0.95.

In pipelines larger than 600 mm in diameter, these ratios of concentrations shall not be less than 0.90 or, where applicable, such higher value as may be necessary to achieve the stated plant performance guarantee. Similar criteria shall apply to flow in channels and rectangular ducts of all sizes except that the concentrations shall be across the horizontal and vertical centre axes.

E9.1.3 Offtake arrangement

In no circumstances shall samples be withdrawn directly from the pipe or channel wall. Sample withdrawal tubes shall project into the bulk fluid flow in a manner which avoids vibration and the collection of entrained gas bubbles or sediment.

Sample tapping points shall not be less than 1" NB. Generally, any reduction in pipe size shall take place after the first isolating valve.

The offtake arrangement up to and including the first isolating valve shall be designed for maximum mechanical strength in addition to hydraulic considerations and the integrity of the main fluid stream shall not be prejudiced by any failure in or damage to the sampling system itself.

E9.1.4 Sampling rate

The sampling rate shall be optimised for each sampling system with due regard to the following:

The purpose of sampling;
Maintenance of sample quality;
Effective monitoring and control, where applicable;
Hydraulic restraints;
Minimisation of wastage.

The sample delivery rate to analysers shall be as recommended by the instrument manufacturers and any necessary pressure or flow regulating device to maintain this shall be provided.

The sample delivery rate to sample taps shall be limited to 2 litres per minute per tap by means of suitable preset or flow limiting valves but not by use of isolating valves.

Generally, samples shall be delivered at rates significantly in excess of those required by analysers and sample taps to satisfy all relevant design criteria. Sample pipework shall not be less than ½" NB under any circumstances and, where hydraulic or water quality conditions dictate shall be larger.

E9.1.5 Sample recovery and disposal

Unless otherwise specified, excess sample water shall be recovered for re-use provided that there is no risk of contamination and that it can be returned to the process at a suitable point and always prior to final disinfection.

In this way, wastage shall generally be limited to discharge of used samples from analysers and from sample taps.

All necessary means shall be provided for collection and disposal of waste sample water with due regard to any contaminants which may be introduced within the sampling facility such as analytical reagents or cleaning compounds.

E9.2 Sample pumps

Unless otherwise specified or approved, sample pumps shall be of the progressive cavity type or centrifugal type with flange mounted three phase cage induction electric motors.

The pumps shall have close grained cast iron bodies, stainless steel impellers and mechanical shaft seals.

Sample pumps shall be installed above flood level wherever possible and shall be readily accessible for maintenance purposes.

Over-pressure protection shall be provided either by means of an integral device or a separate pressure relief valve.

E9.3 Sample pipework

E9.3.1 General

Sample pipework shall be selected to suit the application and type of measurement from either uPVC or stainless steel. In addition, medium density polyethylene pipe may be used where appropriate only for sections run through buried ducts or laid directly in the ground.

E9.3.2 uPVC pipework

uPVC sample water pipework shall be the `hi-impact' type to BS EN 1452 with solvent welded joints and fittings complying with the relevant parts of BS EN 1452.

Screwed connections to metal components such as sample pumps shall be made with proprietary iron to uPVC adaptor fittings. Pipework shall be supported in accordance with manufacturers' recommendations and adequate provision shall be made for thermal expansion and contraction.

uPVC pipework shall not be used where it may influence analytical measurements such as dissolved oxygen concentration.

E9.3.3 Stainless steel pipework

Stainless steel sample water pipework shall be type 316S11 or higher grade to BS 3605 Part 1 with tolerances in outside diameter to Table 1 of BS EN ISO 8434 and tested in accordance with Category 2 requirements.

Pipe couplings shall be light series compression Type A to BS EN ISO 8434.

Pipework shall be supported directly on surfaces with proprietary clips or, where several lines follow a parallel route, they may be clipped to trays dedicated to this service.

E9.3.4 Polyethylene pipework

Polyethylene sample water pipework in accordance with BS EN 12201 may be used for those sections which are run through buried ducts or laid directly in the ground.
Pipe couplings shall be of the electrofusion type as approved by British Gas and shall incorporate pins which pop up to confirm that optimum melt pressure has been achieved.

E9.4 Sample isolating valves

E9.4.1 General

The valves shall be compatible with the main sample pipework system, uPVC or stainless steel.

E9.4.2 uPVC valves

Isolating valves shall be of the diaphragm type with uPVC bodies, glass filled polypropylene topworks and PTFE diaphragms. Assembly nuts and bolts shall be stainless steel.

E9.4.3 Stainless steel valves

Isolating valves shall be of the diaphragm type to BS EN 13397 with weir bodies in stainless steel 316C16 to BS 3100, PTFE diaphragms and topworks in standard proprietary materials. Assembly nuts and bolts shall be stainless steel. The valves shall be tested in accordance with BS 6755 Part 1 and II.

E9.5 Sample taps

Sample taps shall be in chrome plated brass, ½" BSP size, with cross handle and outlet nozzle suitable for sterilisation by flaming. The nozzles shall have protective screw on caps which are attached by means of chain to the tap spindle.

E9.6 Sample sinks

Sample sinks shall be to BS 1206, nominally 455 mm wide by 255 mm deep and length to suit the number of sample taps:

- up to 4 samples 610 mm
- 5 samples 760 mm
- 6 samples 915 mm

The sinks shall generally be supported from a wall on cantilever brackets but where this is impracticable, they may be supported on stanchions from the floor. The base of the sink shall be approximately 700 mm from the floor and shall be fitted with a drain connected to an approved discharge point. Sample sinks in laboratories shall be flush with the bench tops.

The sample tap nozzles shall be positioned at 100 mm centres at a distance of 170 mm from the rear of the sink and at a suitable height above the sink to allow collection of samples in a glass bottle approximately 300 mm high.

E10.0 SAFETY EQUIPMENT

E10.1 Safety showers

Safety showers shall be purpose-designed proprietary units suitable for indoor or outdoor use as specified.

The showers shall incorporate nozzles specially designed to create a deluge of water overhead for rapid decontamination and an additional spray at approximately waist height to direct water onto the lower body and legs. The water supply valves shall be mechanically operated by means of a grab handle. Where specified, the units shall be fitted with limit switches with volt-free changeover contacts for initiation of a remote alarm when the shower is operated.

Showers shall incorporate protection against frost and if necessary a water heater to minimise the initial shock of the deluge when the shower is operated. The heater controls shall include over-temperature protection which shall not interrupt the water flow.

The showers shall be connected to a secure water supply to ensure highest possible availability. A pressure gauge shall be provided for the supply to each unit. The shower collecting tray shall be connected to an approved discharge point.

The appropriate safe condition signs shall be fixed in conspicuous places.

E10.2 Eye baths

Eye baths shall be either self-contained units or integrated with safety showers as appropriate. They shall be of a purpose-designed proprietary type suitable for indoor or outdoor use as specified.

They shall incorporate fine mesh filters and pressure regulators to ensure a safe flow of water for eye irrigation. The water supply valve shall be mechanically operated by means of a tread bar. Frost protection shall be provided.

The eye baths shall be connected to a secure water supply to ensure highest possible availability. A pressure gauge shall be provided for the supply to each unit. The collecting basin drain shall be connected to an approved discharge point.

The appropriate safe condition signs shall be fixed in conspicuous places.

E10.3 Protective clothing

E10.3.1 General requirements

Protective clothing shall be supplied in sets in the quantities specified and shall comprise those articles appropriate to routine operations and maintenance work in the designated areas of the Works.

Where articles are manufactured in various sizes and are not readily adjustable, then each set shall include a range of at least two fittings covering medium and large sizes unless otherwise specified.

E10.3.2 Helmets

Helmets shall be of the general purpose industrial safety type complying with BS 5240 and incorporating an adjustable harness. The colour of the helmets shall be yellow unless otherwise specified.

E10.3.3 Overalls (chemical resistant)

Overalls for chemical handling shall be of the boiler suit pattern manufactured from plasticised PVC or PVC proofed nylon with welded seams and integral hood. Front fastening shall be by means of a zip with button-over protective flap. The overalls shall be impervious and resistant to acids and alkalis at the maximum concentrations used in the Works.

E10.3.4 Gauntlets (chemical resistant)

Gauntlets for chemical handling shall be of the heavy duty pattern with an overall length of at least 400 mm and manufactured from PVC. The external finish shall be smooth.

E10.3.5 Gloves

Gloves for general use including the handling of steel drums and cylinders shall be of heavy duty leather and fabric construction complying with BS 1651.

E10.3.6 Boots

Safety boots shall be in moulded polyvinyl chloride complying with BS EN 345 Part 1 .The boots shall have protective mid-soles and safety toe-caps.

E10.3.7 Storage lockers

Storage lockers for protective clothing shall be of the floor standing single compartment type constructed from 22 swg steel with concealed hinges and key operated locks. Each locker shall have a hat shelf and double coat hook. Lockers shall be located away from hazardous areas but within convenient reach thereof. The lockers shall be suitably labelled as to purpose.

E10.4 Self contained breathing apparatus

Self contained breathing apparatus shall provide complete respiratory protection from the surrounding atmosphere for a period of 60 minutes at normal breathing rate. The apparatus shall comply with BS 7004 and shall be type approved by the Health and Safety Executive.

Each set of apparatus shall incorporate an air cylinder, pressure reducing valve, pressure gauge, demand valve, panoramic vision face mask, bypass valve and adjustable harness with waist strap. The apparatus shall include a warning whistle to indicate approaching exhaustion of the cylinder.

A spare cylinder shall be supplied with each set.

All air cylinders shall be pre-charged with air meeting the requirements of BS 4275.

Each set of apparatus shall be capable of accepting an additional face mask complete with its own demand valve and supply hose.

Each set shall be accommodated in a purpose-designed wall-mounting cabinet of a non-locking type with lift-off front cover. The cabinet shall be suitably labelled.

E10.5 Cartridge type respirators

Cartridge (or canister) type respirators shall comply with BS 2091 and shall be of the full facepiece type unless otherwise specified.

Each respirator shall be supplied with a pack of at least three spare cartridges or canisters.

Each set shall be accommodated in a purpose-designed wall mounting cabinet of a non-locking type or, where specified, in a suitable hand carrying case. Cabinets or cases shall be suitably labelled. The labels shall state the intended use and maximum concentration of the contaminant and exposure time for which the cartridge or canister is suitable.

E10.6 Face masks

Face masks for protection against dust shall comply with BS EN 149 and shall be fully disposable.

Masks shall be supplied in packs of at least 20.

E10.7 Eye protection

Eye protection against gas, liquids and dust shall comply with BS EN 166.

The protection shall be of the goggle type with polycarbonate front lens and anti-mist acetate rear lens.

E10.8 Ear protection

Ear protection shall be of the ear muff type complying with BS EN 352 and tested in accordance with BS 5108.

Ear muffs shall be accommodated in purpose-designed wall mounting cabinets of a non-locking type which shall be suitably labelled. Cabinets shall be located immediately outside areas where sound attenuation is required.

E10.9 First aid kits

First aid kits shall be contained in wall mounting boxes designed to protect the contents from dampness and dust and marked with a white cross on a green background.

Unless otherwise specified, each box shall contain the following items:

- First aid guidance card;
- 20 individually wrapped sterile adhesive dressings of assorted sizes;
- 2 sterile eye pads with attachments;
- 6 individually wrapped triangular bandages;
- 6 safety pins;
- 6 medium sized individually wrapped sterile unmedicated wound dressings (approximately 100 x 80 mm);
- 2 large individually wrapped sterile unmedicated wound dressings (approximately 130 x 90 mm);
- 3 extra large individually wrapped sterile unmedicated wound dressings (approximately 280 x 175 mm).

Additionally, where eye wash bottle sets are not provided separately in the immediate vicinity,

- 3 No. 300 ml of sterile water or sterile normal saline solution (0.9%) in sealed disposable containers.

Additionally, where soap and water of drinking quality are not available in the immediate vicinity,

- 2 individually wrapped moist cleansing wipes.

E10.10 Fire blankets

Fire blankets shall be of the heavy duty industrial type complying with BS 7944 or BS EN 1869 and contained in wall mounting cabinets suitably labelled with white lettering on a red background.

E10.11 Ventilatory resuscitators

Ventilatory resuscitators shall comply with BS 6850 and shall be contained in a carrying case suitably labelled with white lettering on a green background.

E10.12 Safety signs

All labels and signs providing health and safety information or instructions shall comply with BS 5378. Fire safety signs shall comply with BS 5499 Part 1.

Signs which are not integral parts of the safety equipment and which are fixed separately to cabinets or to nearby surfaces shall be manufactured in accordance with Part 3 of this Specification.

E11.0 LABORATORY EQUIPMENT

E11.1 Equipment

Laboratory equipment shall generally consist of standard products. Catalogues or commercial pamphlets describing each major item shall be provided by the Contractor along with details of laboratory furnishings and services.

E11.2 Materials

Materials used in the construction of laboratory furnishings and fittings shall be the best of their respective kinds and shall be selected for their specific applications. Methods of construction shall be of proven design.

E11.3 Flooring

The laboratory floor shall be able to withstand heavy traffic as well as stationary loads. The surface shall be non-slip, resistant to chemical attack and easy to clean.

E11.4 Laboratory benches

E11.4.1 Sectional units

Sectional units shall be designed and constructed to develop maximum strength and rigidity. Each sectional unit shall be completely fabricated ready for placement in the laboratory assembly and shall be a complete integral rigid unit in itself to permit relocation at any subsequent time. Under-bench components located on the laboratory floor shall be equipped with levelling devices, easily adjustable from within the units, to compensate for any unevenness in the laboratory floor. Above-bench units shall include draining and equipment racking and shelving of various kinds. Shelving shall be of a width essential for its purpose and shall be restricted so that only single line capacity is available when used for carrying chemical reagent bottles, glassware or items needing careful handling, in the main laboratory rooms.

Sectional units shall be constructed of timber with either timber or metal underframing. The use of metal shall be generally confined to bench underframing, storage cupboards and shelving.
A specialised titration bench shall be provided in the main laboratory with translucent illuminated work top and back plate, with three double spring clips to accommodate six burettes mounted on the viewing back.

E11.4.2 Bench tops

Materials for the construction of bench tops shall be appropriate for their use. Bench tops for supporting precision balances and sensitive instruments shall be rigid and have a surface that is hard and stable and easily cleaned. Where necessary, anti-vibration supports shall be provided.

For the main laboratory, the bench tops shall be of seasoned hardwood, such as teak or iroko, (the quality of timber and workmanship shall comply with BS 1186)solid grade laminates,solid epoxy resinsor ceramic earthenware.Seasoned hardwood bench tops shall be well oiled and waxed prior to use, unless sealed with special coating such as epoxy resin. Bench tops intended for applications where protection from heat is necessary, shall be of a suitable fire-resistant material of low thermal expansion.

E11.4.3 Fume extraction

Fume cupboards shall be confined working benches spaces equipped with services and provided with an efficient means of removing objectionable fumes.

The fume cupboard shall be provided with an efficient forced extraction system designed to give a face velocity of not less than 0.5m/s. The framing shall be of hardwood protected by a good quality varnish or mild steel painted with a suitable finish. Transparent panels shall be of toughened glass, and opaque panels of highly compressed fibreboard, mechanically strong and resistant to heat. The worktop shall be of black toughened glass of minimum thickness 10mm or approved equivalent material. The sash front window shall be constructed of 6mm toughened safety glass, framed in hardwood or metal, counterbalanced by weights supported by stainless steel sash cords.

Ducting for extraction systems shall be of suitable material such as fibreboard cement, joined together by suitable joining material.

E11.5 Laboratory services

E11.5.1 General

Service pipework shall as far as possible be located behind the sectional units and shall be readily identifiable for purposes of inspection and repair.

E11.5.2 Plumbing

Pipework for plumbing, except drain fixtures and fittings, shall be a red-brass composition containing at least 85% copper, with washers and seats of maximum wear -resistant materials for the specific use. Above-bench fittings and taps shall have a corrosion-resistant polythene finish.

In the main laboratory area, sinks shall be of glazed fireclay, fitted beneath the bench top the bench top being cut to overhang the sink and throated on the underside to provide a water break.

Waste systems shall be supplied in "Vulcathene" or similar high density polythene. All sinks shall be fitted with suitable anti-syphon bottle traps, with removable bases.

E11.5.3 Electrical fittings

Extraction fan motors shall be wound for single phase or three phase 50Hz AC, supplies. Within the laboratory area, all conduits and distribution boards shall be able to provide a minimum of 10% additional capacity. No socket outlet shall be placed on a bench or in a fume-cupboard in such a position that a spill of liquid can constitute a hazard.

E11.5.4 Office furniture

A suitable number of desks chairs, laboratory stools and adjustable height laboratory chairs, shall be provided.

PART E3

APPENDICES

Appendix E3-1 Loss due to abrasion test

The apparatus shall contain a cylindrical perspex column of diameter not less than 50 mm or 50 times the hydraulic diameter of the sample being tested, whichever the greater and height about 500 mm. The bottom of the column shall be fitted with a perforated plate or similar to uniformly distribute water applied underneath over the cross-sectional area of the column. A packing layer may be used to improve the distribution and to retain the sample. A pipe terminating in a fine mesh air inlet shall be connected to the column just above the packing layer. The pipe shall be connected to an air supply and the bottom of the column shall be connected to a clean water supply. Flowmeters shall be provided on both air and water supply. The overflow from the column shall pass through a mesh to retain any sample carry over.

The sample of the filter material to be tested shall first be washed to remove dirt, then dried and sieved. Fill a weighed quantity of dry sample to approximately 250 mm depth. Upwash the sample for 100 hours so that the material just fluidises and the grains are all in contact with each other. After 100 hours remove the material from the column, dry and weigh. Any material collected in the mesh shall be inspected and any complete grains shall be included in the column material. The percentage loss of weight shall be calculated.

Also the column material shall be sieved and the effective size and uniformity coefficient shall be determined and compared with those of the original sample; the results shall not fall out of specification.
For designs where simultaneous application of air and water are specified the sample shall be washed at air and water flow rates to be applied in service.

Reference: The specification for filtering materials for Rapid Gravity Filtration, BW : P. 18.96R, June 1996, British Water, 1 Queen Anne's Gate, London SWIH 9BT.

PART F – ELECTRICAL

F1.0 GENERAL

F1.1 Regulations and Standards

The electrical installation shall comply with all relevant statutory regulations and standards current at date of tender, unless otherwise indicated within this Specification. In general, the following shall apply:-

(a) Indian Electricity Act and rules thereof;
(b) National Electrical Codes of Practice;
(c) Fire Insurance regulations;
(d) Rules laid down by the Chief Electrical Inspector of the State;
(e) Any other regulations laid down by local authorities;
(f) International Electrotechnical Commission (IEC), British Standard, European Standard or CENELEC Harmonised Standards.

If no standard is specified, the relevant Indian Standard or, in the absence of such standard, international standard shall apply.

F1.2 Reference Standards

Unless otherwise approved motors, transformers, generators, switchgear, control gear and associated equipment shall comply with the relevant IEC, ISO, PD, HD, BS EN and BIS Standards. The standards associated with the electrical installation and building services shall be in accordance with the relevant Indian Standards and regulations.

Reference is made in this section to the Standards listed below.

Standards	Subjects
BS 21:1985	Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).
BS 159:1992	Specification for high-voltage busbars and busbar connections.
IEC 60076	Specification for power transformers.
BS 921:1976	Specification. Rubber mats for electrical purposes.
BS 1363-2:1995	13 A plugs, socket-outlets and adaptors. Specification for 13 A switched and unswitched socket-outlets.
BS1363-3:1989	13 A plugs, socket-outlets and adaptors. Specification for adaptors.
BS 1486-1:1959	Lubricating nipples. Lubricating nipples and adaptors for use on machinery and vehicles.
BS 1853-2:1995	Tubular fluorescent lamps for general lighting service. Specification for lamps used in the United Kingdom not included in BS EN 60081, BS EN 60901, BS EN 61195 and BS EN 61199. (Relevant IS reference is mentioned elsewhere).
BS 2484:1985	Specification for straight concrete and clayware cable covers.

Standards	Subjects
BS 2562:1979	Specification for cable boxes for transformers and reactors.
BS 2569-2:1965	Specification for sprayed metal coatings. Protection of iron and steel against corrosion and oxidation at elevated temperatures.
BS 2692-2:1956	Fuses for voltages exceeding 1000 V A.C. Expulsion fuses.
BS 2869:1998	Specification for fuel oils for agricultural, domestic and industrial engines and boilers.
BS 3573:1990	Specification for polyolefin copper-conductor telecommunication cables.
BS 3924:1978	Specification for pressure-sensitive adhesive tapes for electrical insulating purposes.
BS 4444:1989	Guide to electrical earth monitoring and protective conductor proving.
BS 4504-3.3:1989	Circular flanges for pipes, valves and fittings (PN designated). Specification for copper alloy and composite flanges.
BS 4533-102.1:1990	Luminaires. Particular requirements. Specification for fixed general purpose luminaries.
BS 4568-1:1970	Specification for steel conduit and fittings with metric threads of ISO form for electrical installations. Steel conduit, bends and couplers.
BS 4607-1:1984	Non-metallic conduits and fittings for electrical installations. Specification for fittings and components of insulating material.
BS 4678-1:1971	Cable trunking. Steel surface trunking.
BS 4678-4:1982	Cable trunking. Specification for cable trunking made of insulating material.
BS 4999-111:1987	General requirements for rotating electrical machines. Specification for built-in thermal protection for electric motors rated at 660 Volts A.C and below.
BS 4999-140:1987	General requirements for rotating electrical machines. Specification for voltage regulation and parallel operation of A.C synchronous generators.
BS 4999-141:2004	General requirements for rotating electrical machines. Specification for Standard Dimensions.
BS 4999-142:1987	General requirements for rotating electrical machines. Specification for mechanical performance: Vibration.
BS 4999-145:1987	General requirements for rotating electrical machines. Specification for winding terminations.

Standards	Subjects
BS 5000-3:2006	Specification for rotating electrical machines of particular types or for particular applications. Generators to be driven by reciprocating internal combustion engines.
BS 5308-1:1986	Instrumentation cables. Specification for polyethylene insulated cables.
BS 5308-2:1986	Instrumentation cables. Specification for PVC insulated cables.
BS 5372:1997	Specification for dimensions of cable terminations for multi-core extruded solid dielectric insulated distribution cables of rated voltages 600/1000 V and 1900/3300 V having copper or aluminium conductors.
BS 5467:1997	Specification for 600/1000 V and 1900/3300 V armoured electric cable having thermosetting insulation.
BS 5499-5:2002	Graphical symbols and signs. Safety signs, including fire safety signs. Signs with specific safety meanings.
BS 5649-2:1978	Lighting columns. Dimensions and tolerances.
BS 5685-5:1987	Electricity meters. Specification for input and output switching or logic arrangements for multi-rate registers for electricity meters.
BS 5685-8:1991	Electricity meters. Specification for input and output switching or logic arrangements for multi-rate registers for electricity meters.
BS 6004:2000	Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring.
BS 6031:1981	Code of practice for earthworks.
BS 6121-1:1989	Mechanical cable glands. Specification for metallic glands.
BS 6121-2:1989	Mechanical cable glands. Specification for polymeric glands.
BS 6207-3:2001	Mineral insulated cables with a rated voltage not exceeding 750 V. Guide to use.
BS 6231:1998	Specification for PVC-insulated cables for switchgear and controlgear wiring.
BS 6346:1997	Specification for 600/1000 V and 1900/3300 V armoured electric cables having PVC insulation.
BS 6360:1991	Specification for conductors in insulated cables and cords.
BS 6435:1984	Specification for unfilled enclosures for the dry termination of HV cablesfor transformers and reactors.
BS 6622:2007	Electric Cables. Armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV up to 19/33 kV. Requirements and test methods

Standards	Subjects
BS 6651:1999	Code of practice for protection of structures against lightning.
BS 6724:1997	Specification for 600/1000 V and 1900/3300 V armoured electric cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire.
BS 6739:1986	Code of practice for instrumentation in process control systems: installation design and practice.
BS 6910-1:1988	Cold pour resin compound and heat-shrink cable joints in the voltage range up to 1000 V A.C and 1500 V D.C. Specification for materials.
BS 7194:1990	Specification for direct-current and low-frequency electronic measuring instruments with a digital display.
BS 7211:1998	Electric cables. Thermosetting insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring, and having low emission of smoke and corrosive gases when affected by fire.
BS 7430:1998	Code of practice for earthing.
BS 7671:2008	Requirements for electrical installations. IEE Wiring Regulations.
BS EN 10217-3:2002	Welded steel tubes for pressure purposes. Technical delivery conditions. Alloy fine grain steel tubes.
BS EN 50014:1998	Electrical apparatus for potentially explosive atmospheres. General requirements.
BS EN 50086-1:1994	Specification for conduit systems for cable management. General requirements.
BS EN 50086-2-1:1996	Specification for conduit systems for cable management. Particular requirements. Rigid conduit systems.
BS EN 50091-1-1:1997	General and safety requirements for UPS used in operator access area.
BS EN 50091-1-2:1996	Specification for UPS, EMC requirements.
BS EN 50262:1999	Metric cable glands for electrical installations.
BS EN 60034-1:2004	Rotating electrical machines. Rating and performance.
BS EN 60034-8:2007	Rotating electrical machines. Terminal markings and direction of rotation.
BS EN 60034-12:2002	Rotating electrical machines. Starting performance of single-speed three-phase cage induction motors.
BS EN 60044-1:1999	Instrument transformers. Current transformers.
BS EN 60044-2:1999	Instrument transformers. Inductive voltage transformers.

Standards	Subjects
BS EN 60061-1:1997	Specification for lamp caps and holders together with gauges for the control of interchangeability and safety. Lamps caps.
BS EN 60064:1995 +A4:2007	Tungsten Filament Lamps for domestic and similar general lighting purposes. Performance requirements.
BS EN 60076-1:1997	Tungsten filament lamps for domestic and similar general lighting purposes. Performance requirements.
BS EN 60129:1994	Specification for alternating current disconnector and earthing switches.
BS EN 60214-1:2003	Tap Changers. Performance requirements and tests methods.
BS EN 60282-1:2006	High-voltage fuses. Current-limiting fuses.
BS EN 62271-200: 2004	High-voltage switchgear and control gear. A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.
BS EN 60432-1:2000	Safety specification for incandescent lamps. Tungsten filament lamps for domestic and similar general lighting purposes.
BS EN 60439-1:1999	Specification for low-voltage switchgear and control gear assemblies. Specification for type-tested and partially type-tested assemblies.
BS EN 60529:1992	Specification for degrees of protection provided by enclosures (IP code).
BS EN 60598-1:2000	Luminaires. General requirements and tests.
BS EN 60669-1:2000	Switches for household and similar fixed electrical installations. General requirements.
BS EN 60742:1996	Isolating transformers and safety isolating transformers. Requirements.
BS EN 60836:2005	Specifications for unused silicone insulating liquids for electrotechnical purposes
BS EN 60898-2:2006	Circuit-breakers for overcurrent protection for household and similar installations. Circuit-breakers for A.C. and D.C Operation.
BS EN 60903:2003	Live working. Gloves of insulating material.
BS EN 60947-5-1:2004	Specification for low-voltage switchgear and controlgear. Control circuit devices and switching elements. Electromechanical control circuit devices.
BS EN 61000-6-4:2001	Electromagnetic compatibility (EMC). General standards. Emission standard for industrial environments.
BS EN 61008-1:2004	Specification for residual current operated circuit-breakers without integral overcurrent protection for household and similar uses

Standards	Subjects
	(RCCBs). General rules.
BS EN 61008-2-1:1995	Specification for residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs). Applicability of the general rules to RCCBs functionally independent of line voltage.
BS EN 62053-21:2003	Electricity metering eqquipment (AC) Particular requirements.Static meters for active (Class1 & 2).
BS EN 62271-100:2001	High-voltage switchgear and controlgear. High-voltage alternating-current circuit-breakers.
BS EN 62271-102:2001	High-voltage switchgear and controlgear. High-voltage alternating current disconnectors and earthing switches.
IEC 60034-5:2000	Rotating electrical machines. Degrees of protection provided by the integral design of rotating electrical machines (IP code). Classification.
IEC 60034-6:1991	Rotating electrical machines. Method of cooling (IC code).
IEC 60034-9:1997	Rotating electrical machines. Noise limits.
IEC 60051-1:1997	Direct acting indicating analogue electrical measuring instruments and their accessories. Definitions and general requirements common to all parts.
IEC 60073:2002	Basic and safety principles for man-machine interface, marking and identification. Coding principles for indicators and actuators.
IEC 60085:2004	Method for determining the thermal Classification of electrical insulation.
IEC 60136:1986	General requirements for rotating electrical machines. Specification for dimensions of brushes and brush holders for electrical machinery.
IEC 60137:2003	Insulated bushings for alternating voltages above 1kV.
IEC 60188:2001	High pressure Mercury Vapour Lamps. Performance Specifications.
IEC 60255	Electrical Relays.
IEC 60269-1:1998	Low-voltage fuses. General requirements.
IEC 60287-1-1:2006	Electric cables - Calculation of the current rating - Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General.
IEC 60404-1:2000	Magnetic Materials. Classification.
IEC 60439-1:1999	Specification for low-voltage switchgear and controlgear assemblies. Specification for type-tested and partially type-tested assemblies.

Standards	Subjects
IEC 60470:2000	High-voltage alternating current contactors and contactor-based motor starters
BS EN 60076-11:2004	Dry-type power transformers.
IEC 60947-1:2007	Specification for low-voltage switchgear and controlgear. General rules
IEC 60947-2:2006	Specification for low-voltage switchgear and controlgear. Circuit-breakers.
IEC 60947-3:1999	Specification for low-voltage switchgear and controlgear. Switches, disconnectors, switch-disconnectors and fuse-combination units.
IEC 60947-4-1:2001	Specification for low-voltage switchgear and controlgear. Contactors and motor-starters. Electromechanical contactors and motor-starters.
IEC 60947-4-2:2000	Specification for low-voltage switchgear and controlgear. Contactors and motor-starters. A.C. semiconductor motor controllers and starters.
IEC 60947-4-3:2000	Specification for low-voltage switchgear and controlgear. Contactors and motor-starters. Contactors and motor-starters. AC semiconductor controllers and contactors for non-motor loads.
IEC 60947-7-1:2002	Specification for low-voltage switchgear and controlgear. Ancillary equipment. Terminal blocks for copper conductors.
IEC 61000	Electromagnetic Compatibility (EMC).
IS 732:1989	Code of Practice for Electrical Wiring Installations.
IS 2309:1989	Protection of Buildings and Allied Structures Against Lightning - Code of Practice.
IS 2418:Part1:1977	Specification for Tubular Fluorescent Lamps for Lighting Services-Part1:Requirement & Tests.
IS 3043:1987	Code of Practice for Earthing.
IS 3231	Specification for Electrical Relays for Power System Protection.
IS 3854:1997	Switches for Domestic and Similar Purposes - Specification.
IS 6701:1985	Specification for Tungsten Filament Miscellaneous Electric Lamps.
IS 8686:1977	Specification for Static Protection Relays.
IS 13947-2:1993	Specification for Low Voltage switchgear and Low Voltage-Part 2: Circuit Breakers.
IS/IEC 309-1:1988	Plugs, Sockets-Outlets and Couplers for Industrial Purposes-Part 1: General Requirements.

Standards	Subjects
IS/IEC 309-2:1989	Plugs, Sockets-Outlets and Couplers for Industrial Purposes-Part 2:Dimension Interchangeability Requirements for Pin and Contact Tube Accessories.
ISO 1000:1992.	Specification for SI units and recommendations for the use of their multiples and of certain other units.
ISO 1461:1999	Hot dip galvanised coatings on fabricated iron and steel articles. Specifications and test methods.
ISO 2112:1990	Specification for aminoplastic moulding materials.
ISO 3046-1:2002	Reciprocating internal combustion engines. Performance. Declarations of power, fuel and lubricating oil consumptions and test methods. Additional requirements for engines for general use.
ISO 3046-4:1997	Reciprocating internal combustion engines. Performance. Speed governing.
ISO 5657:1986	Fire tests on building materials and structures. Method of measuring the ignitability of products subjected to thermal irradiance.
PD 5304:2000	The safe use of machinery.
SP 30:1985	National Electric Code.
HD 21.1 S4:2002	Cables of rated voltages up to and including 450/750 V and having thermoplastic insulation - Part 1: General requirements.
HD 22.1 S4:2002	Cables of rated voltages up to and including 450/750 V and having cross-linked insulation - Part 1: General requirements.

F1.3 Abbreviations of electrical terms

For the purpose of this Specification, the following abbreviations of electrical terms have been used:—

R	=	red phase
Y	=	yellow phase
B	=	blue phase
N	=	neutral
ac	=	alternating current
dc	=	direct current
A	=	ampere
mA	=	milliamp
V	=	volt
kW	=	kilowatt
kWh	=	kilowatt hour
kVAr	=	kilovolt ampere reactive
kVA	=	kilovolt ampere
MVA	=	megavolt ampere
Hz	=	hertz (cycles per second)
CT	=	current transformer
SP	=	single pole
SPN	=	single pole and neutral
DP	=	double pole
TP	=	triple pole
TPN	=	triple pole and neutral
SPSwN	=	single pole and switched neutral
TPSwN	=	triple pole and switched neutral
LSF	=	low smoke and fumes
MCB	=	miniature circuit breaker
MCCB	=	moulded-case circuit breaker
RCD	=	residual current device
MCC	=	motor control centre

F1.4 Polarity

All cables shall be so connected between main switchboards, distribution boards, plant and accessories so that the correct sequence of phase rotation is preserved throughout the system.

All non-flexible cable cores shall be identified with phase colours for three-wire and four-wire circuits. Single-phase circuits shall be red and black.

Where more than one phase is incorporated on a common system in one room, the live cores shall be red, yellow, or blue as appropriate. All fittings and switch accessories shall be permanently labelled and segregated.

Harmonised systems of phase layouts on plant and equipment, of cable and plant phase identification, and of cable core insulation colouring shall be used throughout the Works.

F1.5 Voltage and frequency

Unless otherwise specified, all apparatus and wiring shall be suitable for use with a three-phase, four-wire, 240/415 volt, 50Hz solidly-earthed neutral supply having a nominal sinusoidal waveform.

Supplies for circuit-breaker control, circuit-breaker spring-charging motors, protection relay, tripping coil, closing coil, alarm and indication functions shall, unless otherwise specified, be 110V dc for high voltage switchgear.

Supplies for incomer and bus section circuit-breaker control, tripping coil, closing coil, alarm and indication functions shall, unless otherwise specified, be 48V dc for low voltage switchboard.

Supplies for transformer tap-changing motors and switchboard anti-condensation heaters shall, unless otherwise specified, be 240V ac.

Supplies for low voltage motor-starter control circuits, contactor coils and relays shall, unless otherwise specified, be 240V ac.

Supplies for high voltage motor-starter control circuits, contactor coils and relays shall, unless otherwise specified, be 110V dc.

Supplies for interposing relays between programmable electronic devices and other equipment shall, unless otherwise specified, be 24V dc.

During construction and installation of the Works, all portable electric tools shall operate from 240V ac. supply. The supply transformer shall be of the double-wound type with an earthed interwinding screen. The transformer secondary winding shall have an earthed centre tap.

F1.6 Units of measurement

All information shall be in SI units in accordance with ISO 1000:1992. Where plant designs exist in Imperial units, the dimensions and tolerances of layouts and terminal points shall be presented in SI units to a degree of accuracy which permits the precise matching of existing components.

F1.7 Electricity supplies

Not less than two months prior to the power supply being required, the Contractor shall arrange for the electricity supply authority to undertake any testing and inspection necessary for the electricity supplies to be connected when required. On completion of the tests and inspections, the Contractor shall supply to the Engineer a copy of his Electrical Installation Completion Certificate and of the electricity supply authority's test certificates.

F1.8 Electrical safety

The Contractor shall be responsible for the electrical safety of all equipment supplied and installed. Whilst any equipment is being installed or tested, the Contractor shall ensure that all necessary precautions are taken to safeguard personnel working on Site. If necessary, this shall include fencing off areas in which a risk is considered likely to exist, and erecting warning notices.

The Contractor shall be responsible for ensuring that the electrical installation is carried out by competent personnel and that the work is carried out in accordance with standard procedures and test requirements. Before any piece of apparatus is energised, it shall be thoroughly examined to ensure that it is free of dirt, water, vermin or other foreign matter.

F2.0 ELECTRICAL MOTORS

F2.1 Motors

F2.1.1 Type

Motors shall be of the ac cage or wound-rotor induction type as specified.

Energy-efficient type motors shall be provided. They shall have minimum efficiencies at rated output, and maximum ranges of efficiency between half- and full-rated output, which meet the following requirements:

Motor rated output (kW)	**Minimum efficiency at rated output** (%)	**Maximum efficiency range half to full-rated output** (%)
250 and above	96	1.5
132 up to 249	95	2.0
55 up to 131	94	2.0
Below 55	92	2.0

F2.1.2 Rating and duty

Motors shall comply with the general requirements for rating and performance as stipulated in BS EN 60034-1:2004 except where amended below. Unless otherwise specified, motors shall be suitable for continuous operation at rated output at any voltage between 94% and 106% and any frequency between 95% and 102% of rated values.

Motors for use with variable-frequency converter-type speed controllers shall be rated for continuous running duty over the specified speed range. The motor design shall take in to account:

- increased heating, vibration and noise arising from a non-sinusoidal supply voltage waveform;
- reduced cooling when operating at lower than rated speed;
- bearing life, lubrication, radial forces and critical speeds when operated at speeds in excess of rated speed.

F2.1.3 Starting

Unless otherwise specified, cage induction motors shall be full or reduced voltage direct-on-line or star-delta started and wound-rotor induction motors shall be rotor-resistance started.

Unless otherwise specified, the starting performance of cage induction motors shall comply with BS EN 60034-12:2002 design ‘N’, ‘NY’ or ‘D’ as appropriate for the starting method specified. The minimum voltage at the motor terminals shall be assumed to be a constant value of 85% of rated voltage during the acceleration period.

Locked rotor current of the motor shall not exceed 600% of the full load current.

The frequency of starting for wound-rotor type motors shall be as specified to suit duty requirements.

F2.1.4 Windings and insulation

Winding insulation shall be Class F or better to IEC 60085:2004 and the maximum temperature shall not exceed that permitted for Class B.

Windings shall be supported, braced, wedged and blocked to provide adequate rigidity under all conditions of service. Special attention shall be given to the windings of direct-on-line started motors and the support of windings of vertical motors to prevent any permanent displacement during the service life. The coil overhang of rotor windings shall be tension banded.

Cage-type rotors shall be designed to provide an adequate factor of safety against mechanical failure due to fatigue during the service life of the motor. Special attention shall be given to the design of cage rotors fitted to motors which are subject to operation at speeds in excess of rated speed, and where flywheels or large inertia loads are involved.

Electrical joints and connections shall withstand the mechanical and thermal stresses under normal and abnormal operating conditions. Stator endwindings shall be blocked and braced to provide high rigidity.

Completed windings, including connections, shall be subjected to a minimum of two cycles of vacuum impregnation with solvent-free resin varnish followed by curing, so as to fill effectively the gaps between individual conductors, to enhance mechanical strength and to provide a high resistance to moisture, oil and chemical contamination.

The insulation of flexible cables connecting stator windings to terminal boxes shall be of the chlorosulphonated polyethylene (CPS) or ethylene propylene rubber (EPR). Natural rubber insulated cables shall not be used. Cables shall be securely fixed to the stator frame.

The winding insulation materials and cable insulation shall be resistant to flame propagation.

F2.1.5 Slip rings

Slip rings and brush gear shall be designed to operate without harmful sparking and to run for not less than 3 months continuous operation without the need for adjustment or replacement. The dimensions of brushes and brush holders shall comply with IEC 60136:1986. Precautions shall be taken to protect the motor windings against the harmful ingress of carbon dust.

Removable covers shall be fitted to provide access to the brush gear and slip rings. Slip rings shall be fitted in such a way as to afford ease of maintenance and removal.

F2.1.6 Degree of protection for motor enclosures

The degree of protection for motor enclosures shall be in accordance with IEC 60034-5:2000. Unless otherwise specified, the following minimum degrees of protection shall apply:

- motors located indoors in a dry and clean environment: IP22
- motors located indoors in damp or wet areas: IP54
- motors located outdoors: IP55

Fans and blades external to the enclosure shall be protected against contact by means of guards. The degree of protection offered by guards shall comply with IEC 60034-5:2000.

Totally-enclosed motors shall be provided with suitable means for breathing and for drainage to prevent the accumulation of water.

F2.1.7 Cooling

Cooling arrangements shall be in accordance with IEC 60034–6:1991. Unless otherwise specified, the cooling classifications shall be as follows:

- motors located indoors in a dry and clean environment: IC01 or IC41;
- motors located indoors in damp or wet areas: IC41;
- motors located outdoors: IC41.

F2.1.8 Dimensions

Motor dimensions shall be in accordance with BS 4999-141:1987.

F2.1.9 General constructional features

Motor frames shall be cast iron, fabricated from steel plate or aluminium as appropriate. Frames shall incorporate substantial internal ribbing to provide high structural strength.

End covers, end shields, external fan cowls and other external components shall be of adequate strength and robustness, and shall be constructed of metal unless otherwise approved by the Engineer.

Plastic components shall be designed to take into account the environmental conditions and the long-term effects of operating temperature, ageing, and thermal stability of the material. Where used for external components, the material shall be resistant to flame propagation. Where plastic covers enclose live parts, the design shall eliminate the risk of electrical shock to personnel during operation of the motor.

F2.1.10 Bearings — general

Bearings shall be capable of accepting:

- the mechanical and electrical forces imposed on them by the rotor;
- the forces imposed by the motor alttitude;
- external forces due to the drive method.

Bearings shall be of the rolling or plain type as determined by consideration of motor rating and speed, shaft system, duty, method of drive and the type of bearing of the driven equipment.

Unless otherwise specified or approved by the Engineer, motors rated up to and including 750kW at 1000rpm, 530kW at 1500rpm and 375kW at above 1500rpm shall be fitted with rolling-type bearings.

Where bearings are insulated from the main frame to suppress shaft circulating currents, they shall be connected to earth at one point via a link. The link shall be removable to permit testing of the bearing insulation. Oil and water pipes, direct-driven oil pumps and any other ancillary equipment shall be insulated as necessary to maintain the integrity of the bearing insulation. The insulation shall not be short-circuited by the application of electrically-conducting paint.

F2.1.11 Bearings - rolling-type bearings

Rolling bearings shall comply with the relevant International Standards and the assembly shall be designed to exclude the ingress of dirt and water. The bearings shall be grease-lubricated or oil-lubricated where the shaft speed is in excess of that permitted by the former. The bearing assembly shall be sealed to prevent leakage of the lubricant along the shaft and shall be designed to permit the easy removal of bearings. Oil-lubricated bearings shall be fitted with a breather.

Rolling-type bearings shall be selected to meet the following requirements:

- a minimum life of 40 000 hours when the forces on the bearing are from the motor only and 32 000 hours when the forces include those from the motor and the driven unit;
- a re-lubrication interval preferably of 8000 hours but not less than 4000 hours;
- a maximum outer-race temperature of 80°C.

Rolling bearings of the ‘sealed-for-life’ type shall operate for a minimum of 18 000 running hours, or for a period of 5 years if the latter occurs sooner.

Grease-lubricated bearings shall be packed with lithium-based grease at the time of assembly.

A separate grease nipple shall be provided for each lubricating point. Grease nipples shall be manufactured from steel and shall comply with BS 1486-1:1959. Bearings shall be provided with facilities to eject surplus grease.

Oil-lubricated bearings shall be provided with an oil reservoir, breather and, if appropriate, an external make-up reservoir. The reservoir shall have a filler plug and an oil-level indicator.

Where there is a danger of vibration from other plant being transmitted to a stationary motor, provision shall be made to prevent fretting damage to the bearings.

It shall be possible for lubrication to be carried out with the motor stationary or running and without the need to remove guards.

F2.1.12 Bearings - plain bearings

Plain bearings shall be self-lubricated by oil rings or discs, or alternatively, shall be forced-lubricated. The bearings shall be designed to exclude the ingress of dust and water, shall have provision for breathing and shall be sealed to prevent leakage of oil. Bearings shall be fitted with an accessible drain plug, provision to permit the cleaning of the oil sump, and a transparent window or other approved facility for observing the oil feed.

The two bearing-shell parts shall have white-metal linings and shall be self-aligning. The two bearing shells shall be located to each other by dowels.

The temperature of the oil leaving the bearing shall not exceed 70°C. Bearings shall incorporate thermometer pockets or shall be fitted with a dial-type thermometer as specified. Dial-type thermometers shall incorporate two sets of adjustable contacts for alarm and motor-trip initiation. The contacts shall be wired to a terminal box.

The oil rings or discs of self-lubricating bearings shall run in an oil-bath. Bearings shall have provision for filling and a clearly-visible oil-level indicator. The oil-level indicator may be fitted externally to the bearing.

Forced-lubricated bearings shall be supplied from a self-priming oil pump driven from the main shaft system or from a separate pump. An oil-flow indicator shall be provided for each bearing together with oil cooler, oil tank filter valves and all interconnecting pipework. Unless otherwise specified, the oil-feed system shall be fitted with a pressure gauge and flow switch. The pressure gauge shall incorporate two sets of adjustable contacts for alarm and motor-trip initiation. The contacts shall be wired to a terminal box.

F2.1.13 Balancing

Rotors shall be dynamically balanced with full key. The rotors of motors fitted with an external fan shall be initially balanced without the fan and then with the previously statically-balanced fan fitted. Any additional weights shall be fitted to the fan balance rings.

F2.1.14 Noise levels

Unless otherwise specified, the mean sound power level shall not exceed those given in IEC 60034–9:1997, class 'Normal'.

F2.1.15 Vibration levels

Unless otherwise specified, the maximum limits of vibration severity for horizontally mounted motors shall be quality grade 'N' (normal) as given in BS 4999-142:1987. For vertical motors, the same limits shall apply to the lower bearings and 1.5 times these limits for top bearings unless otherwise agreed with the Engineer.

F2.1.16 Lifting facilities

All heavy parts of motors shall be provided with facilities for lifting.

F2.1.17 Temperature-monitoring devices

Monitoring devices for motor-winding temperature indication and thermal protection shall be of the resistance or thermocouple type as specified. For thermal protection application only, positive temperature coefficient (PTC) type thermistors shall be used unless otherwise specified.

Resistance and thermocouple monitoring devices shall be distributed evenly around the stator periphery and installed at the hottest points. The devices shall not be directly exposed to the cooling air.

Thermistors shall be installed in the stator end winding and shall be distributed evenly over the winding periphery. The thermistor reference temperatures for alarm and tripping shall be in accordance with BS 4999-111:1987.

Monitoring devices shall be wired to an insulated terminal strip within a dedicated terminal box fitted with an identification label.

Devices for bearing and cooling air temperature monitoring shall be of the thermocouple type.

The requirements for temperature-monitoring devices shall be as specified.

F2.1.18 Anti-condensation heaters

Anti-condensation heaters shall be fitted to all low-voltage motors located outdoors and all high-voltage motors.

The requirement for anti-condensation heaters for low-voltage motors located in other areas shall be specified.

The rating per unit length of the heaters shall be such that the surface temperature of the heater does not exceed 200°C in an ambient temperature of 40°C. The heater voltage shall be 240V unless otherwise specified.

Heaters shall be connected to an insulated terminal strip within a dedicated terminal box by means of flexible butyl rubber insulated leads. The terminal box cover shall be fitted with a warning label advising the need to isolate the supply before removing.

F2.1.19 Terminal boxes

Terminal boxes shall be cast iron or fabricated from sheet steel as appropriate to the motor frame construction and shall have a matching cover. A neoprene-bonded gasket shall be fitted between the box and motor frame and between the box and cover.

Terminal boxes shall be dimensioned to permit external cables to be satisfactorily connected. The cable box design shall take in to account the need to connect oversized cables required for volt-drop or short-circuit considerations.

Terminal boxes shall be provided with a removable cable gland plate and shall be capable of being turned through 360^0 in steps of 90^0. Unless otherwise specified, gland plates fitted to motors for use with variable-frequency converter-type speed controllers shall be insulated from the cable box with facilities for shorting out.

The termination arrangement for low-voltage motors shall be of the air-insulated stud type. The termination arrangement for high-voltage motors shall be of the phase-insulated, phase-separated or phase-segregated stud type as specified.

Terminations, associated leads and terminal boxes shall withstand the effects of a short circuit at the motor terminals without damage. For low-voltage motors, unless otherwise specified, it may be assumed that the supply protective device will be of the current-limiting type. For high-voltage motors, the short-circuit withstand requirements shall be as specified.

Winding terminations and terminal markings shall comply with BS 4999-145:1987 and BS EN 60034-8:2007 respectively.

The terminal boxes shall have a degree of protection of at least IP 55 for outdoor application.

F2.2 Hollow-shaft motor drives for borehole pumps

In addition to the requirements for ‘Electrical motors’, hollow-shaft motor drives shall be designed to permit axial adjustment of the pump drive shaft and shall incorporate a thrust bearing in the upper end shield of the motor.

The thrust bearing within the motor shall be able to support the weight of the rotating parts of pump, drive shaft and motor, combined with hydraulic axial load under all conditions of pumping. The bearing shall be of the Michell tilting-pad type with suitable arrangements for circulating and cooling through a cooling coil in the bearing oil reservoir. A thermometer shall be fitted to indicate the bearing temperature. A visual indicator shall be fitted in the cooling circuit to show that the liquid is flowing. A temperature sensor shall be fitted and shall be arranged to open the starter contactor if the bearing should overheat. The bearing selected shall be suitable for a life of 5 years under the specified operating conditions.

The motor shall incorporate a ratchet of the bass and ramp or similar type to prevent reverse rotation.

F2.3 Paint and Finish

All motor parts exposed directly to atmosphere shall be provided with synthetic enamel finish paints to produce a neat and durable surface which shall prevent rusting and corrosion.

F2.4 Tests

Motors shall be subjected to all the routine tests as per the applicable standard in the presence of the Engineer's Representative. Copies of test certificates of type and routine tests shall be furnished for the Engineer's approval. The Contractor shall provide calibration test certificates from standard laboratories traceable to national/international standards.

F3.0 ELECTRICAL TRASFORMERS

F3.1 Liquid-immersed power transformers

F3.1.1 Standards

Liquid-immersed transformers shall comply with IEC 60076.

F3.1.2 Service conditions

Unless otherwise specified, the normal service conditions as stated in BS EN 60076-1:1997 shall apply.

F3.1.3 Dielectric fluids

Unless otherwise specified, the dielectric fluid shall be mineral oil conforming to BS 148:1998.

Low-flammability fluid shall be synthetic silicone or ester-based as specified.

F3.1.4 Cooling method

Unless otherwise specified, the cooling method shall be natural oil and air circulation.

F3.1.5 Tanks and radiators

Tanks shall be fabricated from mild steel sheet and shall be provided with a skid type base. The tank shall be constructed to prevent distortion when the complete transformer is lifted, jacked or transported.

Unless otherwise specified, mineral-oil-filled transformers shall be of the free-breathing type and shall be fitted with a dehydrating breather. Synthetic-fluid-filled transformers shall be of the sealed type.

Tank covers shall be designed and constructed to prevent the accumulation of water.

Cooling radiators shall be of the detachable pressed-steel panel type or corrugations on the tank side as dictated by the transformer rating and design. Tanks with corrugated sides shall have strengthening bars to provide rigidity and mechanical strength.

F3.1.6 Cores

Cores shall be manufactured from laminations of cold-rolled, low-loss and grain-orientated electrical sheet steel having physical characteristics conforming with IEC 60404-1:2000.

Each lamination shall be coated on both sides with insulation which shall be unaffected by mineral oil or other dielectric fluid and continuous operation at the design temperature of the transformer.

The core shall be of interleaved construction with mitred or step-lap mitred construction, and shall be designed to provide uniform flux distribution throughout the magnetic circuit and minimise flux saturation at corner joints.

The core limb laminations shall be held in compression by heavy-duty cotton tape, bands or bolts depending on core size.

Depending on the physical size of the core, top and bottom yoke laminations shall be clamped between steel channel sections, plates or folded steel clamps. The top and bottom channels, plates or clamps shall be secured to each other by means of steel tie rods to eliminate tensile stress in the core limbs when the core and windings are lifted.

The flux density at any point in the magnetic circuit, when the transformer is connected on the principal tapping and operating at rated voltage and frequency, shall not exceed a value consistent with low loss and noise, with an upper limit of 1.8 Tesla.

F3.1.7 Windings

High-voltage and low-voltage windings shall be manufactured from high-conductivity copper. Conductors shall be insulated with high-quality paper or synthetic varnish according to design requirements. Insulation levels shall comply with IEC 60076 Tables 8 and 9 unless otherwise specified.

High-voltage windings shall be of the layer or disc type depending on voltage and application. Low-voltage windings shall be of the helical layer type. Windings shall be constructed and braced to withstand the forces arising under short-circuit conditions without deformation or movement.

Tapping and phase leads shall be multi-paper covered flexible conductors. The leads shall be rigidly braced and supported to prevent movement under short-circuit conditions. Barriers shall be provided between phase and tapping leads.

Three-phase distribution transformers shall be connected delta-star, connection symbol Dyn 11, unless otherwise specified.

F3.1.8 Tappings

Tappings shall be positioned to minimise voltage stress and to maintain electromagnetic balance of the windings as far as possible over the tapping range.

F3.1.9 Off-circuit tap changing

Unless otherwise specified, transformers shall be fitted with an off-circuit tap-changing facility having a tapping range not less than plus and minus 10% and 10% of nominal supply voltage in steps of 1.25% as specified. Tap selection shall be by means of an externally-operated self-positioning switch.

Provision shall be made for the locking of the tapping switch handle in each position by means of a padlock having a 7mm diameter shackle.

The tap position shall be clearly marked.

F3.1.10 On-load tap changing

On-load tap-changers shall be of the self-contained and fully-automatic type with high-speed resistor-load selector switches. The design shall permit bi-directional power flow at rated current. Tap-changers shall be manufactured and type tested in accordance with IEC 60214-1:2003.

The tap-changer shall be mounted on the side of the main transformer tank. Oil in the switch compartment shall be separate from the oil in the main transformer tank.

The tap-changer shall be fitted with a conservator complete with an oil surge and low oil-level relay with trip contacts, silica gel breather and padlockable drain valve.

The design and construction of the selector and changeover switch shall minimise maintenance, electrical losses, contact erosion and the formation of carbon deposits.

Transition resistors shall be wound from nickel-chrome or nickel-copper conductors.

The driving mechanism shall be an integral part of the tap-changer. The moving contact assembly shall be indexed from tap to tap at high speed using the stored energy of a spring-charged battery. The spring battery shall be charged by an electric motor. A manual spring-charging facility shall be provided.

The design of the tap-changer shall ensure that when a tap-change is initiated, it will be completed independently of the operation of control relays and switches. Failure of the auxiliary supply during the tap-changing sequence shall not prevent the completion of a tap-change. A tap-change shall be prevented when the transformer is operating at a load in excess of the rated current of the tap-changer or under short-circuit conditions.

The following facilities shall be provided:

- local/remote control selector switch;
- local tap-change initiation control switch. The switch shall be clearly labelled to indicate the direction of the tap-change;
- voltage-free auxiliary switches for the remote indication of tap position.

The following operational limitations shall apply:

- it shall not be possible for the local and remote electrical controls to be in operation at the same time;
- operation from the local or remote control switch shall initiate one tap movement and the control switch shall return to the neutral position between successive operations;
- for transformers operating in parallel, it shall not be possible for there to be more than one tap difference.

Electrical equipment for local operation shall be located in an enclosure integral with the tap-changer.

F3.1.11 Cable boxes

Unless otherwise specified, transformers shall be fitted with high-voltage and low-voltage cable boxes. High-voltage cable boxes shall be of the filled type complying with BS 2562:1979 or of the unfilled type complying with BS 6435:1984 as specified. Low-voltage cable boxes shall be of the unfilled type complying with BS 2562:1979.

Cable glands shall be supplied and fitted. Glands for polymeric insulated cables shall be of the mechanical type complying with BS 6121-2:1989. Glands shall be manufactured from brass, except where used with aluminium armoured cable when they shall be of aluminium. Glands shall be Type E1W for armoured cables and Type A2 for unarmoured cables. For armoured cables, the glands shall have an integral earth bond attachment.

Disconnecting chambers shall be fitted when specified.

F3.1.12 Bushings

High-voltage bushings, when specified, shall comply with IEC 60137:2003.

F3.1.13 Conservators

Mineral-oil-filled transformers for rated voltages above 11 000V shall be fitted with a conservator. Transformers of rated voltage 11 000V and below shall be fitted with a conservator when specified.

Conservators shall be manufactured from sheet steel and shall be positioned above the highest point of the oil circulating system. Connections into the main tank shall be at the highest point to prevent air or gas becoming trapped under the main tank cover.

The capacity of conservators shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservators shall be complete with filling point, drain valve with captive cap, oil level gauge, silica-gel type dehydrating breather and provision for access for cleaning. The breather shall be mounted at a height of approximately 1.5m above ground level. The pipe between the conservator and main tank shall be fitted with a valve.

All valves shall be of the gate type, have non-rising spindles and provision for locking in the closed and open positions.

F3.1.14 Standard fittings

The following standard fittings shall be provided:

- diagram and connection plate;
- lifting lugs;
- earthing terminal;
- liquid level indicator;
- drain valve;
- thermometer pocket;
- padlocks.

The following fittings shall be provided as applicable:

- filling hole and cover;
- plain breathing device of weatherproof design;
- pressure-bleed device.

F3.1.15 Optional fittings

One or more of the following optional fittings shall be provided when specified:

- gas and oil surge (Buchholz) relay;
- winding temperature indicator;
- dielectric fluid temperature indicator;
- pressure relief device;
- dehydrating breather.

F3.1.16 Gas and oil surge (Buchholz) relay

Gas and oil-actuated (Buchholz) relays shall be located in the pipework interconnecting the main and conservator tanks. A straight run of pipe shall be provided of minimum length five times the internal diameter on the main tank side and three times the internal diameter on the conservator tank side of the relay. The pipe shall be inclined at an angle recommended by the relay manufacturer. The pipework shall not have sharp bends.

Relays shall be provided with a test cock suitable for the attachment of a flexible pipe for checking operation and main tank side isolating valve. The valve type shall be as specified for the conservator.

Relays shall be fitted with contacts which close on collection of gas or low oil level for alarm initiation and contacts which close on oil surge for circuit-breaker trip initiation.

F3.1.17 Winding temperature indicator

Winding temperature indicators shall be of the dial type and shall incorporate two sets of adjustable voltage-free changeover contacts for the initiation of remote alarm and trip signals.

F3.1.18 Dielectric fluid temperature indicator

Dielectric fluid temperature indicators shall be of the dial type and shall incorporate two sets of adjustable voltage-free changeover contacts for the initiation of remote alarm and trip signals.

F3.1.19 Dehydrating breathers

Dehydrating breathers shall be of the silica-gel cartridge type constructed from heat-resistant glass tubing with strong metal shield. The breather design shall ensure uniform circulation of air through the charge. The whole assembly shall be constructed to form a robust and durable unit.

F3.1.20 Pressure-relief device

Pressure-relief devices shall incorporate a colour-coded mechanical indicator pin and a sealed, weatherproof changeover-switch assemblyfor the initiation of remote alarm/trip signal.

F3.1.21 Drain valves

Drain valves shall be of the gate type with non-rising spindle. Provision shall be made for padlocking the valve in the fully-closed position.

Drain valves fitted to mineral-oil-filled transformers shall be fitted with a plug.

Drain valves fitted to synthetic-fluid-filled transformers shall be fitted with a gasketed cover plate.

F3.1.22 Padlocks

Padlocks for all valves and tapping switch handles shall be provided.

Padlocks shall be of the brass cylinder type with non-rusting hardened shackle. Each padlock shall have a different key number.

Two keys shall be supplied with each padlock.

F3.1.23 Rating and connection plates

Rating and connection plates shall be securely fitted to the transformer. The plates shall be of non-corrodible and durable material.

F3.1.24 Painting

As soon as practical after shot blasting or zinc-spray treatment, the exterior of steel tanks, radiators and conservators shall be given one coat of high-build priming paint. Two coats of durable and weather resistant paint, of contrasting colour, shall be subsequently applied. The paint shall be resistant to the dielectric fluid.

The paint coats shall be applied by a combination of spraying and flood coating to ensure complete coverage of all external areas.

Unless otherwise specified, the finish colour shall be the manufacturer's standard.

F3.1.25 Galvanising and zinc spray treatment

Where specified, panel type radiators shall be hot-dipped galvanised and main and conservator tanks shall be zinc sprayed.

Hot dip galvanising shall be carried out in accordance with ISO 1461:1999 with a deposition rate of not less than 460g/m^2. Zinc spray shall be applied by the flame-gun process and the average weight of zinc deposited shall be not less than 550g/m^2. The treatment shall be applied immediately after shot blasting as a follow-up process, on the same day without outdoor exposure.

F3.2 Dry-type encapsulated winding (cast resin) power transformers

F3.2.1 Standards

Dry-type encapsulated power transformers shall comply with IEC 60076 and IEC 60726:1982

F3.2.2 Service conditions

Unless otherwise specified, the normal service conditions as stated in IEC 60726:1982 shall apply.

F3.2.3 Cores

Cores shall be manufactured from laminations of cold-rolled, low-loss and grain-orientated electrical sheet steel having physical characteristics conforming with IEC 60404-1:2000.

Each lamination shall be coated on both sides with insulation which shall be unaffected by continuous operation at the design temperature of the transformer.

The core shall be of interleaved mitred or step-lap mitred construction, and shall be designed to provide uniform flux distribution throughout the magnetic circuit and minimise flux saturation at corner joints.

The core limb laminations shall be held in compression by tape, bands or bolts depending on the core size.

Depending on the physical size of the core, top and bottom yoke laminations shall be clamped between steel channel sections, plates or folded steel clamps. The top and bottom channels, plates or clamps shall be interconnected by means of core limb side plates or by steel tie rods to eliminate tensile stress in the core limbs when the completed core and windings are lifted.

The fully-assembled cores shall be epoxy resin or silicone varnish coated to enhance mechanical strength, provide protection against corrosion and minimise noise emission.

The flux density at any point in the magnetic circuit, when the transformer is connected on the principal tapping and operating at rated voltage and frequency, shall not exceed a value consistent with low loss and noise, with an upper limit of 1.8 Tesla.

F3.2.4 Windings

High-voltage windings shall be of aluminium foil with high-quality plastic film inter-turn insulation. Each phase winding shall be formed from several separate coils connected in series. The completed windings shall be heated under vacuum to remove moisture, encapsulated with de-gassed resin and cured to form a solid, void-free, moisture-resistant and maintenance-free structure. Insulation levels shall comply with IEC 60726:1982 tables unless otherwise specified.

The resin system shall have proven high electrical thermal and flame-resistant properties. The system shall also possess mechanical properties such that it will not crack under short-circuit or thermal shock conditions.

High-voltage winding ends and tappings shall be connected to threaded copper sockets which shall be encapsulated with the winding.

Low-voltage windings shall be manufactured from aluminium or copper sheet with resin pre-impregnated fibre-glass sheet inter-turn insulation. The width of the conductor shall be equal to the length of the coil to reduce axial short-circuit forces. The winding ends shall be sealed with resin. The completed assembly shall be heat treated to cure the resin to form a solid winding resistant to moisture and atmospheric pollutants followed by a heat-resistant protective coating.

Low-voltage coil ends shall be brought out to pre-drilled busbar terminations.

Winding temperature-rise limits and short-circuit performance shall be in accordance with IEC 60726:1982.

Three-phase distribution transformers shall be connected delta-star, connection symbol Dyn 11, unless otherwise specified.

Low-voltage windings shall be located over the core limbs by silicone rubber strips. The high-voltage outer windings shall be radially located and axially clamped between top and bottom resilient end insulated blocks.

All winding interconnections and phase leads shall be rigidly braced and supported to prevent movement under short-circuit conditions.

F3.2.5 Tappings

Tappings shall be positioned to minimise voltage stress and to maintain electromagnetic balance of the windings as far as possible over the tapping range.

Unless otherwise specified, the tapping range shall be plus and minus 5% and 5% of nominal supply voltage. Tapping selection shall be by off-circuit links.

F3.2.6 Lifting

Substantial lifting lugs shall be provided on the top clamping frame.

For transformers inside an enclosure, suitable facilities shall be provided to permit lifting without distortion of the enclosure.

F3.2.7 Cable boxes

High-voltage cable boxes shall be of the filled type complying with BS 2562:1979 or of the unfilled type complying with BS 6435:1984 as specified. Low-voltage cable boxes shall be of the unfilled type complying with BS 2562:1979.

Cable glands shall be supplied and fitted. Glands for polymeric insulated cables shall be of the mechanical type complying with BS 6121-2:1989. Glands shall be manufactured from brass, except where used with aluminium armoured cable when they shall be of aluminium. Glands shall be Type E1W for armoured cables and Type A2 for unarmoured cables. For armoured cables, the glands shall have an integral earth bond attachment.

F3.2.8 Fittings

Transformers shall be fitted with bi-directional rollers, an earthing terminal and a winding-temperature monitoring system.

The winding-temperature monitoring system shall comprise a control unit and a thermistor probe installed in each low-voltage winding adjacent to the thermal hot spot. The thermistors shall be easily replaceable. The control unit shall incorporate individual winding temperature indication and voltage-free changeover contacts for the initiation of remote alarm and trip signals.

F3.2.9 Forced air cooling

Forced air cooling shall not be required to obtain the specified transformer rated output under normal service conditions.

F3.2.10 Enclosures

Enclosures shall be of the ventilated sheet steel case or cubicle type. The former shall be fitted with bolted type removable panels or doors. Doors shall be lockable and shall additionally be fitted with mechanical-type safety key interlocks to prevent opening unless both the associated high-voltage and low-voltage circuit breakers are open.

Enclosures shall provide a minimum degree of protection of IP 23 to BS EN 60529:1992.

All removable panels shall be fitted with a ‘Danger High Voltage’ hazard warning sign to BS 5499-5:2002.

Enclosure steelwork shall be cleaned and primed with an anti-corrosion primer followed by an under and finishing coat of paint. The finish coat may be epoxy powder or stove enamel. The individual coats shall be of contrasting colours.

The finished colour shall be as specified.

Enclosures shall be provided with a brass earthing terminal of minimum size M12. The enclosure and transformer framework shall be bonded.

F3.2.11 Rating and connection plates

Rating and connection plates shall be securely fitted to the transformer and, for enclosed transformers, on the outside of the enclosure. The plates shall be of non-corrodible and durable material.

F3.3 Dry-type non-encapsulated winding (Class C) power transformers

F3.3.1 Standards

Dry-type non-encapsulated (Class C) power transformers shall comply with IEC 60076and IEC 60726:1982.

F3.3.2 Service conditions

Unless otherwise specified, the normal service conditions as stated in IEC 60726:1982 shall apply.

F3.3.3 Cores

Cores shall be manufactured from laminations of cold-rolled, low-loss and grain-orientated electrical sheet steel having physical characteristics conforming with IEC 60404-1:2000.

Each lamination shall be coated on both sides with insulation which shall be unaffected by continuous operation at the design temperature of the transformer.

The core shall be of interleaved mitred or step-lap mitred construction, and shall be designed to provide uniform flux distribution throughout the magnetic circuit and minimise flux saturation at corner joints.

The core limb laminations shall be held in compression by tape, bands or bolts depending on the core size.
Depending on the physical size of the core, top and bottom yoke laminations shall be clamped between steel channel sections, plates or folded steel clamps. The top and bottom channels, plates or clamps shall be interconnected by means of core limb side plates or by steel tie rods to eliminate tensile stress in the core limbs when the completed core and windings are lifted.

The fully-assembled cores shall be epoxy resin or silicone varnish coated to enhance mechanical strength, provide protection against corrosion and minimise noise emission.

The flux density at any point in the magnetic circuit, when the transformer is connected on the principal tapping and operating at rated voltage and frequency, shall not exceed a value consistent with low loss and noise, with an upper limit of 1.8 Tesla.

F3.3.4 Windings

High-voltage and low-voltage windings shall be manufactured from high-conductivity copper insulated with nylon polyamide tape or other material compatible with the temperature-rise limits specified in IEC 60726:1982. Insulation levels shall comply with IEC 726 tables unless otherwise specified.

High-voltage windings for operation at 3300V and above between phases shall be of the disc type, with individual disks separated from each other by keyed radial spacers.

Low-voltage windings shall be of the helical layer type.

Windings shall have adequate bracing and securing tapes to provide a strong and self-supporting structure to withstand the forces arising under short-circuit conditions without deformation or movement.

Completed windings shall be heated under vacuum to remove moisture, impregnated with silicone varnish and oven-cured to remove all solvents and to provide a strong mechanical bond and moisture-proof seal.

Three-phase distribution transformers shall be connected delta-star, connection symbol Dyn 11, unless otherwise specified.

High-voltage coil ends and tapping connections shall be insulated with silicone-elastomer sleeving. Low-voltage coil ends shall be brought out to pre-drilled terminations.

All winding interconnections and phase leads shall be rigidly braced and supported to prevent movement under short-circuit conditions.

The windings shall be supported by means of noise- and vibration-reducing blocks.

F3.3.5 Tappings

Tappings shall be positioned to minimise voltage stress and to maintain electromagnetic balance of the windings as far as possible over the tapping range.

Unless otherwise specified, the tapping range shall be plus and minus 2.5% and 5% of nominal supply voltage in steps of 1.25% as specified. Tapping selection shall be by off-circuit links. The links shall be mounted on a board.

F3.3.6 Lifting

Substantial lifting lugs shall be provided on the top clamping frame.

For transformers inside an enclosure, suitable facilities shall be provided to permit lifting without distortion of the enclosure.

F3.3.7 Cable boxes

High-voltage cable boxes shall be of the filled type complying with BS 2562:1979 or of the unfilled type complying with BS 6435:1984 as specified. Low-voltage cable boxes shall be of the unfilled type complying with BS 2562:1979.

Cable glands shall be supplied and fitted. Glands for polymeric insulated cables shall be of the mechanical type complying with BS 6121-2:1989. Glands shall be manufactured from brass, except where used with aluminium armoured cable when they shall be of aluminium. Glands shall be Type E1W for armoured cables and Type A2 for unarmoured cables. For armoured cables, the glands shall have an integral earth bond attachment.

F3.3.8 Fittings

Transformers shall be fitted with bi-directional rollers, an earthing terminal and a winding-temperature monitoring system.

The winding-temperature monitoring system shall comprise a dial-type thermometer, the bulb of which shall be installed in the centre phase of the low-voltage winding adjacent to the thermal hot spot, or in a heated pocket supplied from a current transformer located in one output phase. The temperature-monitoring system shall be designed such that its thermal time constant corresponds closely with that of the transformer. The indicator shall incorporate two sets of adjustable voltage-free changeover contacts for the initiation of remote alarm and trip signals.

F3.3.9 Forced air cooling

Forced air cooling shall not be required to obtain the specified transformer rated output under normal service conditions.

F3.3.10 Enclosures

Enclosures shall be of the ventilated sheet steel case or cubicle type. The former shall be fitted with bolted-type removable panels or doors. Doors shall be lockable and shall additionally be fitted with mechanical-type safety key interlocks to prevent opening unless both the associated high-voltage and low-voltage circuit breakers are open.

Enclosures shall provide a minimum degree of protection of IP 23 to BS EN 60529:1992.

All removable panels shall be fitted with a ‘Danger High Voltage’ hazard warning sign to BS 5499-5:2002.

Enclosure steelwork shall be cleaned and primed with an anti-corrosion primer followed by an under and finishing coat of paint. The finish coat may be epoxy powder or stove enamel. The individual coats shall be of contrasting colours.

The finished colour shall be as specified.

Enclosures shall be provided with a brass earthing terminal of minimum size M12. The enclosure and transformer framework shall be bonded.

F3.3.11 Anti-condensation heaters

Anti-condensation heater(s) shall be fitted at the base of the windings. The heater(s) shall be suitable for connection to an external 240V ac supply, and shall be controlled via a thermostat and on/off switch located within the transformer enclosure.

F3.3.12 Rating and connection plates

Rating and connection plates shall be securely fitted to the transformer, and for enclosed transformers, on the outside of the enclosure. The plates shall be of non-corrodible and durable material.

F4.0 ELECTRIC GENERATORS

F4.1 Diesel generator sets — diesel engine

F4.1.1 General requirements

The engine type shall have been in commercial operation for a period of not less than 3 years.

The engine shall be of the 4-stroke, water-cooled direct-injection compression-ignition type with an in-line or vee-cylinder configuration. The engine may be naturally aspirated or turbo-charged. The nominal speed shall not exceed 1500rpm for 50Hz operation.

The engine shall be rated in accordance with ISO 3046-1:2002 and shall be capable of continuous operation at rated output plus a 10% overload for 1 hour in any 12 consecutive hours running.

Unless otherwise specified, fuel oil shall be Class A2 to BS 2869:1998.

All chain and gear drives shall be located in oil-tight cases and shall be pressure-lubricated.

The engine and generator shall be mounted on a common fabricated steel bedplate with anti-vibration mountings of the multiple neoprene type impervious to water and oil.

Torsional vibrations of the complete rotating system shall be within the limits specified in Lloyd's Register of Shipping Rules and Regulations over a range –5% to +10% of the rated speed.

The engine shall accept full-rated load within 20 seconds from initiation of the starting sequence when starting from cold at the minimum specified ambient air temperature. The initial step load shall be not less than 40% of the full-load value unless otherwise specified.

F4.1.2 Lubrication

The engine shall have a forced lubricating system throughout using an integral gear-driven pump with a coarse strainer on the suction side. A full-flow filter of nominal micron rating not greater than 10 and having a pressure-operated by-pass valve shall be provided on the delivery side. Manual lubrication of any part of the engine shall not be accepted. The lubrication system shall not require priming prior to starting the engine.

The engine lubricating oil dipstick shall be easily accessible and minimum and maximum levels shall be clearly marked.

The engine sump shall have an easily-accessible drain point or drain pipe, fitted with a BSP plug.

When engines are specified to be suitable for uninterrupted running over a prolonged period, the following features shall be provided:

(i) dual in-line lubricating oil filters;
(ii) dual in-line fuel filters;
(iii) heavy-duty air filter;
(iv) auxiliary lubricating oil tank for installation adjacent to the engine and fitted with a sight-level gauge;
(v) an oil circulation system.

The maximum allowed period of uninterrupted running shall be stated by the contractor and shall not be less than the specified period.

F4.1.3 Cooling

Unless otherwise specified, cooling shall be by means of a sealed or pressurised radiator of the air-blast type. For radiators mounted on the generating set baseframe, the fan shall be driven by vee-belts from the engine crankshaft. Remote radiators shall be floor-mounted and shall be complete with motor-driven fan or fans. Remote radiators shall be suitable for indoor or outdoor location as specified.

Engine-mounted radiators shall be provide with a flange for the fitting of flexible ducting.

Engine-driven pump(s) shall circulate the jacket water and lubricating oil if appropriate through the radiator sections.

A thermostatically-controlled diverter or by-pass valve shall be fitted in the engine cooling-water discharge pipework, with a return to the circulating pump suction, to maintain the circulating water at the optimum temperature irrespective of load.

The cooling system shall be provided with plugged valves as necessary to enable all parts to be drained.

F4.1.4 Drive belts

Drive belts shall be of the multiple endless vee-type which shall be resistant to fuel and lubricating oils. The number of belts fitted to each drive shall be one more than is necessary to transmit the maximum power requirement.

An accessible belt-tensioning device shall be fitted to each drive and it shall be possible to change the belt(s) without major dismantling and re-assembly.

F4.1.5 Safety guards

All exposed hot or moving parts and in particular, fans, belt drives, couplings and flywheels, shall be guarded in accordance with PD 5304:2000 and to ensure safe operation.

To permit the adjustment and inspection of drives, apertures with secured cover plates shall be provided in the guards at appropriate points.

F4.1.6 Protection devices

Devices shall be fitted and arranged to provide visual alarm indication and automatic engine shutdown under the following conditions:

(a) oil pressure low;
(b) oil temperature high;
(c) coolant temperature high;
(d) over-speed;
(e) fuel low.

A voltage-free set of changeover contacts shall be provided for each of the above conditions for the initiation of a remote alarm. The contacts shall be wired to an enclosed metalclad terminal box.

F4.1.7 Wiring

Engine-mounted wiring shall be insulated with heat resistant insulation to CENELEC Harmonisation Documents HD 21.1 S4:2002 and HD 22.1 S4:2002 and associated parts thereof for use at temperatures of up to 85°C. Conductors shall be multi-stranded copper of minimum cross-sectional area 1.5mm² excepting special types such as screened cables.

All wiring, excluding starter cables, shall be shall be connected to an enclosed metalclad terminal box or terminal boxes mounted on the base frame. Starter cables may be directly connected.

F4.1.8 Pipework

Fuel pipework shall be produced from seamless steel tubing with welded or compression-type steel fittings. All other pipework shall be either seamless copper tubing with brazed or compression-type gunmetal fittings, or seamless steel tubing with welded or compression-type steel fittings.

Flexible sections of pipework shall be synthetic rubber with stainless steel braided sheaths. Flexible fuel and lubricating oil connections shall additionally have flame resistant sleeves.

All pipe flanges shall comply with BS 4504-3.3:1989 and screwed connections with BS 21:1985.

F4.1.9 Heaters

Oil and water heaters to facilitate cold starting shall be of the thermostatically-controlled type. The heating surface loading of oil heaters shall not exceed 7.5kW/m².

F4.1.10 Instrumentation

Instruments as follows shall be provided:

- (a) lubricating oil pressure gauge;
- (b) lubricating oil temperature gauge;
- (c) cooling water temperature gauge;
- (d) turbo-charger air pressure gauge (if applicable);
- (e) running hours indicator;
- (f) tachometer;
- (g) battery charge ammeter for electric start engines;
- (h) engine stop push-button;
- (i) other instruments as considered necessary by the engine manufacturer.

The instruments shall be fitted on an engine-mounted panel supported on anti-vibration mountings. The panel shall be mounted at a convenient height and position for observation and operation.

F4.1.11 Governing

Engine governing shall be of the electronic type having a droop characteristic adjustable over the range 0 to 5%. The governor shall be Type 1 to ISO 3046-4:1997 and shall be Accuracy Class A1 or better. The maximum transient speed change shall not exceed 5% with the maximum power-system step load application as specified elsewhere.

Provision shall be made for remote adjustment.

F4.1.12 Exhaust system

Engines shall be provided with a complete exhaust system comprising rigid and flexible pipework, stainless steel bellows, silencer(s) and all necessary brackets, hangers, wall sleeves and plates and sundries for a complete installation. Pipe wall thickness shall not be less than 3mm.

Unless otherwise specified, silencers shall be of the residential type.

The first section of exhaust from the engine manifold shall include a flexible bellows unit. The next section of pipe shall be supported to allow movement without imposing forces on the manifold.

Exhaust support brackets shall be designed to allow for pipe expansion and contraction movement.

Bends in the exhaust pipework shall be kept to a minimum and shall be of the long radius type.

Where the exhaust pipe passes through a wall, a wall sleeve and plates shall be fitted. The annular space between the pipe and sleeve shall not be less than 25mm. The space between the pipe and sleeve shall be filled with heat-resistant material.

Exhaust terminations shall not be located in close proximity to air inlet grills or opening windows were exhaust gas can re-circulate into the building. The exhaust outlet shall be arranged to prevent the ingress of water.

For long exhaust runs, a water drain point or condensation trap shall be fitted near to the engine.

Exhaust silencers and pipes, flanges, clips and fixings shall be sprayed with metallic aluminium paint in accordance with BS 2569-2:1965 Process ‘D’.

Internal sections of the exhaust system shall be effectively lagged. The lagging shall be clad with aluminium sheet secured by stainless steel band clips.

Where it is not practical to lag any part of the internal section of the exhaust system with which personnel can come into contact, guards shall be fitted.

F4.1.13 Starting systems

Engine starting shall be electric or air systems as specified and shall comply with the following:

(a) Electric:

The starting battery shall be of the nickel-cadmium or lead-acid type and unless otherwise specified, installed on an engine bed plate mounted non-corrodible tray or rack and shall have a cover of insulating material. The battery shall have sufficient capacity for three consecutive start attempts each of 10 seconds duration. In addition, the battery shall have sufficient capacity after the three start attempts to supply the maximum demand of the control panel for a minimum period of 24 hours.

The battery charger shall be of the solid-state design and shall incorporate ‘float’ and ‘boost’ charging facilities. In the ‘float’ charge mode, the charger shall automatically maintain the battery in a fully-charged condition whilst supplying standing loads. In the ‘boost’ charge mode, the charger shall be capable of fully charging the battery from a fully-discharged condition in a period not exceeding 7 hours.

The charging characteristics for the nickel-cadmium vented type battery shall minimise electrolyte gassing.

The charger shall be complete with:

(i) incoming supply on/off switch;
(ii) supply on indication;
(iii) output voltmeter;
(iv) output ammeter;
(v) float/boost charge selector switch;
(vi) charger failed relay with voltage-free changeover set of contacts wired to terminals;
(vii) charger failed indication.

The minimum requirement for the 'charger failed' alarm shall be the detection of ac supply and dc output failure. The relay shall not operate under a transient ac supply failure condition.

(b) Air

Where applicable, the air starting system shall comprise an air receiver, electric motor-driven compressor, hand-start diesel-driven standby compressor, all necessary isolating and pressure-relief valves, interconnecting pipework, gauges, water traps and drain facilities.

The capacity of the air receiver shall be sufficient for three consecutive start attempts each of 10 seconds duration.

The air receiver shall be of the vertically-mounted type complying with BS 5169:1992 and having a corrosion allowance not less than 2mm. Fittings shall include:

(i) pressure gauge;
(ii) pressure relief valve;
(iii) manhole;
(iv) isolating and non-return valves;
(v) automatic and manual drain valves;
(vi) pressure switch for the initiation of a low pressure alarm.

The capacity and operating pressure of the air receiver shall be determined by the Contractor.

The air compressors shall be of the air-cooled type suitably rated to deliver the required quantity of air to recharge the air receiver from minimum start to operating pressure in a period not exceeding 60 minutes.

Compressor inter and after coolers shall be of finned or wire wound copper. The compressor shall be complete with air filter, silencers, automatic fly-weight type unloader for no-load start, non-return valve, pressure gauges, pressure-relief valves and drain cocks for each stage. Pressure gauges shall be mounted on a panel.

The compressor and its driver shall be mounted on a combination steel baseplate. The diesel-driven compressor shall be complete with fuel tank, air intake filter and exhaust silencer and pipe to atmosphere.

The diesel-driven compressor shall be arranged for hand starting.

The motor-driven compressor shall be fitted with a pressure switch for automatic switching of the electric motor. The electric motor shall be of the three-phase cage induction type with appropriate IP rating.

Air piping shall be of the seamless type complying with BS EN 10217-3:2002.

F4.1.14 Fuel system:

The fuel system shall comprise an engine-driven feed pump with duplex filters, daily service tank with supporting structure and drip tray and all interconnecting pipework including flexible engine connection pipe.

The fuel supply system comprising bulk storage facilities, fuel transfer system and engine day service tanks shall be as specified.

When specified, daily service tanks shall be fitted with the following:

(i) high, intermediate and low-level float switches for the control of a fuel oil transfer pump and/or alarm initiation;
(ii) a jettison connection fitted with fire valve, the connection being sized to drain the contents of the tank in a period not exceeding 5 minutes.

Unless otherwise specified, the capacity of daily service tanks shall be sufficient for eight hours full-load operation of its associated generating set.

Fire valves shall be activated from the generator set fire-detection system as specified elsewhere.

F4.2 Diesel generator sets — generator

F4.2.1 General requirements

The generator shall be of the salient pole brushless type complying with BS 5000-3:2006. The generator shall be flange and foot mounted or foot mounted with open coupling, with single or twin end-shield bearings. A single-bearing machine shall be directly coupled to the engine crankshaft. A two-bearing machine shall be coupled through an intermediate flexible coupling.

The generator shall be capable of continuous operation at rated output plus 10% overload for 1 hour in any period of 12 hours without exceeding the temperature rise limits of the insulation system.

Generator windings shall be of the 2/3 pitch design to eliminate triple harmonics on the voltage waveform and fully interconnected damper windings for stable operation during parallelling.

Generator windings shall be star-connected with neutral point brought out to the main cable termination facilities and with provisions for neutral point earthing as specified.

Bearings shall have a minimum life of 40 000 hours and shall have a re-lubrication interval preferably 8 000 hours and not less than 4 000 hours. The bearing speed rating shall not exceed 80% and the bearing outer race temperature shall not exceed 70°C.

The generator enclosure shall provide a minimum protection classification of IP22 to BS EN 60529:1992, unless otherwise specified.

Oil-lubricated bearings shall be fitted with a clearly visible and protected oil-level gauge.

Generators shall be fitted with an anti-condensation heater.

F4.2.2 Excitation system

A permanent magnet pilot exciter shall provide power to the main exciter via the automatic voltage regulator. The main exciter output shall be fed to the main rotor winding through a 3-phase full-wave bridge rectifier. The diode bridge shall be protected against surges and voltage transients.

The excitation system shall sustain a short-circuit current of not less than 300% rated current for a minimum period of 5 seconds to allow external protection to operate.

F4.2.3 Electrical insulation system

The electrical insulation system shall be Class F or better to IEC 60085:2004 and the temperature rise shall not exceed the preceding thermal class.

The generator and exciter stator windings shall be impregnated with a moisture-resistant, oil-resistant and acid-resistant polyester varnish with a final coat of anti-tracking varnish. The generator and exciter rotor windings shall be impregnated with a high-strength thermo-setting epoxy resin to withstand rotational forces.

F4.2.4 Automatic voltage regulator

Automatic voltage regulators shall be of the solid-state three-phase sensing type with in-built protection against sustained over excitation. Unless otherwise specified, the voltage regulation shall be not less than Grade VR2.21 to BS 4999-140:1987.

With the application of the maximum power system step load specified elsewhere at any power factor between 0.2 and 0.8 lagging, the initial voltage shall not drop below 85% of the nominal value, recovering to 94% within 1.5 seconds.

Provision shall be made for remote adjustment.

F4.3 Diesel generator sets — control system

F4.3.1 General requirements

The controls shall be designed to provide the following facilities:

- (a) automatic starting and stopping of the engine;
- (b) manual starting and stopping of the engine;
- (c) simulated mains failure for testing the automatic starting and stopping of the engine.

Subject to the approval of the Engineer, the facilities specified below may be modified to suit the manufacturer's standard control unit conditional on compliance with the overall operating concept.

F4.3.2 Control panel structure

The control panel shall be baseframe, wall or floor mounted as specified and the construction and components shall generally comply with standards specified for switchgear and controlgear.

Unless otherwise specified, the control panel shall be equipped as detailed below.

F4.3.3 Generator output switchgear

Unless otherwise specified, the generator output shall be controlled by a three-pole and neutral air circuit breaker with overload and short-circuit protection for control of the generator output. The overload setting range shall be 0.7 to 1.0. The short-circuit setting range shall be 2 to 4 times the generator rated current.

F4.3.4 Indicating instruments

- phase ammeters or ammeter with phase selector switch;
- voltmeter with phase selector switch;
- wattmeter;
- frequency meter.

F4.3.5 Control switches

- hand / auto / off;
- auto-return on / off;
- key-operated simulate mains failure / off;
- engine heater(s) supply on / off;
- generator anti-condensation heater supply on / off.

F4.3.6 Push-buttons

- engine start / stop;
- engine emergency stop.

F4.3.7 Hand regulating controls

- engine speed;
- generator voltage.

F4.3.8 Indicator lights

- main supply available;
- standby supply available.

F4.3.9 Alarm annunciators

- engine failed to start;
- engine high cooling water temperature;
- engine low lubricating oil pressure;
- engine over-speed;
- engine under-speed;
- generator voltage high;
- generator voltage low;
- generator circuit-breaker auto trip;
- fire detection system operated;
- emergency stop operated;
- battery charger failed;
- daily service tank low level;
- daily service tank low overflow;
- fuel transfer pump fault.

F4.3.10 Automatic mains-failure control system

Unless otherwise specified, generator set controls for single-unit automatic mains failure standby operation shall comply with the following requirements.

The control system shall initiate the automatic generating set start-up and shut-down sequences as described below. The controls shall be designed to operate on an ‘energise to run’ and ‘de-energise to stop’ basis.

F4.3.11 Automatic start-up and shut-down

With the engine control selection switch in the ‘auto’position, the control system shall operate as follows:-

- On loss of both main supply and after a preset adjustable time delay of 0 to 10 seconds, engine starting shall be initiated via a mains failure relay located in the incomer unit of the associate switchboard. Concurrent with the starting of the engine, the inlet and outlet air louvres shall be opened.

- The engine-cranking sequence shall comprise a maximum of three 10–second periods. The control system shall provide facilities for adjusting both the number and duration of the cranking sequence.

- On the generating set reaching full speed and voltage and, after a pre-set adjustable time delay of 0 to 5 seconds, a voltage-free relay contact shall close to initiate the closing of the associated standby supply contactor.

- Should the main supply be restored before the closing of the standby supply contactor, the closing of the main supply contactor shall be initiated and after a pre-set adjustable time delay of 0 to 5 minutes the engine shall be shut-down.

- On restoration of the main supply with the ‘auto-return’ control switch in the ‘on’ position and after a pre-set adjustable time delay of 0 to 5 minutes, opening of the standby supply contactor, closing of the main supply contactor and engine shutdown shall be automatically initiated. The shutdown procedure shall be in accordance with the engine manufacturer’s standard practice.

- On restoration of the main supply with the ‘auto-return’ control switch in the ‘off’ position, the generating set shall continue to supply the load. The automatic shut-down sequence shall be initiated by returning the switch to the ‘on’ position.

F4.3.12 Simulated mains failure test facility

The facility shall permit the testing of the generating set automatic start-up sequence under a simulated main supply failure condition. With the test facility switch in the ‘simulate mains failure’ position, the automatic start-up sequence shall be initiated. The engine shall be stopped by returning the switch to the ‘off’ position.

F4.3.13 Engine lock-out

The engine shall automatically stop and lock-out under the following conditions:

- engine failed to start;
- engine high cooling water temperature;
- engine low lubricating oil pressure;
- engine over-speed;
- engine under-speed;
- generator voltage high;
- generator voltage low;
- generator circuit breaker auto trip;
- fire detection system operated;
- emergency stop operated;
- daily service tank low level.

Alarm and lock-out systems shall be inhibited during normal starting and stopping operations.

Restarting of the engine shall be prevented until the alarm has been reset.

F4.3.14 Emergency stop

The emergency stop shall operate in all control modes.

F4.3.15 Auxiliary contacts

One set of voltage-free changeover contacts shall be provided for remote status and alarm indications as follows:-

- each alarm condition;
- common group alarm for 'generating set failed' comprising each of the single alarms causing engine lock-out;
- generating set running;
- simulated mains failure test selected;
- generating set auto control not selected.

F4.3.16 External emergency stop

Provision shall be made for the connection of an external emergency stop push-button or switch. The associated terminals shall be fitted with a link.

F4.3.17 Fire-detection system

Unless otherwise specified, a fire-detection system shall be installed above the generating set. The system shall comprise fusible links and tensioned operating wires.

Link fusing shall initiate the operation of the engine fuel supply fire valve, daily service tank jettison fire valve when fitted and switches for initiating engine lock-out, remote alarm and, when installed, fuel transfer pump stop.

F5.0 ELECTRICAL SWITCHGEAR & SWITCHBOARDS

F5.1 Alternating-current switchboards and controlgear construction

F5.1.1 Construction

Enclosures shall be fabricated from sheet steel of not less than 2.0mm thick or other approved material. Enclosures shall form a robust and rigid structure. Exterior edges and corners shall be rounded to give a smooth overall appearance and assembly bolts, screws or rivets shall not be visible on the front face.

Low-voltage switch and control boards for use at rated voltages up to and including 1000V, shall be designed and constructed in compliance with IEC 60439-1:1999. High-voltage switch and control boards for use at rated voltages above 1000V and up to and including 52kV, shall be designed and constructed in compliance with BS EN 62271.

Low-voltage switch and control boards and individual enclosures for location in purpose-designed switchrooms with controlled environment shall have a minimum degree of protection of IP31 to BS EN 60529:1992. The protection classification for low-voltage switchboards located in other indoor areas shall be IP54. For outdoor location, the degree of protection shall not be less than IP65.

High-voltage switch and control boards located indoors in a controlled environment shall have a minimum degree of protection IP3X to BS EN 60529:1992.

For other indoor areas, high-voltage switchgear shall have an enclosure protection of IP3X for enclosure withdrawable sections, and for other enclosure sections such as LV compartments, busbar and current transformer chambers, the enclosure protection shall be not less than IP52.

High-voltage switch and control boards located outdoors shall comply with the requirements of the weatherproofing test of BS EN 62271.

Forced ventilation of switchgear enclosures will only be accepted for approved applications.

Unless otherwise approved, floor-mounting enclosures shall not exceed 2300mm in height.

Lifting eyes shall be removable and replaced with bolts after installation.

Wall-mounted enclosures shall be mounted not less than 10mm away from the wall. Wall fixings shall be exterior to the enclosure.

F5.1.2 Arrangement

Enclosures shall, as far as possible, be symmetrically arranged.

Where two or more enclosures are fitted together, they shall form a flush-fronted continuous suite of uniform height. Front doors and cover dimensions shall match.

Enclosures for low-voltage multi-circuit switchboards and motor control centres shall, unless otherwise specified, comply with BS EN 60439–1:1999 Form 4 having busbars, primary conductor risers, and switchgear circuit compartments fully segregated by means of metallic or non-metallic rigid barriers or partitions. Cable termination segregation on low-voltage switchgear shall be as specified elsewhere.

High-voltage switchgear and control gear shall be metalclad pattern compliant with BS EN 62271 with full panel and panel compartment segregation by earthed metallic barriers.

Switch and motor starter enclosures shall be logically grouped to reflect, as far as possible, the process with which they are associated.

Unless otherwise approved, instruments and meters, relays, control devices and indicator lights shall be mounted not less than 450mm and not greater than 2000mm above floor level and recorders shall be mounted not less than 900mm and not greater than 1400mm above floor level.

Indicating instruments, meters, relays, indicator lights, push-buttons and other components shall be arranged in a neat, functional and logical manner and shall be mounted flush with the front of the enclosure and unless otherwise specified mounted on the relevant switchboard circuit compartment or cubicle. Recessed fitting or the use of windows or apertures in panel front doors or covers will not be permitted.

Similar components shall be of the same manufacturer and pattern.

Indicating instruments, controls and relays mounted on different enclosures but having similar functions shall, where practical, be located in a physically similar position.

F5.1.3 Access

The arrangement of equipment within enclosures shall permit easy access for installation and maintenance.

Access from the front of an enclosure shall be through a hinged door or, for withdrawable apparatus, by removal of the withdrawable unit. Enclosure doors and withdrawable units when in the service position shall be lockable.

Where rear access is required for maintenance of operational equipment and components, lockable lift-off hinged doors shall be provided. The hinges of lift-off doors shall be designed so that one shank engages before the other for ease of fitting.

Access to other switchgear compartments containing busbars and similar primary power conductors shall be by bolted cover plates.

Front access doors shall open at least 120° and shall be fitted with a numbered locking handle or handles with three keys. Locking combinations requiring different keys shall be approved before manufacture. Doors shall be secured to ensure firm pressure on the seal around the whole periphery.

F5.1.4 Safety

Electrical equipment shall be designed and constructed to provide a maximum standard of safety for operational and maintenance personnel.

Mechanical interlocking shall be provided to prevent access to live equipment and to protect the equipment and the operator from mal-operation.

Where access to low-voltage enclosures is necessary with equipment energised from an external source, all such equipment and terminals shall be shrouded to prevent accidental contact and warning labels shall be fitted. Shrouds shall have a minimum degree of protection IP30.

Covers fitted to enclosures in which live conductors are installed shall be fitted with a warning label.

Integral distribution boards shall permit safe access to fuse carriers and miniature circuit breakers without the need for isolation. All live connections when fuse carriers and plug-in type miniature circuit breakers are removed shall be fully shrouded.

F5.1.5 Earthing

Single enclosures shall be provided with an earth stud or earth busbar.

Multi-cubicle type enclosures shall be provided with a continuous earth busbar which shall extend over the full length. Each cubicle shall be bonded to the earth busbar.

The earth busbar shall be externally mounted or in an alterative position giving unrestricted access. The earth busbar shall be provided with two terminal assemblies for connection to the electrical system main earth terminal.

All steelwork parts shall be equipotentially bonded. A positive earth connection shall be provided to all enclosure doors on which electrical components are fitted. Earthing via the door hinge will not be accepted.

The short-time current rating of the earth busbar and connections shall be not less than the fault rating of the switchgear. The temperature rise of the busbar and connections under fault conditions shall not cause damage to the connections of any equipment to which they may be connected.

Earth terminal bolts or studs shall be brass and shall not be less than 8mm diameter.

F5.1.6 Cable boxes, gland plates and terminations

Cable boxes, gland plates and terminations shall be arranged to facilitate easy access for installation and connection of cables and cable circuit testing.

Cable gland plates shall be manufactured from sheet steel for multi-core cables and non-ferrous metal for single-core cables. Gland plates shall be mounted not less than 300mm above the base of the enclosure.

Space for cabling within terminal enclosures on switchgear for operation up to 3300 volts shall be in accordance with BS 5372:1997.

Adequate space shall be provided for the termination of over-size cable conductors.

Unless otherwise specified, high-voltage switchgear shall be provided with enclosed metalclad cable boxes with dry-type encapsulated terminations.

Auxiliary cable terminations on high-voltage switchgear shall comprise segregated enclosed cable boxes externally on the switchgear enclosures providing unrestricted safe access.

On low-voltage switchgear and controlgear, full separation shall be provided between power cable terminations.

Power-cable glanding and cable-core termination on incoming feeder panels and on unit panel/cubicle main distribution feeders shall be contained within each respective circuit panel and fully separated by metallic or non-metallic rigid barriers.

On multiple-compartmented outgoing feeder and motor control circuit panels, power cable termination segregation shall be achieved by one of the following:

(i) cable-core termination within the respective circuit unit compartment but with glanding elsewhere;
(ii) core termination and glanding within a common cabling compartment but with each circuit terminal assembly separated by approved insulating covers;
(iii) each functional circuit unit having its own separate and enclosed cable termination and glanding facility.

Where cable glands are remote from the cable terminals, purpose-made cable-tray or trunking shall be provided within the enclosure for securing or accommodating the cable cores.

Terminal assemblies shall be provided for all incoming and outgoing cable conductors, and where applicable, core screen drain wires. The direct connection of external cable conductors onto switchgear and controlgear onto active components will not be accepted.

Terminals for low-voltage application shall comply with IEC 60947-7-1:2002 and shall be of the lug or pillar type unless otherwise approved by the Engineer. Pillar terminals shall be of the indirect pressure type. Screwless-type terminals will not be accepted. High-voltage switchgear cable-core terminations shall be of the lug type.

Auxiliary cable and wiring terminal assemblies in a common compartment associated with different voltages or circuit type shall be segregated into clearly labelled groups. Barriers shall be provided between each terminal group.

Not more than one cable core or internal wiring core shall be connected to a single terminal. Where duplication of terminal connections is necessary, multiple terminals shall be provided with purpose made solid bridging links.

Terminals which remain energised when the main equipment is isolated shall be shrouded and fitted with a warning label.

F5.1.7 Finish

Enclosures shall be subjected to a comprehensive system of preparation, protective coating and stoved finish painting. The finish coat of paint shall be applied by the electrostatic process. The finish colour shall be as specified or as approved by the Engineer.

The preparation and painting system shall be suitable for the environment in which the enclosures will be installed.

F5.2 Local control panels

Local control panels shall be of heavy-duty construction having external fixing brackets and unless otherwise specified shall have a minimum enclosure protection classification IP54.

Small control stations housing up to three control components shall be of moulded polyester or die-cast aluminium construction complete with screw-fixed or bolt-fixed front covers. Larger stations shall be of fabricated sheet steel construction complete with hinged front access doors.

All mounted control equipment and internal components shall comply with that specified for switchgear and control boards.

Control stations shall be provided with bottom-entry cable-termination facilities with adequate glanding space provided for the required number of cables including clearance for the use of spanners.

Cable-core terminal assemblies shall be provided for all cable cores which shall be identified according to the corresponding wiring diagrams. An earthing terminal shall be provided.

Pendant type local control stations for cranes, hoists and the like shall be of moulded neoprene or equivalent heavy, flexible, high impact strength materials. The station shall be connected by a long moulded-in cable-strengthening sleeve, to minimise the possibility of cable fracture at the bending point. The enclosure shall be self-coloured in safety yellow.

Large floor-mounting local control panels wider than 900mm shall have:

(a) anti-condensation heater with fuse;
(b) padlocking facility, padlock and two keys;
(c) earthing bar with terminal holes;
(d) door-controlled internal light with fuse.

F5.3 Marshalling panels and boxes

The cable-marshalling units shall comprise wall-mounting boxes or floor-mounting panels according to size and function.

Marshalling boxes and panels shall be constructed of sheet steel with ample space for routing and terminating cables and cores.

Wall-mounting marshalling boxes shall have front bolt or screw fixed cover plates.

Floor-mounting marshalling panels shall have lockable front access doors.

Construction standards shall be in accordance with the general standards specified for switchgear and controlgear.

Enclosure classification shall be:

- outdoor mounting: IP65
- indoor mounting: IP54

All marshalling boxes and panels shall be arranged for bottom cable entry and termination unless otherwise specified. Undrilled cable-glanding plates shall be provided. Gland plates on floor-mounting marshalling panels shall be located not less than 300mm above floor level, shall permit cable glanding and termination from the panel front and shall provide an effective vermin seal to the panel base.

Cable-core termination assemblies shall be provided for all cable cores including earthing cores and screens, and shall be arranged and grouped according to cable and circuit functions. At least 20% spare terminals shall be provided overall and to each terminal group.

Terminal assemblies shall be generously spaced to permit ease of cable termination, the routing of cable cores from the cable-gland plates, the fitting of core-identification ferrules and their subsequent reading, together with general direct access for inspection and circuit-test purposes.

Terminal assemblies shall be located not less than 150mm from cable-gland plates, panel sides and cover plates.

Cable cores shall be installed between gland plates and terminations in wiring trunking providing a cable to free-space factor not exceeding 50%.

All marshalling panels and boxes shall be provided with an earthing termination, together with front identification labels and internal labelling for the terminal assemblies and all auxiliary equipment.

Large floor-mounting marshalling panels wider than 900mm shall have:

(a) anti-condensation heater with fuse;
(b) padlocking facility, padlock and two keys;
(c) earthing bar with terminal holes;
(d) door-controlled internal light with fuse.

F5.4 Switchboard and control-board busbars and busbar connections

Busbars and busbar connections shall be of hard-drawn high-conductivity copper and shall be suitable for the specified rated voltage, rated and short-time current, frequency and insulation level.

Low-voltage switchgear and control-board busbars and busbar connections shall comply with the performance criteria given in IEC 60439–1:1999.

Low-voltage switchgear busbars and primary conductors shall be:

(a) bare copper for waterworks or similar areas with non-aggressive atmospheric environmental conditions;
(b) tinned copper and/or PVC insulated for wastewater works or similar areas with potentially-aggressive atmospheric environmental conditions.

In all switchgear, busbars and primary conductors shall be contained in segregated compartments accessed only by bolted removable cover plates.

High-voltage switchgear busbars and busbar connections shall comply with BS 159:1992. Busbars shall be of the non-segregated phase metal-enclosed and air-insulated type. Busbars and busbar connections shall be insulated with shrunk-on plastic sleeving or epoxy resin. Joints shall be shrouded by PVC or resin mouldings.

Busbars shall be colour coded at each switchboard section access point.

Busbar supports shall be resin monoblock mouldings.

Busbars and busbar connection arrangements shall have been type tested by an independent testing authority to verify thermal, dielectric and short-circuit withstand performance. Copies of type-test certificates shall be provided by the Contractor at the time of tendering.

In special circumstances and subject to the agreement of the Engineer, the performance of busbar and busbar connections may be substantiated by test data and experience in service on comparable arrangements.

Busbar and busbar connection systems whose performance cannot be verified will not be accepted.

F5.5 Switchboard and control board wiring

Wiring other than interconnections between electronic equipment shall be carried out using 1kV grade PVC-insulated cable complying with type BR of BS 6231:1998. With the exception of current transformer circuits, the cable conductor size shall be not less than 1.0mm². For current transformer circuits, the cable conductor size shall be not less than 2.5mm² subject to the knee point voltage. For interconnections between electronic equipment, the appropriate cable shall be used.

Wiring shall be installed in a neat and systematic manner and shall be securely fixed. Wiring shall be arranged so that access to any equipment or connection point is not impeded. Wiring installed in trunking shall have a cable to free-space factor not exceeding 50%.

Each cable shall be fitted with a full ring interlocking type identification ferrule at each end. The numbering shall read from the terminal outwards. The wiring identification shall correspond with the wiring diagram.

Unless otherwise indicated or approved, wiring shall be coloured as follows:

- phases: red, yellow or blue
- neutral: black
- control (ac): black
- control (dc): grey
- earth: green and yellow

Where wiring passes through metalwork the access hole shall be fitted with a suitable grommet.

At enclosure break points, interposing terminal blocks shall be provided each side of the break.

Wiring on to hinged doors or plates which are subject to movement shall be run in helical binding and shall be supported securely at both ends of the moving section.

Wiring associated with instrumentation and electronic equipment which could be affected by power frequency interference shall be screened and/or physically segregated.

Crimped-on type terminal connectors shall be fitted to all cable ends.

Cable trunking, tray and other supports for accommodating and supporting switchboard and control board wiring, shall be fixed by means of screw fasteners to the board structure; fixing by adhesive will not be permitted.

F5.6 High-voltage switchgear circuit and busbar earthing

High-voltage switchgear in accordance with BS EN 62271 shall be provided with circuit and busbar earthing facilities using either the circuit breaker or integral earth switches. The use of loose attachments will not be accepted.

Earth switches shall comply with BS EN 62271-102:2003.

Earth switches for busbar and feeder circuit application, and circuit-breaker controlled motor circuits shall have a short-circuit making capacity not less than the rated fault capacity of the switchgear.

All incomer and feeder panels shall be provided with a circuit earthing facility. At least one panel in any busbar section shall have provision for busbar earthing.

Earth switches shall be interlocked to prevent operation unless the main switching device is open and shall be fitted with a facility for padlocking in the closed position.

High-voltage switchgear provided with earthing facilities by circuit-breaker transfer shall have circuit-breaker racking facilities provided with positive locations of ‘normal service, isolated, circuit earth’ and ‘busbar earth’ positions. Circuit-breaker position shall be determined by means of a single selector device which shall be lockable in all positions.

The electrical tripping of a circuit breaker shall be inhibited when closed in the earthing position.

Mechanical key interlocks shall remain operative when the circuit breaker is in either earthing position.

F6.0 ELECTRICAL SWITCHBOARD COMPONENTS

F6.1 Switchboard cubicle and enclosure components

The switchboard components shall be as described in the following clauses.

F6.2 Indicating instruments and meters

Indicating instruments and meters shall be flush-mounted and, where practical, shall be of the same pattern and appearance throughout.

Analogue indicating instruments shall comply with IEC 60051-1:1997 and electronic indicating instruments with a digital display shall comply with BS 7194:1990.

Induction-type integrating meters shall comply with BS 5685-5:1987 and BS 5685-8:1991 and shall be fitted with a cyclometer-type register. A maximum demand indicator shall be provided when specified. Alternating current static watt-hour meters shall comply with BS EN 62053-21:2003.

Analogue-type indicating instruments shall have a minimum bezel size of 95mm by 95mm, a 230° scale and a normal maximum reading at approximately 60% of full scale. Ammeters for motor circuits shall have a compressed over-current scale.

Unless otherwise specified, indicating instruments shall have an Accuracy Class Index 1.5 and integrating meters shall have an Accuracy Class 2.

Indicating instruments and integrating meters shall maintain the environmental protection standard of the equipment enclosure on which they are mounted. Where the fitting of supplementary covers is necessary, they shall be fitted with tamper-proof fastenings.

Portable instruments shall be of sub-standard accuracy.

F6.3 Indicator lights

Indicator lights shall comply with BS EN 60947-5-1:1998. Lens colours shall comply with IEC 60073:2002 unless otherwise specified.

The lamps shall operate at not greater than 90% of their rated voltage and shall be suitable to operate at 110Vd.c. on high voltage and low voltage switchboard, and 48V d.c. on incomer and bus section circuit breaker of LV switchboard.

Lenses and lamps shall be easily removable without the use of a tool.
Unless otherwise specified, only clustered LED type lamps shall be used.

Terminals shall be shrouded.

Indicator lights shall be provided with individual or group lamp-test facility.

F6.4 Labels

All electrical plant, switchgear and controlgear shall be fully labelled, identifying the equipment designation/function, all external and internal components, all rating data, detailed equipment operating data and for danger and hazard warning.

Multiple-panel switchgear and control having rear access shall have panel designation labels mounted on the front and rear of each panel. All switchgear withdrawable sections and components shall be labelled identifying the section/component to the switchgear panel to which it belongs.

External identification labels shall be manufactured from white-black-white laminated plastic or rear-engraved plastic.

Equipment rating data labels may, subject to the approval of the Engineer, be the manufacturer's standard type.

Rear-engraved plastic labels shall be clear with black engraving unless otherwise specified. Internal labels shall be white-black-white laminate type inscribed with the component description given on the associated circuit diagram.

Labels for fuses shall identify the circuit function and have the fuse link rating inscribed.

Internal labels shall not be fixed to components or cable trunking covers.

Danger and warning labels shall comply with BS5499-5:2002, and shall unless otherwise approved by the Engineer, be manufactured from rigid plastic.

Labels shall lay flat to the surface and shall be secured by non-rusting screws.

Labels shall be in English unless otherwise specified.

Label and engraving sizes, and label inscriptions shall be approved by the Engineer before manufacture.

Embossed plastic and paper labels will not be accepted.

F6.5 Push-buttons

Push-buttons shall comply with BS EN 60947-5-1:1998. Unless otherwise specified, colours of the buttons shall comply with IEC 60073:2002.

Push-buttons for plant-control functions shall be shrouded type to prevent inadvertent operation.

Emergency-stop push-buttons shall be of the latched type and shall have a mushroom-type button. Emergency-stop push-buttons shall be connected in control circuits so they are effective under all plant operating conditions. Resetting of the push-button shall not automatically re-energise the isolated plant.

Terminals shall be shrouded.

F6.6 Terminal blocks

Terminal blocks shall be of the shrouded DIN rail-mounted type. Terminal mouldings shall be in melamine to ISO2112:1990, polyamide, or equivalent approved non-brittle material.

Terminals shall be of the pillar indirect pressure type compliant with IEC 60947-7-1:2002. Screw-less terminals will not be accepted.

For CT connections disconnecting link type terminal shall be used.

DIN mounting rails shall be of hot-dipped galvanised steel.

At least 20% spare terminals shall be provided at all blocks.

Every terminal block shall have a transparent clip-on cover of material that does not sustain combustion running the full length of the block.

No more than one conductor may be connected to one side of a terminal. Where duplication of terminal connection is required, multiple solid-bridge linked terminals shall be provided.

F6.7 Control and selector switches

Manually-operated control and selector switches for plant control and circuit selection purposes shall conform to BS EN 60947-5-1:1998.

Control and selector switches shall have a rotary action. All switch positions and functions shall be clearly labelled.

Control switches provided for electrically-operated circuit breakers shall be of the three-position type with transit ‘close’, and ‘trip or open’ positions and a central spring-return biased neutral position. The switch operation shall be sequence-interlocked to prevent repetitive circuit breaker ‘close’ signal action.

Unless otherwise specified, switch operating handles shall be pistol-grip type for control functions and spade type for circuit-selection functions.

Contacts of all switches shall be shrouded.

F6.8 Anti-condensation heaters

Unless otherwise specified, each switchboard and controlgear panel and circuit compartment shall be provided with an anti-condensation heater. Alternatively, low-voltage multi-compartmented switchgear may be provided with a common heater located at the base of each panel if appropriate to the manufacturer’s standard design, and providing there is adequate means of internal thermal conduction.

Heaters shall be mounted as low as possible in enclosures and panels. Heaters shall be located to ensure free air flow over the heating element and to have no detrimental effect on temperature-sensitive devices or adjacent cabling.

Heaters shall be fitted with a safety guard the surface temperature of which shall not exceed 60°C.

Heaters shall be rated to ensure condensation does not occur under the ambient air temperature and relative humidity conditions prevailing at the location where enclosures and panels are installed.

Individual panel heaters shall be complete with protective device, on/off switch and thermostat. Heaters provided for multi-compartmented panels shall be complete with a common protective device, on/off switch and thermostat.

Heater circuits not isolated by the enclosure switch-disconnecter shall have all live terminals fully shrouded and a warning label fitted.

Panel sections shall be provided with fluorescent lamp lighting fixtures of 20 W rating protected by MCB and a switch. Alternative arrangement for panel internal illumination, if proposed, shall be subject to Engineer's approval.

Single phase, 240V, 5pin, 5A power socket shall be provided in each incomer cubical for maintenance purpose requirements.

F6.9 Voltage transformers

Voltage transformers shall be of the cast resin encapsulated type complying with BS EN 60044-2:1999. The rated insulation level shall be as the associated switchgear and the accuracy class shall be 1.0 for measurement and 3P for protection unless otherwise specified. The primary voltage, rated output and frequency shall be as specified.

The primary winding shall be connected to the busbar or feeder side of the circuit breaker as specified.

Unless otherwise specified or approved by the Engineer, the rated secondary voltage for transformers connected to single-phase systems or connected line-to-line in three-phase systems shall be 110V.

Primary and secondary windings shall be fitted with fuses. Primary fuses shall comply with IEC 60282-1:2006 and secondary fuses with IEC 60269-1:1998.

Withdrawable-type transformers shall be metalclad enclosed. Racking guides shall be provided to ensure positive transformer movement and alignment. Safety shutters shall be fitted which shall automatically cover the fixed contacts when the transformer is isolated. The shutters shall be coloured red for busbar-connected transformers and yellow for feeder-connected transformers. Padlocking facilities shall be provided for securing the transformer in the service position and the shutters in the closed position.

Voltage transformers used for revenue metering and associated secondary fuse carriers and bases shall have provision for sealing.

F6.10 Current transformers

Current transformers shall comply with BS EN 60044-1:1999 and shall be of the wound primary or ring type as dictated by output, accuracy, short-time current and space considerations.

Unless otherwise specified, the rated insulation level shall be as the associated switchgear, the accuracy class shall be 1.0 for metering, 3.0 for indicating instruments and 5P for protection.

The rated secondary current, rated output, accuracy limit factor for protection application, and frequency shall be as specified. The accuracy class and excitation characteristics of protection-circuit current transformers for differential and zoned earth-fault protection shall be that required to provide protection system performance and operational stability for power system through fault and switching load conditions.

The secondary winding(s) of each current transformer or of each set of star-connected three-phase current transformers shall be earthed at one point only, via a bolted link. The link shall be located in the instrument wiring chamber.

Separate current transformers shall be used for metering and protection. Indicating instruments may be supplied from current transformers associated with non-unit protection.

Multi-ratio current transformer tappings shall be connected to link-boards located in the instrument wiring chamber. Connection options shall be clearly labelled.

Ring-type current transformers shall be fixed to prevent movement under normal service and through-fault conditions, and shall be easily removed.

F6.11 Electrical signal transducers

Where required for instrumentation and control, electrical signals shall be derived from transducers. These shall be connected to CTs, VTs, tachometers or direct to the power system to derive the relevant parameters.

The output from the following transducers shall be 4mA to 20mA:

- cos θ;
- current (I);
- frequency (Hz);
- kVA;
- kVAr;
- motor speed (rpm);
- power (kW);
- voltage (V).

The following shall have transducers or induction disc meters to give pulse outputs:

- kVAh;
- kWh.

Transducers with 4mA to 20mA output(s) shall have easily-accessible potentiometers for adjustment of zero and span. Transducers with pulse outputs, which may operate into computer systems shall have easily-accessible adjustments for the number of pulses equivalent to kVAh and/or kWh and also the pulse duration (width). This is to permit the transducer's outputs to be matched to the scan rate of the computers.

The complete transducer system shall have an accuracy of better than +/-1% of reading from 2% to 120% of nominal range.

Where local indication of electrical parameters derived from transducers is also required on the switchgear/starter panel, a repeater display meter operated from the transducer shall be provided. This shall use a separate circuit from the transducer's 4mA to 20mA output to the instrumentation system and the arrangement shall be approved by the Engineer.

Transducers shall be calibrated by voltage and current injection before installation in the switchgear/controlgear. Their operation shall also be demonstrated during the factory testing of the switchgear and controlgear. The transducers shall be finally calibrated on site.

F6.12 Control transformers

Control transformers shall be of the double-wound, air-cooled and chassis-mounting type designed. An earthed metallic screen shall be provided between the primary and secondary windings.

The primary voltage shall be as specified. The rated secondary voltage shall be 240V unless otherwise specified. One end of the secondary winding shall be earthed. Primary windings shall be connected phase-to-phase on three-phase power systems.

The transformer rated output shall be not less than 20% greater than the total standing load. The combination of the inrush VA of the largest contactor plus the total hold-in VA of all devices shall not result in the transformer secondary voltage falling below 80% of its rated value.

Control transformers shall be provided with primary and secondary winding protection devices.

F6.13 Protection relays

Protection relays shall be mounted on the front of the switchgear or relay panel in such a position that operation and maintenance can be conveniently carried out. Auxiliary relays may be mounted internally and shall be located to be readily accessible.

Protection relays shall be contained in a dust-proof case with a clear front cover providing a minimum protection classification IP52 to BS EN 60529:1992. Cases shall be finished in phenolic black unless otherwise specified.

Unless otherwise specified, microprocessor based numerical relays shall only be used.
Each relay shall have RS 485 port for communication with computer/SCADA system.

Relays shall have provision for testing the operation and calibration without disconnecting the permanent wiring by means of integral or separately-mounted plug-in test terminal assemblies.

Relays shall be flush, draw-out type unless otherwise approved by the Engineer. Each relay shall have an indicator device to show the relay has operated and its specific operating function. Each indicator shall be able to be reset manually. Re-setting devices shall not require the removal or opening of the relay.

Multiple-function relays shall incorporate function and characteristic changing devices.

All relay protection functions shall have controls for protection set point and time setting adjustment. Relay characteristics, functions and settings shall be clearly indicated on the relay element front plate.

Relays used for motor protection shall have provision of auto setting of relay characteristics.

Protection relays shall comply with IEC 60255, IEC 61000, IS 3231 and IS 8686

Relay types and performance characteristics shall be as specified.

F6.14 Low-voltage switches, disconnectors, switch-disconnectors and fuse-combination units

Switches, disconnectors, switch-disconnectors and fuse-combination units shall comply with IEC 60947-3:1999 and shall be suitable for uninterrupted duty.

Switching devices shall be suitable for isolation and shall comply with Over-voltage Category IV to IEC 60947-1:2007.

Unless otherwise specified, the Utilisation Category for switching devices shall be AC–23A for alternating current and DC–23A for direct current.

Operating mechanisms shall be of the independent manual type with provision for locking in the 'off' position and shall be interlocked with the access door.

Fuse links for use in fuse-combination devices shall comply with IEC 60269-1:1998.

F6.15 Fuses and links — general low-voltage application

Fuses shall be cartridge type and, unless otherwise approved, shall comply with IEC 60269-1:1998.

Carriers and bases for fuses and withdrawable solid links shall be made of plastic moulded insulating materials; ceramic materials will not be accepted. Accessible live connections shall be effectively shrouded and it shall be possible to remove the fuse holder with the circuit live without danger of contact with exposed live parts.

Fuses and links functionally associated with the same control or instrument circuit shall be mounted adjacent to each other, either side-by-side (fuse on the left) or vertically (fuse uppermost).

Fuse and link colour shall be to the approval of the Engineer.

A label shall be provided for each fuse, link and fuse-link combination to identify the fuse and/or link as in the circuit diagram and to state the rating and type of fuse cartridge.

F6.16 Earthing and neutral links

Earthing conductor, neutral earth links and earthing links in main power supply circuits shall be solid copper bolted type.

Neutral conductor links and neutral earth links incorporated in enclosed metalclad switchgear shall be positioned to provide direct easy access.

F6.17 Miniature circuit breakers

Miniature circuit-breakers shall comply with BS EN 60898-2:2006.

Miniature circuit-breakers shall directly indicate the true position of the contacts and shall comply with local electrical regulations.

Operating mechanisms shall be mechanically trip-free from the operating handle to prevent the contacts being held closed under overload or short-circuit conditions.

The operating handle shall be of the toggle type and shall have an integral facility for padlocking in the ‘off’ position.

Each pole shall be fitted with a bi-metallic element for overload protection and a magnetic element for short-circuit protection. Multiple-pole circuit-breakers shall be mechanically linked such that tripping of one pole simultaneously trips all the other poles. The magnetic element tripping current classification shall, unless otherwise specified, be Type C.

Miniature circuit-breakers shall be capable of accepting a full range of accessories such as auxiliary switches, terminal shrouds and inter-phase barriers.

Miniature circuit-breakers shall have a rated current and category of duty as specified. The latter shall, unless otherwise specified, be not be less than M9.
The short-circuit rating shall be not less than that of the system to which they are connected. Where this cannot be attained, a back-up fuse link or links shall be fitted.

F6.18 Residual current-operated circuit breakers

Residual current-operated circuit breakers shall comply with BS EN 61008-1:2004 and 61008-2:1995.

Residual current-operated circuit breakers shall be double-pole for single-phase and four-pole for three-phase and neutral circuits. The rated current shall be as specified.

Unless otherwise specified, the trip settings shall be as follows:

(a)	rated current up to and including 40A:	30mA;
(b)	rated current above 40A and up to 100A:	100mA;
(c)	rated current above 100A:	300mA.

No intentional time-delay shall be fitted unless specified.

F6.19 High-voltage circuit breakers

High-voltage circuit breakers shall be of the air-break, vacuum or sulphur hexafluoride (SF6) type as specified, complying with BS EN 62271-100:2003.

Circuit breakers shall be of the withdrawable vertical or horizontal isolation type. Circuit breaker trucks shall be of rigid fabricated sheet steel construction.

Circuit breaker carriage racking/withdrawal facilities and operating positions shall be fully labelled and interlocked to ensure correct and safe operation. Busbar and circuit isolating spout safety shutters shall be labelled and colour coded to the approval of the Engineer.

Unless otherwise specified, circuit breakers of the same rating shall be interchangeable.

The operation of vacuum circuit breakers shall not give rise to over-voltages harmful to insulation when switching inductive loads such as motors, transformers and capacitors.

SF6 circuit breakers shall be fitted with a gas-filling device and low-pressure detector with facilities for alarm and lock-out initiation.

Vaccume circuit breakers shall be fitted with surge suppressor.

Circuit-breaker operating mechanisms shall be of the independent manual or power-operated spring-charged stored-energy type as specified.

For power-operated mechanisms, the recharging of the closing spring shall be automatically initiated after discharge. All limit switches for automatic control shall be an integral part of the mechanism.

Power-operated mechanisms shall be provided with the facility for manually charging the closing spring.

Spring release shall not be possible unless it is fully charged and the means for charging has been removed or disconnected.

Unless otherwise specified, power operated closing mechanisms shall be fitted with a manual release with means for locking.

Vibration and mechanical shock shall not release the closing mechanism spring.

All mechanisms shall have mechanical ‘on’, ‘off’, ‘spring charged’ and ‘spring discharged’ indicators, manual and electrical trip facilities, and voltage-free contacts wired to terminals for external ‘spring charged’ and ‘spring discharged’ indication. The manual trip facility shall have means for locking.

Circuit-breaker operating mechanisms shall be trip-free to prevent the contacts being held closed under overload or short-circuit conditions.

Circuit-breaker auxiliary switches shall comply with the requirements of BS EN 60947-5-1:1998 Class 1. They shall be readily accessible and enclosed in a transparent plastic cover. A minimum of four spare auxiliary switches, two normally-open and two normally-closed shall be provided.

Circuit breakers shall be provided with interlocks as per BS EN 62271.

Where mechanical key interlocking is fitted, circuit-breaker tripping shall not occur if an attempt is made to remove a trapped key from the mechanism.

Spring-charging motor, electrical closing release coil and trip-release coil voltages shall be as specified.

F6.20 Low-voltage circuit breakers

F6.20.1 General requirements

Circuit breakers shall comply with IEC 60947-2:2006, shall be of the air-break type, and shall be moulded-case or open-construction design.

Circuit breakers shall be Utilisation Category B and shall have an ultimate short-circuit capacity not less than the prospective short-circuit current at the point of installation.

Circuit breakers for control of incoming supplies shall have a service short-circuit breaking capacity equal to the ultimate short-circuit capacity.

Feeder circuit breakers shall have a service short-circuit breaking capacity not less than 50% of the ultimate short-circuit capacity.

All circuit breakers shall be suitable for circuit-isolation duty and shall comply with Over-voltage Category IV to IEC 60947-1:2007.

The specified rated current shall be that with the circuit breaker mounted within an enclosure.

F6.20.2 Open-construction circuit breakers

Unless otherwise specified, open-construction circuit-breakers shall be used for rated currents of 630A and above.

Circuit breakers shall be of the withdrawable or fixed type as specified. Fixed circuit breakers shall be easily removable.

Withdrawable circuit-breaker draw-out mechanism shall incorporate full operational and safety interlocks and facilities compliant with IEC 60947-2:2006.

In addition, the fixed part of withdrawable circuit breakers shall be fitted with shutters over the bus bar and circuit-side main contact openings. The shutters shall be automatically operated by the withdrawal and engagement of the circuit breaker. Shutters shall be padlockable in the closed position and colour coded and labelled to the approval of the Engineer.

Circuit-breaker closing mechanisms shall be of the independent manual or power operated type as specified. It shall be possible to manually charge power-operated closing mechanisms. Circuit breakers shall be padlockable in the ‘off’ position.

Unless otherwise specified, open-construction circuit breakers shall be fitted with a solid-state protection system. The protection system shall be fully self-contained, needing no separate power supply to operate the circuit-breaker tripping mechanism. Protection requirements and characteristics shall be as specified.

Accessories such as shunt trips, under-voltage releases, auxiliary contacts and motor mechanisms shall be as specified.

Circuit-breaker auxiliary switches shall comply with the requirements of BS EN 60947-5-1:1998 Class 1. They shall be readily accessible and enclosed in a transparent plastic cover. A minimum of four spare auxiliary switches, two normally-open and two normally-closed, shall be provided.

Handling trucks shall be provided as necessary to enable the safe removal of withdrawable circuit breakers.

F6.20.3 Moulded-case circuit breakers

Each pole of moulded-case circuit breakers shall be fitted with a bi-metallic thermal element for inverse time delay protection and a magnetic element for short-circuit protection or electronic trips as applicable. Thermal elements shall be adjustable. Adjustments shall be made simultaneously on all poles from a common facility. Thermal elements shall be ambient temperature compensated. Where available, thermal and magnetic elements shall be interchangeable.

For plug-in type circuit breakers, covers shall be provided for the fixed contacts in the plug-in base.

Current limiting circuit breakers designed for fuse less motor feeders called as “Motor Protection Circuit Breakers” shall be used for motor feeder application, as specified. The circuit breakers shall fulfil the isolation conditions as per IEC 60947-3 and additional test conditions for circuit breakers with isolation characteristics as per IEC 60947-2 in concurrence with IS 13947-2.

F6.21 Low-voltage ac motor starters

Motor starters shall be combination-type as defined in and complying with IEC 60947-4-1:2000, IEC 60947-4-2:1999, IEC 60947-4-3:1999 and shall comprise combinations of fused switch connector/contactors or circuit breaker/contactors as specified.

Motor starter contactors shall be of the electromagnetic type.

Utilisation Category shall be selected to suit the application of the motor starter, but shall be not less than AC–3.

Unless otherwise specified, motor starters shall be suitable for uninterrupted duty.

Motor starters shall be fixed or withdrawable pattern as specified.

Motor starter operating and control circuits shall be 240V ac. Control circuit supply shall be derived from individual starter integral control transformers, unless otherwise specified.

Motor starters shall have Type 2 short-circuit co-ordination. The protective device, contactor and overload-relay combination shall have undergone and passed all the tests specified for full Type 2 co-ordination.

Unless otherwise specified, overload protection shall be provided by a hand-reset ambient temperature compensated direct-acting thermal relay. The relay shall operate under single phasing conditions.

Contactor auxiliary switches shall comply with the requirements of BS EN 60947-5-1:1998 Class 1. They shall be readily accessible and enclosed in a transparent plastic cover. A minimum of four spare auxiliary switches, two normally-open and two normally-closed, shall be provided.

Motor starters shall be equipped with the following controls and indications:

- (a) start and stop push-buttons;
- (b) running, available and fault indicator lights.
- (c) local-remote switch.

Other control push-buttons, control switches and indicator lights shall be provided as specified.

Motor starters shall be equipped with an ammeter and hours-run meter when specified.

Motor starters shall be provided with the following voltage-free changeover contacts wired to terminals:

- (a) running/stopped;
- (b) healthy/failed;
- (c) available/unavailable.

Additional contacts shall be provided as specified.

Provision shall be made to enable control circuits to be tested with the main circuit supply isolated.

Where control and interlock circuits are broken via plugs and sockets on withdrawable type starters, one interconnecting lead shall be provided for each size and type to facilitate testing in the withdrawn position.

F6.22 Motor starters — high-voltage

High-voltage motor starters at 3.3kV, 6.6kV or 11kV shall be of the metalclad totally-enclosed pattern in accordance with BS EN 62271, and with construction and general component standards in accordance with those specified for ac switchboards and control gear.

High-voltage starters shall be of single-tier withdrawable truck-mounted pattern and compliant with IEC 60470:2000.

Fixed housings shall be provided with automatic safety shutters on the busbar-isolating spouts for motor or single end circuit control. Feeder-isolating spout shutters shall be fitted when specified.

Breaker/Contactors shall be operated by 110V dc derived from battery and charger unit.

Each starter shall have low-voltage and high-voltage equipment fully segregated.

Contactors, high-voltage HBC fuses, control transformers and associated components shall be mounted on the starter withdrawable truck providing safe maintenance access to all main active equipment. Truck-mounted low-voltage equipment shall be segregated from the high-voltage circuit by an earthed metallic screen.

Contactor auxiliary switches shall comply with the requirements of BS EN 60947-5-1:1998 class 1. They shall be readily accessible and enclosed in a transparent plastic cover. A minimum of four spare auxiliary switches, two normally-open and two normally-closed, shall be provided.

Separate segregated low-voltage compartments shall be provided accessed by separate hinged doors.

Contactors shall comply with IEC 60470:2000 Part 2 and shall have utilization category AC–3 and duty of Class 0.03 unless otherwise specified.

Contactors shall be vacuum or air as specified. Operation of vacuum contactors shall be such that current is broken at, or very near to zero, to minimise current chopping.

High-voltage HRC fuses shall comply with BS EN 60282-1:2006 and BS 2692-2:1956 and shall be of the striker-pin pattern. Fuse protection shall be fully co-ordinated with the contactor performance throughout the range of operation of all starter components under voltage over-current and earth-fault conditions. Striker-pin operation shall ensure contactor opening under single-phase fault conditions.

Comprehensive interlocking and padlocking shall be provided to ensure correct operation and operator safety.

High-voltage starters shall incorporate an integral fully interlocked manual/automatic feeder-circuit earthing switch. The switch shall be mounted on the starter fixed housing and its operation shall be fully interlocked with the operation of the contactor isolating truck. Earth-switch operation shall be from the front of the starter and operable only with the starter in the isolated position. Earth-switch automatic operation shall be as follows:

- automatic opening when moving the contactor truck from the ‘isolated’ to ‘service’ position;
- automatic closing upon the full withdrawal of the contactor truck from the fixed housing.

Viewing facilities shall be provided permitting visual checking of the position of the switched position of all earth-switch contacts with the cubicle door closed and the truck in the isolated position.

Earth switches shall comply with BS EN 60129:1994, and shall have performance rating fully co-ordinated with the starter service application. For motor starter control duty, the earth switch shall have a short-circuit making capacity compatible with the maximum potential stored energy of a rotating machine of output rating consistent with the AC-3 rating of the contactor, or 10kA peak and a short-time rating of 4kA rms for 1 second, whichever is greater.

The earth-switch mechanism shall have padlocking facilities and means of opening the switch to permit feeder circuit testing.

Starter control, protection, instrumentation, and metering facilities shall be as specified.

F6.23 Variable-speed drive controllers and soft starter

F6.23.1 Supply system

The frequency converter shall operate from a 3-phase, 3-wire supply system at any frequency between 47Hz and 52Hz. and with a voltage variation of +/-6% from nominal value. The complete drive system shall produce rated output under the above supply conditions.

The complete drive system shall also continue to function, with a +/-10% voltage fluctuation. The supply system neutral point will be solidly earthed and the supply fault level will be specified.

The frequency converter shall operate satisfactorily from the supply specified above. Should the contractor consider that a separate frequency transformer be necessary or consider that the frequency converter be fed from a higher voltage point in the supply network then such proposal shall be submitted for approval.

If the primary voltage of any frequency converter transformer is 415V, then the transformer shall be housed within the frequency converter enclosure.

The harmonic current spectrum of each frequency converter generated at the point of common coupling shall be stated in the Schedule of Particulars and Guarantees when running at maximum duty.

Serial communication port shall be provided to facilitate remote monitoring and control.

F6.23.2 General design and construction of equipment

The frequency converters shall either be mounted as part of the switchboard or in free-standing enclosures compatible in appearance with the switchboard.

For motor outputs of less then 250kW, the frequency converters shall be designed to feed a standard cage induction motor. The motor stator may be wound to accept maximum inverter output voltage at maximum duty speed, provided that an emergency bypass facility is not required.

For motor outputs in excess of 250kW, other types of frequency converter may be offered, designed to feed brushless synchronous motors or slipping induction motors (slip-energy recovery system).

The type of frequency converter, type of power semiconductors and type of motor offered shall be clearly stated in the Schedule of Particulars.

The motor and frequency converter shall be compatible in all respect. In particular, the following points will be addressed:

- the drive motor shall be rated to produce 110% of the maximum load power when frequency converter fed;
- the motor shall be sized to allow for continuous running under all load conditions throughout the specified range taking into account particularly the higher machine losses when inverter-fed and the reduction of cooling fan output at reduced speeds, although the possibility of using a separate drive for the motor cooling fan may be considered where appropriate;
- the drive system shall be designed to achieve the highest practicable overall efficiency, taking into account the motor efficiency degradation when inverter-fed and the losses in any power factor correction/harmonic filter networks;
- the drive system shall develop sufficient starting torque to start the driven equipment under any operating conditions;
- the Contractor shall ensure that any torque pulsations produced by the drive system do not cause torsional resonance in the shaft system at any point in the whole speed range;
- the drive control system (for pump applications) shall be such that over-current trips do not occur during any hydraulic conditions, irrespective of the pump characteristics, so that in the case, for example, of a pump exhibiting a rising-power run-out curve, the motor speed shall automatically be reduced until the drive reaches a stable operating point within the continuous capability of the motor-inverter system.

F6.23.3 Equipment and features

Cubicles shall contain all necessary equipment for the correct control, operation, protection, maintenance and sequencing of the drives and shall include:-

(a) Incoming triple-pole load-break, fault-make circuit breaker with over-current trips, either type of device being mechanically interlocked with cubicle door. A minimum of 2 sets of auxiliary changeover contacts shall be fitted to the incoming devices.

(b) Main contactor to IEC 60947-4-1:2000, feeding the input bridges, intermittent duty class 0.1, utilisation category AC-3, electrical endurance 300 000 operations minimum. The contactor shall also meet the requirements of the eight-hour duty as defined in IEC 60947-4-1:2000.

(c) MCCBs or MCBs for isolation of reference, excitation and control supplies.

(d) Three-phase input bridges, dc-link component, inverter bridges and all necessary control equipment.

(e) Surge-suppression devices and device snubber networks.

(f) Isolator, fuses (or MCCB), contactor and thermal-overload protection for ventilation fan motor.

(g) Total load ammeter.

(h) Speed (or, if speed signal not available, inverter output frequency).

(i) Hours-run meter.

(j) Local / off / remote and manual / auto control selector switches as required.

(k) Emergency stop button operational in all control modes - latching mushroom type, coloured red and lockable in the stop position. The push-button shall be of the key reset type. An emergency stop shall also be located at the plant. Emergency stops shall be connected in series to directly break the main contactor control supply and open the main contactor.

(l) Stop and start push-buttons.

(m) Speed limit pre-setting potentiometers or programmable controls shall be provided to enable the minimum and maximum speeds to be set. The setting of these shall determine the variable range within which the speed of the motor can be controlled.
The above controls (and any other controls that can be expected to be adjusted on site) shall be easily accessible, without the need for special extension cards or modules not integral with the basic drive control electronics.
Speed-adjusting facilities shall be provided for each of the following:
- Manual control - by adjustment of a speed setting potentiometer or programmable control externally mounted on the drive.
- Auto control - this shall be capable of accepting a proportional 4mA to 20mA instrumentation speed-reference signal and shall not present an impedance greater than 500 ohms. The signal will be arranged such that:
  4mA = Low-duty speed.
  20mA = High-duty speed.

(n) Anti-condensation heaters and thermostats for the enclosure. Circuitry for 240V motor anti-condensation heaters, with fuse and switching contactor.

(o) Test facilities for operation/testing of the inverter under no-load conditions: with motor disconnected when switched to test mode.

(p) Internal lighting and an RCD-fed 13A, 240V, 50Hz switch socket outlet shall be incorporated for testing and maintenance purposes.

(q) RS-232 serial port for transmission of operation status of the frequency converter to SCADA system for control and monitoring.

(r) Replaceable surge or lightning protector shall be provided to properly protect the frequency converter against electrical surge and lightning.

F6.23.4 Protection

The frequency converter shall incorporate as a minimum, the following protection:

(a) instantaneous and inverse-time over-current protection for frequency converter and motor protection;
(b) high-speed fuses for protecting converter/inverter semiconductor devices with intertrip;
(c) phase failure or reversal;
(d) over-voltage;
(e) under-voltage;
(f) earth fault;
(g) for all motors a thermistor protection relay shall be included.

The operation of voltage-sensitive protection relays shall be time-delayed to prevent unnecessary tripping of the controller in the event of transient supply-voltage variations and be suitable for distorted supply voltage waveforms.

The facilities listed are the minimum foreseen. Any additional facilities which the Contractor considers necessary for the satisfactory operation and maintenance of the controllers shall be provided.

Indication of the reason for failure shall be by lamps or LEDs which shall be visible from the outside of the enclosure without the need to open the enclosure.

Such lamps or LEDs shall 'latch' once a fault has been indicated and be reset by a reset push-button.

F6.23.5 Power factor correction/harmonic filters

Each drive system shall operate with an input power factor between 0.95 lagging and unity throughout the speed and load range. On power-factor correction systems detuning reactors shall be fitted, if necessary, to limit total rms capacitor currents to rated values. Such reactors and similar reactors within harmonic filters, shall be fitted with extra core clamps, anti-vibration mounts, or any other features the Contractor considers necessary to limit the propagation of magnetostrictive noise. Each of the above harmonic filter reactors shall be fitted with temperature detectors which will each operate a warning lamp on the front of the enclosure to indicate which reactor has overheated.

The above precautions concerning reactor noise shall also apply to all other reactors within the drive system, such as line reactors and dc link chokes.

The fifth harmonic current distortion at the frequency converter input terminals shall be less than 35% during operation within the variable speed range.

F6.23.6 Radio frequency interference

Under all conditions of operation, the frequency converter shall not emit signals that may interfere with radio transmission or reception.

The radio frequency interference generated by the variable speed drive shall not exceed the limit specified in BS EN 61000-6-4:2001.Values of radio interference voltage shall meet the requirements of current Indian Standards and any local statutory requirements. In the event of there being differences between Standards or Regulations, the most stringent shall apply.

F6.23.7 Interlocks

Electrical interlocks shall include the following in addition to any others considered necessary by the Contractor for the safe operation and protection of the equipment:-

(i) Thermal protection of thyristor converter and inverter bridges for naturally and force-ventilated bridges.
(ii) Thyristor bridge cooling air flow switch interlocks (if force-ventilated bridge).
(iii) A minimum of one normally-open and one normally-closed contact corresponding to the following control relays/functions, shall be wired to the main cubicle terminal rail for future interlocking:
  - ‘Drive Healthy’, meaning it is in a state ready to start if called to do so;
  - ‘Drive Running’, meaning main contactor is closed, all electronic and inhibits released and no fault conditions are present. Preferably this contact will detect motor rotation;
  - ‘Drive Tripped’, meaning drive has stopped due to a fault condition within the drive system.

F6.23.8 Harmonics and waveform notching on mains supply system

The Contractor shall ensure that the Electricity Council Recommendations G5/4 Stage 2 limits for harmonic currents generated at the Electricity Supply Authority point of common coupling are not exceeded.

The Contractor shall ensure that the above requirement is met taking into account the pre-conditions listed of G5/4.

Furthermore, the Contractor shall demonstrate that the addition of the new variable-speed drive equipment shall not adversely affect any part of the existing plant and is not likely to affect proposed new items of plant. This assurance shall be gained by a process including, but not confined to, the following points:

(i) The total harmonic voltage distortion at any point on the LV-distribution system shall not exceed the levels stated for 415V in table 3 of G5/4. The voltage distortion is to be calculated under the condition where all drives (both new and existing) that may operate simultaneously are running at full load.

(ii) It shall be taken into account that many drive types produce harmonic currents derived from the inverter bridge commutation frequency. These harmonics, known as 'non-integer' or 'inter' harmonics are a synchronous with the mains supply waveform. They shall be minimised in amplitude by suitable sizing of dc link components or other means to ensure that resonance or 'beats' do not occur in the running range.

(iii) Frequency converters that incorporate a line-commutated converter input bridge, produce notching of the mains sinusoid. The size of these notches shall be limited to the values in ANSI/IEEE guide 519–1981, General System Class unless otherwise specified, or by raising the effective pulse number of the drive systems or by other means.

F6.23.9 Noise

When running at any combination of speed and load, the frequency converter system shall not create a sound pressure level greater than 85dBA measured at a distance of one metre in any direction from the surface of the frequency converter enclosure. The noise measurements shall be carried out in a similar manner to that described in IEC 60034-9:1997.

F6.24 Switchboard ancillary equipment

The following ancillary articles shall be supplied with each switchboard:

(a) 1 no. black fluted rubber safety mat to BS 921:1976 running the length of the switchboard, 5mm thick, 750mm wide.
(b) 2 pairs rubber gloves to BS EN 60903:2003 - class according to rated voltage of switchboard.
(c) 1 no. 'treatment for electric shock' metal enamel instruction plate suitable for screen attachment.
(d) Special tools and appliances required for operation, maintenance and testing purposes.

F7.0 EARTHING AND LIGHTNING PROTECTION

F7.1 Earthing

F7.1.1 Design

The earthing system shall be designed and installed in accordance with BS 7430:1998 and BS 7671:2008 in concurrence with IS 3043:1987.

The materials used and the method of installation shall be such as to ensure effective and reliable operation over a prolonged period under the conditions appertaining to the Site.

The earthing installation shall comprise earth electrode(s), main earthing terminal, earthing circuit protective conductors and equipotential bonding conductors.

The metalwork of all items of electrical plant, electrical system neutral points, power and auxiliary cable armouring and screens and extraneous metalwork including structural steelwork, pipework, fences and gates, shall unless otherwise specified, be connected to the earthing installation.

F7.1.2 Earth electrodes

The earth electrode installation shall be provided to suit the site ground conditions, which shall be as detailed elsewhere, or which shall be determined by site survey, as specified.

The earth electrode installation shall be subject to the approval of the Engineer and shall comprise one of the following:

(a) a system of interconnected driven rods;
(b) a grid configuration of horizontal buried bare copper/MS/GS tapes or stranded cable;
(c) a single or system of interconnected buried copper/MS plates;
(d) other approved system to suit extreme ground conditions.

The earth electrode system shall be installed at least 1 metre below ground water level with full allowance made for seasonal variation in water level.

The electrode system shall, where possible, comprise the rod type incorporating copper/GS or copper-clad high-tensile low-carbon steel cored rods. Copper-clad type rods shall have a minimum copper thickness of 0.25mm which shall be molecularly bonded to the steel core. Rods shall have hardened tips and driving caps to prevent damage during installation.

Couplings shall be manufactured from aluminium bronze and shall have completely enclosed threads to prevent damage and corrosion.

Where soil conditions are very aggressive, solid copper earth rods shall be used.

Where multiple rods are installed, they should be separated by a distance of not less than their driven length. Bare copper/MS/GS tape or multi-stranded cable, buried at a minimum depth of 400mm, shall be used for the interconnection of rods. Each rod shall be provided with a non-ferrous clamp for the connection of the earthing conductor.

The connections to rod or alterative design electrodes shall be made in concrete or other approved material inspection chambers set flush with the finished ground level. The inspection chambers shall be permanently marked ‘electrical earth’.

The resistance to earth of the earth electrode system shall be as specified.

F7.1.3 Conductors

Earthing, circuit protective, and equipotential bonding conductors shall be high-conductivity copper tape/MS/GS tape or 1kV-grade PVC-insulated multi-stranded cable. The conductors shall be sized in accordance with the Reference Standard. PVC cable insulation shall be green and yellow. Cable lengths shall be continuous.

Where aggressive atmosphere may be present, the copper tape shall be tinned or PVC-covered.

Cable armouring and screens shall be bonded to earth at both ends unless otherwise specified. Earthing of instrumentation cable screens shall be as specified elsewhere. Cable armouring shall not be used as the only earth protective conductor.

The earthing conductor interconnecting the main earthing terminal and electrode shall be PVC-insulated copper/GS tape or multi-stranded cable.

F7.1.4 Earthing terminal

The main earthing terminal shall be mounted in an accessible location and shall provide facilities for connecting:

(i) the earthing conductor(s) between the earthing terminal and electrode(s) or electricity supply company earth terminal;
(ii) circuit-protective conductors between the earthing terminal and exposed conductive parts;
(iii) the main equipotential bonding conductors between the earthing terminal and extraneous conductive parts; and
(iv) the system neutral earthing conductor (where specified).

Facilities (i) and (ii) shall be removable with a tool to permit measurement and testing.

The earthing terminal shall comprise a terminal block or busbar on an insulated frame as appropriate. A label shall be provided inscribed ‘main earth terminal’.

F7.1.5 Installation

The earthing installation shall be of robust construction and protected from mechanical damage and corrosion.

The circuit-protective conductors and equipotential bonding conductors shall be of the radial, grid or ring form as dictated by the plant layout. Joints in tape conductors shall be tinned rivetted and soldered, or brazed, or exothermically welded. Non-corrosive flux shall be used for soldered joints. Compression-type lugs shall be provided for the termination of earthing cables.

The conductors shall be secured to building structures, cable racks and trays using proprietary fixings. Protective, earthing or bonding conductors extending between buildings or to external plant shall comprise PVC-insulated cable direct-buried or installed in buried ducts.

The interconnection of conductors below ground to or forming part of the electrode system shall be by means of exothermic welding or brazing.

F7.1.6 Earthing of extraneous metalwork

(a) Fences:

Metallic fences, including plastic-covered chain-link fencing, associated metallic support posts, stays, gates and anti-climbing fittings, shall be earthed.

Metallic fences separated from the electrical earthing system and exposed and extraneous conductive parts connected to the electrical earthing system, by a distance of not less than 2m, shall be independently earthed.

Metallic fences which are situated within the area of the electrical earthing system or cannot be separated from it by a minimum distance of 2m, shall be bonded to the electrical earthing system. Additionally, a bare conductor shall be installed around the fence perimeter. The conductor shall be buried 0.5m deep and 1m outside the fence, and shall be bonded to the fence at intervals not greater than 50m.

The earthing requirements for independently-earthed fences and for fences bonded to the electrical earthing system shall comply with BS 7430:1998.

(b) Structural steelwork:

All structural steelwork within the Site, including handrailing, ladders, walkways and the like, shall be bonded to the electrical earthing system.

(c) Pipework:

An equipotential bond shall be provided to all metal pipework at the point of entry into a building or chamber where electrical apparatus is installed. Electrical continuity across all pipe joints within the structure shall be ensured. Where pipework incorporates a compression coupling (such as a Viking-Johnson coupling), a bond shall be provided to any isolated section.

F7.1.7 Instrumentation earthing system

An instrumentation earthing system shall be provided throughout in accordance with the requirements of BS 6739:1986. The instrument earthing system shall be isolated from the main electrical earthing system except at their point of connection which shall be at the main earth terminal in the relevant process area.

Instrumentation earth cables shall be segregated from other power and earth system cables in order to reduce electrical interference on the instrument earthing system.

The instrument earthing system shall be used for the connection of any signal system zero-volt point and all communications and instrumentation cable screens. Cable screens shall be earthed at one end only. Instrument cable armours shall not be used as protective screens. Instrument cable armours shall be earthed to the electrical earth system at one end only.

Avoidance of earth loops shall be paramount in the design of the instrument earthing system.

Each instrumentation, control, communications and telemetry panel shall be provided with an:

- electrical system earth bar bonded to the metalwork of the panel and providing earth connections for all cable armours and power circuit protective conductors;
- instrumentation earth bar insulated from the panel metalwork for connection of signal system zero-volt connections and connection of all signal cable screens.

The design of the instrument earthing system shall be incorporated as part of design of the overall earthing system for the works.

F7.2 Neutral earthing resistors

Neutral earthing resistors shall comply with the relevant parts of IEC 60947-4-1:2000.

Earthing resistors shall be of the non-inductive grid resistance type.

Resistors shall be used for power transformer and generator winding star point earthing and their performance duty and rating factors, comprising line to neutral voltage, current and short time factor and resistance values shall be as specified. Unless otherwise specified, resistance values shall be at 20°C with 10% design tolerance.

The resistor elements shall be of continuous non-corrodible chrome-aluminium steel alloy strip formed onto mica or ceramic-insulated stainless steel rods designed to permit free expansion and contraction under temperature variation. The resistance elements shall be assembled in tiers onto insulator-supported steel frames, and interconnected by bolted tinned or nickel-plated copper strip. The arrangement shall permit the disconnection and removal of individual resistor elements. Copper strip connections shall also be provided to the cable terminations.

The element alloy material shall have a temperature coefficient of less than 2% increase in resistance per 100°C rise over the operating temperature range.

The resistors shall be mounted in fabricated sheet-steel ventilated enclosures providing a minimum enclosure protection classification of IP23. Terminal facilities for main earthing cables and for auxiliary cables shall be by segregated integral enclosed cable boxes. Access to internal components shall be by bolt-fixed removable cover plates. The enclosure bases shall be totally closed and vermin-proof.

Enclosures for outdoor mounting shall be of hot-dipped galvanised or stainless steel. Internal mounted enclosures shall be painted to associated switchgear standards.

Facilities for mounting protection system equipment and integral or separately mounted earthing switchgear shall be as specified.

Eye bolt lifting facilities shall be provided.

F7.3 Lightning protection

F7.3.1 Design

The lightning protection installation shall be designed and installed in accordance with BS 6651:1999 and as specified in concurrence with IS 2309:1989.

F7.3.2 Materials

Materials used for the manufacture of the component parts of lightning protection installations shall comply with BS 6651:1999 and IS 2309:1989.

Conductor material shall be bare or PVC-covered copper or aluminium tape or solid circular conductor or GS/MS tapes as specified. The colour of PVC-covered conductors shall be agreed with the Engineer.

Careful attention shall be given to the selection of materials to minimise the risk of corrosion, including galvanic corrosion.

F7.3.3 Dimensions of component parts

The dimensions of component parts shall be not less than those specified in BS 6651.

F7.3.4 Fittings

Fittings shall be mechanically robust and shall have a high degree of resistance to corrosion and erosion by the environment in which they are installed.

F7.3.5 Metallic building fabric

Metallic building fabric used for air terminations shall be electrically continuous. Comprehensive details of the methods to be used for ensuring electrical continuity and making connections to structural steelwork and down conductors shall be submitted for the approval of the Engineer.

F7.3.6 Bonds and clamps

Bonds shall be mechanically and electrically effective and shall be protected from corrosion.

Bonds to structural steelwork, reinforcing bars and pipes shall be made using proprietary clamps. The drilling of metallic building fabric to secure bonds shall not be carried out without the approval of the Engineer.

When the reinforcement in concrete structures is used for down conductors, the metal bars shall be interconnected, either by welding or by metal binding wire, to provide definite electrical continuity. The interconnection shall be provided for both vertical to vertical and horizontal to vertical bars. The external conductor shall be connected to the reinforcing bars via a proprietary non-ferrous built-in type bonding point. The bonding points to be cast into the structure shall be provided by the Contractor together with a drawing showing the required location.

F7.3.7 Conductor fixings

Conductors shall be fixed to the building structure using proprietary clips and holdfasts. The fixings shall be purpose-made for the conductor type used and shall allow for expansion.

Non-metallic clips shall be manufactured from high-grade polypropylene. The material shall be stabilised against degradation by sunlight and shall not become brittle at the minimum temperature at the location where installed.

No welding or drilling of structural steelwork or drilling or cutting of the outside building fabric for the attachment of fixings shall be carried out without the approval of the Engineer.

Fixings shall be securely attached to the building structure; mortar joints shall not be used.

F7.3.8 Joints

Joints in conductors shall be kept to a minimum and shall be mechanically and electrically effective. Joints shall be clamped, rivetted, bolted or welded. The overlap of conductors shall not be less than 50mm.

Contact surfaces shall be thoroughly cleaned and coated with a suitable anti-corrosive compound to inhibit oxidation. For bi-metallic joints, a separate abrasive shall be used to clean each metal.

Bi-metallic connectors shall be used for joints between two dissimilar metals.

Bi-metallic joints shall not be made at test joints or in the conductor between the test joint and the earth electrode.

F7.3.9 Test joints

A test joint shall be provided in each down conductor in a convenient position.

The connection between the test joint and earth electrode shall be PVC-insulated copper/GS tape.

F7.3.10 Earth electrodes

Earth electrodes shall normally comprise copper or copper-clad high-tensile low-carbon steel cored rods. Copper-clad type rods shall have a minimum copper thickness of 0.25mm which shall be molecularly bonded to the steel core. Rods shall have hardened tips and driving caps to prevent damage during installation.

Couplings shall be manufactured from aluminium bronze and shall have completely enclosed threads to prevent damage and corrosion.

Where soil conditions are very aggressive, solid copper earth rods shall be used.

Earth rods shall penetrate a minimum of one metre below ground water level. Due attention shall be given to seasonal variation in ground water level.

Where multiple rods are installed, they should be separated by a distance of not less than their driven length. Bare copper/MS/GS tape or multi-stranded cable, buried at a minimum depth of 400mm, shall be used for the interconnection of rods.

Each rod shall be provided with a non-ferrous clamp for the connection of the earthing conductor. The connection shall be made in a concrete or other approved material inspection chamber set flush with the finished ground level. The inspection chamber shall be permanently marked 'lightning protection earth'.

Where soil conditions make the use of rod type electrodes impractical or uneconomical, a grid configuration shall be used. The grid shall comprise horizontally buried bare copper/MS/GS tape or multi-stranded cable.

The resistance to earth of the earth electrode system shall be as stated in BS 6651:1999.

F7.3.11 Bonding to other services

Unless otherwise specified, the lightning protection and electricity supply earth electrode systems shall be interconnected.

F8.0 CABLING INSTALLATIONS

F8.1 Cabling — general requirements

Cables shall be supplied from an approved manufacturer and, where possible, the same manufacturer shall be used for all cables and wires. Each drum or coil of cable shall be accompanied by a certificate stating the manufacturer's name, rating of cable, result and date of tests.

All cables shall be delivered with cable ends effectively sealed. When a cable is cut from a drum, both ends shall be immediately sealed to prevent ingress of moisture.

Cables shall be adequately rated for current-carrying capacity under normal and short-time fault conditions at the specified voltage.

Assessing the rating and cross section of any cable shall be in accordance with IEC 60287-1-1:2006 and shall take into account the following factors:

- (a) maximum voltage drop permissible;
- (b) type and magnitude of load;
- (c) fault level and duration related to circuit protection;
- (d) over-current setting of relays;
- (e) method of laying;
- (f) route length and disposition of cables;
- (g) ambient temperature, including ground thermal resistivity for buried cables.

Unless otherwise specified, cable sizing with respect to power system voltage depression shall be based on the following parameters.

Cable sizes in conjunction with electrical-plant operating characteristics shall ensure the maximum circuit volt drops are not greater than:

- main feeder cables to and between system switchboards at rated circuit current: 1%;
- feeder circuits from control switchgear and panels to terminal equipment at rated load current: 2%;
- the transient voltage depression at the started motor terminals is not greater than 10%;
- the transient voltage depression at the busbars of any power system switchboard does not exceed 5%.

Transient voltage drops for motor starting conditions shall include the dynamic loading of all running plant.

Cable schedules shall be submitted for approval detailing ratings, sizes, lengths, method of installation and function of all individual cables.

F8.2 Cables

F8.2.1 Cable conductors

Cable conductors shall be plain annealed copper complying with BS 6360:1991.

Unless otherwise specified, low-voltage three-phase and neutral power cables shall not incorporate a reduced neutral conductor.

F8.2.2 Power cables

Unless otherwise specified or approved, all power, control and instrumentation cables shall be galvanised steel wire or tape armoured with PVC overall sheath. Single-core power cables shall have non-magnetic armour of hard-drawn aluminium.

Cross-linked polyethylene (XLPE) insulated cables for rated voltages 600/1000V and 1900/3300V shall comply with BS 5467:1997. XLPE-insulated cables for rated voltages from 3800/6600V to 19000/33000V shall comply with BS 6622:2007.

PVC-insulated power cables for rated voltages of 600/1000V and 1900/3300V shall comply with BS 6346:1997.

Low smoke and fume (LSF) cables for rated voltages up to 1900/3300V shall comply with BS 6724:1997.

Low smoke and fume cables for rated voltages of 3800/6600V and 6350/11000V shall comply with BS 6622:2007 but shall have bedding and oversheath material complying with the LSF requirements of BS 6724:1997.

F8.2.3 Control cables

Multi-core cables shall be of the PVC-insulated or LSF-type having a rated voltage 600/1000V. PVC-type cables shall comply with BS 6346:1997. LSF cables shall comply with BS 6724:1997.

F8.2.4 Instrumentation cables

Instrumentation cables shall be of the polyethylene or PVC-insulated type rated voltage 300/500V complying with BS 5308-1:1986 and BS 5308-2:1986 as specified.

Unless otherwise specified, conductors shall be 24/0.2mm (0.75mm²) multi-strand type.

Individual and/or collective screens shall be provided in accordance with the recommendations of the associated equipment manufacturer.

LSF cables shall have bedding and oversheath material complying with the LSF requirements of BS 6724:1997.

F8.2.5 Telephone cables

Cables for use with telephone systems and speech-band telemetry systems shall be of the solid polyethylene-insulated type rated voltage 110V ac / 150V dc and petroleum jelly filled complying with BS 3573:1990 'Specification for telecommunication distribution cables'. The minimum conductor diameter shall be 0.9mm. A minimum of 10 pairs shall be provided.

Telephone cables for use in office and administration area shall be provided in accordance with the local national standards, and shall be installed in trunking systems.

F8.2.6 Cables for conduit and trunking wiring systems

Cables shall be single-core PVC-insulated non-sheathed type complying with BS 6004:2000 or LSF-type complying with BS 7211:1998 as specified.

The minimum conductor size shall be 1.5mm² for lighting circuits and 2.5mm² for socket outlet and heater circuits.

F8.2.7 Mineral insulated cables

Mineral insulated copper sheathed cables shall comply with BS 6207-3:2001. Unless otherwise specified, mineral insulated cables shall be provided with a standard PVC covering, coloured orange.
Voltage-surge suppressors shall be fitted to all cables associated with inductive loads.

F8.2.8 Use of proprietary cable types

Where a proprietary cable type is required for a particular item of equipment, the Contractor shall submit a detailed specification and application of the cable type to the Engineer for consent. Where the cable is to be installed in outdoors, in plant areas, in ducts or clipped direct or on cable tray, the cable shall be armoured and provided with an overall PVC sheath.

F8.3 Cable glands, terminations and joints

F8.3.1 Cable glands

Cable glands shall comply with BS EN 50262:1999 and unless otherwise specified, shall be manufactured from brass. Glands for use with aluminium armoured cables shall have zinc or nickel plated armour clamp and spigot.

Glands for single-core armoured cables and armoured instrumentation cables shall be earthed at the source end only and insulated from earthed metalwork with facilities for shorting at the other end.

Glands for armoured cables shall be fitted with earth tags.

Cable glands for use outdoors shall have cable inner and outer sheath seals. Glands for indoor use shall have a cable outer sheath seal.

Mineral insulated cables shall be terminated using proprietary termination kits comprising moisture seal, insulating sleeving and gland. The type of seal shall be compatible with the continuous operating temperature of the cable. The termination kit and cable shall be of the same manufacture.

Exposed cable glands, that is those not contained within an enclosure, shall be fitted with PVC shrouds.

F8.3.2 Cable termination, joints, sleeves and tape - general

The Contractor shall employ personnel who are fully-qualified and competent for the types of joints and terminations to be made. Proof of competence for all personnel shall be submitted to the Engineer before any jointing or termination work commences.

The Contractor shall provide evidence to the Engineer that the materials or kits to be used for jointing and termination are suitable for the type of cable to be jointed or terminated.

Full details of jointing and terminating arrangements supported by manufacturers' literature shall be submitted by the Contractor to the Engineer prior to commencement of cable installation.

Cables shall not be cut or uncapped until the jointing or termination is ready to start. Cable ends shall be free from moisture.

Jointing and termination shall, wherever practical, be completed without interruption. During the work all reasonable precautions shall be taken to prevent damage and ingress of moisture and impurities.

Where circumstances prevent the completion of jointing and termination work, the cable end or ends shall be sealed.

Where cores need to be crossed to preserve phasing, a cross core joint of adequate dimensions to incorporate the cores, shall be used. Where numbered cores are jointed to coloured cores, the system adopted shall be consistent throughout all cable runs and, on sites with existing installations, consistent with the system already in use.

For joints in armoured cables, a bonding conductor of sufficient size to withstand the system earth fault current, shall be connected across the armouring. A split ferrule shall be placed under the armouring to prevent deformation of the cable by the clamp.

F8.3.3 Terminations

Cables shall be terminated in an unfilled type cable box or air insulated enclosure using a mechanical type gland. A proprietary heat-shrink type termination kit shall be used for terminating high-voltage cables.

Conductor terminations shall be by means of compression fittings or mechanical clamps.

Aluminium conductors shall not be clamped in pinch-screw type tunnel terminals unless the terminal is certified for such use.

Cable sockets shall be of the correct size for the conductor. Oversize sockets will not be accepted.

Compression connectors and associated dies for the compression tool shall be the correct type and size. The tool shall be so designed that the correct compression force must be applied before it can be released.

F8.3.4 Joints

Unless otherwise specified, joints for direct burial in the ground shall be of the cast-resin type and those located in chambers or indoor areas shall be of the proprietary heat-shrink type. Joints for 1.1kV grade cables shall comply with BS 6910-1:1988.

Resin-based compounds shall, as far as is reasonably practicable, be safe and without risk to health. Each pack shall include warnings as to any hazards in use, such as dermatitic or toxic properties, with details of the precautions which the user must take and package disposal instructions.

F8.3.5 Sleeves

Sleeves shall be of the shrink type. They shall provide sufficient thickness of insulation to suit the particular application.

F8.3.6 Tape

Insulating tape used in joints and terminations shall be compatible with, and have a temperature rating and insulating property not less than, the cable insulation, and shall comply with approved standards. Pressure-sensitive adhesive tapes shall comply with BS 3924:1978. All tapes shall be stored in sealed containers until required.

F8.4 Cable installation

F8.4.1 Cable installation - general

To avoid the risk of damage, cables having PVC insulation and/or sheathing shall not be handled or installed if both they and the ambient temperature is below 0°C. For LSF cables, the temperature may be −10°C. Cables shall have been kept at or above the stated minimum temperature for at least 24 hours immediately prior to installation; any special measures to achieve this shall be approved by the Engineer.

Care shall be taken to prevent damage to the cable oversheath during installation. At the discretion of the Engineer, minor damage may be repaired. Full details of the repair procedure shall be provided for approval. In the case of major oversheath damage, the Engineer reserves the right to have the whole section of the cable replaced at no cost to the Employers.

Cables shall not be bent during installation to a radius less than that recommended by the cable manufacturer. Where practical, larger radii shall be used.

Cable drums shall be unloaded carefully by means of either a crane or ramp. Cable drums shall not be dropped onto the ground. Cable drums unloaded using ramps shall be guided by holding ropes with the aid of winches or block and tackle.

Cable drums shall be supported on axles and axle stands during the unwinding operation. Under no circumstances shall cables be unwound from a drum-laying flat. Drums shall be turned during unwinding to prevent the cable being subjected to damaging tensile stresses.

Cables shall be pulled using a pulling eye or stocking. Where cables are supported on rollers, they shall be spaced to prevent the cable being dragged over the ground or other surfaces which could cause damage to the oversheath or other corrosion protection.

Where cables are pulled by a winch, the following measures shall be taken:

(a) a continuous check shall be carried to ensure the tensile stress on the cable does not exceed the permissible value;

(b) a shearing pin or other rupturing device to interrupt the pulling if the maximum permissible tensile stress is exceeded shall be provided at the winch.

F8.4.2 Arrangement of single-core cables in three-phase systems

Three-phase cable systems comprising two or more single-core cables per phase shall be arranged in three-phase, that is red, yellow and blue, groups. This is to equalise, as far as practicable, mutual inductance. The three-phase groups may be in trefoil or flat formation as dictated by the cable system design. Cables shall not be arranged in groups comprising the same phase.

F8.4.3 Cable spacing

Unless otherwise specified, the minimum space between cables shall be as follows:

High-voltage:	50mm;
Low-voltage:	Touching unless current rating considerations dictate otherwise;
High and low-voltage:	300mm;
High-voltage and control:	300mm;
Low-voltage and control:	150mm;
High-voltage and instrumentation telephone:	300mm;
Low-voltage and instrumentation telephone:	150mm;
Control:	Nil.

Where cables are installed in close proximity to or cross those of authorities such as telecommunication, electricity supply and railway, spacing shall comply with the regulations of those authorities.

F8.4.4 Cable and core identification

All cables shall be permanently identified at each end and at entry and exit points of ducts. Identification shall be by means of approved cable markers with semi-rigid black PVC carrier strip which shall be fixed axially by means of two PVC straps or other marker type approved by the Engineer.

On rotating plant and transformers where, to achieve the required direction of rotation or phasing, it is not possible to connect the phase cores to the appropriate terminals, additional core ferrules shall be fitted to identify each core with the terminal to which it is connected.

Control cables shall have individual cores identified by means of suitable permanent ferrules bearing the same number at both ends. Core identification shall occur at every point of termination using an approved system of ferrule markers. The size of the ferrule markers shall be such as to match the overall diameter of conductor plus insulation. Numbering shall read away from the termination on all cores.

F8.4.5 Installation in buildings

Surface-run cables shall be secured by cleats, installed on trays or ladders, or installed in conduit or trunking.

Surface-run cables, trays, ladders, conduits and trunking shall be neatly installed vertical, horizontal and parallel to walls, beams or other structural members.
Conduit systems concealed by wall finishes shall be installed vertical and horizontal.

Cables in structural trenches shall be secured to the trench side by cleats or installed on trays as applicable.

Cables shall be installed in accordance with the recommendation of the cable manufacturer and/or BS 7671:2008.

Cables on tray and ladder systems shall be installed to minimise crossovers.

The spacing of fixings shall be in accordance with BS 7671. The method of securing fixings shall be by means of non-corrodible screws.

Plastic self-locking cable ties shall be as the 'Insulok' range manufactured by Hellermann Insuloid or similar.

Plastic cable ties for outdoor use shall be resistant to ultra-violet degradation. Cable ties for use with LSF cables shall be manufactured from flame-retardant material.

Plastic ties for use with cable tray shall be of the two-part type having lugs for retention behind the tray slot.

Plastic cable ties shall not be used for fixing groups of single-core cables forming a three-phase circuit. Proprietary cable cleats shall be used for this purpose.

All cables installed on ladder systems shall be fixed by means of proprietary cleats.

Cable cleats shall be manufactured from materials which shall have no deleterious effect on cable sheaths. Cleats for single-core cables carrying alternating current shall be manufactured from non-magnetic material. Trefoil, three-way flat, two-way or single-way cleats shall be used as required by the cabling system design.

Cleating arrangements for single-core cables shall be of sufficient strength to withstand short-circuit forces.

Unless otherwise specified or approved, where several cables are terminated in an enclosure, they shall approach the enclosure from a common direction and shall be terminated in a neat and systematic manner.

Cables shall be installed not less than 150mm from water service pipework and below heating and hot water pipework. Cables and chemical pipework shall not be installed in the same trench or service duct unless approved by the Engineer.

Cable installations crossing structural expansion and settlement joints shall have provision for movement. Conduits shall have a flexible section. Trunking shall be fitted with purpose-made expansion couplings.

F8.5 Cable systems

F8.5.1 Conduit

Conduit systems shall be of the steel or plastic type as specified.

Steel conduit and fittings shall comply with BS 4568-1:1970 and BS EN 50086-1:1994, shall be screwed and hot-dip zinc coated inside and outside. The nominal size of conduit shall be not less than 20mm.

The ends of conduits which are liable to be left open for any length of time during building work shall be plugged to prevent the ingress of dirt and covers shall be fitted on all boxes.

No holes shall be drilled through any structure without prior approval.

Damaged galvanising shall be cleaned and immediately painted with two coats of an approved zinc-based paint. This treatment shall be carried out as the work proceeds.

Non-metallic conduit and fittings shall be of the rigid PVC heavy-duty type complying with BS EN 50086-2-1:1996 and BS 4607-1:1984.

Joints into couplers, slip-type bends and spouted fittings shall be made using silicone grease or a permanent solvent. Silicone grease shall be used for expansion couplings.

Expansion couplings shall be fitted in surface installations at intervals as recommended by the manufacturer.

PVC conduit shall not be installed in areas that receive direct sunlight.

The installation of metallic and non-metallic conduit systems shall be carried out in accordance with BS 7671:2008.

F8.5.2 Trunking

Trunking shall be manufactured from hot-dip zinc-coated steel or heavy-duty plastic as specified complying with BS 4678-1:1971 and BS 4678-4:1982.

When fitted, partitions shall be of the same material as the trunking. The gap between the partitions and the trunking cover shall be a minimum to ensure the segregation of circuits is maintained.

Trunking shall be installed using factory-made accessories. Site-fabricated fittings will not be accepted.
Blind ends of trunking runs for future extensions shall be fitted with removable covers.

Trunking with covers on the side or bottom shall be fitted with removable cable-retaining straps at intervals not exceeding 1000mm.

Where trunking runs vertically, cables shall be supported at intervals not exceeding 5m. The method of support shall allow for future easy removal or addition of cables and shall be subject to approval.

Bonding links shall be provided at each joint of steel trunking which shall be secured by screws, shakeproof washers and nuts. The bonding link shall make contact with the metal of the trunking or fitting, and continuity shall not depend on contact through screws nor on the removal of a paint finish.

Factory-made connectors shall be used at joints.

Non-flammable fire barriers shall be inserted where the trunking passes through walls or floors. Conduit connections to trunking shall be made by flanged couplings and male bushes.

Trunking shall be supported at intervals not greater than 2m horizontally or 2.5m vertically.

All cut or drilled edges in steel trunking shall be treated with an approved zinc-based paint.

F8.5.3 Tray

Cable tray shall be heavy-duty hot-dip galvanised steel, stainless steel or glass reinforced plastic as specified. Plastic tray shall be heavy duty with return flanges.

Wherever possible, galvanised steel cable trays shall be installed in full lengths without cutting. Cut edges shall be treated with an approved zinc-based paint.

Cable trays shall be installed using proprietary accessories and support systems.

Plastic tray and accessories shall be approved by the Engineer.

All cables shall be firmly secured to the tray using approved purpose-made fixings.

Cable tray shall be mounted not less than 25mm from the face of the structure.

F8.5.4 Ladder

Cable ladders shall be heavy-duty hot-dip galvanised steel, stainless steel or glass reinforced plastic as specified.

Wherever possible, galvanised steel cable ladders shall be installed in full lengths without cutting. Cut edges of steel ladders shall be treated with an approved zinc-based paint.

Cable ladders shall be installed using proprietary accessories and support systems.

All cables shall be firmly secured to ladders using approved purpose-made fixings.

F8.5.5 Installation directly in the ground

Unless otherwise specified, the minimum cover for cables shall be as follows:

- low-voltage: 500mm;
- control and instrumentation: 500mm;
- high-voltage: 800mm.

Cables shall be laid on a minimum thickness of 75mm soft fill or sand extending the full width of the trench. After laying, cables shall be covered with a further layer of soft fill or sand of minimum thickness 75mm. All cable bedding shall be well-compacted; power rammers shall not be used for this purpose.

Where more than one horizontal layer of cables is laid, the level of the upper layer shall be gauged from the bottom of the trench and marked on the side of the trench at regular intervals to ensure the correct vertical separation is maintained.

Where high-voltage and low-voltage cables are laid in the same trench, the former shall be laid at the bottom and covered with bedding material and protective tiles. The low-voltage cables shall be then laid on a further layer of bedding material at the required separation distance.

During cable laying, sharp metal tools shall not be used in the trench or placed in such a position that they may fall into the trench.

Cables shall only cross other cables at junctions at which point clearances between the cables shall be maintained.

F8.5.6 Installation in ducts

Unless otherwise specified or approved by the Engineer, power, control and instrumentation cables shall not be installed in the same duct.

Cables shall, where necessary, be lubricated to facilitate drawing in. The lubricant used shall have no deleterious effect on the cables. Where cables leave duct ends to enter a trench, a permanent support shall be provided to reduce the possibility of damage to cables due to ground settlement.

F8.5.7 Excavation of cable trenches

The exact route of each trench shall be approved by the Engineer before excavation starts. Trenches shall be kept as straight as possible and shall be excavated in accordance with BS 6031:1981.

Excavated trenches shall be kept free of water and protected against damage or collapse. All necessary sheeting, timbering, strutting and shoring shall be supplied, erected and subsequently removed to ensure the safety of persons and the protection of structures, buildings, roads, sewers and other services from damage.

The bottom of all trenches shall be graded evenly and cleared of loose stones. Where the level of the trench bottom has to change, the slope shall be gradual and shall not exceed 1 in 12.

After cable installation, trenches shall be backfilled in layers, and each layer shall be compacted. The first two layers shall be 100mm deep and shall be compacted by hand. The remaining layers shall not be greater than 200mm deep and power compacting may be used. Where applicable, top soil and turf shall be replaced. Damaged road, hardstanding and paved areas shall be reinstated to an approved standard.

F8.5.8 Cable ducts

Cable ducts shall be manufactured from polyethylene and shall have an internal diameter as specified. Unless otherwise specified, duct colours shall be as follows:

- electric cables: black;
- telecommunication cables: grey or white;

Proprietary couplings, bends and other accessories shall be used.

F8.5.9 Installation of cable ducts

The route of all ducts shall be approved by the Engineer and shall be installed and jointed in accordance with the instructions or recommendations of the manufacturer.

Ducts installed under roads, hardstandings and paved areas shall extend 1000mm beyond the boundary.

The formation and spacing of ducts for power and auxiliary cables shall be as specified or agreed with the Engineer.

Where site conditions require a surround of concrete, the thickness shall be not less than 100mm.

After installation, all ducts shall be checked for alignment and the ends temporarily, but effectively, sealed to minimise the risk of ingress of water, other materials and vermin.

A polypropylene draw rope with a 6kN breaking strain shall be installed in each duct.

Draw chambers shall be provided at changes in duct direction and at intervals along the duct run. The size and spacing of the chambers shall be determined by cable minimum bending radii and permitted maximum pulling forces.

F8.5.10 Cable-protection tiles and warning tapes

Cable tiles shall be reinforced concrete or clayware complying with BS 2484:1985. Cable tiles manufactured from other materials shall not be used without prior approval of the Engineer.

The width of the tile or tiles shall provide a minimum of 50mm overlap on each side of a cable or group of cables. If more than one tile is used for covering a group of cables, the tile width shall be such that the longitudinal joint between tiles is above the space between the cables and not immediately above a cable.

Cable tiles shall be provided for all high-voltage cables and for other cables when specified. Tiles shall be laid directly on the cable-bedding material.

A warning tape shall be placed above individual or groups of cables and cable ducts. The tape shall be laid at a depth of 300mm below the finished surface level or as otherwise approved by the Engineer. For groups of cables or ducts where it is impractical to install individual tapes, a single tape shall be installed above the each outer cable or duct unless otherwise instructed by the Engineer.

Warning tapes shall be of polythene not less than 150mm wide and 0.1mm thick and shall incorporate a metal foil or braid. They shall be yellow in colour and shall be continuously marked ‘caution — electric cable below’, or similar, in black letters not less than 30mm high.

F8.5.11 Marking of buried cables and joints

The route of buried cables shall be permanently identified by reinforced precast concrete marker posts or blocks of an approved type with impressed characters ‘HV cable’ or ‘LV cable’ as appropriate.

The position of buried cable joints shall be permanently identified by reinforced precast concrete marker posts or blocks of an approved type with impressed characters ‘HV cable joint’ or ‘LV cable joint’ as appropriate.

Cable marker posts and blocks shall be located on the precise line of the cable at regular intervals not exceeding 50m, at changes in direction and at points of entry into buildings. Marker blocks shall be installed flush with the finished ground level.

F8.5.12 Sealing of cable entries into buildings

Where cables pass through walls below ground level, the point of entry shall be sealed against the ingress of water by means of silicon foam or proprietary cable-transit system.

F8.5.13 Obstructions

When, in the course of the Works, obstructions are encountered which necessitate diversion of existing service installations, other underground works, alterations to buildings or foundations or when conditions require the adoption of a special form of trench or duct system, the Contractor shall immediately notify the Engineer, who will instruct the Contractor in writing of the action to be taken.

F9.0 BUILDING SERVICES

F9.1 Building and external services — power distribution

F9.1.1 Design

Building services installations shall be designed and installed in accordance with Indian Electricity Rules and the Chartered Institution of Building Services Engineers (CIBSE) Guide, BS 7671:2008 in concurrence with IS 732:1989.

F9.1.2 Distribution boards

Distribution fuseboards and miniature circuit breaker boards, herein referred to as distribution boards, shall comply with BS EN 60439-1:1999.

Distribution board enclosures shall be fabricated from heavy-gauge sheet steel with an all-welded construction. Exterior edges and corners shall be rounded to give a smooth overall appearance. Assembly bolts, screws or rivets shall not be visible from the front. Doors shall be lockable.

Distribution boards shall have a minimum degree of protection IP31 to BS EN 60529:1992 when located in clean and dry rooms. The protection classification for distribution boards located in other indoor locations shall be IP54. For outdoor locations, the degree of protection shall be not less than IPW55.

Distribution boards shall be fitted with removable top and bottom undrilled gland plates, each with a brass terminal stud.

Phase, neutral and earth busbars shall be provided, each clearly identified.

The phase busbars shall be fully insulated. The busbar current rating shall be not less than the sum of the maximum rated currents of the outgoing ways.

The neutral busbar shall have a terminal for each outgoing circuit.

The earth busbar shall be directly connected to the earth terminal without dependance on the exposed conductive parts of the enclosure. The earth busbar shall have a terminal for each outgoing circuit.

Each outgoing circuit including spare ways shall be controlled by a miniature circuit breaker as specified.

Outgoing circuit terminations shall be shrouded and covers shall be fitted over all live parts to prevent accidental contact. Incoming supply terminals, including the cable socket, shall be enclosed in an insulating housing which shall extend over the cable insulation. Warning labels shall be fitted to all removable covers.

Unless otherwise specified, distribution boards shall be fitted with a switch disconnector complying with IEC 60947-3:1999 for isolation of the incoming supply. For three-phase distribution boards, the switch disconnector shall be four-pole. For single-phase ac and dc distribution boards, the switch disconnector shall be two-pole.

Outgoing circuits shall be clearly identified. Neutral and earth busbar terminals shall be identified as their respective outgoing way. Embossed plastic and paper labels will not be accepted.

A circuit identification chart in a clear and durable plastic wallet shall be mounted on the inside of the door.

Distribution boards shall be fitted with an identification label manufactured from white-black-white laminated plastic or rear-engraved perspex as specified. The label shall lay flat to the surface and shall be secured by non-rusting screws.

Danger and warning labels shall comply with BS 5499-5-2002 in concurrence with IS 9457:1980.

F9.1.3 Bulk switching contactors

Bulk switching contactors for the control of lighting and heating loads shall be of the electromagnetic type complying with IEC 60947- 4-3:1999. The contactors shall be rated for uninterrupted duty and shall have a utilisation category compatible with the type of load being controlled.

Contactors shall be double-pole for single-phase ac and dc and four-pole for three-phase loads.

Enclosure construction shall be as specified for distribution boards.

F9.1.4 Low and extra low voltage supply transformers

Low-voltage and extra-low-voltage supply transformers shall comply with BS EN 60742:1996 and shall, unless otherwise specified, be of the single-phase type. Transformers shall be supplied complete with fixing bracket.

The rated output and voltage shall be as specified.

F9.1.5 Electrical earth proving and monitoring units

Where supplies are taken to portable tools or appliances at 240/415V, the supply point shall incorporate electrical earth proving and monitoring complying with BS 4444:1989. The supply point shall also incorporate residual-current protection. The residual-current circuit breaker shall comply with BS EN 61008-1:2004 and BS EN 61008-2-1:1995.

The plug and socket-outlet shall comply with IS/IEC 309-2:1989 and shall incorporate pilot contacts.

F9.1.6 Solar time switches

Solar time switches shall be of the synchronous motor wound clockwork type with a 30–hour spring reserve.

The solar dial shall have a gearing to suit the latitude and longitude of the site and shall incorporate facilities for setting the month and day of the month.

Dial settings shall be with respect to sunset and sunrise within a range of +/-1 hour and facilities shall be provided for an 'off' period from midnight +/-1 hour to 6 am +/-1 hour to be selected.

The time switch shall incorporate a test on/off switch which shall not interfere with the time clock and auto-winding mechanism.

F9.1.7 Building services wiring

Unless otherwise specified, internal services wiring shall be carried out in heavy-duty hot-dipped galvanised steel conduit and trunking incorporating 750V grade, single-core PVC-insulated cable. Wiring installation shall comply with the provisions of IS 732:1989 and SP 30:1985-National Electrical Code.

Wiring shall be carried out on the looping-in system. No joints other than at looping-in points will be allowed.

Cable sizes shall be not less than 1.5mm² for lighting circuits and 2.5mm² for socket outlets, heating and small power circuits.

Conduit systems shall be surface or buried within building plaster/screed finishes as specified.
External services shall be cabled in multi-core PVC-insulated armoured cable, surface-run on building structures and steelwork or direct-buried as appropriate.

F9.2 Building services — lighting

F9.2.1 General requirements

The building internal lighting design shall take into account:

- the operating environment;
- the type and style of architectural finish;
- the activities to be performed in the areas;
- access for equipment maintenance;
- operating life.

The minimum service illumination levels shall comply with the minimum recommendations of the CIBSE Code for the appropriate building area and operational function, or as otherwise specified. Illumination levels shall apply to floor levels.

In no case shall the illumination be below that necessary to perform work or other essential activity in any particular location.

In areas housing rotating machinery, lighting shall be arranged on multiple-phase circuits to prevent stroboscopic effects.

Where adjacent luminaries are connected to different phases of the supply, a label shall be fitted internally, warning of the presence of the phase-to-phase voltage.

F9.2.2 General-purpose luminaires

Luminaires shall be of the fluorescent, tungsten or gas-discharge type as specified, and shall comply with BS EN 60598-1:2000.

General-purpose fluorescent luminaires shall be manufactured from zinc-coated sheet steel of minimum thickness 0.7mm with white epoxy polyester powder or equivalent finish. Luminaires shall be fitted with a trough reflector or prismatic diffuser as specified.

Luminaires for installation in clean and dry areas shall have a minimum degree of protection IP20 (without a diffuser) and IP40 (with a diffuser) to BS EN 60529:1992.

Luminaires for use in a corrosive environment shall have a glass reinforced plastic body with a prismatic acrylic or polycarbonate diffuser. The degree of protection shall be IP65 to BS EN 60529:1992. Covers shall be sealed to the body with a neoprene gasket and shall be secured using stainless steel fixing catches. The catches shall be hinged to the body.

Bulkhead luminaires shall be of the heavy-duty type and shall have a diecast corrosion-resistant aluminium body and front frame with epoxy polyester powder or equivalent finish, and prismatic cover. Covers fitted to luminaires located outdoors shall be impact-resistant polycarbonate. The cover shall be sealed to the body with a silicon rubber gasket and shall be secured using stainless steel captive screws. Retaining hinges shall be stainless steel.

Bulkhead luminaires for indoor location shall have a minimum degree of protection IP54 and for outdoor location IP65 to BS EN 60529:1992.

Floodlighting luminaires shall be of similar construction to the bulkhead luminaires except they shall be fitted with a clear toughened glass panel. Floodlighting luminaires shall be complete with high-purity anodised aluminium reflector and galvanised steel mounting bracket. Reflector characteristics shall be selected to suit the floodlight application.

Fluorescent luminaires shall be of the switch-start type unless otherwise specified.

F9.2.3 Emergency lighting luminaires

Unless otherwise specified, emergency lighting luminaires shall be of the self-contained type complying with BS 4533-102.1:1990 and shall incorporate a fluorescent lamp. The rated duration of emergency lighting luminaires shall be 3 hours.

Exit-type emergency luminaires shall be of the maintained type.

F9.2.4 Luminaires For hazardous areas

Luminaires for location in Zone 1 and Zone 2 hazardous areas shall comply with BS EN 50014:1998. The Apparatus Group and Temperature Class shall be as specified.

F9.2.5 Lamps

Tungsten filament lamps shall comply with BS EN 60064:1995+A4:2007 and BS EN 60432-1:2000 and shall have a minimum rated average life of 2000 hours. Tungsten lamps shall have a reinforced internal construction to provide increased resistance to filament breakage caused by jolts and vibration. Lamps for special applications shall be as specified.

Tungsten lamps rated up to and including 150W shall be fitted with a bayonet-type lamp cap. For lamp wattage above 150W, the lamp cap shall be of the Edison-screw type. Lamp caps shall comply with BS EN 60061-1:1997 in concurrence with IS 6701:1985.

Energy-saving fluorescent lamps used as a direct replacement for tungsten filament lamps shall have integral controlgear and a minimum rated average life of 8000 hours.

Fluorescent lamps shall comply with BS 1853-2:1995 in concurrence with IS 2418-Part1:1977 and shall have caps of the bi-pin type. Unless otherwise specified, lamps for installation in industrial areas shall have a correlated colour temperature of 3500K (white appearance) and for other areas shall have a correlated colour temperature of 3000K (warm appearance). The minimum rated average lamp life shall be 3000 hours.

Mercury discharge lamps shall comply with IEC 60188:2001.

F9.2.6 Ceiling roses

Ceiling roses shall be of insulating material having ignitability characteristic ‘P’ as specified in ISO 5657:1986. Extension flanges shall be fitted to all surface mounted ceiling roses where the wiring installation is concealed in the building fabric.

Where plug-in connections are specified for luminaires, 2A three-pin outlets and plugs shall be provided which shall be suitable for mounting on to a circular conduit box. When specified, the plug shall be retained in the socket by means of a locking ring.

F9.2.7 Pendants and chain suspensions

A plain pendant shall comprise a ceiling rose, flexible cord and lampholder. Unless otherwise specified, the flexible cord shall be 0.75mm² and the insulation shall be suitable for a maximum operating temperature of 85°C. Where the lampholder has a metal exterior, the flexible cable shall include a protective conductor which shall be connected to the earth terminal of the lampholder and ceiling rose.

A tube pendant shall comprise a ball and socket cover to fit a circular conduit box and steel conduit not less than 20mm diameter. At the conduit entry to the luminaire a backnut shall be used.

A chain suspension shall comprise a hook cover fixed to a circular conduit box and a chain having a load carrying capacity not less than twice the weight of the luminaire.

F9.2.8 Supports and fixings

Where fluorescent luminaires 1200mm or more in length are supported directly by the conduit system they shall be fixed to two circular conduit boxes both of which shall form an integral part of the conduit system.

Where the weight of the luminaire is supported by a conduit box or trunking, the fixing of the conduit box or trunking shall be adequate for the purpose.

Luminaires fitted with tungsten filament lamps and having metal backplates shall not be fixed directly to a conduit box in which a thermoplastic material is the principal load-bearing member.

Support of luminaires from cable trunking shall be by means of proprietary clamps or brackets.

Where luminaires are supported from the structure other than by the conduit or trunking system, they shall be fixed by approved purpose-made clamps, bolts, washers and nuts, expanding anchors or proprietary wall plugs and non-ferrous screws as appropriate.

Luminaires mounted on or recessed into suspended ceilings shall be independently supported.

F9.2.9 Wiring connections

Where luminaires, other than tubular fluorescent, are fixed directly to circular conduit boxes or are supported by pendants or chains, the final circuit wiring shall terminate at a terminal block in the conduit box.

Where fluorescent tube luminaires are fixed directly to circular conduit boxes, the final circuit wiring may be terminated within the luminaire. The wiring shall enter each luminaire at the conduit entry nearest to the terminal block and, where a loop-in wiring system is used, leave by the same entry. Wiring shall not pass through the luminaire.

Where luminaires are mounted on or recessed into a suspended ceiling, connection shall be by flexible cord from a plug-in ceiling rose unless otherwise specified. The plug-in ceiling rose shall be located not more than 500mm from the access in the ceiling and shall be firmly fixed.

Where high-bay discharge luminaires are suspended from the structural ceiling, the connection between the fitting and fixed wiring shall be by plug and socket.

Cables and flexible cords for final connections to luminaires shall be suitable for the operating temperature of the luminaire. Flexible cords for chain suspensions shall have a white sheath.

Cables and cords passing close to a ballast within a luminaire shall be suitable for the operating temperature of the ballast.

Where adjacent luminaires are connected to different phases of the supply, a label shall be fitted internally, warning of the presence of the phase-to-phase voltage.

A protective conductor shall connect the earth terminal of each luminaire to an earth terminal incorporated in the adjacent conduit box. Where the final connection is by flexible cord, the protective conductor shall be integral with the cord.

F9.3 Building and external services — roadway lighting

F9.3.1 Columns

Roadway lighting columns shall be constructed and installed in accordance with BS 5649-2:1978. The base compartment door/cover shall be fitted with a tamper-proof fastening.

Columns shall have bolted base mounting plates for installation on concrete foundation blocks which shall incorporate bottom-entry cable ducts.

Columns shall be complete with baseboard, fuse unit and wiring between the fuse unit and luminaire.

The fuse unit shall have a non-hygroscopic plastic case designed to prevent the ingress of moisture and condensation, integral double-entry cable termination chamber with detachable front cover and enclosed-type fuse complying with IEC 60269-1:1998.

F9.3.2 Lanterns

All lanterns shall be of the high-pressure mercury or sodium type fitted with high-efficiency lamps and complete with integral controlgear.

F9.4 Building services — sockets and switches

F9.4.1 Socket-outlets and couplers

Commercial-type socket-outlets shall comply with BS 1363-2:1995 and BS1363-3:1989 in concurrence with IS 1293:1988, and shall be supplied complete with boxes and fixing screws. Socket outlets shall be white plastic or metalclad pattern according to the installation area and as specified.

Socket-outlets shall be of the flush-mounting type in plastered and tiled areas. In all other areas, socket-outlets shall be of the surface-mounting type.

Industrial pattern socket-outlets and couplers shall comply with IS/IEC 309-1:1988 and IS/IEC 309-2:1989. Industrial-type switched socket-outlets shall be mechanically interlocked to prevent the plug being inserted or withdrawn unless the switch is in the 'off' position. It shall not be possible for the switch to be moved to the 'on' position unless the plug is completely inserted.

Socket-outlets for indoor location in process or damp areas shall have a minimum degree of protection IP55 to BS EN 60529:1992. For outdoor locations, the degree of protection shall be not less than IP65.

Socket-outlets for locations in chemical-handling areas shall have plastic enclosures resistant to the particular chemical.

In office and control-room areas, socket-outlets shall be installed at 0.5m above floor level. In plant areas, socket-outlets shall be installed at 1.2m above floor level. The height of socket-outlets shall only be changed with the approval of the Engineer.

Residual-current circuit breakers fitted to socket-outlets shall comply with BS EN 61008-1:2004 and BS EN 61008-2:1995 and shall have a tripping sensitivity of 30mA with an operating time not exceeding 30ms.

F9.4.2 Switches

Switches shall comply with BS EN 60669-1:2000 in concurrence with IS 3854:1997 and shall be supplied complete with box, cover plate and fixing screws. Switches shall be white plastic or metalclad type according to the installation area and as specified.

At multi-switch positions for lighting, the switches shall be contained in multi-gang boxes.

Multi-phase switch assemblies shall be phase-segregated and a separate cover shall be fitted over each phase section. The phase shall be marked on the covers and a label warning of the presence of a three-phase supply shall be fitted.

Switches shall be of the flush-mounting type in plastered and tiled areas. In all other areas, switches shall be of the surface-mounting type.

External lighting switches shall have rotary switch action and, unless otherwise specified, a hot-dipped galvanised cast-iron enclosure with tapped spouted entry.

Switches for indoor locations in process or damp areas shall have a minimum degree of protection IP55 to BS EN 60529:1992. For outdoor locations, the degree of protection shall be not less than IP65.

Switches for locations in chemical-handling areas shall have plastic enclosures resistant to the particular chemical.

Switches shall be installed 1.4m above floor level.

F9.5 Switchgear battery units

F9.5.1 General requirements

Switchgear battery units shall comprise a floor-mounting or wall-mounting enclosure accommodating charger, battery, control equipment and distribution facilities.

Enclosures shall be of sheet steel construction having a degree of protection IP31 to BS EN 60529:1992, with well-ventilated and fully-segregated compartments for charger, battery cells and dc distribution, with independent lockable access doors to the compartments.

The battery units shall be located in rooms having an ambient air temperature in the range 15°C to 25°C.

F9.5.2 Battery

The battery shall comprise the appropriate number of high-performance sealed or vented type nickel-cadmium type cells having a minimum service life of 10 years.

Vented nickel-cadmium batteries shall have high-impact translucent plastic containers with high and low electrolyte markings.

Cell terminals shall be of the bolted type and interconnections and connections between the battery and output protective devices, links and terminals shall be made using PVC-insulated multi-stranded cable. Terminals shall be shielded with impact-resistant plastic to prevent inadvertent contact.

Cells shall be arranged on tiered shelves and shall be easily accessible for inspection, testing and, for vented-type cells, topping up. Mounting shelves shall have plastic cell trays or other approved electrolyte-corrosion-resistant finish.

The nominal battery voltage shall be 24V, 48V or 110V.

Unless otherwise specified, the battery capacity shall be adequate to supply all connected standing loads for a period not less than 8 hours. For switchgear control duties, at the end of the 8–hour period, the battery shall have sufficient capacity to complete 25 circuit-breaker trip/close operations. At the end of the trip/close operations, the battery voltage shall be not less than 90% of its nominal value with the standing loads connected.

F9.5.3 Chargers

Battery chargers shall comprise a double-wound transformer, silicon rectifier, smoothing circuit and solid-state regulated constant voltage/current supply and shall have ‘float’ and ‘boost’ charging regimes. In the ‘float’ charge mode, the charger shall maintain the battery in a fully-charged condition whilst supplying its rated current. In the ‘boost’ charge mode, the charger shall be capable of fully charging the battery from a fully-discharged condition in a period not exceeding 7 hours.

The charger output voltage shall be maintained within the limits of +/-2% under all loading conditions for the specified mains supply voltage tolerance.

The charging characteristics for the nickel-cadmium vented-type cell shall minimise electrolyte gassing.

Battery chargers shall be complete with the following facilities as a minimum:

(a) mains supply on/off switch;
(b) 'supply on' indication;
(c) output voltmeter;
(d) output ammeter;
(e) float/boost charge selector switch, if applicable;
(f) 'charger failed' relay with voltage-free contacts for remote indication wired to terminals;
(g) 'charger failed' indication.

The minimum requirement for the 'charger failed' alarm shall be the detection of ac supply and dc output failure. The relay shall not operate under transient ac supply failure conditions.

F9.5.4 Distribution facilities

Double-pole circuit-breakers shall be provided as required.

F9.5.5 Battery earth fault monitoring

For unearthed dc supply systems double-polarity type earth monitoring shall be provided with the following facilities:

(a) 'system healthy' indicating light;
(b) 'earth fault positive' indicating light;
(c) 'earth fault negative' indicating light;
(d) voltage-free changeover contact wire to terminals for remote alarm initiation.

F9.5.6 Calculations

Battery capacity calculations shall be submitted to the Engineer for consent.

F9.6 Uninterruptible power systems

F9.6.1 General

Uninterruptible power supply (UPS) units shall be designed and manufactured to comply with BS EN 50091. It shall comprise rectifier, battery charger, batteries, dc to ac converter, static bypass switch and manual system bypass facility mounted in a sheet steel floor-mounting or wall-mounting enclosure.

Unless otherwise specified, enclosures shall have a minimum degree of protection IP21 and shall be vermin-proof. The arrangement of internal equipment shall permit reasonable access to components for inspection, maintenance and replacement.

Removable undrilled gland plates shall be provided at cable-entry points.

Where forced enclosure ventilation is necessary, duplicate fans shall be provided and the equipment shall be capable of operation at rated output with one fan out of operation.

F9.6.2 Isolation and fault protection

UPS units shall be provided with a lockable main-supply isolating switch and shall incorporate protection against damage resulting from over-current including output short-circuit, and failure of internal components. Solid-state components shall be protected by fast-acting current-limiting fuses. Operation of such devices shall initiate and audible and visual alarm.

F9.6.3 Operating requirements

UPS units shall be suitable for operation from mains and, where specified, local standby generated supplies.

The UPS shall not generate noise in excess of a sound pressure level of 60dBA measured one metre from its surface, under any mode of operation and at any load up to the maximum rating.

F9.6.4 Battery support time

The UPS system with a fully-charged battery or batteries shall, on loss of mains supply, be capable of supplying the connected load for the specified period.

F9.6.5 Output waveform

The output waveform shall be sinusoidal with total harmonic voltage distortion not greater than 5% and individual harmonic voltages not greater than 3% of the fundamental value.

F9.6.6 Steady state regulation

Steady-state regulation of the output voltage shall be not greater than +/- 1.0% due to simultaneous variation of 0 to 100% load and specified mains-supply voltage variation.

F9.6.7 Transient response

Output voltage transient response shall be not greater than 5% on application or rejection of 100% step load, with recovery to 2% after a period not greater than 30 milliseconds.

F9.6.8 Frequency variation

Frequency variation when free running in absence of mains power shall be not greater than 0.2%.

F9.6.9 Rectifier and battery charger

The rectifier shall be continuously-rated to supply the rated load of the unit plus, where applicable, the maximum current necessary for battery charging.

The rectifier shall be not less than 6–pulse and shall be designed not to absorb even and triplen harmonic currents from the mains supply.

The harmonic currents generated by the rectifier shall ensure that the total harmonic voltage distortion at the point of common connection with the main electrical power supply does not exceed 5% with individual harmonic voltage distortion not exceeding 4% (odd) and 2% (even).

The generated harmonic currents and resulting power system harmonic distortion shall also be limited to prevent the possibility of resonance with any installed system power factor correction capacitors.

Over-voltage and over-current protection and charger failure detection shall be provided on the battery charging system. Operation of any protection or detection device shall initiate an audible and visual alarm.

Where the battery or the dc supply are not connected to earth or to an earthed system, an earth fault indicator and alarm shall be provided.

F9.6.10 Battery

The battery shall comprise the appropriate number of high performance sealed lead-acid type cells having a minimum service life of 10 years.

The battery cells shall be easily accessible for inspection and testing.

Cell terminals shall be of the bolted type and interconnections and connections between the battery and output protective devices, links and terminals shall be made using PVC-insulated multi-stranded cable. Terminals shall be shielded with impact resistant plastic to prevent inadvertent contact.

A dc circuit breaker shall be provided for the supply from the battery.

The battery and charger system shall be capable of performing the following duty cycle:

(a) discharge at the rated UPS output power for the specified period of autonomy;
(b) recharge for a period of 3 hours;
(c) discharge at the rated UPS output power for a period of 80% of the specified battery support time.

F9.6.11 Inverter

The inverter shall be capable of supplying 150% rated load at nominal voltage for a period of not less than 10 seconds.

F9.6.12 Static bypass

A static bypass switch shall be provided to affect a no-break transfer of load from the UPS supply to the bypass supply in the event of an equipment malfunction or overload.

Following operation of the static switch due to an overload, the load shall be automatically restored to the UPS when normal conditions return. Following operation for any other cause, restoration to normal conditions shall require manual operation.

Transfer of load to or from the automatic bypass shall be inhibited when the UPS output is not in synchronism with the bypass supply.

F9.6.13 Manual bypass

A manual bypass switch shall be provided to transfer the load from the UPS to mains supply for maintenance purposes.

F9.6.14 Indications

The following indications shall be provided as a minimum:

(a) mains on;
(b) charger on;
(c) inverter on;
(d) bypass on;
(e) overload;
(f) output fail;
(g) battery low;
(h) auto by-pass.

F9.6.15 Indicating instruments

The following indicating instruments shall be provided:

(a) inverter output ac voltmeter;
(b) inverter output ac ammeter;
(c) inverter output frequency meter;
(d) battery charger voltmeter;
(e) battery charger ammeter.

F9.6.16 Alarms

Audible and visual alarms with accept and reset facilities shall be provided for all fault conditions.

F9.6.17 Diagnostic indicators

In addition to the specified indications a comprehensive system of indicators shall be provided to assist in identifying component faults.

F9.7 Solar power systems

Solar power systems shall typically comprise the following configuration:

- solar panel array;
- battery system;
- control panel;
- power distribution system.

The solar panel array shall comprise a series of high-power photovoltaic type polycrystalline silicon cell panels mounted in a sturdy aluminium frame. The whole structure shall be either ground or building mounted and shall be constructed in a manner appropriate to the environment in which it is to be installed. The cells shall be encapsulated in a protective, easily cleanable, weatherproof coating. The coating shall not affect the efficiency of the solar cells. The Contractor shall pay particular attention to the requirements of the local planning authorities, particularly in areas of environmental sensitivity. In all cases, the panel array structure shall be designed to withstand a minimum wind loading of 100mph in any direction. The structure shall be designed so that the tilt angle can be adjusted in order to obtain the optimum operating conditions. The cable-connection facilities at the panel array shall be provided in marshalling enclosures protected to a minimum of IP55.

The size of the solar array shall be determined by the following requirements:

- average ambient temperature (shall be taken as 40°C if not otherwise given in the particular specification);
- number of peak sun hours in a 24–hour period;
- size of load plus 25% spare capacity;
- battery-system charging requirements (fully charging within a single 24–hour period with the load operating at full capacity).

Each solar panel certified peak power output shall be guaranteed for a minimum of 15 years.

The battery system shall comprise a series of maintenance-free lead-acid or high-performance nickel-cadmium type cells. The battery system shall be installed generally as specified in 'Batteries and battery chargers'. The battery system shall be sized to provide continuous operation of the plant on loss of power from the solar cells for a period of 26 hours.

The control unit shall comprise a wall-mounted or panel-mounted unit providing control of battery charging and regulation of the power supply to the load equipment. Unless otherwise specified, the output voltage shall be 24V dc +/-6% and the controller shall be provided with a volt-free alarm output to warn of supply voltage low for connection to a remote alarm system.

The distribution of power from the solar energy power system shall be provided by a miniature circuit breaker distribution board providing circuit protection for each individual load.

All solar cells shall be works tested for peak power output and for voltage and current at peak power output at an illumination level of $1kWm^2$ at a spectral density of A 1.5. This test shall be carried out at the normal operating temperature of the cell. This shall be taken as the ambient temperature required by the specification.

F9.8 Telephone System

F9.8.1 General

The telephone system including the complete telephone distribution network and private telephone exchange system shall comprise of the following:

- telephone distribution installation
- electronic private automatic branch exchange (EPABX)
- main distribution frame (MDF)
- EPABX peripheral equipment
- operator's console
- telephone sets
- power supply equipment
- ancillary equipment
- all measures for approval by and connection to the local telephone company

A modern state-of-the-art telephone system based on digital signal transmission shall be installed.

The system shall be capable of being connected to the Employers proposed state wide IP telephony system.

The proposed telephone system including all components and installations shall comply with appropriate regulations and the requirements of national and international standards.

The operation voltage on site shall be 240 V/50 Hz.

EPABX and related equipment shall be tested at manufacturer's premises, and test certificates, certified by an official testing authority, are to be submitted to the Engineer before shipping and delivery to site.

F9.8.2 Telephone Distribution Components

Telephone distribution cabinets and Boxes shall be made of steel or metal alloy, general purpose enclosures, for surface or concealed mounting, of a suitable size with a spatial reserve of at least 30%, dust-proof, IP 42 protection for indoor mounting and IP 55 for outdoor mounting, with tamper-proof screwed covers for up to 50 pair capacity.

Terminal blocks shall be of the screw or plug-in quick connect type in moulded high insulation resistance phenolic base, fixed by two captive screws, with double-ended nickel-plated brass connectors, and plug-in or set-screw terminals for connection of conductors with diameters between 0.5 and 1 mm.

Telephone cabling shall be carried out with two-pair and multi-pair cables for indoor and outdoor cabling. The cabling shall be polyethylene insulated, tinned solid copper conductors, twisted into pairs, colour coded, minimum diameter of conductor is to be 0.8 mm.

Cables are to be rated for maximum operating voltage of 150 V with insulation resistance of 10,000 mega ohm/km, and tested at 500 V dc applied core-core and core-earth.

Telephone outlets are to have modular grid box and cover plates similar to other socket outlets and switches described elsewhere, with cord-grip cover and fixed mounting set-screw terminal block inside box.

F9.8.3 Electronic Private Automatic Branch Exchange system (EPABX)

The EPABX-design shall permit station numbers to be assigned to lines at time of installation, in accordance with customer-desired numbering plan, and reassignment while in service to allow personnel moves without requiring number changes.

It shall be possible to assign to each extension, restriction for outward calls as follows:

- Non-restricted: having unrestricted access to external lines for outward calls either by direct dialling or through operator.
- Semi-restricted: having access to external lines only for local calls by direct dialling orthrough operator.
- Restricted: having no access to external lines neither through direct dialling nor through operator.
- It shall be possible to segregate external trunk lines as follows:
- Lines for outgoing calls accessible only by operators.
- Lines for outgoing calls accessible by operators and by all remaining non-restricted and semi-restricted extensions.

The EPABX shall be fully electronic, digital stored program, microprocessor controlledwith LSI switching circuits. Reed relays, mini-switches, cross-point switching and cross-bar techniques are not acceptable. The EPABX shall be designed for use as a universal telephone exchange system for all applications. It shall be possible to connect any combination of DTMF and rotary dial telephones to the EPABX, with the provision of manufacturer-made interface modules as necessary within the EPABX and without the need to modify the assembly.

The capacity has to be suitable to connect a sufficient number of telephones as specified in particular specification.

The power supply for the whole telephone system shall be supported by an Uninterrupted Power Supply (UPS).

F9.8.4 System Performance

As a minimum the following features shall be provided:

- Station-to-station calling: Station user is to be able to directly dial other stations within EPABX system without assistance of operator.
- Direct outward dialling (DOD): Non-restricted and semi-restricted station user shall be able to gain access to exchange network, without assistance of operator, by dialling an access code, receiving a second dial tone and then dialling desired network exchange number.
- Executive override (break-in): Station user shall be able to enter existing two-party busy station connection; this intrusion is to be preceded by a warning tone; if a person called releases his line, he is automatically called back.
- Camp on busy: If internal extension called is busy, it shall be possible to dial a digit and to hang up; the two telephone stations are automatically called back as soon as they are simultaneously free.
- Enquiry call: When telephone user is in conversation with the outside he shall be able to put his communication on hold, dial an internal number, consult privately, and then take back first communication.
- Call transfer: This shall enable any extension in the installation to directly divert an external communication to another extension without going through the operator.
- Dial access to operator: Station users within switching system shall be able to reach operator by dialling a single digit, and operator may complete these calls to trunk facilities or other stations.
- Line lockout with warning: This shall give 30 seconds warning tone and then holds the line out of service when a station line remains off-hook for longer than 10 seconds without dialling; the hold out-of service shall be released when station goes on-hook.
- Splitting: Station user shall be able to consult privately with one party on a call without third party heading.
- Power failure transfer: This shall allow a limited number of pre-assigned station to get access to or from the network in case of battery failure.
- Call-back queuing for trunks: This shall allow the user to wait for a trunk to be idle when the trunk is idle, the exchange rings back, and then wait for user to go off-hook and dial the number.
- Direct distance dialling (DDD): This shall allow user to dial long distance calls without intervention of operator.
- Single digit dialling shall be provided.
- As a minimum the operator’s console features shall include at least the following:
- Facility to check status of any individual trunk or extension line.
- Ring-when-free facility for external calls transferred to a given busy extension.
- Automatic return to operator if an extension does not answer an outside call within 15 seconds.
- Time reminder: Operator is to be automatically alerted after e.g. 30 seconds when an internal or outside call on the console is waiting.
- Calling number display: visual display of EPABX station seeking attendant assistance.
- Transfer or incoming call to wanted extension made by push-button key set.

- Priority: Operator is to be able to interfere in an established communication for special announcements or transfer of incoming calls; warning tone is to be sent to both conversing parties.
- Splitting: Operator is to be able to consult privately with one party on a call without the other party hearing.
- Operator is to be able to connect any internal extension or outside trunk line with any other internal extension; operator is to be able to place an outgoing call for a station user without requiring the station user to hang up.
- Call hold: Calls that cannot immediately be extended, are to be placed in a hold buffer; when required extension becomes available, the call is to be retrieved from hold buffer and extended to extension.
- Abbreviated dialling: Operator is to be able to assign short dial codes for frequently called destinations.
- Automatic call supervision: If an unannounced extended call is not answered within a predetermined time, the call is to be automatically returned to the operator.
- Fault indication: Any fault within the system is to be automatically detected and signalled by an alarm buzzer and an indicating lamp.
- Automatic and manual switch-over to night service: Incoming trunk calls during night operation are to be routed to predetermined answering stations; routings are to be on a flexible basis by the attendant and are to remain in effect until changed.
- Do not disturb: Operator shall, upon request, be able to prevent selected station lines or groups of lines from receiving any calls. When activated, restricted calls shall be routed to the operator. The restricted station shall return automatically to normal upon lighting the hand-set of the restricted station.

F9.8.5 System Peripheral Equipment

The EPABX shall contain disk storage of all system and user data, to serve as back-up storage for protection of system configuration data and operating system software.

Facilities shall be included to store and print upon request the full list of outward calls, with indication of number called, number of internal extension originating the call, date, time and duration of call.

The exchange components shall be grouped in a single modular, totally enclosed, sheet metal cabinet, with lockable front access doors. The cabinet shall be dust and insect proof and adequately ventilated. Range of temperatures recommended for continuous operation of the system shall be submitted to the Engineer.

Electronic circuits and components shall be plug-in cord type, with solid state electronic components. Equipment shall be assembled neatly in racks. Sensitive equipment shall have dust protection covers.

The operator's console shall be equipped to enable operator to provide all services required and have full control of system operation.

F9.8.6 Main Distribution Frame (MDF)

The size of the main distribution frame shall be suitable for ultimate capacity of EPABX regarding a spatial reserve of at least 30%. All internal and external lines of EPABX system shall be connected to MDF.

Protection against over-voltage on all trunk circuits shall be provided

Terminals shall be identified by numbered tags corresponding to respective lines and extensions. Proposed numbering scheme shall be submitted for approval. Internal and external lines shall be connected by “plugged” twin terminals. Soldering will not be allowed.

F.9.8.7 Telephone Extension Sets

Telephones shall be placed on tables or on the wall. Dialling shall be push button operated, dual tone multi-frequency type (DTMF) and pulse type, switchable.

The set shall have an impact resistant and temperature-stable plastic, two dish fells with an infinitely variable belt loudness level, receiver with high grade plugable microphone and receiver capsules. Those sets which may be installed in wet areas shall have a corrosion-resistant housing.

F9.9 Local Area Network (LAN) Cabling System

F9.9.1 General

The Contractor shall maintain conductor polarity identification at the main equipment room and network rooms in accordance to all relevant codes of practices.

All cables installed by the Contractor shall be fully tested for continuity prior to installation.

It shall be the responsibility of the Contractor to furnish any special installation equipment or tools necessary for the proper functioning of the system. This shall include, but not be limited to, tools for terminating cables, testing and splicing equipment for copper/fibre cables, communication devices, jack stands for cable reels, or cable wenches.

The Contractor shall not route any distribution communication cabling alongside power lines, or share the same conduit, channel or sleeve with electrical apparatus.

The Contractor shall ensure that the maximum pulling tensions of the specified distribution cables are not exceeded and cable bends maintain the proper radius during the placement of the facilities. Failure to follow the appropriate guidelines will require the Contractor to provide in a timely fashion the additional material and labour necessary to rectify the situation at his own expense. This shall also apply and all damages sustained to the cables by the Contractor during the implementation.

The Contractor shall install any equipment or electronics exactly as documented on the approved plans. In the event any variance is determined to be necessary, the Contractor must secure the approval of the Engineer.

In additional to the general standards, the following standards and reference documents will be applicable to the structured cabling system:

EIA/TIA 568A	CommercialBuilding Telecommunications Wiring Standard
EIA/TIA 569	CommercialBuilding Standard for Telecommunications Pathways and Spaces
ISO 11801	Communication Cabling Systems for Commercial Premises

All equipment supplied shall be tested by international/local institutions for example, the Under-writer’s Laboratories (UL). The Contractor shall submit such test certificates to the Engineer.

F9.9.2 Cabling system

The LAN Cabling System to be provided shall incorporate all features and facilities listed in this specification and must include the following :

(a) The Work Area subsystem at the user end shall include of the wiring from the terminal devices to the information outlets on the faceplates. Each faceplate can have one or more information outlets. It consists of RJ45 jack on angles faceplate, station cord and the termination of horizontal cable to the RJ45 jacks.

(b) All installed cables shall be fixed and supported in an appropriate manner to a surface. No loose or trailing cables are permitted. Trunking shall be used in ceiling voids and on walls. There shall be no exposed cable at the junction s between the trunking and each outlet.

(c) Trunking shall not be filled above 50% capacity. All cables shall be laid as flat as possible to prevent kinks. All cable ends shall be protected against ingress of water and physical damage. The cables should be a distance away and not sharing the same shafts or voids used by power cables and lightning conductors. The minimum separation of 500mm will be required.

(d) The maximum physical distance of the FTP from the faceplate to the patch panel or hub shall not be more than 90m. There shall be a slack of 2m of cable for each point in the rack and at the receiving end.

(e) The system includes cross connects and interconnects that links the various subsystems together. It shall comprise of patch panels, distribution units, cable management, patch cords and equipment racks.

(f) A cable management panel shall be provided for every two-patch panels and every fibre panel. Additional cable management panel shall be provided to enhance the tidiness of the cables.

(g) All transmission media proposed shall be protected against rodent attack and weather damages.

(h) The Structured Cabling System shall be warranted by the Manufacturer for a period of fifteen (15) years to be free from defects in material and workmanship.

F9.9.3 FTP Cable

The FTP Cable used shall conform to the latest edition ISO/IEC 11801, CAT 6 FTP specification.

(a) The CAT 6 FTP cable proposed shall come with the following technical features.

(b) The FTP cable shall be 100 Ohms, foil-shielded horizontal cable containing four twisted pairs.

(c) The FTP cable shall be housed in Low Smoke Zero-Halogen, flame-retardant jacket (LSZH-FR)

(d) The FTP cable shall conform to ISO/IEC 11801, Category 6 requirements.

(e) The FTP cable shall meet ISO/IEC DIS 11801 and ANSI/EIA/TIA 568 TSB-36.

(f) The FTP cable shall meet EN50081-1, EN50082-1, EN55022, EN55024 and ISO/IEC 11801 emission standards.

(g) The FTP cable shall conform to the minimum mechanical characteristics stated in Table A

Wire insulation	**Foam skin PE or equivalent**
Sheath material	Low Smoke Zero-halogen, flame-retardant (LSHF-FR) material
Deployment	Indoor
Temperature range (installation)	0 to +50 °C
Temperature range (at rest)	-20 to +60 °C
Min. bend radius	5 x Diameter
During installation	7 x 5 Diameter

(h) The FTP cable shall conform to UL 1581 VW-1 Flammability Test and Flame retardant to IEC 332-1 and IEC 332-2 standards.

(i) The FTP cable shall conform to the typical FTP cable construction and shall have the following features:

(i) Copper conductor with 0.51mm diameter (AWG 24);
(ii) Foam skin PE insulation;
(iii) Wires twisted into pairs with the following colour coding.

Pair 1	White/Blue
Pair 2	White/Orange
Pair 3	White/Green
Pair 4	White/Brown

F.9.9.4 Rack

The number of racks required shall be determined by the LAN points served by each floor. The arrangement for the racks for the LANs point in the server room shall be as follows:

Rack 1 – 1 core switch + 40 FTP points

Rack 2 – 1 core switch + 40 FTP points

Rack 3 – For FTP points exceeding sum of Rack 1 & Rack 2 (i.e. 40+40) up to 120 point per rack.

LAN Room – up to 120 points per rack

The innermost rack shall be fully occupied first. Racks shall not be provided for the servers.

F.9.9.5 Labelling requirement

The Contractor shall tag all the cables, equipment and information outlets. All information outlets shall be labelled with a unique identifier.

The labels and markings shall be durable and legible and shall not degrade within the lifetime of the system. The label markings shall be indelible and waterproof.

PART G – INSTRUMENTATION

G1.0 INSTRUMENTATION — GENERAL

G1.1 Scope

This part covers the general requirements for the design, supply, installation, inspection and testing of the instrumentation and associated plant and materials.

G1.2 Reference standards

Unless otherwise approved, instrumentation shall comply with relevant quality standards test procedures and codes of practice collectively referred to as Reference Standards including those listed below in accordance with the requirements detailed elsewhere in this specification.

IEC 60381-1:1982	Analogue signals for process control systems. Specification for direct current signals.
IEC 60947-4-1:2000	Specification for low-voltage switchgear and control gear. Contactors and motor-starters. Electromechanical contactors and motor-starters.
IEC 60947-4-2:1999	Specification for low-voltage switchgear and control gear. Contactors and motor-starters. A.C. semiconductor motor controllers and starters.
IEC 60947-4-3:1999	Specification for low-voltage switchgear and control gear. Contactors and motor-starters. Contactors and motor-starters. AC semiconductor controllers and contactors for non-motor loads.
IEC 60770-1:1999	Transmitters for use in industrial-process control systems. Methods for performance evaluation.
BS ISO 1217:1996	Displacement compressors. Acceptance tests.
ISO 2112:1990	Specification for aminoplastic moulding materials.
ISO 6817:1997	Measurement of conductive liquid flow in closed conduits. Method using electromagnetic flow meters.
BS EN 837-1:1998	Pressure gauges. Bourdon tube pressure gauges. Dimensions, metrology, requirements and testing.
BS EN 1057:1996	Copper and copper alloys. Seamless, round copper tubes for water and gas in sanitary and heating applications.
BS EN 1092-1:2002	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges.
BS EN 1563:1997	Founding. Spheroidal graphite cast iron.
BS EN 60529:1992	Specification for degrees of protection provided by enclosures (IP code).
BS EN 60534-1:1993	Industrial-process control valves. Industrial-process control valves. Control valve terminology and general considerations.
BS EN 60546-1:1993	Controllers with analogue signals for use in industrial-process control systems. Controllers with analogue signals for use in industrial-process control systems. Methods for evaluating performance.
BS EN 60584-2:1993	Thermocouples. Tolerances.
BS EN 60654:1998	Operating conditions for industrial-process measurement and control equipment. All relevant parts.
BS EN 60751:1996	Industrial platinum resistance thermometer sensors.
BS EN 60873:1993	Methods of evaluating the performance of electrical and pneumatic analogue chart recorders for use in industrial-process control systems.

BS EN 61000-6:2001	Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments.
BS 89:1990	Direct acting indicating analogue electrical measuring instruments and their accessories. All parts.
BS 90:1975	Specification for direct-acting electrical recording instruments and their accessories.
BS 476	Fire tests on building materials and structures. All parts.
BS 1042-1.4:1992	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2.
BS 1041-2.1:1985	Code for temperature measurement. Expansion thermometers. Guide to selection and use of liquid-in-glass thermometers.
BS 1041-2.2:1989	Code for temperature measurement. Expansion thermometers. Guide to selection and use of dial-type expansion thermometers.
BS 1041-3:1989	Temperature measurement. Guide to selection and use of industrial resistance thermometers.
BS 1041-4:1992	Temperature measurement. Guide to the selection and use of thermocouples.
BS 1042-1.4:1992	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2.
BS 1123-1:1987	Safety valves, gauges and fusible plugs for compressed air or inert gas installations. Code of practice for installation.
BS 1203:2001	Hot-setting phenolic and aminoplastic wood adhesives. Classification and test method.
BS 1553-1:1977	Specification for graphical symbols for general engineering. Piping systems and plant.
BS 1571-2:1975	Specification for testing of positive displacement compressors and exhausters. Methods for simplified acceptance testing for air compressors and exhausters.
BS 1646-1:1979	Symbolic representation for process measurement control functions and instrumentation. Basic requirements.
BS 1646-2:1983	Symbolic representation for process measurement control functions and instrumentation. Specification for additional basic requirements.
BS 1646-3:1984	Symbolic representation for process measurement control functions and instrumentation. Specification for detailed symbols for instrument interconnection diagrams.
BS 1646-4:1984	Symbolic representation for process measurement control functions and instrumentation. Specification for basic symbols for process computer, interface and shared display/control functions.
BS 1794:1952	Specification for chart ranges for temperature recording instruments.
BS 2765:1969	Specification for dimensions of temperature detecting elements and corresponding pockets.
BS 3680	Measurement of liquid flow in open channels. All relevant parts.
BS 3693:1992	Recommendations for design of scales and indexes on analogue indicating instruments.
BS 4675-2:1978	Mechanical vibration in rotating machinery. Requirements for instruments for measuring vibration severity.

BS 4999-142:1987	General requirements for rotating electrical machines. Specification for mechanical performance: vibration.
BS 5169:1992	Specification for fusion welded steel air receivers.
BS 5728-3:1997	Measurement of flow of cold potable water in closed conduits. Methods for determining principal characteristics of single mechanical water meters (including test equipment) .
BS 6004:2000	Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring.
BS 6739:1986	Code of practice for instrumentation in process control systems: installation design and practice.
BS 7671:2001	Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition.

Instrument Society of American Standards and Recommended Practices:

S 5.1	Instrumentation symbols and identification
S 5.4	Instrument loop diagrams
S 7.3	Quality standard for instrument air
RP 16.1	Terminology, dimensions and safety practices for indicating variable 2, 3 area meters
RP 16.4	Nomenclature and terminology for extension-type variable-area meters (rota meters)
RP 16.5	Installation, operation, maintenance instructions for glass tube variable area meters (rotameters)
RP 16.6	Methods and equipment for calibration of variable area meters (rotameters)
RP 18.1	Specifications and guides for the use of general purpose annunciators
S 26	Dynamic response testing of process control instrumentation
RP 31.1	Specification, installation and calibration of turbine flow meters
S 37.1	Electrical transducer nomenclature and terminology
S 37.3	Specifications and tests for strain gauge pressure transducers
S 50.1	Compatibility of analog signals for electronic industrial process instruments
S 51.1	Process instrumentation terminology
RP 60.08	Electrical Guide for Control Centres

G1.3 Statement of compliance

The Contractor shall provide a list of the reference standards used and shall provide a compliance/non-compliance statement.

All standards which the Contractor intends to use but which are not referenced herein shall be submitted to the Engineer for consent before any design against that standard proceeds.

Installation works shall comply with all relevant local Indian Regulations including the Code of Practice for Electrical Wiring Installations – IS 732.

G1.4 Submissions by Contractor

G1.4.1 General

The Contractor shall make submissions to the Engineer of all design drawings and schedules relating to instrumentation and control equipment and systems provided under this Contract. These submissions shall include, where relevant, the following:

G1.4.2 Functional design specification

The Contractor shall submit a complete functional design specification (FDS) for approval by the Engineer. This document shall serve as the primary mechanism by which the Engineer may confirm that the Contractor possesses an accurate understanding of the system and its control requirements. The Contractor is encouraged to obtain clarifications and to suggest refinements to the control descriptions contained in this Specification.

The FDS shall comprise an overall description of the plant, its functioning and control, and a detailed description of each section of the control system covering modes of operation, manual overrides, set-point and parameter selection and adjustment. The detailed description shall include a step-by-step control description which defines the function of each piece of equipment and each control action and interlock, including details of the program in each programmable item. The format of the program details may be chosen by the Contract, however it is suggested that this format be chosen to satisfy the requirements of the software design documentation, if applicable, as described elsewhere.

The FDS shall describe the 'fail-safe' features incorporated into the design for the event of failure of a plant item or system, or loss of an input signal affecting a control loop or process sequence.

The FDS shall describe control actions taken and monitoring functions which remain available during a power failure, and any automatic controls or sequencing which take place during system start-up and shut-down.

The FDS shall be presented in a clear and precise manner and shall include figures or drawings where appropriate.

The Contractor shall submit and obtain approval of the FDS from the Engineer before beginning the detailed control system design. The contractor should take note of the importance of this obligation.

G1.4.3 Drawings and schedules

(a) Process and instrumentation diagram which shall comply with BS 1646 (all parts) and BS 1553-1:1977.
(b) General arrangement drawings of field-mounted instruments showing installation details.
(c) General arrangement drawings of instrument and control panels, fully-dimensioned in plan and elevation views, showing foundation and fixing details, access doors, clearances, cable-entry positions, weight and lifting arrangement.
(d) Layout drawings of panel fascias showing instruments, controls and details of all labels.
(e) Layout drawings of panel interior showing equipment, terminal blocks and cable ways.
(f) Annunciator arrangement and engraving details.
(g) Internal circuit and wiring diagrams for instrument and control panels.
(h) Schematic control diagrams.
(j) Instrument loop diagrams.
(k) Instrument wiring and piping diagrams.
(l) Interconnection wiring diagrams.
(m) Cable block diagrams, drawings and schedules.
(n) Instrument system and panel power distribution diagrams.
(p) Programmable-device functional design specifications which shall include hardware details, logic flow charts, ladder diagrams and program listings.
(q) Schedules of inputs to and outputs from programmable controllers and telemetry outstations.
(r) Labelling schedules.
(s) Comprehensive testing schedules for all off-site, on-site, pre-commissioning and commissioning tests and take-over tests.

All other drawings necessary for the provision of ducts, openings, trenches, fixing holes for panels and the like and for the complete understanding of the operation, maintenance and extension of the system including any required for the Purchaser to dismantle, repair, maintain, modify or extend the Plant.

G1.4.4 Data and calculations

(a) Manufacturers' catalogues and data sheets.
(b) Calculations to support control system design.
(c) Specification for protective coatings and painting.

G1.4.5 Certificates

(a) Manufacturers' works tests.
(b) Pre-installation checks.
(c) Pressure-testing schedules.
(d) Instrument loop test check sheets.
(e) Installed instrument performance tests.
(f) System tests.
(g) Statutory certificates of compliance (such as hazardous area equipment).

G1.4.6 Operation and maintenance instructions

Composite manual describing the functional and operation of each piece of equipment.

Composite manual for testing and servicing every system and individual item.

G1.5 Basic features

Each instrumentation system shall be designed, manufactured and installed to achieve the following basic requirements:

- to maintain the highest standards of availability, reliability and accuracy and to give clear warnings of any deterioration in performance;
- to suit the abilities of the staff who will:
  (a) use the systems;
  (b) service the systems.
- to measure, indicate, process, store and control the relevant parameters, as specified;
- to give clear warnings of dangerous and other abnormal conditions and to initiate plant safety procedures, shutdowns and corrective measures as specified to assure the safety of 'operations and maintenance' personnel and plant and to store and collate the data, as required;
- to derive, present and utilise, as required, such additional data as required to facilitate:
  (a) the most efficient operation of the plant;
  (b) the routine maintenance of the plant.

G1.6 Design requirements for instrumentation systems

The instrumentation, control and automation installations shall fully comply with design standards, regulations and the material and workmanship requirements of the Specification.

The electrical plant installations associated instrumentation control and automation systems shall also comply with and be tested in accordance with the latest edition of ‘Requirements for Electrical Installations’ BS 7671:2001, and with the relevant standards of Indian in which the plant is to be installed. All electrical consumable items shall be readily available within Indian.

All installations, shall also comply in conjunction with associated mechanical and electrical power plant installations with the UK’s Health and Safety at Work Act 1974 (or the latest edition) and the Electricity at Work Regulation 1989 (or the latest edition), which specify standards of safety for industrial plant installations, and with the relevant standards of the Country in which the plant is to be installed.

All equipment and materials incorporated in the system shall be selected, designed and rated to operate under the defined performance duties and specified site conditions and to maintain a high level of operational reliability.

The instrumentation control and monitoring system equipment and materials shall have an operational life of not less than 15 years, unless otherwise consented to by the Engineer.

G2.0 PANEL DETAILS

G2.1 Enclosures and mounting boards

Enclosures shall be any form of board, cabinet, panel, desk, box or case used to protect, contain or group instrumentation, telemetry or control equipment.

All equipment in or on enclosures shall be arranged logically and, as far as possible, symmetrically, with projections kept to a minimum. Each enclosure and board shall be designed on ergonomic principles and shall permit in-situ and safe access for any normal adjustment, maintenance and servicing. The tops of plant-mounted enclosures shall be sloped downwards from front to rear.

The minimum degree of protection shall be IP 31 in purpose designed control rooms and IP 54 for other indoor locations.

Enclosures for use outside buildings or in places where splashing may occur shall have a minimum rating of protection to BS EN 60529:1992, IP 56 and have tops which project sufficiently to protect the vertical faces of the enclosure and any component mounted thereon from splashing, inclement weather and direct sunlight. Also, when enclosures for use outside buildings are located where exposure to direct sunlight will give rise to high top-panel surface temperatures such that the internal temperature rises above the manufacturer’s recommendation (normally 40°C), the enclosure shall include a sun shield fitted to the top of the enclosure.

Fixing arrangements for surface-mounting enclosures shall be external to the enclosure and shall ensure that the rear face of the enclosure is not in contact with the surface to which it is fixed.

Enclosures shall have hinged access doors, fitted with recessed lockable handles. Doors shall be of rigid construction and provided with close-fitting flexible seals in recesses to prevent the ingress of liquids, moisture, dust and vermin. Hinges shall be of the lift-off pattern and one hinge shall engage before the other for ease of fitting. Wherever necessary, removable access covers secured by quick-release fasteners shall be provided to ensure ease of maintenance for all installed apparatus. Mounting plates, brackets and racks shall be provided for all other internal equipment which shall be hinged or otherwise arranged with quick-release fasteners or captive screws to give quick and easy access to equipment, securing screws, terminals and wiring.

Enclosures for two or more devices with electrical circuits shall have gland plates and terminal blocks as specified elsewhere.

Each enclosure shall be designed for the safe testing and servicing of equipment with the power on. Each part which may be live under any circumstances shall be so covered or shielded as to prevent inadvertent contact.

G2.2 Panel design and construction

Unless otherwise specified, all instrument panels, instrument cubicles, control panels, control consoles and desks, associated equipment and terminal racks, telemetry and electronic equipment racks and the like shall be free-standing, floor-mounted units and shall conform to the requirements of this part and will hereafter be referred to as panels.

The design and dimensions of control consoles and desks shall be determined according to their intended function but shall be in accordance with the requirements of the Specification drawings. The height shall not exceed 1400mm above the finished floor level.

Unless otherwise specified or shown in the Specification drawings, the height of panels shall be not greater than 2130mm overall (excluding lifting devices) above finished floor level.

Front-of-panel instruments and controls shall be mounted so that the height of their centres above the floor shall be generally between 1800mm and 900mm for indicators, 1400mm and 900mm for recorders and process controllers, 2000mm and 750mm for alarm facias and signal lamps and 1500mm and 750mm for manual controls. Controls, switches and push-buttons shall be positioned below or adjacent to any associated reading instrument. Panels for use in locations such as pumping stations and machinery rooms shall have anti-vibration mountings.

The clearance between the extremities of apparatus mounted on the internal walls shall allow safe and unobstructed access to all terminals and to parts requiring maintenance.

Panel layout drawings shall normally include a list of all instruments, accessories and components contained therein. If the drawings have insufficient space for the list, a separate schedule of instruments, accessories and components shall be provided and the panel drawing shall contain a cross reference to the contents list and an indication of the panel location of each item on the list.

G2.3 Panels — major

Panels shall be constructed generally as specified in the preceding clause and as shown in the Specification drawings. Panel material shall be prime-quality, cold-rolled and annealed mild steel or zinc-coated mild steel sheet, suitably braced and stiffened as necessary with flat bar or angle to form a rigid structure.

Panel fronts shall be flat and free from bow or ripple. Exterior corners and edges shall be rounded or welded and ground to give a smooth overall appearance. Flanged edges shall be straight and smooth.

Materials shall be chosen with due regard to the panel size, number of cut-outs, instrument weight and position of centre of gravity and method of fabrication, with the following minimum thicknesses except where otherwise shown in the Specification drawings.

- instrument bearing surfaces, gland plates and pneumatic distribution plates: 3mm;
- internal mounting plates: 3mm;
- doors, covers and filler panels: 2mm.

No design involving the use of externally-visible assembly or fixing bolts and screws nor any design resulting in dust or water-collecting crevices will be accepted.

Stiffeners and supporting frameworks shall be provided where necessary inside panels. Framework shall be hinged or fixed, suitable for the installation of instruments, components and internal equipment for which it is provided and located to give easy access to adjacent equipment.

When a panel is constructed in sections, the sections shall be designed for ease of assembly during installation and, in any case, shall not exceed 2m in length. All necessary nuts, bolts, washers and the like shall be supplied and included in the same shipment as the relevant sections. Sections exceeding 1m in length shall be provided with double doors.

Unless otherwise shown in the Specification drawings, each panel shall be mounted on a self-draining base frame fabricated from 150mm deep, steel channel section which shall be drilled or provided with clamps for bolting to the floor. The base frame shall be set back from the panel front face to give a toe space of not less than 25mm. The outside of the base frame shall be covered with an approved kicking strip.

Ceiling and other filler panels shall be fabricated from sheet steel and adequately stiffened. Each section shall have 50mm returned edges along all four sides and shall be braced to the main steelwork of the panel.

A chequer-plate floor shall be provided inside and above the level of the base frame, having openings suitable for the bottom entry of cables when applicable. Sufficient removable undrilled gland plates, in sections convenient for handling, shall be fitted close to the appropriate terminal blocks and not less than 230mm above the panel floor or not less than 230mm below the panel top. The gland plates shall have removable side covers giving access to both sides of the gland plate and ensuring vermin-proof and dust-proof construction. Gland plates of a surface-mounted enclosure may form a part of the base or top.

Panels containing pneumatic or other instruments using a fluid as the transmission medium shall have distribution plates with bulkhead unions for the termination of internal and external pipework.

All doors shall open outwards and all doors in one panel assembly shall use the same lock and key combination.

Panel design shall ensure adequate ventilation and air circulation without permitting the entry of vermin or dust. Panels installed in control rooms or other clean condition areas shall have louvres to allow air circulation. Temporary closures shall be provided to prevent the entry of dust and vermin during transit and installation. After commissioning has been completed, all entries except air-circulation louvres shall be sealed.

No equipment other than front-of-panel items shall be mounted on panel wall surfaces.

If electrical and non-electrical instruments are mounted in the same panel, the panel shall be subdivided internally to separate the electrical and non-electrical sections. All connections shall be arranged to ensure that no accidental damage to cabling or electrical components can occur in the event of failure of any non-electrical component or connection.

Provision shall be made for safe and easy handling during transit and installation. If lifting eyes are provided, they shall be reversible and panel tops shall be reinforced where necessary.

Where equipment is specified to be installed at a future date, space shall be allocated, and cut-outs with removable masking plates, brackets, supports, wiring, terminals and piping and the like shall be provided.

Panels shall be finish-coated at the place of manufacture before commencing the installation of apparatus and other fittings.

G2.4 Panels — minor

Panels for installation on the Plant which contain relatively few items of equipment, or where so specified elsewhere, shall be classed as minor panels and shall be constructed generally as specified in the preceding clause and comply with this Clause.

Panels shall be fabricated from sheet steel or other approved material less than 2.5mm thick suitably braced to form a robust and rigid structure. Exterior corners and edges shall be rounded to give a smooth overall appearance and assembly bolts, screws or rivets shall not be visible on the front face.

The design shall be such as to ensure adequate ventilation and air circulation where required, without permitting the entry of vermin. Openings for cables shall be made vermin-proof. Doors shall be hinged and shall be provided with close-fitting flexible seals in recesses to prevent the ingress of liquids, moisture, dust and vermin. Unless otherwise specified, panels shall be suitable for floor mounting and shall not exceed 2000mm in height. Where surface-mounted panels are provided, the fixing shall prevent the ingress of moisture and the rear of the enclosure shall be not less than 10mm from the wall.

Lifting eyebolts shall be removed, issued to the Purchaser and subsequently replaced with bolts after installation.

Panels shall be extensible, and symmetrically arranged as far as possible with projections kept to a minimum. Where two or more panels are fitted together, they shall form a flush-fronted continuous panel of uniform height. Front door and top cover dimensions shall match. Instruments, relays, and control devices shall be mounted at a height not more than 2000mm and not less than 300mm from floor level.

The arrangement of equipment within each enclosure shall be such as to permit easy access for installation and maintenance. No instruments, relays or other components shall be mounted on rear access doors or removable covers.

G2.5 Panels — composite

In situations where space limitations preclude the use of separate instrumentation, control and automation (ICA) and switchgear panels and, at the sole discretion of the Engineer, ICA equipment may be combined within a single enclosure subject to the following conditions:

- the observance of all other clauses herein relating to enclosures, mounting boards and minor panels;
- the written assurance of each supplier of ICA equipment that the proximity of the switchgear will have no detrimental effect on the life or performance of any ICA component;
- the total segregation of ICA equipment and switchgear including the glanding and termination facilities;
- the absence of any voltage exceeding 250V ac or 50V dc from any compartment containing ICA equipment;
- the use of the full height of the panel (excluding the busbar chamber and cable space) for any ICA equipment compartment.

G2.6 Panels — glass reinforced plastic (GRP)

Any panel required to be installed outside buildings shall, unless otherwise approved by the Engineer, be manufactured from double-skin, resin-bonded fibreglass, with a totally-encapsulated infill of rigid weatherproof and 'boilproof' plywood to BS 1203:2001 between the two skins to provide a rigid and vandal-proof enclosure. The environmental rating shall be IP 56 or better.

For any application in a non-temperate climate or where so specified elsewhere, the roof section shall be sloping and have a totally-encapsulated infill of end-grain balsa instead of plywood.

Box-section steel shall be encapsulated into door edges and door frames. Door locks, handles and hinges shall be of a high tensile strength, non-corroding alloy with stainless steel pins and through fixing bolts. Large plane surfaces shall have adequate reinforcing to ensure rigidity.

The doors shall be complete with latching handles and locks. All door catches and locks shall latch onto steel-reinforced surfaces.

Threaded studs shall be incorporated into the design of the panel for the mounting of sub-frames within the panel. Any panel drilled to provide fixings for internal equipment will not be accepted.

Each cubicle shall be provided with a floor or deck with a removable gland plate for cable entry.

The laminate material shall have flame-retardant characteristics in compliance with BS 476 Class 2, and shall retain 'stability, integrity and insulation' for 30 minutes.

Colour-impregnated gel coats backed by coloured resin shall be used to ensure maintenance-free and 'colour-fast' finishes. The external finish colour shall be advised by the Engineer and the internal finish colour shall be white.

The fronts of externally-visible instruments and windows shall be of glass. An air-gap of 100mm shall be provided between the top surface of the panel and its protective canopy.

All internal equipment shall be mounted on supports built into the fibreglass structure. Fixing bolts through the skin will not be accepted.

G2.7 Panel protection

Adequate facilities for isolation and protection by miniature circuit breaker or fuse for each instrumentation and control circuit and sub-circuit shall be provided and shall be so arranged that any interruption causes minimum disruption of plant, operates the appropriate alarm and cannot result in any unsafe operating condition.

All fuses shall be of the cartridge pattern and main fuses shall be of the high rupturing capacity type. Fuse and solid-link carriers and bases shall be of plastic-moulded insulating material of an approved make. Ceramic materials will not be accepted. Live connections shall be efficiently shrouded and it shall be possible to change fuses with power on without danger of contact with live metal. The fuses shall be rated to give maximum protection to the equipment in circuit and the rating shall be permanently inscribed on the fuse label and on the fuse carrier. Unless necessary for the protection of particular equipment, miniature circuit breakers used for individual circuits in a panel or control desk shall not trip on over-voltage or under-voltage.

Bases for solid links shall not be interchangeable with those for fuses. Fuses and links in the same circuit shall be mounted opposite each other in separate adjacent rows and shall not alternate in the same row. At least 10% and not less than two unallocated miniature circuit breakers or fuses and links shall be provided in each panel distribution board. Miniature circuit breakers and fuses of similar size and rating shall be of the same make and type.

At least 10%, and not less than two, spare fuses and links of each rating shall be provided and fitted in clips inside the panel.

Each instrument requiring a power supply shall be individually wired and protected so that, in the event of a failure in one circuit, the remainder are unaffected. Power supply circuits shall be of sufficient rating that any protective device may operate without reducing the voltage at the terminals of any other component to an unacceptable level. Remote alarms shall be operated on failure of the electrical supply to a panel or to any internal sub-circuit.
Clearly identifiable, switched socket outlets of 15A minimum rating to comply with IS 4615, supplied at the main cabinet operating voltages shall be fitted within the panel at the rate of one for each operating voltage per metre of panel length; for a panel whose length is less than one metre, one switched socket outlet for each main operating voltage shall be provided.

Suitable socket outlets for portable tools and handlamps shall be provided as specified elsewhere.

G2.8 Panel isolation

Clearly-labelled isolating circuit breakers shall be provided for each incoming power supply. Switches shall be of the quick make-and-break type with spring-loaded contacts that close fully without requiring full operation of the handle. The handle and cover shall be interlocked so that the handle cannot be operated when the cover is open and the cover cannot be opened unless the switch is in the 'off' position. The 'on' and 'off' positions of each switch shall be indicated clearly.

Circuit breakers for panel power supplies shall be mounted near an access point and in positions where they may be operated easily from a standing position.

Plug-in isolating links or devices of an approved type shall be provided in any circuit that may still be live when the power supply isolators are in the 'off' position, as, for example, in circuits controlling equipment whose power supply is independent of the panel. Such links or devices shall be properly screened and, if not incorporated in or adjacent to their associated outgoing terminals, shall be labelled with suitable warning notices.

Any item of panel equipment to which panel internal wiring is connected with a plug and socket instead of terminals shall be wired in flexible cable of adequate rating between the 'free' plug and a socket mounted adjacent to the device.

The power supply connector shall be a socket.

G2.9 Panel terminal blocks

External wiring for panel power supplies shall be terminated on the appropriate isolator. Signal cables from strain gauges, analysers, resistance thermometers, re-transmitting slide-wires and thermocouples may be terminated at their appropriate instruments.

A terminal block shall be provided as the interface between the corresponding conductors of each internal and external wire and each internal and external connection except those listed above. The terminal blocks shall be mounted vertically where possible and not nearer than 230mm to the floor or less than 230mm from an incoming cable gland.

Terminal block rows shall be spaced apart by not less than 150mm and arranged to permit convenient access to wires and terminals and to enable ferrule numbers to be read without difficulty.

Other circuits shall be grouped on the terminal blocks according to the classification given in the clause for ‘Panel internal wiring’ which shall be clearly marked along the corresponding section of each terminal board. Groups of different voltages on the same board shall be separated by insulated barriers.

All connections shall be made from the front of terminal blocks and no live metal shall be exposed at the back. All terminal blocks shall be of the type which clamps the wire securely and without damage between two plates by means of a captive screw and which permits removal of any terminal without disturbance to adjacent terminals. Pinch-screw type terminal blocks will not be accepted. Terminal mouldings shall be in melamine to ISO 2112:1990, polyamide or equivalent. Terminal rails shall be hot-dip galvanised. Current bars between the two connection points of each terminal block shall be of copper or brass with tin/lead alloy plating. All steel parts shall be zinc-plated and passivated with a yellow chromate layer. Terminal blocks for input and output analogue signals and for circuits containing volt-free contacts internal or external to the cabinet shall be of the Klippon type SAKCor equivalentwhich permit the connection of a test milliammeter or continuity meter without disconnecting any wiring. Terminal blocks for power supplies for equipment external to the panel shall permit the isolation of the item of external equipment without affecting the operation of any other circuit within or outside the panel.

No more than one core of external cables, or one internal wire shall be connected to any terminal. If terminal blocks are used as common points for two or more circuits, individual terminals with the appropriate number of permanent cross-connections shall be provided. The lengths of exposed cable cores shall be sufficient to reach any terminal in the appropriate row or rows. The cores shall be formed into a neat loom and a separate loom shall be provided for each cable. Identification ferrules as specified in the clause for ‘Panel wiring identification and termination’ shall be fitted on each core of all external cables and on each internal wire.

The size of the terminals shall be appropriate to the size and rating of the cable cores which will be connected to them but shall not be smaller than Klippon type SAK2.5 or equivalent unless otherwise agreed with the Engineer.

Each row of terminal blocks shall contain at least 25% spare terminals over the number required for terminating all cores of external cables in that row. Unless otherwise specified or shown in the Specification drawings, each external cable shall contain at least 20% spare circuits, with a minimum of one spare circuit.

Terminal blocks shall be numbered consecutively in a sequence different from that used for identifying wiring. The terminal numbers, voltage grouping and terminal board layout shall correspond precisely with wiring diagrams so that quick and accurate identification of wiring can be made.

All the terminal boards shall be provided with covers of transparent insulating material that does not sustain combustion and shall be sectionalised where possible to give access to groups of terminals without uncovering all boards. Terminals which may be live when the panel is isolated from its main supplies shall be suitably labelled to minimise the risk of accidental contact.

G2.10 Panel internal wiring

Panel circuits shall be segregated into the following categories:-

Group 1: Power control and very-high-level signal wiring (above 50V):

1.1 ac power supplies;
1.2 dc power supplies;
1.3 ac current signals above 50mA (such as CT circuits);
1.4 ac voltage and control signals above 50V (such as PT circuits).

Group 2: High-level signal wiring (6V to 50V dc):

2.1 signals from conventional electronic transmitters and controllers (such as 4mA to 20mA);
2.2 circuits to alarm annunciators and other solid-state devices (excluding those in categories 2.1, 2.5, 3.1, 3.2 and 3.3);
2.3 digital signals;
2.4 emergency shut-down and tripping circuits;
2.5 on/off control circuits;
2.6 intrinsically safe circuits;
2.7 speech-frequency circuits.

Group 3: Low-level signal wiring (5V dc and below):

3.1 signals from thermocouples;
3.2 signals from resistance thermometers and re-transmitting slide-wires;
3.3 signals from analytical equipment and strain gauges.

For Group 3 wiring, internal connections to the instruments shall be made by one of the following methods:

(a) the twisted, screened conductors of the external cable shall be led direct to their appropriate instruments via ducting systems installed for this purpose during construction of the panel;
(b) the conductors of the external cables shall be terminated on terminals segregated from all other categories and the connections to the appropriate instruments shall be made using twisted pairs with individual screening installed for this purpose during construction of the panel.

Internal wiring for all circuits in Group 2 except those sharing a common connection shall be multi-stranded, twisted pair, 0.75mm² minimum copper conductor with HPDE or PVC-insulated cable of adequate grade and rating in accordance with BS 6004:2000. Wiring for circuits in other Groups or sharing a common connection shall be run in stranded, 1.0mm² minimum copper conductor with 250V grade, PVC-insulated cable of adequate grade and rating. Wiring sheath colours shall be black for ac circuits, and grey for dc circuits (excluding thermocouple circuits) and blue for Group 2.6 circuits. Circuits operating at 240Vac and 110V dc, shall also be physically segregated from each other and from other circuits. Access to wiring and components of circuits having voltages exceeding 240V shall not be possible unless and until the circuit has been isolated.

Separate ducts, trunking, cable looms, tray work and the like shall be provided within the panel for each category with at least 150mm between parallel paths of Group 1 and those of any other Group. Intrinsically-safe circuits and their terminals shall be segregated from other circuits and terminals.

All wiring shall be neatly and securely fixed by insulated cleats, bunched and secured by approved plastic strapping or run in approved insulated wiring trunking or non-corrodible flexible tubing. Not more than 75% of the capacity of trunking, ducts, looming, or tubing shall be used. Insulated earth wiring shall be so arranged that access to any equipment or connection point or the removal of any item of equipment is unimpeded. Wiring for future equipment shall be secured and terminated on terminal blocks. Lacing for wiring looms shall be of rot-proof cord or plastic strips. Inter-section wiring in multi-section cabinets shall be via a terminal block in each section.

G2.11 Panel wiring identification and termination

Identification ferrules shall be fitted at both ends of each wire. The numbers or letters used shall correspond with the appropriate wiring diagram. The ferrules shall be of plastic insulating material with permanent black characters on a colour-coded background for numbers and on a white background for letters, unaffected by oil or water. They shall be so arranged that they can be read logically from left to right when viewed normally.

The system of wire identification shall be such that wires in the same circuit on opposite sides of a terminal shall have the same reference, and this system shall be continued through all external cabling.

Terminal ferrules (spade, tongue, crimped connections) shall be provided on each conductor.

G2.12 Panel earthing

A continuous copper earth bar of not less than 25mm x 6mm cross section shall run the full length of each panel and shall be securely fixed and bonded electrically to the main frame. The cable gland-plates and the earth bar shall be provided with suitable brass terminals of not less than 6mm diameter for connecting the metal cladding or armouring of all incoming and outgoing cables to the station earthing system.

A second continuous copper earth bar of not less than 25mm x 6mm cross section, electrically isolated from the steelwork of the panel and metal cladding and armouring of cables, shall be provided for earthing the signal earth connection of each instrumentation and control device and the screen(s) of each instrument cable not earthed elsewhere to the station instrumentation earth plate. The earth bar shall have sufficient brass terminals as specified above for each instrumentation and control device and the screen of every shielded cable plus 25% spare terminals.

In multi-section panels, each earth bar shall be electrically bonded to the corresponding bars in the adjacent section(s).

Instrumentation and instrument cable screen earthing shall comply with BS 6739: 1986, Section 10, unless otherwise stated in this clause.

G2.13 Panel heating

Each panel shall have one or more thermostatically-controlled tubular or ribbed panel heaters to prevent condensation and assist ventilation and which shall be adequate for ambient temperatures down to 5°C. The heater rating shall not exceed 0.2W/mm and the surface temperature of any part which could be contacted accidentally shall not exceed 60°C. Heaters shall be so situated that no deterioration can be caused to any equipment or wiring in the panel. The heating circuits shall be switched and fused independently of the instrumentation

and control equipment and manually controlled by an enclosed switch mounted in an accessible position within the panel. Thermostats shall be mounted remote from the heaters and other sources of heat and shall be fully adjustable over a range of not less than 0°C to 50°C. Thermostats shall cut out each heater when the internal temperature of the panel exceeds a pre-setvalue; differential thermostats shall be used to maintain the panel internal temperature at a pre-set value above the external ambient temperature.

If the permanent power supply is not available at the time of installation of the panel and condensation is detected, a temporary power supply shall be connected to the panel of sufficient rating to operate the heaters.

G2.14 Panel lighting

Each panel shall be adequately illuminated internally, as evenly and as free from dazzle as possible, by fixed fluorescent lighting controlled from totally-enclosed light switches and by totally-enclosed door-operated switches positioned so as not to interfere with access. There shall also be one installed inspection lamp per three metres of panel length or part thereof with adequate flexible connection cable to reach any point in the panel. The control switch for an inspection lamp shall form part of the lamp assembly. Lighting circuits shall be fused independently of any instrumentation and control circuit and designed to allow lamps to be replaced safely and shall be fed from a distribution board and circuit breaker connected on the live side of the main panel ac supply circuit breaker.

G2.15 Panel ventilation

Each panel shall be provided with ventilation fans as required to ensure that equipment within the panel is maintained within manufacturer's recommendations, with due regard to the environment in which the panel will be mounted. Fans shall be controlled by a suitably-labelled enclosed switch mounted internally in an accessible position.

Fans shall be mounted with their axis horizontal and shall be arranged to draw clean air into the panel. Air entries shall have filters which can be renewed from outside the panel and shall be designed to prevent the entry of rain, spray, injurious fluids, sand or dust.

G2.16 Panel piping and tubing

Panels containing equipment using a supply of compressed air shall have a common air pressure-reducing station with duplicate pressure-reducing valves and filters. The pressure-reducing station shall also include isolating valves upstream and downstream of each filter/reducing-valve set, pressure-relief valve, pressure indicator and low-pressure alarm unit for the low-pressure header and a pressure indicator for the high-pressure pipework. The pressure-reducing station components shall be mounted in a clear space inside the panel, supported on a suitable framework between the lower horizontal row of instruments and the main low-pressure header.

All piping, fittings and valves downstream of the pressure-reducing station shall be of brass, copper or plastic. PTFE tape shall not be used downstream of the main filters.

The low-pressure header shall be brass and shall be near the panel floor with drain valves and tundishes piped to a drain. Branch air headers shall be of brass (15mm diameter minimum) and shall run vertically from the header to the instrument. The low pressure header and each branch shall have a 6mm minimum, non-ferrous shut-off valve for each instrument requiring
an air supply and a compression coupling for each air-purge connection. At least 10% spare connections for possible future instruments shall be provided in each panel section. Any header dismantled before shipment shall have brass unions or flanges at each panel-section junction.

Panel-mounted instruments shall be piped to bulkhead fittings on a gland plate during assembly at the manufacturer's works. Piping shall be colour-coded in accordance with Recommended Practice ISA–RP 7.2 issued by the Instrument Society of America and shall be segregated from wiring so that any leakage is harmless. Each panel-mounted pressure gauge shall have a stainless steel flush-mounted shut-off and fine-regulating valve mounted vertically below. A drip tray shall be provided below each row of gauges.

Exhaust and de-pressurising pipework shall be routed out of the panel.

G2.17 Panel labels

Labels shall be provided for every panel to describe the duty or otherwise identify the panel and its sections and every instrument, component and item of equipment mounted internally and externally. The Contractor shall submit drawings to show the general arrangement of all labels with their proposed inscription clearly identified. Wording shall be clear, concise and unambiguous and shall be subject to review by the Engineer before manufacture. Each label shall be permanently secured to the surface near the item to which it refers. Externally-fitted labels shall be of perspex or other approved transparent plastic, with letters and numbers rear-engraved and filled with black. The rear surface of each perspex label shall be finished with a coat of paint of the same colour as the panel external finish. Instrument duty labels fitted externally shall be below the item to which they refer. Embossed tape or similar adhesive labels will not be approved.

Laminated materials or rear-engraved and filled plastic shall be used for internally-fitted labels, which shall be white with engraved black letters.

Labels conforming with the requirements of the preceding paragraphs or other approved means shall be provided:

- to describe or identify circuits or circuit components;
- to identify dc polarity;
- to warn or remind about dangerous or potentially-dangerous circumstances;
- wherever elsewhere specified.

Unless otherwise specified, all engraving shall be in plain block letters, 4mm high. The minimum practicable number of different sizes shall be used.

Manufacturers' nameplates shall not be fitted on panel external surfaces.

G2.18 Panel finish

For control and instrument panels, desks and cubicles a hard, smooth, durable finish, free of blemishes, shall be provided. Before painting, all external welds and any rough areas shall be smoothed, and all surfaces shall be thoroughly cleaned and free from scale, contaminates, corrosion or grease. If rust-proof or Zintec steel has not been used in the construction, the panel shall be treated with a passivating agent such as phosphoric acid. All internal surfaces shall have a minimum of three coats of paint of which the first shall be an approved anti-rusting priming coat and the final coat shall be an opaque gloss white enamel.

All external surfaces shall have not less than five coats of paint of which the first shall be an approved etch-priming coat, and the second and third suitable undercoats, all of which shall be rubbed smooth when dry before application of the next coat. The undercoats shall be easily distinguished in shade or colour from the priming and finishing coats. The two final coats shall be of stove enamel paint, gloss or semi-matt finish, to a colour and finish to be advised by the Engineer. Stoving shall be carried out in accordance with the recommendation of the paint manufacturer. The overall dry film thickness (DFT) shall be between 85 and 120 microns.

Nuts, bolts, washers and other fixing devices which may have to be removed for transit or maintenance purposes shall be galvanised or otherwise finished to an approved standard.

A 500ml tin of matching touch-up paint shall be provided and packed with each panel.

The colour of glass reinforced plastic panels shall be to the approval of the Engineer.

G3.0 INSTRUMENTATION EQUIPMENT

G3.1 Components, equipment and system design

All equipment shall be designed for rapid fault-diagnosis and replacement of major sub-assemblies and components, which shall be mounted on printed-circuit boards or plug-in type bases with high-grade, non-ageing plugs and sockets with gold-plated contacts. Components on printed circuit boards shall be tropicalised and varnished. All transformers shall be double-wound with an earthed screen between primary and secondary windings. All transformers shall be vacuum-impregnated and all except power transformers shall be epoxy-resin encapsulated. Routine maintenance and repair shall, as far as possible, require neither highly-skilled personnel nor soldering and wire-wrapping techniques.

Integrated circuits shall be used and, except in protection and shut-down circuits, solid-state devices shall be used in preference to moving-armature relays and electro-mechanical timers. Relays shall be of the plug-in type and shall have polycarbonate covers. When used in tropical locations, the relays shall be hermetically sealed. The standards of reliability for moving armature relays and electro-mechanical timers shall not be less than specified in IEC 60947-4:1999 or equivalent for medium-voltage contactors of Class 3 mechanical endurance. Operating coils shall be vacuum impregnated or epoxy-resin encapsulated.

Electronic units shall be fully solid state and the selection and installation of components shall give the maximum life possible. Wire-wound resistors shall be on ceramic formers and embedded in fire-proof and damp-proof material.

Plant state indication systems shall be designed so that a failure of any component or circuit or power supply associated with the indication system cannot lead to the masking or inhibition of the indication of a potentially dangerous state.

Plant protection and control systems shall be designed so that their outputs are de-energised or neutralised whenever a failure occurs of any component or circuit or power supply associated with that protection or control circuit.

No single equipment fault shall prevent the correct operation of any protection or shut-down circuit whenever necessitated by a plant fault condition or control action.

Under emergency, failure or shut-down circumstances, each regulating device shall move to the appropriate safe condition or stay-put in accordance with the relevant part of the Specification.

G3.2 Instruments and ancillaries — general

All instruments, gauges and control equipment which perform similar duties shall be of uniform type and manufacture throughout the Works in order to facilitate maintenance and the stocking of spare parts.

All equipment shall be fully tropicalised and suitable for the worst environmental operating conditions. Panel-mounted instruments shall have damp-proof and dust-proof cases. Instruments mounted outside instrument panels shall have weatherproof and dust-proof cases. Instrument cases shall be of corrosion-resistant material or finish. Instrument screws (unless forming part of a magnetic circuit) shall be of brass or bronze. Access to terminal compartments of instruments mounted outside panels or other enclosures shall not expose any working part. Moving parts and contacts shall be adequately protected from the ingress of dust.

Unless otherwise specified, instruments shall be finished in the manufacturer's standard colour. Instrument dials shall be of such material that no peeling or discolouration will take place with age under tropical conditions.

Plant-mounted indicators and gauges shall be sized to give full legibility when viewed from a position with convenient and easy access or from the point at which any operation requiring observation of the gauge is performed. The minimum diameter for any gauge shall be 100mm except where forming part of standard instruments and accessories such as air-sets.

Dials and bezels shall be of bronze and internal components shall be of stainless steel, bronze or other corrosion-resistant material.

Unless otherwise specified, all functions shall be transmitted electrically and all analogue signal-transmission systems shall be in accordance with IEC 60381-1:1982 or equivalent and shall use a signal of 4mA to 20mA dc or communication protocol FieldBus, DeviceNet or equivalent using RS485 connection. Where possible, measuring systems shall be designed so that any necessary power supply is taken from the appropriate instrument panel.

Transmitting devices shall have integral indicators to monitor the output signal or connections suitable for use with a portable test meter, and shall be capable of meeting the performance requirements specified in the appropriate part of IEC 60770-1:1999 or equivalent.

Equipment mounted in enclosures shall be suitable for continuous operation at the maximum internal temperature possible in service, due account being taken of internally-generated heat and heat dissipated by other plant. All components shall be rated adequately and circuits shall be designed so that change of component characteristics within the manufacturers' tolerances shall not affect the performance of plant. All equipment shall be designed to operate without forced (or fan) cooling.

Equipment provided with anti-condensation heaters shall be capable of operating without damage if the heaters are left on continuously. Unless provided with unalterable factory configured ranges, measuring instruments shall have zero and span adjustment.

Instruments not mounted in panels shall be supplied complete with all brackets, stands, supporting steelwork and weatherproof enclosures (separate from the instrument cases) necessary for securing them in their working positions and affording complete protection at all times including periods of servicing, adjustment, calibration and maintenance. The installation arrangements for meters measuring conductivity, pH, dissolved oxygen, chlorine residual and ionic concentration shall include a sample bench and other facilities for operating portable test meters. Each installation shall incorporate a valve and pipework for obtaining a sample representative of the fluid at the position of the permanent meter, tundish and drain. If the measuring and sampling points are remote from each other, the test and sample facilities shall be provided at both points. Sample transport times shall be minimised by provision of a by-pass and drain with control and isolating valves and a local flowmeter to enable the correct sample flow to be adjusted.

G4.0 FLOW-MEASURING EQUIPMENT

G4.1 Differential-pressure flowmeters

Flowmeters of the differential-pressure type shall be designed and installed in compliance with BS 1042-1.4:1992 or equivalent. Primary devices shall be a stainless steel carrier-ring type orifice assembly with a stainless steel orifice plate or venturi tube which shall include two sets of gaskets, fixing bolts and isolating valves for each primary device. All materials shall be appropriate to the metered fluid and service conditions. Full details of the calculations and location of the differential-pressure flowmeter shall be supplied to the Engineer.

Orifice assemblies shall have identification tags showing the direction of flow, orifice diameter and position of drain hole.

Differential-pressure transmitters shall have over-range protection up to 1.5 times the maximum line pressure. They shall convert the differential pressure into an analogue electrical or pneumatic signal. They shall be adjacent to the primary element and shall be connected to the tappings via a five valve manifold with provision for connection of a portable instrument for calibration purposes.

Where the transmitted signal is to be linearised, a square root extraction device shall provide a 4-20 mA output signal proportional to flow of the same electrical range as the input signal.

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.

The Contractor shall arrange for calibration tests of primary elements to be carried out and shall provide certified records, in triplicate, of the test readings.

After installation the calibration of each flowmeter system shall be proved to the satisfaction of the Engineer by applying fixed measured differential pressures to the input of the converters

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G4.2 Electromagnetic flowmeters

G4.2.1 Construction

Flowmeters shall operate on the electromagnetic induction principle and shall consist of a measuring sensor and measuring transmitter complying with ISO 6817:1997. The flowmetering system shall provide pulse and analogue current outputs proportional to volume and rate of flow respectively.

Measuring sensors shall have a full bore stainless steel metering tube and non-conductive, abrasion-resistant lining to suit the fluid being metered. For potable water applications, the lining material shall be of an approved material. For other applications the lining material shall be suitable for the fluid being measured.

Measuring sensors shall be fitted with an anti-roll system to prevent damage during storage and shall be flanged to BS EN 1092:2002. The flanges shall be compatible with those specified for the associated pipework.

Measuring sensors shall have factory-sealed power and signal cables. Unless otherwise specified, the cable lengths shall be sufficient to permit termination external to the chamber, either at a junction box or at the measuring transmitter.

Measuring sensors installed within a chamber shall have a degree of protection IP68 and shall be suitable for indefinite submersion under a head of water equal to the chamber depth or 3 metres whichever is the greater.

Measuring sensors shall be installed on a steel cradle or concrete plinth with upstream and downstream straight pipe lengths not less than those recommended by the manufacturer. When fitted in lined non-metallic or internally-coated pipework, measuring sensors shall have an earthing electrode or corrosion-resistant earthing rings.

Measuring sensors shall be bonded by tinned copper braid links at each end to the adjacent pipework to ensure a good connection between the body and the metered liquid.

Measuring sensors installed in a cathodic protected pipeline shall have isolation and bonding in accordance with the recommendations of the manufacturer.

The measuring transmitter supply voltage shall be 230V 50Hz unless otherwise specified. The measuring transmitter shall provide a precise current input to the field winding of the measuring sensor and shall convert the resultant signal from the electrodes to analogue and pulse outputs in accordance with IEC 60381-1:1982. The signal processing facilities of the converter shall ensure that the output signals are unaffected by interfering voltages, stratified flow, changes in fluid electrical conductivity within the limit stated, non-homogeneity of the fluid and the presence of ferrous particles. The instrument zero shall be set at the manufacturer's premises and thereafter this zero shall be maintained automatically without interruption of flow or output signals. The zero and output signals shall be unaffected by partly-fouled electrodes.

The following measuring transmitter features shall be provided as a minimum; additional requirements may be stated elsewhere in the Specification:-

- Pulsed d.c. field excitation.
- Scaled pulse output for integration counter drive.
- Capability of bi-directional measurement with differing forward and reverse ranges and with local and remote indication of flow reversal.
- Contact operation at a programmable measured value.
- Integral display of flow and integrated quantity.
- Galvanic isolation between each output circuit and between the electrode circuit and output circuit.
- Output circuit isolation from earth within the instrument but suitable for earthing at any point in the external circuit.
- Key entry for basic parameters.
- Commissioning and re-scaling to require no special programming knowledge.
- Adjustable low flow cut-off.
- Self-diagnosis.
- Continuously adjustable velocity and flow range settings.
- Terminals accommodated in a compartment separate from electronic components.

▪ Outputs including:	analogue	-	4-20mA
	pulse	-	two programmable outputs
	alarms	-	two outputs programmable for high/low flow, polarity, forward/reverse, instrument fault, liquid sensing fault condition including partially empty pipe.

G4.2.2 Performance

The following performance shall be available as a minimum; superior standards shall be met where stated elsewhere in the Specification or where so required by the metering and/or control requirements.

Overall flow system accuracy for local and remote display (including pulse counter):-

True flow as % of full scale setting	Maximum error
50 to 100%	+/- 0.5 % of true value
10 to 50%	+/- 1.0 % of true value
5 to 10%	+/- 2.0 % of true value
Repeatability	Not exceeding □ □ □ 0.2 of true value

Measuring transmitters shall be interchangeable with those of any other electromagnetic flowmeter of the same design. Calibration checking shall require no auxiliary test meter or simulator.

Plant-mounted measuring transmitter enclosures shall have a degree of protection of not less than IP 65 to BS EN 60529:1992. Measuring transmitters installed within a panel located in a building may be of the rack-mounted type having a degree of protection not less than IP 20. Measuring transmitters shall not be located in flowmeter chambers or areas subject to flooding.

G4.2.3 Testing

Each detector head and converter shall be wet-tested and calibrated in the presence of the Engineer's Representative, with the velocity programmed to a value not exceeding that appropriate to the specified application in a permanent test rig having a valid Quality Assurance Certificate or Calibration Certificate issued by the National Standards or Calibration Authority of the country of origin of the flowmeter. If a certified test rig is not available in that country, the Contractor shall arrange for the tests and calibration to be performed on a certified test rig in United Kingdom or, subject to the Engineer's permission, in a third country. (Two inspection engineers from the Engineer's Representative will be arranged to witness the wet-test and the expense to incur for their transportation, accommodation and the like shall be deemed to be included in the Contract.)

G4.3 Variable-area flowmeters

Variable-area flowmeters shall have a float moving vertically in a tapered tube, the position of the float being proportional to the flow. The meter tube shall be provided with a scale calibrated for the specific fluid in volumetric flow units. The calibration conditions shall be engraved on the tube.

The flowmeter shall have glass or metallic tubes according to the particular application.

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 ‘O’ 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.

Glass metering tubes shall be of borosilicate glass and shall be adequately shielded with safety glass on the reading side and amply vented on sides, back and bottom.

Variable-area flowmeters shall be installed in locations free from vibration and with sufficient clearance for the removal of the float. If used in conjunction with a flow-regulating valve, the valve and meter shall be close together, with the valve downstream of the meter. There shall be a minimum of five diameters of straight pipework upstream of the meter. Pipework shall be supported, having regard to the weight of the meter. The outlet connection shall be at the top of the meter.

Variable area flowmeter shall be provided with adjustable volt-free contacts to detect low flow with an accuracy tolerance of better than $0.1m^3$/hr.

G4.4 Helix-type flowmeters

Flowmeters or water meters of the volumetric rotary-piston type shall be designed for long life, maintained accuracy at all flow rates, minimum wear and shall conform with the relevant parts of BS 5728-3:1997.

Each water meter shall be provided with body material suitable for the application and size of meter.

Water meters for domestic installations shall be provided with inlet and outlet connections threaded according to the nominal pipe size for the meter. Each meter shall be provided with a 7–digit counter, the least significant figure representing 1 litre increments unless otherwise agreed with the Engineer.

Provision for pulse output for remote reading of totalised flow shall be provided where specified.

For larger flows in supply and distribution systems, in-line helical-vane rotary type meters shall be provided.

The measuring mechanism shall comprise a magnetic drive between the measuring element and the sealed counter unit. Counter units shall provide a clearly legible seven-figure counter incorporating a centre sweep hand which enables precise readings to be taken. The meter body shall be cast in spheroidal graphite iron BS EN 1563:1997 with end flanges drilled to suit the piping installations.

Pulse output units with submersible connections shall be provided where specified for all meters installed in flowmeter chambers.

Accuracy of helix-type flowmeters shall be +/-2% of peak flow or better.

G5.0 LEVEL-MEASURING EQUIPMENT

G5.1 Float-operated level indicators

Float operated level indicator shall comprise a float actuated with a float operating on fixed guide wires. The float shall be connected by a stainless steel cableto an indicator unit which moves up and down a marker board fitted to the external wall of the tank as the product level falls and rises. Pulleys shall be of stainless steel construction.

The switch assemblies actuated by the moving indicator shall be used for fitting to the marker board to provide high or low alarms and control initiation.

Indicator scale shall be of aluminium, brass or cedar wood construction graduated in metric linear or volumetric units.

The range of the instrument shall be 0 up to 20m (or equivalent volumetric units) and the accuracy/repeatability shall be ±10mm.

G5.2 Float operated level transmitters

Float operated level transmitters shall comprise a float and counterweight or tension device. Floats and counterweights shall be of corrosion resistant material or shall be coated with epoxy resin.

The float shall be suspended by a stainless steel wire or perforated tape which shall operate the transmitter installed above the float stilling well or measuring chamber.

The transmitter shall provide a 4 to 20mA d.c. output signal proportional to the level measurement range and shall be housed in an enclosure protected to IP 65, BS EN 60529:1992.

The accuracy of the measuring system shall be as specified for the particular application.

G5.3 Ultrasonic level measuring system

Ultrasonic level measuring systems applied to open channel flow measurement or liquid level measurement shall comprise a sensor and control unit.

The sensor shall be suitable for flange or bracket mounting as required and have a minimum protection to BS EN 60529:1992, IP 66.

The accuracy of the sensor shall be ±1% or better.

The associated control unit shall be mounted in an enclosure with protection to BS EN 60529:1992, IP 65. It shall be programmable with an integral programming keyboard and include a digital display, 5 No adjustable relays for alarm, control and system fault and shall provide an isolated 4 to 20mA dc output signal.

For flow applications a totaliser pulse output shall be provided.

The design and application of ultrasonic level meters shall take into account the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size etc.

The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation.

If turbulence exists, shielding, stilling tubes or other measures shall be provided to avoid effects on the measurement.

G5.4 Conductivity type level detection system

The level detection system shall consist of one or more sensing electrodes and controller containing switching circuitry and control relay(s).

Electrode rods shall be stainless steel, or other material suitable for application. Materials used for electrode heads shall be non-corrodible.

For deep well application, borehole type electrodes shall be used. These shall be shrouded to prevent spurious operation and provided with a stainless steel cable in accordance with BS 6920. The cables shall be adequate supported in accordance with the manufacturers' recommendations.

A clear stilling tubeof not less than 75mm diameter adequately fixed shall be provided to smooth surface turbulence and protect the instruments from damage by the pumping plant installation and maintenance activities.

Controllers located within panels shall be of the chassis type and shall have a minimum degree of protection to BS EN 60529:1992 IP20, adjustable sensitivity and response time settings, facility for setting fail safe operation at high or low level, light emitting diode output relay operating indication and double pole voltage-free changeover type output contacts. The controller shall be supplied from the mains.

Controllers not mounted in panels shall be provided with surface mounting enclosures having a degree of protection to BS EN 60529:1992 IP54 for indoor location and IP65 for outdoor location.

G5.5 Pressure transducer type level and depth measuring systems

Pressure transducer level and depth measuring systems shall comprise a strain gauge or linear voltage displacement transformer (LVDT) type transducer and a signal conditioning or power supply transmitter. Signal conditioning and power supply units if externally mounted shall have a degree of protection not less than IP56 or better to BS EN 60529:1992.

Where transducers are located in an area susceptible to lighting strikes, LVTD type transducers shall be used.

Transducer housings shall be of the all-welded Grade 316 stainless steel or equivalent and shall be hermetically sealed. Non-interacting zero and span adjustments shall be provided on each transmitter. The transducer measuring device shall be isolated from the process fluid by a non-corrosive barrier diaphragm.

The transmitter shall produce a 4 to 20mA signal proportional to level or depth.

For hazardous area installation a 4 to 20mA repeater power supply unit shall be provided giving a fully floating 17.5V supply to power the sensor and shall have a fully floating 4 to 20mA d.c.

repeater output. The repeater unit shall be certified to CENELEC standards. If mounted externally to a control panel, the appropriate protection shall be provided.

The mean time between failure for measuring systems shall be not less than 15 years.

The performance of the measuring system shall be as given below or better:-

▪	Accuracy	±0.25% of calibrated span.
▪	Repeatability	±0.1% at maximum span.
▪	Stability	±0.1% of span over 6 month period.
▪	Over pressure	Sustain a 200% over pressure without damage.
▪	RF1/EM1	Less than 1% of span with 500 MHz at 5 Watts direct contact.
▪	Power supply variation	0.01% per volt variation.
▪	Load variation effect	±0.0002% per Ohm of loop resistance variation.
▪	Temperature	-29^{o}C to +82^{o}C; total thermal error of □ 0.75% of span over 0^{o}C to 50^{o}C.

Hydrostatic type pressure transducers shall be suspended by a polyurethane vented and screened cable which has been factory sealed to the transducer to provide a waterproof assembly to IP68. The transducer shall be designed for immersion in water a minimum depth of 10m below its maximum installed level or depth.

A clear stilling tube of not less than 75mm diameter shall be provided to smooth surface turbulence to avoid affects on measurement.

Transmitters shall be either integral to the transducer or shall be located in an accessible position in the immediate vicinity of the transducer. The transmitter shall be mounted in a housing compatible with the location.

At the point of entry to the structure the transducer cable shall be adequately supported to prevent slippage. The cable entry opening shall be sealed.

G5.6 Hydro-static level transmitters

Hydro-static level transmitters shall be flange-mounted on the vessel and shall comprise a diaphragm operated sensor and an electronics module. The materials of construction shall be compatible with the fluid with which they are in contact.

The output of the transmitter shall generally be 4-20 mA d.c. proportional to liquid level. Where the transmitter is fitted to a horizontal cylindrical storage tank for contents measurement, a converter shall be incorporated in the measurement loop to give a linear output proportional to contents.

The electronics module with all adjustments and terminations shall be enclosed in a housing with degree of protection of IP 54 for indoor installation, IP 65 for outdoor installation or IP 68 for locations liable to flooding..

The transmitter accuracy shall be ±0.5% fsd or better.

G5.7 Sight glass level indicators

Sight glass level indicators shall be provided with a protective housing, borosilicate glass tube and isolating valves.

The gauge shall be suitably calibrated in volumetric S.I. units unless otherwise specified that level units are required.

Where necessary, the gauge shall be provided with flushing and drain points with valves and hose connections.

G5.8 Buoyancy level switches

Level switches of the buoyancy type shall consist of a mercury switch with changeover action enclosed in a non-corrodible material. A balance weight shall also be incorporated in the switch to counteract the buoyancy effects for the specific gravity of the particular fluid. The connecting cable shall be sealed into the switch.

Buoyancy switches shall be installed with a minimum of two meters of spare connecting cable neatly coiled at a supporting bracket which shall be fitted as shown in the Specification drawings or in a manner as approved by the Engineer. The connecting cable fixing shall facilitate any alteration in operating level within the limit of the spare cable referred to above.

G6.0 PRESSURE-MEASURING EQUIPMENT

G6.1 Pressure gauges and transmitters

Pressure gauges shall comply with BS EN 837-1:1998. Pressure gauges and transmitters shall have over range protection up to 1.5 times the maximum line pressure and shall be capable of withstanding full line pressure on any side with the other side vented to atmosphere without damage or effect on the calibration. No plastic material shall be used in their construction. Internal parts shall be of stainless steel, bronze or approved corrosion-resistant material.

Where necessary, a special diaphragm shall be used to segregate the gauge tube from corrosive fluid media. In ammonia applications, the diaphragm shall be in stainless steel. In chlorine applications, the diaphragm shall be in silver or tantalum. In sulphur dioxide applications, the diaphragm shall be in tantalum.

The minimum diameter for any pressure gauge shall be 150 mm unless specified otherwise or where the gauge forms part of a standard item of equipment.

Where compensation of more than 2% of the instrument span is needed for the difference in level between the instrument and the tapping point, the reading shall be suitably adjusted and the amount of compensation shall be marked on the dial.

The zero and span of a pressure transmitter shall not change by more than ±0.1% of the span per ^{0}C change in ambient temperature. After application for 10 minutes of pressure at 130% of maximum pressure, the change in zero and span shall not exceed ±0.1% of the span.

Pressure transmitters shall have an accuracy typically better than ±0.25% of span, depending on the application and shall be protected to BS EN 60529:1992, IP 65 standard or higher. For transmitters installed in locations liable to flooding or underwater applications, they shall be to IP 68 standard and shall operate up a to maximum submergence of 20 metres of water.

Pressure transmitters shall provide a 4 to 20mA d.c. output proportional to the pressure range.

G6.2 Pressure switches

Pressure switches shall be of the electronic type with either acermanic sensor for low pressures and thin film senor for pressures above 16 bar. Pressure switches and differential pressure switches shall have contacts with differing `cut-in' and `cut-out' pressure values. The nominal pressure values at which pressure and 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 or LED digital display. Pressure switches shall have over range protection.

Pressure switches shall be housed in cast bronze or aluminium alloy enclosures. The degree of protection to BS EN 60529:1992 shall be IP 54 for indoor installation, IP 65 for outdoor installation or IP 68 for locations liable to flooding with a maximum submergence of 20 metres.

G7.0 CHEMICAL-MEASURING EQUIPMENT

G7.1 Temperature meters

Unless otherwise specified, platinum resistance elements shall be used for measuring spans of up to 200°C and chromel-alumel thermocouples for spans exceeding 200°C.

Each temperature sensor, unless otherwise specified, shall have a stainless steel thermowell, or pocket-and-extension assembly, non-corrodible metal sheath and waterproof terminal head. Pockets for steam, oil and pressurised-water lines shall be welded; pockets for other duties shall be screwed.

The sensor assembly shall be designed to permit removal of the temperature element without twisting the leads.

G7.2 Platinum resistance thermometers

Platinum resistance thermometers shall comply with BS 1041 Parts 2 and 3 and BS EN 60751:1996. Sensors shall have a resistance of 100 ohms at 0°C and shall conform to the European standard curve (DIN 43720), where Alpha = 0.00385. Each element shall be artificially aged during manufacture. Terminal heads and amplifiers shall be designed for four-wire connections between head and amplifier.

Platinum resistance elements shall be spring-loaded and fully encapsulated in ceramic material and the elements and high-temperature-resistant lead wires shall be hermetically sealed. The associated resistance-to-current converters shall have zero and span adjustments and input-output circuit isolation.

G7.3 Thermocouples

Thermocouples shall be of the mineral-insulated type and unless otherwise specified shall be of the chromel-alumel (nickel-chromium v nickel-aluminium) type and shall comply with BS 1041-4:1992 and BS EN 60584-2:1993. Thermocouple junctions shall be welded. Ceramic-insulation material may be used for base-metal thermocouples but low-silicon insulation material shall be used for noble-metal thermocouples. Thermocouple systems shall have thermoelectric ice point reference chambers or receivers or amplifiers with automatic cold junction compensation.

Thermocouple receivers and amplifiers shall also have zero and span adjustment, common and series mode interference rejection circuits, radio-frequency filters, input-output circuit isolation and thermocouple break feature whereby the output is driven to zero or full-scale, as stipulated by the Engineer, when the receiver or amplifier input circuit is broken.

Thermocouple elements shall be electrically isolated from their sheaths but each terminal head shall have facilities for earthing the thermocouple and for terminating the screen of the extension or compensation cable. Amplifier chassis shall have facilities both for being earthed to the instrument case via a capacitor and for being electrically isolated from the instrument case.

G7.4 Temperature switches

Temperature switches shall have contacts with differing 'cut-in' and 'cut-out' values. Their nominal operating points shall be fully adjustable over the whole range of the instrument and the set-value shall be clearly indicated by a dial and pointer.

G7.5 Analysis systems

Instrumentation for the measurement of electro-chemical or water-quality parameters shall be classified as analysis systems and shall be subject to the general requirements below.

Where more than one parameter is being measured and where practical, analysis systems shall be mounted and piped on a backplate which forms part of a rack on which shall also be mounted all accessories such as isolating and flow-control valves, flow and pressure indicators, tundishes and the like. All components, materials and fittings used in the construction of the rack shall be suited to the particular environment.

Each throttling valve shall be downstream of the sensor with which it is used.

Pipework materials and configuration shall be as specified under 'Plant instrument piping', and 'U' sections shall be incorporated to ensure that measuring cells remain full. The rack shall be assembled and tested in the factory. All pipework shall be neatly run and rigidly fastened to the rack with clips. Tundishes shall be incorporated to collect used samples and surplus liquid shall be provided and connected at Site to appropriate approved disposal points. Facilities for taking hand samples and for the checking and servicing of each analyser shall be provided.
Any associated transmitter, signal amplifier, marshalling box, distribution board isolator and the like shall also be mounted on the rack.

Sample lines shall be as short as possible and the flow rate shall be such as to avoid undue sample transport delays. Sharp bends, changes in cross-section and other features which could lead to the accumulation of debris shall be avoided. Line routing shall avoid sources of light and heat which could encourage biological activity. Where appropriate, bypasses shall be provided around measuring cells to maintain an acceptable sample velocity.

Where possible, any analyser rack shall be installed in a building; if this is not possible, the rack shall be contained in a weatherproof and vandal-proof cubicle whose size or canopy area shall also afford protection against climatic conditions to personnel and test equipment during normal usage and servicing.

Each analyser shall have an integral local indicator or a separate one mounted adjacent to the analyser. Each analyser shall have an RS 232 port as well as terminals for its isolated 4mA to 20mA dc analogue signal.

G7.6 Residual chlorine meters

Residual chlorine meters shall comprise measuring cells, transmitters and indicator units. These shall be arranged for continuous monitoring of the residual in samples delivered to measuring cells from selected locations.

The residual measuring cells shall be either located in floor-standing plastic/composite cabinets of modular construction or in wall mounted cabinets of the same construction. Each measuring unit shall include a bi-metallic cell generating a micro-ampere signal proportional to the residual chlorine in the sample passed through the cell. Where necessary, each unit shall incorporate the facility for addition of a buffer solution to minimise the effect of pH variations on cell output or to increase cell output at high pH. The sample flow-rate through the cell shall be adjustable by means of a spring and diaphragm regulator or similar device. The materials of construction and sealing shall be compatible with the sample fluid. Cells shall incorporate means of maintaining the electrodes free from fouling.

Each cell shall be capable of measuring both free available chlorine and total chlorine. Where required, a facility for addition of a buffer solution containing potassium iodide shall be installed.

Where reagents are used, they shall require replenishment not more frequently than once per 10 days. The reagent feed shall be stopped automatically in the event that sample flow is lost.

Unless otherwise specified, means shall be provided of detecting that sample flow is healthy and, where applicable, that a reagent supply is available. Volt-free contacts shall be provided for remote signalling of these conditions and/or alarm initiation.

The transmitter shall incorporate an integral indicator and produce a 4–20mA signal proportional to residual chlorine. The unit shall be housed in a surface mounting enclosure protected to IP 54. The fascia shall have indicator lights for high and low alarm conditions, alarm set-point adjustment, lamp-test facility and volt-free changeover contacts for re-transmission of high and low alarm conditions.

The overall accuracy of the residual chlorine meter shall be better than $\pm 0.04 \times$ M mg/l and the repeatability shall be better than $\pm 0.02 \times$ M mg/l where M is the maximum value of the selected meter range. Subject to replenishment of reagents, where applicable, the meter performance shall be maintained without manual intervention for a minimum period of 30 days.

G7.7 pH meters

Each pH-metering system shall comprise electrode assembly, pre-amplifier (if appropriate) and analyser transmitter.

The pH electrode assembly shall be of the same manufacture as the associated pre-amplifier and analyser and, unless otherwise specified, shall be of the flow-through type.

Electrode assemblies shall comprise a glass electrode, a calomel reference electrode and a resistance thermometer for temperature compensation in an immersion type housing.

The measuring electrode shall be of glass and shall be designed for resistance to breakage and low electrical resistance. The flow direction in flow-through electrode assemblies shall be such as to give a self-scouring action at the electrodes.

Electrode assemblies shall be easily detachable from their cells for buffering. Flow-through electrode mountings shall be designed to accommodate a beaker for containing buffer solutions and two such beakers shall be supplied with each flow-through electrode assembly.

The pre-amplifier shall, according to the particular application, be:

- integral with the electrode assembly; or
- in a separate enclosure mounted in the vicinity of the electrode assembly.

The pH analyser when mounted externally to a panel shall be housed in a watertight, GRP housing protected to IP 56 or better and shall be suitable for surface mounting. The analyser shall have an integral indicator and shall produce an isolated 4-20mA output which is linear to pH.

The analyser span shall be adjustable after installation and the range shall be easily varied to cover a minimum pH range of 2 to 12. Calibration adjustments shall be provided for each end of the measuring range.

The overall accuracy of the pH meter shall be better than ±0.1pH and the repeatability shall be better than ±0.05pH. This performance shall be maintained without manual intervention for a minimum period of 30 days. The response time shall not exceed 15 seconds.

Controls shall be provided on the front of the analyser or at the side of the panel-mounted pull-out module for:

- automatic/manual temperature compensation;
- calibration adjustment.

The analyser shall have a run/test switch, to isolate the input from the electrode assembly during fault-finding and adjustment. The switch shall have auxiliary contacts for external use where required.

Each analyser shall be provided with two sets of fully-adjustable relay contacts which may be set to operate anywhere in the range of the analyser.

Where specified, pH-metering systems shall incorporate equipment for automatic pH control in conjunction with equipment specified elsewhere.

G7.8 Conductivity meters

The conductivity measurement system shall comprise conductivity cell, conductivity indicator, interconnecting cable, etc.

Conductivity cells shall be of the same manufacturer as the associated indicator and shall be of the insertion type with facilities including gate valves and packing glands to permit their removal from a running plant, at full line-pressure without allowing an escape of liquid. The cable-entry fitting shall be waterproof.

The mounting positions for electrode cells shall ensure good circulation and that the measurement is representative of stream.

Conductivity transmitters shall have:

(a) a built-in check circuit which permits calibration checks at any time;
(b) automatic temperature compensation using a reference of 25°C;
(c) accuracy within one scale sub-division;
(d) response time from zero to full-scale in less than seven seconds;
(e) two SPDT micro-switches, independently adjustable over the full range.

G7.9 Turbidity meters

Turbidity meters shall be continuous flow, continuous reading, on-line instruments using the nephelometric principle of measurement. They shall utilize a single silicon photodiode to detect the level of light scattered by particles at 90° to the incident light beam which in turn converts it to an electrical signal for display.

The turbidity meter shall be provided with an auto-ranging digit display with automatic decimal point positioning to eliminate range-setting and reading errors. Two fully-adjustable volt-free turbidity alarm contacts and instrument failure alarm contacts shall be provided.

A 4mA to 20mA dc output signal programmed to cover any part of the instrument range shall be provided.

Each instrument shall be provided with an integral bubble trap.

Means shall be provided for the checking and adjusting of the instrument calibration which does not require the use of standard solutions and reduces the maintenance of the measuring cell to a minimum.

Enclosures for the turbidimeter and control unit for indoor use shall provide a degree of protection against dust, falling dirt and dripping non-corrosive liquids (NEMA–12) or an equivalent approved by the Engineer.

The overall accuracy shall be better than ±5% of reading or 0.25 NTU whichever is greater and the repeatability shall be better than ±2.5% of reading or ±0.1 NTU whichever is greater. The instrument performance shall be maintained without manual intervention for a minimum period of 30 days.

G7.10 Aluminium, iron and manganese monitors

Analytical instruments for the determination of dissolved and total aluminium, iron and manganese shall use colorimetric methods giving output signals and local indications representing concentrations in milligrams per litre. For total measurements, acid at a minimum temperature of 90°C shall be added automatically prior to measurement.

Meters shall be of the continuously-operating type with measurements from any sample point at intervals of not more than 10 minutes. The instrument accuracy shall be ±0.1mg/l or better and the repeatability shall be better than ±1% of span.

Automatic re-calibration shall be provided with the interval adjustable. Automatic cleaning shall prevent fouling of the optical surfaces. Volt-free contacts shall be incorporated for remote indication of high concentration and instrument failure. The high concentration set-point shall be adjustable over the full range of the instrument.

Built-in storage facilities shall be provided for any reagent used. Reagents shall not require replenishment more frequently than once every ten days.

Meters shall respond to power failure and sample-flow failure and shall restart automatically when healthy conditions are restored.

G7.11 Chlorine leak detectors

Leak detection equipment shall comprise detector heads and remote mounted transmitters/ monitors.

The detector heads shall be of the bimetallic amperometric or solid state types designed for stability and minimum maintenance. The leak detection system shall operate on a continuous basis with a maximum response time to low level leaks of 5 seconds. They shall be wall-mounted and reasonably equidistant from potential sources of chlorine.

Each detector head shall be connected electrically to its associated transmitter/monitor. Multi-point "sniffer" type pumped sampling systems with a common detector head will not be acceptable.

The chlorine detector shall not respond to a leakage of any other gases.

The cells shall be suitable for operation in an indoor environment with a temperature maintained above freezing point (0^0C).

The monitoring units shall have wall mounting enclosures protected to at least IP 54 or shall be panel mounted. The units shall not be mounted in the gas hazard area. They shall incorporate solid state circuit cards of the plug-in type. The units shall have self-checking circuitry and detector failure alarm indication, the latter with provision for re-transmission. They shall be equipped with a back-up battery power supply to maintain unit operation for a minimum period of four hours in the event of mains power failure. In normal operation, the batteries shall be trickle-charged.

The detection systems shall not be susceptible to radio frequency interference.

Leakage alarms shall be adjustable from 5% to 100% of the instrument range to facilitate setting of the following trip levels:

Chlorine	- low level 0.5 ml/m^3
	- high level 1.0 ml/m^3

The monitors shall have indicator lights for both alarm levels and at least two sets of volt-free changeover contacts for re-transmission of the alarms to:-

- Ventilation system controls (inhibit action) and external warning lamp;
- Remote monitoring system.

Local alarm indication and contact position shall be maintained until an alarm reset button is activated at the monitor.

The monitors shall incorporate a test button to facilitate the checking of satisfactory operation of the electronic circuits and alarms. Any consumable items that may be required for testing or re-calibration of the leak detection system shall be supplied in a sufficient quantity to last at least twelve months from take-over.

G8.0 RECORDING EQUIPMENT

G8.1 Chart recorders

Chart recorders shall be microprocessor-controlled or have auto-balancing potentiometric movements and conform with BS 90:1975 where applicable and shall be able to pass each test specified in BS EN 60873:1993 or equivalent standard.

Recording instruments shall have an accuracy of ±0.5% full-scale deflection or better. The operating temperature range shall be 0°C to 50°C.

The recorder shall be equipped with indicating scales and pointers for each measured variable. The pen and a reasonable length of chart shall be visible without opening the case.

Strip-chart recorders shall be electrically driven and have monthly or fanfold charts of not less than 100mm width which shall advance at a minimum of three selectable rates, including 20mm per hour.

Recorder inks and inking systems shall be suitable for use both in highly-humid conditions and in air-conditioning. Inks of differing colours shall be used for recording two or more quantities on the same chart.

Each recorder chassis shall be easily withdrawable from its housing for chart changing without interrupting its circuits.

Recorder scales and charts shall be in accordance with BS 1794:1952 and BS 3693:1992 or equivalent as applicable. Single-pen recorders used for more than one measurement shall have rotary-switch selectors with plates engraved to show the identity of the selected measurement.

G8.2 Electrical indicators and integrators

Indicators for use with analogue signal-transmission systems shall comply with BS 89:1990 or equivalent and have an accuracy class index of 1.0. Indicator movements shall be critically damped (dead-beat). Indicators for use on more than one circuit shall have rotary switches to select the circuit, with engraved plates to show the circuit selected.

Indicators shall have circular scales or shall be of the vertical edgewise type and shall be designed to avoid parallax error. Scales shall be clearly marked in SI units and shall comply with BS 3693:1992 or equivalent. All instruments mounted on one panel or board, or in adjacent groupings, shall have similar styles of figures and letters. Dials shall be white with black scales and lettering not subject to fading.

The material for scales shall be such that no peeling or discolouration will take place with age under any environmental conditions.

Major scale marks and numerals shall be of the same size and thickness and shall be separated by not more than twenty-five minor marks. Pointers shall taper to the width of the scale marks.

Integrators shall be of the multi-digit cyclometer type. Integrators operating in conjunction with an electromagnetic or ultrasonic flowmeter shall use the pulse output from the flow transmitter. Any integrator operating from a device without a pulse output shall have an integral or separate current-to-pulse converter with sufficient adjustment of the pulse rate to avoid the use of any multiplying factor except in integer power of 10. Each integrator shall incorporate an adjustable limiter whereby any input below a pre-set value is inoperative. Unless otherwise specified, integrators shall have a minimum of eight digits with a decimal point where applicable.

G9.0 ALARMS AND PANEL EQUIPMENT

G9.1 Alarm systems

Alarms shall be initiated by the opening or closing of volt-free contacts which shall remain unchanged throughout the periods in which the alarm conditions exist. Alarm circuits shall be capable of conversion from open-healthy to open-alarm or vice versa by a simple modification after installation, which requires no additional parts or special equipment.

Each alarm shall initiate the operation of both visual and audible devices.

The sound intensity of each audible device shall be suitable for the maximum sound level of its environment.

Audible devices in the same room or area shall have distinguishable sounds and adjustable sound levels.

G9.2 Alarm annunciators

Each alarm shall initiate a visible and audible indication of the specified condition. Unless otherwise specified, alarm indicators shall be grouped together in annunciator units each having at least 20% spare ways. Alarm indicators shall be of similar design to indicator lamps and shall have screens engraved with legends as shown in the Specification drawings or subsequently approved by the Engineer. The legend area of each indication shall not exceed 40mm high and 75mm wide.

When any alarm condition occurs, an audible device common to an alarm annunciator system shall sound and the appropriate indicator shall flash on and off. The flashing rate shall not be less than 2Hz and shall not exceed 5Hz. On pressing an integral accept push-button, the audible device shall be silenced and the flashing light shall become steady. The alarm indicator shall remain illuminated until the alarm condition ceases and a reset push-button has been operated.

The operation or acceptance of one alarm shall not inhibit the operation of the audible device or the flashing of the appropriate alarm indicator if a further alarm condition occurs. At un-manned locations, alarms operated on two or more annunciators shall require acceptance at each annunciator. Alarms shall be accepted automatically and the appropriate audible device silenced after an adjustable period of 1 to 5 minutes.

Where specified or shown in the Specification drawings, each alarm indicator shall show, by a change in colour or otherwise, the first alarm to operate in a sequence of near-simultaneous occurrences and this state shall revert to the unilluminated only after the condition has become normal and a ‘first-up-reset’ push-button has been operated.

An integral ‘test’ push-button shall be provided to illuminate each lamp in the appropriate group and to operate the audible device but shall not cause a spurious alarm condition on any other annunciator.
Alarm circuitry shall be arranged so that spurious or transient alarm states persisting for less than 0.5 seconds do not initiate any action.

Alarm annunciator/indicator legends or labels shall be arranged with three lines of text as follows:

▪ top line:	location;	Example:	RESERVOIR 1
▪ middle line:	parameter;		LEVEL
▪ bottom line:	status.		HIGH

G9.3 Push-buttons and indicator lights

Push-buttons in control circuits shall have shrouds, guards or other suitable means for preventing inadvertent operation.

Status-indicator lights shall be of the high-intensity LED type. Indicator lights shall be of a design which allows easy LED replacement from the front. Indicator lights shall be easily visible above the ambient light level when viewed from within an included angle of 120 degrees. LEDs shall be chosen to ensure clear discrimination between the energised and de-energised states and to ensure an average working life of not less than 3000 hours. A 'lamp-test' push-button shall be provided for each group of indicator lights.

The colours of push-buttons and indicator lights on instrument panels shall be as follows:

Duty	**Push-button**	**Signal lamp**
Start or on (energise)	Green	—
Stop or off (de-energise)	Red	—
Open valve	Black*	—
Close valve	Black*	—
Accept	Black	—
Lamp test	Black	—
Reset	Black	—
Motor running (energised)	—	Red
Motor stopped (de-energised)	—	Green
Valve open	—	Red
Valve closed	—	Green
Urgent alarm	—	Red
Non-urgent alarm	—	Yellow
Plant healthy or ready for use	—	White

* Panel-mounted push-buttons for valve operation shall be coloured black, unless otherwise agreed with the Engineer, with the duty clearly defined by legend on an associated label.

G9.4 Analogue signal transmission

Unless otherwise specified, analogue signal-transmission systems shall be in accordance with BS EN 60546-1:1993 and shall use a signal of 4mA to 20mA dc. Transmitting devices shall have integral indicators to monitor the output signal or connections suitable for use with a portable test meter. Transmitters shall be capable of meeting the performance requirements laid down in the appropriate part of IEC 60770-1:1999.

G9.5 Analogue process controllers

Analogue controllers shall use solid-state components and shall have outputs containing three terms with negligible interaction. The controller fascia shall have measured value, set value and output indication, manual set-value and output controls, auto/manual switch for control mode and remote-local transfer switch for set-value control. Manual control stations shall have measured-value and set-value indication, local/remote switch and control available lamp indicator.

Each controller shall have the means to restrict its output signal to a predetermined, fully adjustable band so that the regulating device is not moved to unsafe positions. The adjustment of these safe operating limits shall be by means of accessible, clearly marked, internal components. A continuously adjustable proportional band of not less than 5 to 500% shall be provided. Integral and derivative action times shall be adjustable over ranges which shall not be narrower than 6 seconds to 25 minutes and 0-to 10 minutes respectively. If the integral or derivative action times' adjustments are in steps, the ratio of successive steps shall not exceed 2. The controls used to set the P, I and D values may be at the front of the instrument or mounted internally in an accessible position.

Each controller shall be designed so that in the event of failure, it shall be possible to plug a portable manual station into the controller case and to control the regulating device manually.

Controller design shall ensure automatic procedure-less, bumpless transfer whenever the instrument is switched from "auto" to "manual" or vice versa.

Controller action shall be adjustable from direct to reverse and vice versa by the operation of an internal switch. Analogue process controllers shall be capable of meeting the performance requirements laid down in the appropriate part of BS EN 60546-1:1993.

G9.6 Programmable logic controllers

G9.6.1 General

A programmable logic controller (PLC) shall be any digitally-operating electronic apparatus which uses a programmable memory for the internal storage of instructions for performing particular operations (e.g., logic, sequencing, timing, counting, analogue and arithmetic). This apparatus shall control, via digital and/or analogue input/output modules, various items of plant or processes and provide inputs to other controllers and to associated data acquisition systems. A PLC shall comprise a central processor, input/output interfaces, logic memory, data storage memory and a programming device and shall have the necessary input and output facilities to provide correct interfacing with plant to achieve the specified system operation.

A PLC shall have immunity to mains-borne and radiated electrical interference. Input interfaces shall be optically isolated and digital integrated circuits shall use the latest hybrid semiconductor technology in keeping with industry standards.

The highest possible level of "user friendliness" shall make PLC programming, interrogation and operation simple and easy to understand.

A PLC shall have diagnostic routines to identify any component and circuit failure and to neutralise the effects of any such failure.

G9.6.2 Memory

PLC program and data memory shall be provided with a minimum of six months integral battery back-up.

A minimum of 20% spare programme memory and 20% spare data register memory shall be available when final commissioning is complete. In addition, the memory shall be expandable, using expansion modules, to provide a further increase in capacity of at least 50% for future use.

G9.6.3 Diagnostics

PLCs shall be provided with diagnostic capabilities to identify failures to the circuit board level. Diagnostic indication shall as a minimum, consist of notification of processor failure, input or output module failure, communications failure, and battery low. these conditions shall also be available as outputs from the outstation for panel indication. These diagnostics shall all be available as digital outputs for remote indication.

G9.6.4 Communications

PLCs shall be capable of connection and incorporation into a network of devices for data communication. The communication protocol shall include a state-of-the-art error detection scheme to ensure error-free data transmission and reception. The communication protocol shall include repeated attempts at error-free transmission before a network device (node) is declared as "failed".

Where dual redundant communication facilities have been specified, interface facilities shall be provided in all PLCs for connection to the dual redundant communication system. The communication system shall automatically take action such that a single interface failure does not render the PLC unable to communicate.

Communication failure at a network node shall not effect communications at any other node.

Software development facilities shall be provided for defining, modifying and monitoring the communication network.

PLCs shall contain sufficient communication ports such that a portable programming device may be connected and operated without disconnecting other wiring.

G9.6.5 Input/output

PLCs shall be fitted with input and output circuits to interface with field devices for data acquisition and control. Input and output circuits shall be arranged on plug-in modules to facilitate replacement. Plug-in input and output modules shall be fitted with connects which allow replacement of the module without disconnection of field interface wiring. All field inputs, both analogue and digital, shall be optically isolated.

Inputs and outputs for any particular set of duty/standby equipment shall be arranged over multiple I/O cards wherever possible such that a failure of a single I/O card does not prevent the operation or monitoring by the PLC of more than one device of the set.

When commissioning is complete, PLCs shall have a minimum of 20% spare inputs and outputs of each type (ie digital inputs, digital outputs, analogue inputs and analogue outputs).

Input and output capacity shall be expandable, using additional input and output modules, to give a minimum of a further 50% additional inputs and outputs of each type for future use.

The Contractor shall be responsible for considering each output load in detail to ensure that the loading capabilities of the PLC are adequate.

G9.6.6 Operator interface

All programming of a PLC shall be possible via integral or portable plug-in programming devices which shall be supplied with each instrument. The programming device shall also provide local manual control as well as the facility to interrogate the PLC for more detailed diagnostics than those previously mentioned.

The programmer keyboard shall have keys for controlling and editing functions and for entering arithmetic, timer, counter, basic and special instructions and numerical values. Programming shall be simple to understand and carry out. A key switch or other approved security facility shall be provided to restrict access to the program to authorised persons.

Complete software of the latest version and revision shall be provided, fully loaded and operational, on the portable programming device.

G9.6.7 Failure

Any control circuit output of a PLC shall be de-energised or neutralised whenever a failure of a circuit, component or power supply occurs in the input or output loop associated with the particular output. The equipment shall automatically detect failures of input circuits and output devices and take action to avoid any unsafe or operationally-undesirable condition.

G9.7 Signal-conditioning devices

Signal-conditioning devices shall include isolators, amplifiers, current-to-pulse and pulse-to-current converters, arithmetic modules, trip amplifiers and similar units.

Each device shall be designed for mounting within an enclosure using a mounting plate, rack or rail. The operating power supply shall be a nominal 110V ac or 24V dc. An indication of ‘power supply on’ shall be provided at the front of each unit.

Input and output circuits shall have impedances to suit the signal sources and loads with which they operate. Each analogue input and output circuit shall have independent zero and span adjustments. Set-points on the instrument front shall be fully adjustable by means of a knob with an engraved lid. Input, output and power circuits shall be mutually isolated up to 1000V rms and from earth.

The states of relays used in conjunction with digital inputs or outputs shall be indicated at the front of the unit. Analogue inputs or outputs shall be indicated on the front.

Each device shall be immune to normal industrial interference and RF up to 400MHz.

G10.0 MISCELLANEOUS EQUIPMENT

G10.1 Vibration monitoring

Permanently-installed vibration monitoring of pump units shall comply generally with the requirements of BS 4999-142:1987 for the monitoring of vibration or rotating machines.

Vibration transducers shall be of the piezoelectric accelerometer constant-current type.

Each transducer shall be supplied factory-calibrated, complete with a calibration curve showing the measured frequency response typically over the range 5kHz to 20kHz.

The transducer shall be housed in a stainless-steel housing sealed to IP 67 minimum complete with the measuring cell and pre-amplifier device. The transducer case shall be provided with a threaded stud for machine mounting. The stud shall be part of the case and shall be not less than M10. The mounting arrangements shall be uniform across the whole plant.

Transducer sensitivity shall be typically 100 mV/g at 80Hz and the transverse sensitivity of the device shall not exceed 5% of that in the measured direction. The minimum operating temperature range for vibration transducer shall be –25°C to +100°C.

Vibration monitors shall be mounted in a monitoring panel adjacent to the plant being measured. The monitors may be either backplate or rack-mounted units.

Each monitor shall be provided with the following:

- integral indication of vibration measurements (calibrated in acceleration of velocity as appropriate to the machine malfunction conditions);
- relay outputs for high and extra high vibration, with relay operation derived from the analogue vibration signal and settings adjustable over the full range of the instrument;
- time-delay settings adjustable between 3 and 30 seconds for each relay;
- analogue output of 4mA to 20mA representing the RMS value of the acceleration signal.

Accuracy of the monitor system shall not exceed ±5% of full scale.

G10.2 Hygrometers

Hygrometers shall comprise a probe assembly, amplifier-transmitter and indicator unit.

The probe assembly shall operate on the capacitance principle and shall be suitable for measurement of the moisture content of air or process gas as specified. The probe assembly shall be mounted in the gas sample pipework which shall be fitted with a pressure gauge or manometer. Process gas shall be discharged to an approved point.

The amplifier-transmitter and indicator unit shall be suitable for wall mounting or panel mounting as required. Wall-mounting units shall have enclosures with a degree of protection of IP54 to BS 5490.

The indicator shall be calibrated with an arbitrary 0–100 linear scale and a dew point scale engraved from –80 to –20°C unless otherwise specified. Two high-value alarm points shall be provided with indicator lights, alarm set point adjustment, lamp test button and voltage-free contacts for re-transmission of both conditions.
The transmitter shall produce a 4–20mA output signal proportional to the linear indicator scale.
The overall accuracy of the hygrometer shall be better than ±3°C and the repeatability shall be better than ±1.5°C.

G11.0 INSTALLATION OF INSTRUMENTATION

G11.1 Installation of instruments and sensing devices

Each instrument and sensing device shall be installed in accordance with the recommendations or instructions of the manufacturer for the particular application. Each mounting position shall be chosen to give correct operation of the equipment, faithful reproduction of the quantity to be measured, ease of operation, reading, maintenance and servicing, freedom from any condition which could have adverse effects and with particular regard to the safety of personnel and plant. Each item of plant shall be levelled and securely fixed to the surface, bracket or framework on which it is mounted.

Instruments to be installed in areas of high or low temperature or high humidity shall be provided with adequate protection from adverse effects.

G11.2 Instrument air supply

The instrument air supply shall comply with Standards ISA–S7.3 and ISA–S7.4 issued by the Instrument Society of America. The installation shall include inter alia:

- two identical electric motor drive oil-free air compressor sets complete with all associated equipment;
- at least two compressed-air receivers each complete with all accessories including gauge, drain valve, alarm and control pressure switches, isolating and check valves;
- at least two after-coolers, filters and pressure regulators.

The air supply shall be dry, clean, oil-free and of constant, uninterrupted pressure and of adequate quality to suit the service requirements.

Intake filters shall be protected against adverse conditions. All components shall be designed and installed to ensure the minimum by-passing.

Cooling water circuits for compressors and after-coolers shall have twin filters. Filters shall be readily accessible and shall be designed to prevent the passage of scale.

The system shall permit extension at a future date and shall include connections with air-tight, screw-down valves and air-tight blank flanges.

The systems shall be designed so that either compressor may be selected as the duty unit and the other compressor as the stand-by unit. Manual stop and start controls shall be provided for the duty compressor and thereafter the compressor shall be controlled automatically by the pressure-unloading valve associated with it to maintain the pressure in the air receivers within the limits necessary for the satisfactory operation of all associated plant.

The stand-by compressor shall start automatically and deliver air to the air receivers if the pressure in the air receiver falls to a pre-set value which shall be above the minimum value necessary for the satisfactory operation of all associated plant. The stand-by compressor delivery shall be controlled automatically by its own pressure-unloading valve. The system capacity shall be adequate for the maximum service demand including an allowance for the pressure drop in pipework and fittings, repeated operation of several heavy loads simultaneously and air leakage. Compressors shall be sized so that one compressor working alone is capable of supplying the maximum total quantity of air thus calculated plus a margin of 10%.

Air receivers shall be sized so that with one receiver out of service, system pressure fluctuations do not affect the efficient operation of the plant under any circumstances and ample air reserve is provided for changing compressors.

Air compressor sets shall be designed for continuous operation over long periods. They shall not require dismantling for maintenance at intervals of less than 24 months.

Each compressor shall be driven by an electric motor rated to provide not less than 5% power in excess of the maximum power absorbed by the compressor working at any possible operating condition. Each motor and compressor shall be mounted on a common baseplate. Coupling may be by vee-belts or other approved arrangement. Flange-mounted direct-coupled motors may be used but drives incorporating gears will not be accepted.

Each compressor delivery shall be controlled by an electrically-actuated pressure-unloading valve which shall be opened and closed automatically at pre-set, adjustable pressures. Each pressure-unloading valve shall have two sets of volt-free contacts for the remote indication of valve fully-open and fully-closed respectively. When a pressure-unloading valve is open, the compressor delivery shall be discharged to atmosphere through an efficiently-silenced outlet.

Each compressor intake shall have an efficient air filter and silencer which shall be sized to prevent excessive pressure drop.

Air intakes shall draw air from inside the compressor room. The Contractor shall provide two air filters for mounting in the outside wall of the compressor room, to filter the air drawn in to the compressor room. Filters for compressor and compressor-room air intakes shall be designed for easy cleaning, shall be readily accessible and shall not require cleaning in normal operation more frequently than once every 30 days.

Compressor starters shall be mounted on a panel in the compressor room.

Primary cooling water systems shall use fresh water. The primary circuit may be cooled by a heat exchanger using sea-water as the secondary coolant or by other approved means such as a radiator. Contractor shall provide all pipework, isolating valves, temperature control valve and fittings to connect the equipment to the fresh-water and seawater systems. The maximum seawater temperature at any point in the system shall not exceed 45°C. Easily visible indication of primary and secondary (if used) cooling-water flow shall be provided.

Each compressor shall be fitted with easily visible instruments to indicate jacket cooling-water exit temperature. For each measurement a safety control shall be provided which shall prevent further operation of the tripped machine until all conditions are normal and a manual reset push-button has been operated. Indications of compressor running and tripped shall be provided in the control room and/or as detailed hereafter.

Air receivers shall comply with BS 5169:1992 and shall include a corrosion allowance of at least 2mm. Fittings shall comply with BS 1123-1:1987.

Air receiver drain connections shall be fitted with readily-accessible screw-down valves near the receivers and shall be piped to the nearest suitable point of the drainage system. Each air receiver shall be thoroughly cleaned internally and externally by shot blasting. The interior shall then be painted with phosphoric zinc oxide paint.

Manholes shall be provided so that the interior of each vessel is readily accessible for maintenance. Each air receiver shall be provided with a pressure gauge and an additional readily-visible indication of receiver pressure shall be provided in the compressor room. Initiating contacts shall be provided for operating the compressor-unloading valves, to start the stand-by compressor and to indicate in the control room the occurrence of abnormal conditions.

The Contractor shall provide all necessary pipework, valves, drains, filters and fittings to form a complete system to supply clean dry compressed air to each pneumatic instrument. The pipework in the compressor house shall include connections from compressors to receivers which shall be so arranged that any compressor or receiver may be withdrawn from service with no interruption to the air supply.

Each compressor shall be able to charge either or both of the air receivers. Pipework shall be so sized that the maximum pressure drop anywhere in the system does not exceed 5% of the nominal system working pressure. Where practicable, air pipework shall be installed with a fall in the direction of air flow. Branch connections shall be taken from the top of the air main. Each branch connection shall be fitted with a readily-accessible screw-down isolating valve next to the air main. Automatic drain air filters, shall be fitted in each branch connection and at all low points on the system and drains shall be piped to the nearest suitable point of the drainage system.

Each compressor shall be tested in accordance with BS 1571-2:1975. Each air receiver shall be tested in accordance with the relevant section of BS 5169:1992.

G11.3 Pneumatic actuators, positioners and converters

Pneumatic actuators, positioners and electro-pneumatic converters shall be suitable for operation from the air supply specified. Each device shall be installed with readily accessible isolating and regulating valves and an air filter. Control valves with diaphragm actuators shall be installed in horizontal sections of pipework with their actuators vertical and above the pipeline.

G11.4 Plant instrument piping

Instrument piping shall be in accordance with the manufacturer’s recommendations for the specific applications. All connections from plant pipework and vessels to instruments shall be made with grade 316 seamless stainless steel 15mm outside diameter, minimum wall thickness 1.5mm. Air supply connections shall be Sch 40 galvanised and screwed carbon steel of 10mm NB minimum. For groups of 2 to 5 instruments, the air header shall be 15mm NB minimum and for groups of 6 to 20 instruments, 25mm NB minimum. For each instrument, a 12mm block valve, filter and regulator shall be provided irrespective of the size of the supply header. Other piping shall be in compression-jointed, PVC-covered, heavy-gauge seamless copper soft-annealed in accordance with BS 1057:1996 or equivalent or as otherwise specified.

Fittings shall be designed for use with the particular piping and service conditions. Sample water pipework and fittings for water quality monitoring shall be sized and selected to suit service conditions generally in the range of 12mm to 25mm NB and shall be in uPVC or grade 316 stainless steel as applicable. Sample pipework and fittings for dissolved oxygen meters shall be in grade 316 stainless steel or titanium.

Piping shall be neatly run and shall be clipped to walls, ceilings or other building structures or shall be supported on galvanised mild steel tray. Piping routes shall be chosen to avoid obstructing traffic or personnel movement through the plant and to avoid interference with accessibility for the removal of plant. Piping shall be routed away from hot environments, places of potential fire risk or mechanical abuse. Piping routes shall also avoid areas where liquid spillage or vapour or gas leakage may occur. Piping and supports shall avoid vibrating structures or equipment. Piping shall slope continuously upwards or downwards with a minimum slope of 1 in 10 and in accordance with any other recommendation of the equipment manufacturer and sharp bends shall not be used. Drain and vent facilities shall be provided at the lowest and highest points respectively according to service.

Pipework to pressure gauges, transmitters and switches shall incorporate fluctuation dampers, instrument isolating valves and plant connections with either isolating valves or valve manifolds suitable for portable test gauges or manometers. Pipework to differential-pressure-operated devices shall include a five-valve manifold near the device. Pipework to steam, oil and high pressure lines shall have to isolating valves near the instrument. Tapping points for instruments connected by impulse pipework shall have additional isolating cocks. Level meters used with an air-reaction system shall be installed at the highest point of the piping. Variable-area meters shall have isolating valves upstream and downstream with a drain valve between the upstream valve and the meter.

Pipework shall be arranged to minimise the transmission of vibration. Pipework to steam lines or vessels shall contain a syphon, loop or condensate chamber and shall be lagged. Each instrument and accessory shall be supported independently of its pipework.

All pipework for fluids which may contain solid particles shall contain joints and bends of the 'cross' type for rodding-through and shall contain valves and connections for blowing down. The length of any line under vacuum shall be as short as possible. Gas-analyser sample-venting lines shall be sloped downwards away from the instrument or other precautions taken to prevent condensate flowing back to the cell.

Impulse piping to flowmeters shall be run in accordance with BS 1042-1.4:1992. Capillary tubing shall be clipped to mild steel, galvanised tray and shall not be pierced, stretched or twisted. The minimum bending radius shall be 100mm. Any excess length shall be neatly coiled at the measuring instrument and clipped in coils of not less than 200mm diameter.

Process fluids which solidify or are highly viscous at the lowest ambient temperature shall be prevented from entering impulse pipes and instruments by the use of seal pots, which shall be filled with a suitable inert, non-toxic liquid which shall not evaporate under process conditions, solidify, mix or react with the process fluids. If large displacements of fluid are possible, seal pots shall be provided close to the process connections. Seal pots shall have isolating, filling and venting valves.

Before connecting any instrument to its associated impulse or air supply pipework, all isolating valves shall be opened and the pipework blown through to clear any matter. Each line shall be flow-tested for continuity, followed by a pressure test at 2 bar, or as otherwise specified using clean dry air. Instruments and other ancillary equipment shall be connected immediately after the successful completion of the pressure test, if possible, and all open tube ends shall be sealed against the ingress of moisture.

PART H - DATA ACQUISITION AND CONTROL SYSTEMS

H1.0 DATA ACQUISITION – GENERAL

This part covers the requirements for the supply, installation, inspection and testing of the data acquisition and control (control) system, associated plant and materials.

H1.1 Reference Standards

Unless otherwise specified or approved, the data acquisition and control system shall comply with the current version of the relevant Reference Standards including those listed below:—

IEC 60381-1:1982	Analogue signals for process control systems. Specification for direct current signals.
IEC 60381-2:1978	Analogue signals for process control systems. Specification for direct voltage signals.
BS EN 60529:1992	Specification for degrees of protection provided by enclosures (IP code).
BS EN 60546-1:1993	Controllers with analogue signals for use in industrial-process control systems. Controllers with analogue signals for use in industrial-process control systems. Methods for evaluating performance.
BS 1646-1:1979	Symbolic representation for process measurement control functions and instrumentation. Basic requirements.
BS 1646-2:1983	Symbolic representation for process measurement control functions and instrumentation. Specification for additional basic requirements.
BS 1646-3:1984	Symbolic representation for process measurement control functions and instrumentation. Specification for detailed symbols for instrument interconnection diagrams.
BS 1646-4:1984	Symbolic representation for process measurement control functions and instrumentation. Specification for basic symbols for process computer, interface and shared display/control functions.
BS 6739:1986	Code of practice for instrumentation in process control systems: installation design and practice.

Instrument Society of America Standards and Recommended Practices:

S 5.1	Instrumentation symbols and identification
S 5.4	Instrument loop diagrams
S 26	Dynamic response testing of process control instrumentation
S 50.1	Compatibility of analogue signals for electronic industrial process instruments
S 51.1	Process instrumentation terminology
RP 60.08	Electrical guide for Control Centres

IEE Guidelines for the documentation of computer software for real-time and interactive systems. International and local guidelines for programmable electronic systems in safety-related applications.

H1.2 Submissions by the Contractor

The submissions by the Contractor pertaining to the data acquisition and control system shall be in accordance with the requirements detailed elsewhere and shall comprise the following as a minimum:-

(a) A functional design specification (FDS) for the data acquisition and control system. This shall be combined with the FDS for instrumentation, control and automation to form a complete document and shall comply with the specification of the FDS for instrumentation, control and automation. This document shall serve as the primary mechanism by which the Engineer may confirm that the Contractor possesses an accurate understanding of the system and its control requirements. The Contractor is encouraged to obtain any necessary clarifications and to suggest refinements to the control descriptions contained in this Specification. The FDS shall include a detailed block diagram of the control system with a description of the communications scheme to be provided. The FDS shall include operational details of the control system which have an effect on plant operations, such as power failure response, communication failure response, and automatic shut-down and start-up of the system. The FDS shall include a description of the interface of the control system with any existing or planned future control equipment. The Contractor shall submit a preliminary FDS and obtain approval before the system architecture design is finalised or detailed design takes place. The Contractor shall formally notify the Engineer for approval of any amendments or additions to the approved FDS. The final FDS shall be submitted for approval before submission of the factory acceptance test definition documents. The Contractor should take note of the importance of this obligation.

(b) Layout drawings for each piece of equipment fabricated or assembled by the Contractor, showing the position of each component with required clearances where applicable, and with overall dimensions.

(c) Wiring diagrams indicating each component of the system and all wiring and cabling thereto, showing manufacturers, types, duties, ranges and nomenclature, referencing the P&I diagram where applicable, with inputs, outputs, cable wiring and terminal identifications clearly marked.

(d) Mimic video displays in the form of hard copies or photographs which are clearly legible and are notated to indicate dynamic data and control pick points where applicable.

(e) Control video displays in the form of hard copies or photographs which are clearly legible and are notated to indicate dynamic data and control pick points.

(f) Logic diagrams of plant operation and control system interaction (including modes of failure and shutdown routines).

(g) Complete input and output list giving type, circuit number, tag name, short description, outstation, database reference, associated field device, range (if applicable), critical/non-critical alarm status and the like.

(h) Description of quality control methods and approvals.

(i) Detailed works and acceptance test procedures.

(j) Programme for manufacture, delivery, installation and commissioning.

(k) Appendices, as necessary, to include manufacturer’s literature for each item of equipment supplied.

(l) Operation and maintenance manuals detailing the following:

- general description and operating principles;
- technical description of the equipment -manufacturer's standard brochures only being acceptable if the particular item of equipment described is clearly designated, adequate information is supplied, and irrelevant information is deleted or otherwise delineated;
- complete operating instructions defining the sequence of operations, including flow charts;
- procedures for dismantling, cleaning, servicing, replacing parts and reassembling, including recommended clearances and tolerances;
- details of all instrument and equipment settings as applicable to this contract;
- maintenance and lubrication schedules;
- fault diagnosis procedures;
- dated and priced list of significant spare parts and special tools, including identification numbers and sources of supply;
- simplified arrangement drawings showing all components of the equipment.

(m) General operating manual comprising the following:

- general description and operating principles;
- operating instructions for normal procedures in a step-by-step format including control operations, requirements for display or printing of data, performance monitoring, response to alarms or failures, changing of operational parameters, and manual data entry.

H1.3 Format of submissions

The above documentation shall be on A4-size loose-leaf numbered sheets, bound in hard¬cover ring or lever-arch type files, labelled on the cover and spine with the Employer's name, title of Scheme and/or Contract, Contractor's name, volume number and reference numbers.

All sketches shall be on A4-size, or A3-size folded to A4; all drawings shall be on A1 or A3¬size sheets folded to A4 and bound in a separate volume and include:

- Employer's name and title of Contract;
- Contractor's name;
- Title of drawing and drawing number;
- Date and originator;
- signature of Contractor to the effect that the drawing has been checked by him before submission.

H2.0 SOFTWARE DOCUMENTATION

The Contractor shall provide complete software documentation for each programmable piece of equipment. The material to be provided shall include, as a minimum:

(a) All of the manufacturer's standard published reference materials and user's guides.

(b) Complete documentation for any packaged software incorporated into the system including software written by other manufacturers.

(c) A working copy and complete documentation for any program-development software used for this project. This software and documentation shall be of the same version and revision numbers used for development under this contract.

(d) A working copy and complete documentation for any database management, report generation, screen graphic builder or other similar software used for development under this contract. This software and documentation shall be of the same version and revision numbers used for development under this contract.

(e) Hard-copy documentation of all configuration data, all user-accessible source code including control program code, reports and database contents including listings. All program listings shall be clearly and completely commented so as to convey to the reader a full understanding of the function of the program. So-called 'self¬documenting' code without additional, supplementary comments will not be acceptable.

(f) A complete input and output list giving type, circuit number, tag name, short description, outstation, database reference, associated field device, range (if applicable), critical/non-critical alarm status and the like.

(g) A Software System Specification document which describes all control programs furnished with the system. Design documentation shall include, as a minimum:

- a description of the software development environment, including development procedures, limitations, restrictions, configuration management, documentation standards and compatibility;
- an overall description of the software design, including application structure and subsystem divisions, control strategy, monitoring and display hierarchy, data acquisition and storage, notational and operational conventions and operator access restrictions;
- a description of each application sub-system;
- an English-language description of each control scheme;
- a flow chart or 'pseudo-code' description of each program module detailing the flow of control throughout the module;
- a list of files used by the system, including location and a brief description.

All packaged and system software licenses shall be registered by the Contractor in the name of the Employer.

H3.0 MASTER STATION

H3.1 General requirements

The master station shall consist of a computer system complete with central processor(s), VDU console(s), input/output devices, communication facilities and all peripheral equipment required for proper operation, as specified herein. Master station equipment shall be from a standard line of equipment manufactured and supported by a manufacturer approved by the Engineer.

If an uninterruptible power supply is not specified to power the master station, power to the equipment shall be provided with a transient protection barrier. Protected power cabling shall be provided with sheath colour coding or another method which distinguishes it from other service cables.
Programming of an outstation shall be possible from the master station.

H3.2 Central processor

The central processor(s) shall be of industrial quality and of proven high reliability suitable for continuous operation.

The RISC based central processor unit or Pentium equivalent CISC shall operate at frequency as specified in the Volume 1 Particular Specification Part B7.

The processor shall be furnished with a real-time calendar clock with battery back-up which provides the current time and date during system boot-up with no operator action required.

The processor shall contain sufficient memory for all requirements described herein, including future requirements, and 30% spare capacity when all application programmes are loaded and operating, but not less than 20 G-byte. The memory shall be field-expandable to 4 Gegabytes minimum and shall consist of high-speed semi-conductor RAM which is capable of detecting data corruption or memory failure.
The central processor shall be equipped with storage facilities consisting of:

- Random access memory (RAM) for the storage of all current data (real-time database);
- Large capacity, fast access, mass storage magnetic (hard) disks for on-line data storage;
- High density cartridge or streaming tape drive or optical disk system, with removable media, for off-line archiving of data;
- An IBM PC compatible floppy diskette drive with removable media. (preferably a 1.44 Mbyte or more 3.5 inch diskette);
- DVD Read/Writer, for off-line archiving of data;
- Hard disk of not less than 300GB capacity.

Additional high capacity fixed and removable storage media, in the form of magneto-optical devise shall be supported.

The floppy drive shall store data in a format readable by and compatible with the PC/AT standard unless otherwise approved by the Engineer. Each floppy disk or tape cassette drive shall be located to allow convenient access by operators.

At least 50% of the hard disk shall remain unused and available for other uses after all database, program, historical and working files required by the system are resident. The disk drive shall possess a maximum access time of 15 milliseconds.

The operating system and application software shall reside on the hard disk. Upon power-up, power restoration after power failure or warm start, the system shall automatically load and become fully operational without the need for operator action.

The operating system and application software shall also be stored on removable media. Should data corruption or hardware failure occur to the hard disk such that the system will not function or re-boot properly, it shall be possible to reload this software onto an operable hard disk and the system brought on-line by an operator following step-by-step procedures, which shall be supplied by the Contractor as part of the O&M manual, without the need for outside support.

The central processor shall be provided with self-test diagnostic routines which are automatically executed every time the processor is powered up or the bootstrap routine is initiated.

H3.3 Dual redundant processors

The master station shall be provided with two identical central processors configured such that either may provide full autonomous functioning of the system.

The system shall be designed and implemented such that the failure of a single processor does not inhibit full functioning of the system for more than 4 minutes. In the event of such a failure, full functioning shall resume automatically.

The Tender shall include a full description of the method by which his system meets this specification including a block diagram and step by step narrative.

H3.4 Visual display unit console

Visual display unit consoles shall be provided either as individual units comprising a visual display unit (VDU), a keyboard, a cursor positioning device and any processor required for complete man-machine interface functioning, or as a console on which more than one set of the above hardware is available as an integrated system, together with the associated logging and graphic printers as specified. Space for up to two telephones shall be provided on the console. Console construction shall be as defined in the general requirements for panel construction unless otherwise agreed by the Engineer.

H3.5 Visual display unit

The VDUs shall be designed for continuous operation, ie 24 hours per day. Polarizing filters shall be provided by the Contractor to minimise reflected glare.

VDUs shall be a minimum of 21” and have at least 25 lines and 80 characters per line and full graphics with a minimum resolution of 1280 x 1024 pixels, displaying ASCII characters and graphical symbols.

The workstation shall have a structured, segmented, multiple window screen. A window is defined as an area of the screen through which the user can view any display produced by the system. Use of a WIMP (Windows Icons, Mouse and Pull-down Menus) environment shall be preferred as long as this does not compromise other requirements of this Specification.

H3.6 Keyboard

Unless otherwise specified, keyboards shall be equipped with upper and lower case alphanumeric keys as well as a minimum of 10 function keys. Each key shall be clearly and permanently labelled to show its purpose.

Standard editing keys such as tab, insert, delete and backspace shall be provided.

Cursor control shall be available for the keyboard giving right, left, up, and down movements.

Keyboards located in the process area shall be protected from dust and splashed water.

Certain keys shall be programmable. A minimum of 8 keystroke-sequences, apart from the standard functions, shall be available after project completion for assignment of programmable functions.

Contractors proposing alternative keyboards shall submit full details for approval.

Keyboards for use in program modifications shall be of the standard QWERTY configuration with separate 10-key pad for numeric input.

H3.7 Cursor-positioning device

Cursor-positioning devices shall be of the mouse or track-ball type or otherwise approved by the Engineer. Two select buttons shall be provided as a minimum.

H3.8 Printer Requirements

Two types of printers shall be supplied for reports, alarms and events as detailed below. It shall be possible to configure any text based output from the master station to either of these printers.

It shall be possible to add additional printers if required. Additional printers shall be capable of being assigned the functions of alarm/event logging, or report printing.

Alarm/Event printers, shall offer at a minimum of 100 characters per second, upper and lower case ASCII character set with true descenders, a minimum of 132 characters per line, and a self-test facility capable of printing automatically the entire character set.

The minimum size of printer buffers shall be 4k characters.

Each printer type shall connect to the system using the standard interfaces such as RS232/Ethernet with both RTS/CTS control signal and XON/XOFF data transfer control methods supported.

All printer types shall be of a low noise type or shall be provided with acoustic hoods to ensure the ambient noise level never exceeds 30dBA.

Printer types shall be provided with all necessary cables and connectors.

Should a printer be off-line when an output is ready, the control system shall send a message to the operator.

H3.9 Alarm/Event printers

The Alarm/Event printer shall be a dot matrix printer with a minimum of four colours available. Alarms shall be highlighted by coloured printing (i.e. plant alarms red/system alarms orange/return to normal green) while events and alarm acceptance shall be printed in black. This printer shall be located in the Control Room in a self-contained printer stand. The Contractor shall supply and install all necessary cables and connectors etc.

H3.10 Report colour printers

The report colour printer shall be an A4 printer capable of producing high quality text and graphical reports for plant and management purposes and full colour high quality prints of screen display mimics, trends etc. In text mode the printer shall be capable of up to 7 pages per minute for text and 1 minute per page for graphics. The resolution shall be 600 by 600 dpi for colour and 600 by 600 dpi for black as a minimum. The printer shall be capable of receiving and printing data formatted for an Hewlett Packard printer. It shall be located in the control room. The Contractor shall supply and install all necessary cables, and connectors etc.

H3.11 Programmer's console

For systems which require it for modifications or additions to be made to the operating system or application programmes, a programmer's terminal shall be provided of the type recommended by the system software and hardware manufacturers.

H3.12 Diagnostic capability

The system shall be provided with the capability to diagnose hardware malfunctions in the master station and related peripheral equipment. Diagnostic programmes shall be password-protected to prevent unauthorised use. The diagnostic procedures shall be able to be performed by operations personnel with a minimum of training. Software routines shall be provided which can isolate a single problem to the circuit board level. The routines shall be menu-driven to allow for ease of use. Complete documentation of diagnostic procedures shall be provided as part of the system documentation.

H3.13 Master-station earthing

The master station and all related equipment earths shall be electrically bonded to the instrumentation earthing system or be provided with a separate independent isolated earth terminal bonded directly to the main station earth terminal in accordance with BS 6739.

H3.14 Master station power and UPS

The master station processor(s), VDUs, logging printer and communications equipment shall be powered through an uninterruptible power supply (UPS) via a dedicated distribution system. The UPS shall provide for full functioning of this equipment for a minimum of three hours in the event of a power failure. UPS capacity shall be over-sized in terms of rating and power duration by 50% to provide for future additional equipment. UPS batteries shall be sealed lead acid maintenance free type.

The UPS distribution cable sheaths shall be of a colour which distinguishes them from other service cabling. Each master station device shall be provided with a local isolating device such as a fused spur or switched socket outlet.

H4.0 MASTER-STATION SOFTWARE

H4.1 General requirements

The Contractor shall provide all software and licences, fully configured to accomplish the requirements of the Specification, including any supporting or configuration software used to generate the system.

The Contractor shall provide all necessary licenses to use all items of software on all processors in the system for the projected life of the installed system. All licenses shall be in the name of the Employer.

All software shall be standard, fully-debugged programs currently in use by the system supplier on similar systems. All software shall be of the most recent version and revision available at the completion of the Contract unless otherwise agreed by the Engineer. All software shall be fully-maintained by the Contractor throughout the Contract and warranty periods.

Contractor supplied enhancements to the operating system shall be accepted only if the following conditions are satisfied and demonstrated to the Engineer:

- The warranty validity shall not be affected.
- Upgrades, fixes and future releases of the operating system shall be implemented without modification to the application software.

The system shall be provided with a pre-emptive multi-tasking operating executive, capable of simultaneously executing multiple background tasks.

H4.2 System security

The system shall be protected from unauthorised changes to the operating system and application programs.

The system shall prevent unauthorised users from re-booting the system or aborting or suspending system-related programs.
The system shall provide three levels of operator access to the system as a minimum, with the first level permitting access to viewing selected plant conditions as described below and the highest level intended for the system manager.

A mechanism shall be provided which prevents users operating at a lower level from accessing functions assigned to a higher level.

The system shall provide a password-protected, user log-on facility for definition of the user access level. Passwords entered during the log-on process shall not be printed or displayed. The system shall log the current user off after a definable extended period of no operator interaction with the system and produce a printed log-off message.

System-generated log messages relating to operator actions, such as alarm acknowledgements or set-point changes, shall include the identification of the current logged-on user.

The Contractor shall provide the following defined user access levels, unless otherwise instructed by the Engineer:

(a) Normal viewing only (default level): The default level shall permit users to view all displays except those specifically assigned to a higher level of access.
(b) Daily access: The daily access level shall allow viewing (ie default level) and printing of trend displays.
(c) Operator level (remote control): The operator level shall permit authorised users to access lower levels and to carry out the following actions:
    - perform control actions;
    - acknowledge alarms;
    - enter or modify manually-entered data for inclusion into reports.
(d) Monthly and yearly data archiving:
    The level shall permit authorised users to access lower levels and shall provide the facility to down load specific data to long term data storage for archive purposes.
(e) System builder level:
    The system builder level shall permit authorised users to access lower levels and to carry out and use the following facilities:
    - modify alarm and control set points, dead bands and time delays;
    - enter or modify historical data;
    - add, delete or modify individual I/O points or point attributes;
    - add, delete or modify field device configurations;
    - create, delete or modify control algorithms;
    - create, delete or modify graphic displays;
    - create, delete or modify system reports;

- configure trend displays;
- access the operating system;
- perform any other system maintenance function.

(f) System administrator: The system administrator level shall allow full access to the system (ie all lower levels) including the facility to view and assign user log-on access levels.

H4.3 Signal processing

The system shall continuously receive data from the field devices, unless otherwise specified, such that a ‘significant’ change in field conditions shall be detected, processed and displayed by the system in less than 5 seconds. A ‘significant’ change is defined to mean any change of state of a discrete point or any change of an analogue point outside a definable deadband.

The scan rate to individual site units shall be configurable between 2 seconds and one hour with a 1 second resolution for local and directly connected remote site units and 5 minutes to 24 hours with a 5 minute resolution for PSTN/radio/GSM/satellite connected site units.

A report by exception method for acquiring field data is acceptable. However, in this case, no change of an analogue variable outside a dead band, in percent of full span, shall go undetected by the system. A full scan of each field device shall take place at least every 30 minutes for site based communications and every 6 hours for PSTN/radio/GSM/satellite connected sites.

An analogue or discrete input point shall be definable by the authorised operator from the master station as blocked, in which case the input value of the point shall not be scanned by the system. The operator shall be able to assign a fixed value to a blocked point. The O&M manual shall point out the risks associated with leaving points in the blocked condition. Defining a point as blocked shall be a system manager level function.

H4.4 Alarm processing

The system shall process alarm conditions in the form of process abnormalities, field device failures, sequence faults, outstation system component malfunction and other configurable events. Alarm processing and display shall comply with the following as a minimum:

(a) A minimum of two alarm priorities shall be provided to distinguish between critical and non-critical alarms. The Contractor shall define critical or non-critical status to all alarm conditions in the system, unless otherwise defined in the Specification, and shall submit these definitions for approval by the Engineer.

(b) An alarm acknowledgement function shall be provided. Acknowledged alarms where field conditions revert to normal (see also (c) below) shall clear. Unacknowledged alarms where field conditions revert to normal shall not clear until acknowledged. Alarm conditions which clear shall generate a log entry.

(c) An hysteresis band shall be definable for analogue points such that a change of value from an alarm condition to the normal condition will not clear the alarm until the value has crossed back over the limit value by at least the hysteresis bandwidth. A limit alarm shall not re-trigger unless the alarm has previously cleared.

(d) The system shall provide a convenient method for acknowledgement of alarms by the user. Systems requiring the user to type the point name of each point to be acknowledged are not acceptable. Each alarm acknowledgement shall be logged. The log entry shall include as a minimum the point identification, the time and date of acknowledgement, the operator identification and the type of alarm. If the Contractor provides a 'global' alarm-acknowledgement function as part of his standard package this function shall be assignable to any of the security access levels to prevent unauthorised usage.

(e) Each new alarm condition shall activate an audible alarm and generate an alarm log entry as specified in the clause entitled 'Alarm and event logging'. The audible alarm shall be able to be disabled through use of a keyboard function. This function shall be assignable to any of the security access levels to prevent unauthorised usage.

(f) Any alarm condition shall be designated as such on any dynamic display which depicts the process involved. Unacknowledged alarms shall be distinguishable from acknowledged alarms. Symbols for discrete alarm conditions shall change colour and/or the symbol itself shall change when an alarm condition is present.

(g) The system shall allow an authorised user to inhibit alarm processing for any desired analogue, discrete or calculated point. All other processing by the system of an alarm-inhibited point shall continue. The O&M manual shall point out the risks associated with leaving points in the alarm-inhibited condition. Defining a point as alarm-inhibited shall be a system manager level function.

(h) Limit alarms shall be definable for all analogue points for over range, extra high alarm, high alarm, low alarm, extra low alarm and under range. Over-range and under-range alarms shall be provided for all analogue points.

(j) A delay-before-alarm interval shall be definable for each analogue point such that an alarm condition is not registered until the current value remains outside alarm limits for a period of time exceeding the interval. Each discrete point designated as an alarm shall have a definable delay-before-alarm interval.

(k) A change of state of a discrete point shall be definable as either an alarm, a logged condition or information only. A change of state of a point designated as a logged condition shall generate a log entry but not an alarm event.

(l) Control alarms shall be generated whenever control actions are attempted by the system and no status is received by the system indicating that the requested action has taken place.

(m) The occurrence of an alarm shall be definable as an event which can be used by the system to trigger subsequent definable actions.

The processing specified in (b), (c), (h), (j) and (l) above shall take place in the field device unless otherwise approved by the Engineer.

H4.5 Alarm and event logging

The system shall provide for the generation of a log of events detected by the system. Events to be logged shall minimally include: all alarm and alarm-clear conditions, all alarm acknowledgements by the operator, all changes of state of discrete points which have been designated as a logging condition, all user operations which cause a change in the data base including control actions.

Log entries associated with events detected by a field device shall include the date and time of occurrence as detected by the field device. Other types of log entry such as operator actions shall include the current date and time.

If the event is associated with a particular process variable, the log entry shall include:

- the point name and short description;
- the current state or value in engineering units;
- the current alarm status if appropriate; and
- a descriptive phrase of the event.

If the event is associated with a user operation, the entry shall include:

- the point name and short description;
- the operation;
- the operator identification;
- the previous state or value; and
- the new state or value.

An authorised user shall be able to inhibit logging through use of a user function. The alarm-logging-inhibited condition shall be defined as a non-critical alarm.

The system shall provide for display and/or printout of all logged events for the previous 1000 events. The user shall be able to page forwards and backwards through the event log display.

The user shall have the option of defining which items appear in the event display/printout with the following query conditions as a minimum:

- Process area(s): define which process areas/sites are selected for inclusion.
- Point name(s): define which points are selected for inclusion.
- Date/time window: the earliest and latest date and time for which the events are to be included.
- Maximum: the maximum number of entries to be included.

H4.6 Control commands

An authorised user shall be able to control the operation of each piece of controllable equipment and override each automatic control scheme through use of control commands at the VDU console. Each command shall follow a sequence which requires operator confirmation of the command before the command is executed by the system.

Control and alarm parameters, such as set-points, shall be modifiable by an authorised user through use of commands at the VDU console. Parameters which are intended to be modified on a regular basis shall be modifiable through use of graphic mimic displays.

H4.7 Calculations capability

The system shall be provided with calculations capability which allows the user to define calculated points, either discrete or analogue, for use in control and reporting. Actual discrete and analogue points as well as calculated points shall be usable in calculations. As a minimum, the following functions shall be provided:

- arithmetic operations: add, subtract, multiply and divide;
- square root;
- absolute value;
- exponential (base e);
- natural logarithm;
- average, maximum and minimum values (from historical data);
- Boolean functions: AND, OR, NOT and exclusive OR;
- conditional function: IF... THEN;
- tests for equivalence, less than, greater than, zero, alarm status, out of range;
- dates and times.

The user shall be able to define the calculation to be performed through an interactive screen-based method, with on-screen syntax error checking.

The system shall permit the user to input data manually into calculated points during on-line operations.

H4.8 Database definition

The system shall be supplied with an interactive database definition (DBD) utility. The DBD utility shall permit only authorised users to define, delete or modify elements of the system data base including but not limited to: point descriptions, field devices and communications network configuration.

The DBD utility shall prompt the user for required data on a step-by-step basis through use of VDU displays in a simplified ‘fill in the blanks’ format.

The DBD utility shall provide for the definition of the following points as a minimum:

- analogue inputs;
- analogue outputs;
- 2-state status: indication from a two-state device;
- 3-state status: indication from a three-state device using two discrete inputs;
- pulse accumulator: maintains a pulse or rising-edge count for flow accumulation and kWh measurement, ‘number of starts’ tally and the like;
- calculated point: a discrete or analogue point whose value is derived from manual entry by the user or from other points using the calculation facilities described herein. It shall be necessary to manually enter a value once only;
- discrete outputs.

H4.9 On-line data storage

The control system shall include automatic data logging, storage and retrieval of plant data, configuration information, alarms, events, operator commands, help pages, etc., to the disk system. This on-line archive store shall consist of the past 100 days worth of data to the following specification :

(a) All data logged or derived by the control system for a maximum of 2048 real or derived analogue data points. The resolution of storage of data values shall be according to user configurable selection and shall be either the same as or less than the scanning rate;

(b) All alarms and events logged or derived by the control system for a maximum of 6144 real or derived alarm/event points. The maximum size of the 100 day store shall be calculated and submitted to the Engineer for approval.

The on-line archiver shall also provide the following functions:

(a) Generate system alarms, with configurable priority, as the hard disk becomes, 75%, 90% and full;

(b) A menu driven system with password protection of facilities for the management of the files on the disk, (eg. for off-line storage or deletion);

(c) All historical and event logs shall be in the form of rolling circular buffers or files, which shall operate over the periods specified above. Following this period the oldest data in the buffer or file shall be overwritten with new data.

H4.10 Storage capacity

The size of the fast access, hard disk system shall be based on, but not be limited to, the sum of the storage required by each of the items identified below. The Contractor shall allow for any additional storage required due to the design offered.

(a) The computer operating system, which shall include disk space set aside for the following:

- Control system software and management;
- Swap space;
- Paging file space.

(b) Configuration data, which shall include:

- 8192 point/tag information;
- 40 report pro forma's;
- Programmable controller sequences as defined in tender documents;
- 80 help pages;
- Control system housekeeping information;
- 100 mimic background static displays.

(c) Plant dynamics:

- 100 day on-line archive store size to be based on logging data points at 15 minute intervals and having an alarm/event store with sufficient capacity to hold 15 changes of state/point/24 hour period;
- One month of reports;
- Statistical Process Control data;
- Space required for the retrieval of a 100 day file from off-line storage.
-

(d) Third party software:

- Database environment and executable code;
- Spreadsheet environment and executable code.

The control system shall be supplied with the spare capacity as defined elsewhere within this specification.

H4.11 Data Exchange

The control system shall provide a method of real-time data exchange with the following application programs:

(a) Relational database
(b) Third party PC spreadsheet packages
(c) Report generation and graphical manipulation packages

The Contractor shall provide and demonstrate a method of exporting data on-line across a network using the control system, standard transport protocols and an open communications architecture, which is independent of the associated operating systems.

Data exchange with third party PC spreadsheet packages shall also be provided via floppy disk transfer.

This data exchange facility shall enable an 'untrained' user to select a set of archived data points over a selected time frame and then automatically create text files which can be exported onto floppy disks. The requirement is for the user to be able to load these text files directly into a Microsoft excel spreadsheet software package. The data exchange facility shall include, but shall not be limited to, the features described below:

(a) The user shall have access to all data points (of all types, i.e. analogues, digitals, system and derived points) across the whole control system from any operator workstation and shall be able create and amend a list of data points for export to the floppy disk drive to the user's workstation.

(b) The user shall be provided with the facility to select the signal name using wildcard text search facilities to quickly locate the input/output point name description. In addition the user shall be able to select the required time frame for the data.

(c) The time period at which analogue data shall be exported shall be the default archived data interval of 15 minutes. Event type data shall be exported with the time at which the change of state occurred.

(d) For each analogue signal selected, the user shall also be able to select any combination or all the statistical data options, e.g. instantaneous value, mean value, minimum value and maximum value.

(e) Facilities shall also be provided to enable the user to create, save, save as, delete, and re-name the export files. In addition the user shall be able to list the files stored on the hard disk and floppy disk. It is also a requirement that the user is able to select the files on the hard disk that are required to be transferred to the floppy disk.

(f) Warning messages shall be provided prior to exporting the data if the size of the file(s) exceeds the capacity remaining on the floppy disk.

H4.12 Historical data management

An historical data management (HDM) system shall be provided for archive storage and retrieval of operational data comprising field input data, manually-entered data and calculated points.

Archived historical data shall minimally include averages, minima and maxima for each analogue value compiled over hourly, daily and monthly time periods, with a minimum capacity of 1000 points. The HDM system shall be capable of selectively increasing the rate of data capture based on events, such as process variable status, discrete inputs, or operator command. Minimum and maximum data shall include the time and date of occurrence. Gaps in collected data caused by faulty instruments or control system equipment shall not be included in average, minimum and maximum compilations. Archived historical data shall also include flow totals, equipment run times and number of starts compiled over daily and monthly time periods.

The HDM system shall provide for a minimum of sixty-five (65) days of data to be on-line at all times. These data shall be kept current such that the most recent data obtained by the system are available. These data shall be written automatically to archive storage media at least once every 24 hours.

A data-retrieval facility shall be provided which permits the operator to retrieve selected data for display or reporting. The stored data shall include a 'time stamp' to facilitate accurate retrieval.

A user interface to the HDM shall be provided which allows the definition of data to be stored, and entry or modification to either on-line or archived data. Access to the HDM user interface shall be security protected.

Full details of the HDM scheme proposed by the Contractor shall be submitted to the Engineer for approval.

H4.13 Report generation

The system shall be provided with a report generator utility which shall enable authorised users to create, delete or modify report definitions. The report definitions shall allow for retrieval of data from the on-line database and from historical data files and for formatting the data for output to the printer.

The format of each report shall be definable by the user to include: the definition of static or background data, the placement of data base values, the number of significant digits of a value, the date and time of the report and calculated values.

Calculation capabilities of the report-printing facility shall include but not be limited to:

- arithmetic operations: add, subtract, multiply and divide;
- square root;
- absolute value;
- average, maximum and minimum values (from historical data) including time and date stamp;
- Boolean functions: AND, OR, NOT and exclusive OR;
- conditional function: IF ... THEN;
- date and time manipulation;
- tests for equivalence, less than, greater than, zero, alarm status, out of range.

The system shall also be provided with a report-scheduling facility for the calculation and printing of the report. Report printing shall be schedulable either on a definable periodic basis, at a specific definable time and date, or on demand via an operator command from the system console.

H4.14 Graphic display generation

The system shall be provided with an interactive on-screen graphic generation utility which shall allow an authorised user to create new graphic displays and modify or delete existing displays at any workstation including those associated with the LCP/outstations. The generation utility shall include an interactive linkage process allowing the user to link symbolic, numeric and bar graph representations and data entry locations to dynamic data base variables.

The graphic display system shall be capable of making full use of the VDU resolution in the composition and display of graphic information.

Graphic symbols shall be definable by the user for display of static and dynamic data. The user shall be able to assemble a library of symbols which shall be retrievable into any graphic display.

Text and symbols shall be able to be enlarged, shrunk, moved, mirrored or rotated with reference to a given display.

The system shall be able to represent dynamic analogue data on a graphic display as a variable-length, sizeable bar graph, as well as numeric text.

H4.15 Displays - general

All displays, excepting those containing data derived from historical files, shall be completely displayed within 2 seconds of the operator request. Dynamic data shall be continually updated while being displayed.

All screen displays shall as a minimum provide the following displays which are fixed in their locations to normal operations:

(a) alarm banner window at the bottom of the screen display showing the last three highest priority unaccepted alarms. Where the system allows the contents of the banner to be limited (eg by the user name or group) then the selection criteria applied shall be displayed with the banner;

(b) Main display area for user selected displays e.g. mimics, alarm lists, etc;

(c) System dialogue banner window at the bottom of the screen shall display relevant system information such as error message and user prompts;

(d) A day, date and time indicator shall be able to show local time.

An alarm banner area shall be included on all displays which provides information regarding the most recent alarm events. The system shall allow the operator to obtain details of the most recent alarm event from any operational screen display through direct operation using a maximum of two keystrokes or selections.

The system shall allow the operator to obtain a print of any display, including graphics through use of a standard system command. Screen displays shall appear identical in printed form. Dynamic data contained on a display shall not change during screen print such that a ‘snapshot’ of conditions is portrayed.

Each display shall include the time of day in hours, minutes and seconds and the date in day, month and year format.

A facility shall be provided which allows ‘paging’ to related displays through the use of ‘page’ forward or backward keys, or through the use of pick points.

H4.16 Generic displays

The system shall produce various generic displays automatically. The minimum requirements for generic displays are outlined in the following paragraphs. In addition, an on-line interactive graphic display generator utility shall be furnished as described herein:

(a) Alarm summary:

Alarm summary displays shall be provided which can be quickly called up by the operator through a maximum of two key strokes. Alarms of both analogue and discrete conditions shall be presented on the same screen in reverse chronological order. Unacknowledged alarms shall appear in flashing mode. The alarm summary screen shall update automatically to reflect any changes. As a minimum, the point name and short description, the current state or value in engineering units and the type of alarm shall be indicated for each alarm.

Alarm entries associated with events detected by a field device shall include the date and time of occurrence as detected by the field device. Other types of alarm entry shall include the current date and time.

(b) Dynamic graphic trend display:

Dynamic graphic trend displays shall be similar in appearance to chart recordings with the variable(s) plotted against a definable timescale. Points which may be plotted shall include analogue, discrete and calculated points.

The displays shall be selectable for a single-point or a multiple-point presentation of a minimum of 4 points simultaneously, with colour coding and a legend. The points to be displayed shall be selectable by the operator. A minimum of 50 trend display definitions shall be maintained by the system and shall be automatically available upon system boot-up.

(c) Historical graphic trend display:

The historical graphic trend display shall conform to the specification of the dynamic trend display with the exception that data for trending shall be retrieved from historical files. The system shall extract data appropriately from either the on¬line storage or from archive files. The system shall detect if the requested data is not present and prompt the user for the correct archive file. Through use of a cursor, it shall be possible for the operator to select a point on the plot and obtain a numerical reading of the value and the time and date of that point.

(d) Alarm-inhibited summary:

This display shall list all points whose alarming has been inhibited (see ‘signal processing’).

(e) Blocked-point summary:

This display shall list all points which have been blocked (see ‘alarm processing’)

H4.17 Non-generic displays

The system shall be provided with the following displays, which may be either generic or non-generic, i.e. configurable.

(a) System display: The system display shall provide a list of all outstations with the current status of each, i.e. scan status, service status and communication status. This display shall update automatically whenever any related status condition changes.

(b) Process control display: A screen display shall be provided to give a working understanding of each process control strategy in the system. These displays shall be configured for use by operations personnel. Modifications to the control parameters shall be able to be made through use of this display. Any modified parameters residing in an outstation shall be downloaded to the outstation by the system and an alarm shall be generated if this downloading fails to take place correctly. As a minimum, the following information shall be displayed as applicable for each process control strategy:

- equipment or process identification;
- current set-point value;
- control output;
- current controlled measured variable value;
- intermediate calculated values;
- associated points and parameters;
- alarm status (alarm/normal/inhibit);
- tuning parameters;
- control status (manual/off/auto);
- set-point, measured variable and output range;
- alarm limits; • output limits.

All numeric values not having the same engineering unit as the variable itself shall be displayed along with the appropriate engineering unit designation. A control loop output which has reached the maximum or minimum output limit shall be indicated on the display.

Set-point, control parameter and alarm setting modification shall be prohibited by the system for unauthorised users.

(c) Sequential control displays: A screen display shall be provided to give a working understanding of each sequential control strategy in the system, as described above for process control displays. The sequence state shall be readily ascertainable from the display. Fault conditions for each state shall be indicated when appropriate with textual detail such that a clear understanding of the nature of the fault is conveyed. Provisions for operator abort of the sequence shall be available from this display.

(d) Graphic mimic displays: Graphic mimic displays shall be configured by the Contractor, similar to process and instrumentation diagrams, which depict the current status of equipment and process variables and which update dynamically whenever a change is detected by the system.

The system shall provide a menu of all mimic displays, which allows an operator to choose one for display.
The graphic mimic displays which shall be supplied with the system are to include but not be limited to the following:

- an overall plant summary diagram showing the basic process groups;
- a diagram of each process;
- a diagram of each grouping of major equipment, such as raw water pumps, filters, chemical plant, etc

The diagrams shall depict layers of progressive detail such that the lowest level contains each measured variable and equipment status associated with the process or equipment group and that no diagram contains more data than can clearly and comfortably fit on a screen display. The Contractor shall submit reproductions or drawings of proposed mimic displays to the Engineer for approval before factory acceptance testing.

Any point shown in a display which is in an unacknowledged alarm state shall be shown in a contrasting colour or highlight and as flashing. A point in an acknowledged alarm state shall be shown in a highlighted or contrasting colour and steady state.

The mimic displays shall allow the operator to control any controllable equipment which is being displayed. The Contractor shall provide sufficient graphic mimic displays for complete monitoring and supervisory control of the system by an operator.

The Contractor shall use consistent standards for all displays for the following details:

- symbols and symbol colours;
- process lines and colours;
- point/tag name representations;
- dynamic conditions of analogue and discrete variables.

The Contractor shall submit details of these standards for approval by the Engineer prior to configuration.

(e) Manual entry point summary: This display shall list all manual entry points defined in the system and the current value of each point. This display shall allow authorised users to enter data into the system. The display shall update dynamically to reflect any related changes.

H4.18 Electronic mail facility

If specified, the system shall be provided with a fully functioning electronic mail package linked to operator log-in passwords at each workstation. The system shall include server and modem facilities for linking the electronic mail facilities with off-site locations such as the Employer's regional offices and headquarters. The electronic mail software package shall be from a major supplier of such software and approved by the Engineer. The Contractor shall include details of the system software, hardware and functionality in his tender.

H4.19 User help facility

The system shall be provided with help messages and screens that can be called by the operator with a single key press at any time regardless of the function being performed.

In particular the help facility shall be available for alarms. In this case, when an alarm is selected from an alarm list, the system shall automatically make available a pre-defined alarm help page which the operator can display if required through a standard and simple action. For alarms associated with the control system itself rather than site operational alarms, these system help pages shall be configured by the Contractor.

In addition the system shall provide specific plant related help pages that are accessible through help buttons that are located on the plant/process mimics.

This shall take the form of the Works Operations Manual imported on to the WCS in HTML format.
This shall than be “bookmarked” using “HTML” functions and links provided from both the process/plant mimics via help buttons, and also from appropriate alarms.

The Contractor shall install the system manuals onto the WCS. It shall be possible to view and print pages of the documentation "on demand".

H5.0 SYSTEM RESILIENCE AND REDUNDANCY

The system shall be designed and implemented such that the failure of a central processor or VDU console does not inhibit continuous automatic control of the plant. In the event of such a failure, historical data shall be recoverable to a condition where a worst-case maximum of 15 minutes of historical data is lost.

Failure of a single outstation or communications to that outstation shall not effect control or operation of any other outstation, unless the failed outstation provides essential data to another outstation, in which case the signals associated with the control or operation shall be hard-wired. If such a failure does affect the control of other healthy outstations, the non-failed outstations shall revert to a fail-safe/stay-put mode as appropriate.

Dual redundant communications circuit cards and cabling shall be provided and implemented such that automatic switch-over to the back-up communications system shall take place upon failure of the duty communication system. An alarm shall be generated whenever a communications system failure occurs.

H5.1 Environmental Requirements

The equipment shall be required to operate in a variety of locations with a wide variety of environmental conditions. It shall do so independently of external sources of heating, ventilation and air conditioning. All equipment shall be suitable for continuous operation in the environmental conditions for Tamil Nadu State which are given elsewhere within this specification.

(a) Storage
Equipment shall be suitably packaged to meet the requirements of the specification with a storage temperature range of -40°C to +85°C.

(b) Transportation
Equipment shall be transported to site and off-loaded in such a manner as to ensure no damage can be incurred and that it shall be ready for immediate installation.

(c) Normal Operation

All control system equipment, peripherals and outstations/PLCs shall be suitable for operating continuously without degradation of performance over the following temperature and humidity ranges:

- Ambient Temperature +0°C to +40°C
- Humidity 5% to 95% RH

H 6.0 SYSTEM EXPANSION

H 6.1 General

The control system shall be capable of expansion in the areas defined while still meeting the performance criteria as defined within this specification.

H6.2 Software

The control system shall provide facilities to transfer process data in real-time to proprietary software packages (e.g. spreadsheet, database) for further analysis. These programs shall be able to operate in either a multi-tasking mode running on the control computer, or in an independent system connected via a serial link to the control system. The system shall support data exchange to other computer systems in flat ASCII format.

H6.3 Hardware

H6.3.1 Works Operations Centre

The control system shall provide expansion space to increase the Works Operations Centre hardware:

- User workstations, up to a maximum of 4 fixed and 2 portable;
- Printers, up to a maximum of 7;
- Serial data communication links (including multidrop types) up to an additional 4 over and above those specified.

H6.3.2 Field

The control system shall offer easy to use facilities to increase the number of field mounted programmable controllers, scanning I/O units, etc., without taking the control system off-line. The system shall support equipment from a number of site and field unit suppliers and shall include the necessary interface software to enable the easy integration of other (including future) site units.

H6.3.3 System Inputs/Outputs

The control system shall allow I/O expansion for connected site units as follows:

- At least 25% spare I/O channels of each type to be delivered in the basic scope supply which shall enable an immediate increase with no further purchase of hardware;
- At least 25% increase in I/O channels of each type to be achieved by fitting new cards into available card slots;
- At least 25% increase in I/O channels of each type to be achieved by the addition of new I/O cards slots to the system;
- The system shall be able to address and scan the total system I/O defined above without a reduction in performance.

H6.4 Capacity

The installed capacity of the control system shall be greater than that required to meet this specification by the stated amount in the following areas, unless otherwise stated in the tender documents:

- 40% control system computer memory;
- The on line disk shall be of sufficient size to meet the needs specified elsewhere.

For particular requirements for the test regimes to be used to prove the system performance, see the testing and installation section.

H7.0 COMMUNICATIONS

The system shall communicate with outstations via one or more networks. Communications along the outstation network shall incorporate state-of-the-art error-detection schemes to ensure error-free data transmission. The communications protocol shall include repeated attempts at error-free transmissions before a network node is declared as failed. The system shall automatically initiate a ‘health check’ periodically on a failed node which has not been removed from the active node list in an effort to re-establish communications.

Communications network shall be by fibre optic or copper network, as specified.

Communication failure at any one network node shall not affect communications at any other node. Failure of the central processor to communicate with an outstation shall generate a ‘communication failure’ alarm and an alarm log including the outstation name, date and time as a minimum. Repeated alarm events shall not be generated unless error-free communications are re-established and then fail again as described above. Communication system diagonistic software shall allow the interrogation of communication error statistics.

H8.0 CONTROL ROOM FURNITURE

In addition to the control system equipment, the Contractor shall provide furniture to complement or match both the colour and styling of the equipment. Control room furniture shall comply with relevant IEC standards for ergonomic design. Details of the control room furniture shall be submitted to the Engineer for approval.

The Contractor shall provide fabric-covered upholstered swivel-type adjustable arm chairs with casters, a rigid and lockable steel cupboard for the storage of operating and maintenance manuals, drawings, logger paper, charts, disks and the like.

The visual display unit consoles or VDU desk shall incorporate at least one drawer unit with drawers for operators' use and for standard files.

H9.0 TESTING AND INSTALLATION

Various tests outlined in this section supplement testing clauses elsewhere within sections of the Specification. Where any discrepancy or contradiction arises between these various sections of the Specification, the control system testing clauses shall take precedence and supersede those other testing clauses.

H9.1 Factory acceptance test

The Contractor shall conduct a full programme of tests of the control system at the Contractor's testing facility in the presence of the Engineer to verify that all features of the system have been provided, are operating correctly and are in full compliance with the Specification. Unless otherwise specified or agreed by the Engineer, the entire control system shall be assembled and tested together as an integrated system, including all master station equipment, all operator's consoles, all outstations and telemetry equipment including modems, all instrumentation panels and uninterruptible power supplies included in this Specification. The scheduled date for the factory acceptance test shall be as agreed by the Contractor and the Engineer at least four weeks before the test.

Not less than one month before the scheduled factory acceptance test, the Contractor shall submit to the Engineer for approval two copies of a comprehensive manual detailing each test to be conducted. The manual shall include a results form on which the results of each test will be entered, including spaces for numerical values where appropriate and witness signatures.

Not less than 7 days before the scheduled factory acceptance test, the Contractor shall give written notification to the Engineer that a complete dry-run of the factory acceptance test has been performed successfully and that, in the opinion of the Contractor, the system exhibits stable operation and is ready for the formal factory acceptance test.

The factory acceptance test shall be considered successfully completed only when the system has successfully passed all factory tests. The system shall not be delivered to Site until the successful completion of the factory acceptance test is certified by the Engineer or unless otherwise approved by the Engineer. Delay in the delivery of the system due to failure of the factory acceptance test shall not constitute an unavoidable delay. If the system fails the factory acceptance test, the test shall be extended or rescheduled at the discretion of the Engineer.

All hardware to be used in the testing of the system shall have passed an agreed preliminary hardware performance test to ensure known hardware operability before software testing begins.

After successful completion of the factory acceptance test, no software changes shall be made to the system without written authorisation by the Engineer. Any changes to the system which effect the system software documentation, such as input scale modifications or changes to the control logic, shall be entered into the system documentation before delivery of the system to Site.

H9.2 Factory acceptance test documentation

As a minimum, the following information shall be included in the factory acceptance test manual for each test:

- test identification number;
- test name and description;
- list of all equipment to be tested including any special test equipment required;
- description of the test procedure broken down into logical steps;
- description of the expected system response verifying the completion of each logical step;
- space for recording the results of the test and the time and date of the test;
- space for signatures of the Contractor and the Engineer.

In addition, the Contractor shall provide a method for recording and tracing all problems, discrepancies, queries and suggestions regarding the system and software, and for formalised control of any modifications to the system.

H9.3 Factory acceptance test procedures

The scope of the tests shall include the proving of every aspect of hardware and software operation and functions as detailed below.

H9.3.1 Hardware tests

- Verify the correct inventory of hardware including cables and printed circuit boards;
- Demonstrate that all spare-memory, disk-capacity and system-expansion requirements have been met;
- Demonstrate that all input and output expansion requirements have been met, including wiring and signal isolation, and verify that power supplies are capable of supporting the increased load for this expansion;
- Demonstrate all hardware and software diagnostics;
- Verify all power supply voltages are within tolerance;
- Verify proper earth connections and isolation of instrumentation earth for all equipment;
- Demonstrate operation of test simulation and indication equipment and its suitability for adequate functional testing of all system functions.

H9.3.2 Software tests

- Demonstrate the editing of all system parameters including set-points, timers, etc;
- Demonstrate system configuration capabilities including the addition and deletion of input and output points, outstations, and all data base parameters;
- Demonstrate the addition, deletion and modification of mimic displays and report formats;
- Demonstrate modification of the communications network;
- Demonstrate the capabilities of the communications monitoring and diagnostic facilities.

H9.3.3 Functional tests

The functional tests shall verify proper operation of every specified system function as an integrated system. These tests shall be conducted in conjunction with functional tests of instrumentation and control panels as specified elsewhere. All failures or discrepancies found shall be documented in the test manual.

Following a failure of any functional test, should software or hardware modifications be required it shall be the decision of the Engineer whether the factory acceptance test is to continue, re-start or be aborted. If testing is allowed to continue, any changes which are required shall be described in a system-modification document, signed by both Contractor and Engineer and be incorporated into the final factory acceptance test documentation. The failed test shall be re-conducted and the Engineer may require the re-test of functions which may be affected by the modification.

The functional tests shall include, as a minimum, the following:

- Verification of proper scanning and data acquisition from all outstations using the actual communications hardware to be used on-site where possible;
- Demonstration that the system meets the requirements of the Specification for response time and speed of screen update;
- Verification of the accuracy of all analogue input points in the system. The procedure shall include applying the appropriate signal to each analogue input at a minimum of three points within the range of the input, checking for expected numerical results, and verifying appropriate update of related mimic displays. Proper sensing and action by the system to high and low out-of-range inputs shall also be verified;
- Verification of the proper logic sense, pulse accumulation and rate computation where appropriate, of all digital inputs and verifying appropriate update of related mimic displays;
- Verification of all control and sequencing operations and proper operation of all digital and analogue outputs. The procedure shall include simulation of all related process variables for both normal and abnormal conditions, including instrument and component failure, and demonstration of fail-safe response of the system. System outputs shall be indicated with appropriate lamps and indicators;
- Simulation of outstation communications errors and failures and demonstration of error detection and handling, failure detection and handling, and appropriate changes to control actions as designed and specified;

- Verification of fault detection and diagnostics by inducing a sufficient variety of fault conditions in the system to ensure that detection processes and fail-safe operation are adequately tested;
- Demonstration of proper operation of all mimic displays, help pages, reports, operator procedures and historical data accumulation;
- Demonstration of proper operation of all outstations following a simulated master station central processor failure;
- Demonstration of proper operation of all equipment during either a system-wide or isolated power failure, and following power restoration. The procedure shall include the demonstration of battery backup of both master station and outstation for the full length of time specified, and proper operation of power fail, low voltage warning and all associated alarms;
- Where redundant systems are specified, demonstration of switch-over to back-up systems, including automatic switch-over where specified;
- Verification of the accuracy of all calculated variables and parameters;
- Demonstration of the proper operation of all approved changes to the specified system.

H9.3.4 Reliability test

After successful completion of the functional tests a 48-hour continuous run of the system shall be performed. The test shall be passed if no system function is lost or no hardware or software failure occurs. Hardware failure is defined for this test as the loss of a major component such as the computer, an outstation, a VDU or a peripheral device. Non-repetitive mechanical failures of loggers, push-buttons, etc are excluded.

During this test, the system shall be exercised with simulated inputs and conditions in a manner which approximates the on-site operational environment. Unstructured testing by the Engineer shall be included during this test. Upon any system failure during this period, it shall be the decision of the Engineer whether the reliability test is to continue or be aborted. If testing is allowed to continue any changes to the system which are required shall be described in a system-modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final factory acceptance test documentation.

H9.4 Installation

The system shall be delivered to the Site after the factory acceptance test is successfully completed and its completion is approved by the Engineer. Before any item of equipment is delivered to the Site, the Contractor shall satisfy himself that the mounting place and environment are ready for that item and that there are no conditions present which can in any way be damaging to the equipment. If such conditions exist, but it is advantageous to deliver the item to Site, the Contractor may, after approval of the Engineer, provide a store which gives a standard of environmental protection equal to or better than that intended when the Plant is operational and keep the equipment in the store until installation can proceed.

Throughout the period from delivery to Site until the issue of the Taking-over Certificate, the Contractor shall ensure that each item of equipment is safeguarded against any potentially detrimental condition. In particular, equipment doors, covers and the like shall be closed except when work on them is in progress.

As soon as possible after delivery to Site, the Contractor shall inspect each item of equipment for damage and shall report accordingly to the Engineer and carry out any required remedial work to the approval of the Engineer.

The Contractor shall ensure that installation and commissioning of control system equipment is co-ordinated with work in the same area by other trades.

The location at which each item of equipment is installed shall be as shown in approved drawings or as otherwise agreed with the Engineer. Each mounting position shall be chosen to give correct operation of the equipment, ease of operation, reading, maintenance and servicing, freedom from any condition which could have adverse effects and with particular regard to the safety of personnel and plant.

H9.5 Pre-commissioning tests

The Contractor shall perform pre-commissioning, or preliminary, testing of the control system in accordance with that specified for instrumentation. The purpose of pre-commissioning tests is to confirm readiness of the system for commissioning.

The scope of pre-commissioning tests shall be generally as specified for factory acceptance tests but real field inputs and final control elements shall be used wherever practical to provide inputs to the system and to confirm proper outputs. Where this is impractical, simulation signals shall be injected as near as possible to their ultimate sources so as to include in the tests as much of the cabling system as possible.

Each process system shall be set to work under manual control and the system tested to confirm proper operation.

After proper operation of manual control mode has be verified, tests of automatic controls of each process system shall be conducted wherever practical.

H9.6 Commissioning tests

The Contractor shall submit all relevant draft operating manuals for the control system to the Engineer for approval prior to commissioning tests. Any faults or failures of the system detected during the previous tests shall be noted and corrected to the satisfaction of the Engineer before commissioning is allowed to commence.

The control system shall be commissioned in accordance with procedures described elsewhere in this Specification, and subject to routine tests as required by the Engineer.

H9.7 Availability test

As part of commissioning, the control system shall be tested for availability for a continuous period of 14 days. During this period, the system shall perform the normal functions according to the procedures described in the Contractor's documentation.

The system shall have passed the availability test if all major components have been free from fault or failure and exhibit full error-free functionality for 98% of the total duration of the test, unless otherwise agreed by the Engineer. Major components include all master station equipment, outstations, communications facilities and instrument panel components, excluding push-buttons, switches and lamps and any equipment not supplied by the Contractor.

During the availability test, no modifications to the system shall be made by the Contractor without the written approval of the Engineer. Erroneous functioning which requires software modifications or re-configuration to correct, other than set-point or parameter changes, shall constitute a failure of the availability test. Any changes to the system which are required and approved shall be described in a system-modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final test documentation. The test shall be restarted after corrections have been completed.

During the availability test, a minimum of one power failure for each outstation and for the master station shall be simulated. Improper operation during power down or power recovery shall constitute a failure of 1% of the test duration.

During the availability test, a minimum of one failure for each component with redundant back-up unit shall be simulated. Improper switch-over to the back-up unit shall constitute a failure of 1% of the test duration.

If a situation arises during the availability test which renders the system unavailable but which, in the opinion of the Engineer, does not accurately reflect the true system availability, the unavailable period shall be ignored and the test extended for an identical time period.

After the availability test period is complete, if the test objectives have not been met the test shall be extended until the required system availability is achieved over a consecutive 14-day period. If the test is extended in this manner for over 8 weeks, the Engineer, at his discretion, may discontinue the test and the issues be resolved in accordance with contractual terms.

In order to establish that all failures have been satisfactorily repaired no repeat failure shall have occurred within 72 hours of the failure. The test shall be extended if necessary to satisfy this requirement.