



**Ministry Of Water
Sanitation And
Irrigation**



County Water Department of Wajir



Wajir Water and Sewerage
Company (WAJWASCO)

Technical Specifications for Construction, Rehabilitation and Expansion of Groundwater – Based Rural Water Supply Schemes - Batch 1 Schemes in Wajir County Volume 2 of 3

Lot 3: Dadaja Dulla, Tesorai, Haragal, Masalale and Riba

RFB No: *KE-WAJIR-503206-CW-RFB-LOT 3*

Project: *The Horn of Africa Groundwater for Resilience Project, Kenya (P174867)*

Employer: **County Government of Wajir – Wajir Water and Sewerage Company (WAJWASCO)**

Country: **Kenya**

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Preface

This Bidding Document for Procurement of Works has been prepared by Water Sector Trust Fund (Water Fund) and is based on the Standard Bidding Document for Procurement of Works issued by the International Development Association (IDA),¹ dated June 2018.

The Standard Bidding Document for Procurement of Works reflects the structure and the provisions of the Master Document for Procurement of Works issued by the Multilateral Development Banks, except where specific considerations within the World Bank Group have required a change.

1 "Bank" shall mean the World Bank.

Standard Bidding Document

Specification

These specifications cover the construction of the project as shown on the drawings and listed in the Bills of Quantities and shall be read in conjunction with the Contract Documents as listed in Instructions to Contractors.

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TECHNICAL SPECIFICATIONS FOR THE CONSTRUCTION, REHABILITATION AND EXPANSION OF GROUNDWATER – BASED RURAL WATER SUPPLY SCHEMES - BATCH 1 SCHEMES IN WAJIR COUNTY

SECTION 1: PRELIMINARY AND GENERAL

1 GENERAL (PRELIMINARIES)

1.1 Introduction

These specifications cover the construction of the project as shown on the drawings and listed in the Bills of Quantities and shall be read in conjunction with the Contract Documents as listed in Instruction to Contractors.

All references given are intended solely for the convenience of those using the above documents and shall in no way exclude the application of the other clauses in the documents which may, in the opinion of the Engineer have any bearing on the point in question.

The site of works shall be the area where the permanent works and the temporary works are to be executed by the Contractor under the Contract. including, quarries, borrow pits, spoil areas, access roads and deviations, Contractor's installations, Storage areas, Camp site, Engineer's offices, laboratories and accommodation, shown on the drawings or established specifically for the Contract with the approval of the Engineer.

1.2 General Scope of Works for Wajir Lot III Project

- i. **Location of Site - Lot III comprises the following Five Rural Water Supply Schemes (RWSS);**
 - Dadaja Bulla RWSS in Wajir South Sub- County.
 - Tesorai RWSS in Wajir South Sub-County.
 - Haragal RWSS in Tarbaj Sub-County.
 - Masalale RWSS in Eldas Sub-County.
 - Riba RWSS in Wajir East Sub-County.
- ii. **Boreholes, Pumps and Power Supply** – Typically, the works shall cover;
 - Works for the rehabilitation, installation and testing of the boreholes, where necessary, as detailed in the Bills of Quantities.
 - Supply and installation of various ratings Submersible Multistage centrifugal borehole stainless steel Pumps and Motor, continuously rated and capable of pumping the required flow of water against the total head as necessary. The pump shall have in-built non-return valve, tail strainer, cable guard, etc. The pump to be supplied complete with water tight cable splicing kit and connection ripple. The contractor to attach catalogues and 5years minimum Warranty for the pumps model proposed.
 - Supply and installation of Borehole CTD-Diver-D128x with the capacity to do Data Acquisition and Monitoring for Water Levels, Temperature, PH, Conductivity and Pressure within the Boreholes. The Specifications for the Diver; Length 135mm, Diameter 22mm, weight 100g, Housing Stainless steel 316L, Pressure sensor- piezzo resistive ceramic, conductivity sensor -Platinum electrode, Battery life of up to 10 years, Sample interval of 1 sec to 99hrs, Sample method as fixed interval or event

dependent, Communication-RS232 2G, 3G, 4G/LTE. Temperature range - -20 to 80 degrees and Conductivity 0 to 30 or 12mS/cm2

- Supply and installation of Diver -LINK- DN4xx with data logging and transmission, compact enclosure, Universal SIM card, Battery Operated, Internal and external Antenna, Barometric data logger, IP67 rating magnet operated, Bluetooth smart enabled, over-the-air firmware update and compatible with all Diver data loggers and cables. The Power supply battery life of 5 or more years 2 D-cells with option of solar or mains 3 to 16V, 500mA. Capacity to transfer Diver data to a secure FTP servers, send data to emails, notifications, warnings, thresholds, Alarms, Incremental data upload. The Configurations to be Auto and remote control through HUB401-403 Diver-Hub web portal
- Supply, install, test and commission of an array of solar with varying specifications but generally 550W solar panels, Monocrystalline Silicon PV with 25 years warranty plus the solar support structures. The power output of the modules should generate enough power such that the power output at the connection point to the distribution board is not less than 15kW-35kW (depending on the scheme) on a bright sunny day at midday taking into account the system losses. Where necessary, rehabilitation and maintenance of existing, usable solar panels has been provided for.
- Supply, Deliver, Install, Test and Commission new various ratings Power Back-up Generators. A provision has also been made for Maintenance of Generator Engine, Rewiring or replacement of the Alternator, Checking and repair of cooling system, fuel systems, filters, mountings, exhaust and general repairs of the existing Generators, where necessary.
- Summary of Lot 3 Schemes Borehole Details

| Borehole | Coordinates | | Yield m ³ /h | Safe Yield m ³ /h | Pumping Head (m) | Solar Arrays | Generator KVA |
|---------------------------|-------------|------------|----------------------------|------------------------------------|---------------------|-----------------|------------------|
| | Lat.(deg) | Long (deg) | | | | | |
| Tesorai BH 1 | 0.930181° | 39.892946° | 18 | 12.6 | 185 | 0 | 35 |
| Tesorai Community BH | 0.925004° | 39.891000° | 5.55 | 3.885 | 185 | 20 | 30 |
| Haragal Main BH | 2.361193° | 39.873927° | 10 | 7 | 185 | 12 | 30 |
| Masalale BH 1 | 2.543456° | 39.563709° | 14 | 9.8 | 208 | 30 | 30 |
| Masalale BH 2 | 2.543227° | 39.562384° | 14 | 9.8 | 208 | 30 | 30 |
| Dadaja Bulla Main BH1 | 0.536581° | 40.873472° | 10 | 7 | 146 | 8 | 30 |
| Dadaja Bulla Orahey BH | 0.528498° | 40.877840° | 18 | 12.6 | 180 | 12 | 30 |
| Dadaja Bulla Inshallah BH | 0.527700° | 40.883330° | 18 | 12.6 | 220 | 60 | 40 |
| Riba BH 1 | 1.870768° | 40.622455° | 10 | 7 | 185 | 0 | 30 |
| Riba BH 2 | 1.888874° | 40.639358° | 10 | 7 | 185 | 0 | 30 |

iii. Central Storage Tanks and Community Water Points (CWPs)

The works shall cover;

- Supply of all materials, tools and equipment and installation of a tank tower of 15 or 18 meters high, ladder with ladder guard inside ladder, safety hand rails, columns, bracings

and necessary appurtenances as per the detailed drawings or as approved by the Engineer.

- Supply of all materials, tools and equipment and erection of appropriate size (as per Bills of Quantities) steel sectional tank of the Braithwaite type or equally approved standard include walkway with walkway guard, water level gauge and tank cover, provision of air vent, support rails, inlets and outlet for pipes etc., for complete installation.
- Rehabilitation of the existing steel elevated tanks, if any, to the extent captured in the Bills of Quantities.
- The construction and equipping of two types of water kiosks – Type 1 (with overhead tank) and Type 2 (without overhead tank) as per the drawings and the Bills of Quantities.
- The Summary of the provisions are as per the table below;

| Scheme | Water Kiosks | Elevated Steel Tanks | |
|--------------|--------------|-----------------------|--------|
| | | New | Rehab. |
| Tesorai | 10 | 1Nr 50m ³ | |
| Dadaja Bulla | 8 | 1Nr 100m ³ | |
| Riba | 8 | 2Nr 50m ³ | |
| Haragal | 10Nr. | 1Nr 75m ³ | |
| Masalale | 8Nr. | 1Nr 50m ³ | |

iv. Institutional Water Points (Elevated Plastic Tanks)

These works shall cover;

- Fabrication, supply and installation at site a metal tower, 2.5m x 2.5, 3 m high from ground with a platform to receive the tank, walkway, rail guard to prevent the tank from falling and cat ladder. Rate to include transport of all materials to site, fabricating, erecting and overheads. Using 100mm X 100mm x4mm RHS and 70mm x 70mm x 4mm RSA for the internal member.
- Supply plastic tank of capacity 10,000ltrs. Rate to include transport to site and overheads.
- Construction of a masonry lockable inspection chambers at the tank base 1000mm by 1000mm by 1000mm.
- The Summary of the provisions are as per the table below;

| Scheme | Elevated Plastic Tanks |
|--------------|------------------------|
| | 10m ³ |
| Tesorai | 7Nr |
| Dadaja Bulla | 6Nr |
| Riba | 6Nr |
| Haragal | 5Nr |
| Masalale | 5Nr |

v. **Livestock Water Storage and Points (Water Troughs)**

For livestock water storage, the works shall cover the supply of all necessary materials and the construction or rehabilitation of a 50m³ ground masonry storage tank. The tank shall include all structural and plumbing components as detailed in the drawings. Construction works shall encompass site clearing, setting out, excavation, foundation works, masonry walling, plastering, inlet and outlet pipework, as well as provision of a concrete cover slab or roof as specified.

Where rehabilitation is required, the works shall include demolition of damaged sections, structural repairs, re-plastering, waterproofing, and replacement or reconnection of pipework and fittings as directed by the Engineer. All works shall be executed in accordance with the provided drawings and the corresponding Bills of Quantities.

For water troughs, the works shall cover the supply of all necessary materials and the construction of a cattle/camel and shoats trough. The troughs should include all structural and plumbing components as per the drawings. The area around the trough should be rip-rapped and sloped as shown in the drawings. The construction shall include all required excavations, setting out, and installation works.

The works shall be carried out strictly in accordance with the provided drawings and the corresponding Bills of Quantities, taking into account the differences between the cattle/camel trough and the shoats' trough and rehabilitation works of troughs as indicated in the drawings and BoQs.

The Summary of the provisions are as per the table below;

| Scheme | Ground Masonry Tanks | Cattle Troughs | Shoat Troughs | Rehabilitation of WTs |
|---------------|--|-----------------------|----------------------|------------------------------|
| Tesorai | Construction of a new 1Nr. GMT | 4 | 4 | |
| Dadaja Bulla | Construction of 1Nr. New GMT and rehabilitation of 1Nr. tank | 3 | 4 | |
| Riba | Rehabilitation of 3Nr. GMT | 4 | 1 | 7 |
| Haragal | Rehabilitation of 1Nr. GMT | 2 | 2 | |
| Masalale | Construction of 1Nr. New GMT | 1 | 2 | |

vi. **Pipe Works**

The works shall cover the supply of all necessary materials and the construction and/or replacement of HDPE pipelines of varying diameters. The works shall include all required excavation, pipe laying, jointing, anchoring, thrust blocks (where applicable), backfilling, and compaction in accordance with the design drawings and specifications. The contractor shall ensure proper alignment, gradient, and support for the pipelines throughout the network.

Where pipeline replacement is involved, the works shall include removal of the existing pipes, careful handling of connections and fittings, and restoration of any disturbed infrastructure or surroundings to their original state or better.

The works shall be carried out strictly in accordance with the provided drawings and the corresponding Bills of Quantities, taking into account variations in pipe sizes, pressure class, and installation details as indicated in the design and technical specifications.

The Summary of the provisions are as per the table below;

| Scheme | Pipe Diameter (mm) | PN | Length (m) | Total length (m) |
|--------------|----------------------|-----|------------|------------------|
| Tesorai | Rising Main | | | 6433 |
| | 25 | 10 | 20 | |
| | 32 | 10 | 10 | |
| | 50 | 10 | 21 | |
| | 63 | 10 | 566 | |
| | Gravity Main | | | |
| | 25 | 10 | 358 | |
| | 32 | 10 | 519 | |
| | 40 | 10 | 272 | |
| | 50 | 10 | 238 | |
| | 90 | 10 | 110 | |
| | Distribution Network | | | |
| | 25 | 10 | 1845 | |
| | 32 | 10 | 463 | |
| | 40 | 10 | 301 | |
| | 50 | 10 | 1418 | |
| 63 | 10 | 292 | | |
| Dadaja Bulla | Rising Main | | | 13564 |
| | 25 | 10 | 29 | |
| | 32 | 10 | 171 | |
| | 63 | 10 | 55 | |
| | 75 | 10 | 451 | |
| | 90 | 10 | 958 | |
| | 125 | 10 | 486 | |
| | Gravity Main | | | |
| | 25 | 10 | 1,366 | |
| | 40 | 10 | 203 | |
| | 50 | 10 | 417 | |
| | 63 | 10 | 35 | |
| | 75 | 10 | 63 | |
| | 90 | 10 | 113 | |
| | 110 | 10 | 185 | |
| | 125 | 10 | 87 | |
| | Distribution Network | | | |
| | 25 | 10 | 5228 | |
| | 32 | 10 | 291 | |
| | 40 | 10 | 2033 | |
| 50 | 10 | 937 | | |
| 63 | 10 | 456 | | |
| Riba | Rising Main | | | 9452 |
| | 63 | 10 | 40 | |
| | Gravity Main | | | |
| | 25 | 10 | 139 | |
| | 32 | 10 | 422 | |
| | 40 | 10 | 713 | |
| | 50 | 10 | 40 | |
| | 75 | 10 | 251 | |
| | 90 | 10 | 546 | |
| | Distribution Network | | | |

| Scheme | Pipe Diameter (mm) | PN | Length (m) | Total length (m) |
|--------------|----------------------|-----|------------|------------------|
| | 25 | 10 | 1,330 | |
| | 32 | 10 | 1,263 | |
| | 40 | 10 | 1,990 | |
| | 50 | 10 | 653 | |
| | 63 | 10 | 31 | |
| | 75 | 10 | 148 | |
| | 90 | 10 | 74 | |
| | 110 | 10 | 1,812 | |
| Haragal | Rising Main | | | 4178 |
| | 50 | 10 | 3 | |
| | 63 | 10 | 218 | |
| | Gravity Main | | | |
| | 32 | 10 | 555 | |
| | 40 | 10 | 1025 | |
| | 63 | 10 | 153 | |
| | 75 | 10 | 550 | |
| | 90 | 10 | 278 | |
| | 110 | 10 | 102 | |
| | Distribution Network | | | |
| | 32 | 10 | 61 | |
| 40 | 10 | 767 | | |
| 50 | 10 | 466 | | |
| Masalale | Rising Main | | | 6090 |
| | 40 | 10 | 6 | |
| | 50 | 10 | 12 | |
| | 63 | 10 | 143 | |
| | 90 | 10 | 1,217 | |
| | Gravity Main | | | |
| | 40 | 10 | 450 | |
| | 50 | 10 | 335 | |
| | 63 | 10 | 83 | |
| | 110 | 10 | 2,126 | |
| | Distribution Network | | | |
| | 32 | 10 | 393 | |
| | 40 | 10 | 852 | |
| | 50 | 10 | 237 | |
| | 63 | 10 | 236 | |
| | 25 | 10 | 9 | |
| | 32 | 10 | 333 | |
| | 40 | 10 | 537 | |
| | Gravity Main | | | |
| | 32 | 10 | 296 | |
| | 50 | 10 | 112 | |
| | 63 | 10 | 571 | |
| | Distribution Network | | | |
| | 25 | 10 | 157 | |
| | 32 | 10 | 349 | |
| | 40 | 10 | 164 | |
| Total Length | | | | 39,717 |

vii. Water Treatment

Chlorination: The works shall involve the supply, installation, and commissioning of a complete inline chlorination system, designed for a flow rate of up to 30 m³/hr, comprising a high-capacity Dosatron D8RE3000 proportional dosing pump (0.2–2% adjustable dosing), 100-litre GRP dosing tank with outlet and stand, suction hose kit with integrated filter and

non-return valve, inline pressure regulator (5–6 bar), 2-inch non-return valve and Y-strainer, all necessary fittings and accessories, including installation, testing, and operator training.

The installation shall also include construction of the housing or protective structure, electrical works (where applicable), and operator access provisions. All works shall be carried out strictly in accordance with the provided drawings, manufacturer's installation guidelines, and the Bills of Quantities. The contractor shall ensure correct calibration of dosing equipment and undertake testing and commissioning of the system upon completion.

Reverse Osmosis: In these five schemes, the works shall cover the supply, installation, and commissioning of a 1m³/hr water treatment plant consisting of a pre-treatment (ultrafiltration) unit and a reverse osmosis unit designed for a maximum TDS of 5,000 PPM. The scope shall include all associated pipework, electrical works, brine discharge systems, and structural supports.

The installation shall also provide for operator access, adequate maintenance space, and protection from environmental elements, including a housing structure (plant room) as specified in the drawings and the Bills of Quantities. Brine discharge shall be managed through appropriate infrastructure namely evaporation ponds unless directed otherwise by the Engineer.

In addition, the contractor/supplier shall be required to provide operations and maintenance (O&M) services for the reverse osmosis systems for a period of thirty-six (36) months, commencing from the date of operation or as instructed by the Engineer. The O&M services shall be undertaken in accordance with the technical specifications herein outlined in section 5, and as detailed in the Bills of Quantities and related project documents.

The works shall be executed strictly in accordance with the design drawings where applicable, manufacturer's specifications, and the Bills of Quantities, ensuring proper assembly, testing, water quality verification, and full commissioning of the system.

viii. Ancillary Works

The works shall cover the supply of all necessary materials and the construction or rehabilitation of ancillary facilities associated with the water supply system. These works shall include, but are not limited to, the erection or part replacement of a perimeter fence using chain-link mesh supported on concrete posts, installation of a vehicular gate and a pedestrian gate, and any associated access control and yard lighting infrastructure.

Additionally, the works shall include the construction or rehabilitation of the operator's building, incorporating all necessary masonry, roofing, finishes, plumbing, and electrical components as shown in the drawings and the Bills of Quantities. Where applicable, construction of a guard house shall be undertaken, including associated finishes, fittings, and provisions for visibility and security.

The works shall also include the construction of pit latrines as per the drawings and, where required, the construction or rehabilitation of generator houses complete with all structural,

mechanical, and electrical provisions necessary to accommodate power units safely and securely.

Where applicable, the works shall include the construction or upgrading of a booster station, consisting of pump housing, installation of surface booster pumps and associated pipework, control panels, storage tanks (where specified), and electrical connections. The booster station shall be constructed to ensure safe, efficient, and reliable operation in line with the system's hydraulic design and shall include reasonable access for operation and maintenance.

All works shall be carried out strictly in accordance with the provided design drawings and the corresponding Bills of Quantities.

1.3 Existing Water and Sanitation Services

In Wajir County, water supply is largely rural in nature, with the exception of Wajir town and its immediate surroundings, typically within a 20 km radius, which are served by the Wajir Water and Sewerage Company (WAJWASCO). Beyond this urban zone, the county relies heavily on decentralized rural water systems.

Most rural residents access water through boreholes and shallow wells, which are commonly managed by WAJWASCO, Community Based outfits, religious outfits or individuals (private sources). Improved sources in the county include wells, boreholes, few rainwater harvesting systems, and piped networks to households where infrastructure exists. Unimproved sources, still widely used in certain areas, include open water pans, unprotected wells and springs, seasonal rivers (laggas), and informal water vendors.

Distance to water points varies widely across the county. On average, residents in rural areas travel between 5 and 10 kilometres to fetch water. However, in more remote locations the distance can extend to between 10 and 20 kilometers. In some market centers and settlements, community-based initiatives have managed to pipe water closer to households, thus easing access.

Due to Wajir's arid climate and unreliable rainfall patterns, surface water sources are rare and short-lived. Consequently, groundwater remains the dominant and most reliable source of water for domestic use, livestock, and institutional needs across the county.

1.4 Extent of Contract

The works specified under this contract shall include all permanent and temporary works, works of every kind (other than Contractor's Equipment) required on Site for the execution and completion of the Permanent Works and the remedying of any defects to the extent as

shown on the drawings and these specifications and any other instructions that may be issued by the Engineer from time to time whether specifically mentioned or not in the clauses of this specification.

1.5 Contract Drawings

Two sets of full-sized drawings will be issued to the Contractor, at the commencement of the Contract to facilitate the construction of the Works in complete conformity with and to the full intent of the Contract. Additional copies of these drawings that may be required by the Contractor can be obtained from the Engineer; in which case the Contractor will be required to reimburse the cost of producing such additional copies.

The Engineer may from time to time in order to enable the satisfactory completion of the Works, revise, amend, or supersede any of these drawings. It shall be the Contractor's responsibility to construct all Works in conformity with the latest revision, amendment or superseding drawings, provided that the Engineer has given to the Contractor in writing such reasonable prior notices of intention to revise, amend or supersede as the nature of the intended change requires and the relevant drawings have been issued to the Contractor.

The Contractor may be required to demolish, alter and/or correctly rebuild at his own expense any part of the Works not in conformity with the drawings currently forming part of the Contract at the time of construction of such Works, provided always that such current drawings had previously been issued to him.

1.6 Standards

In the Specifications, Bills of Quantities, and Drawings reference has been made to relevant British Standard Specifications and Codes of Practice – to which the materials and workmanship should comply with. However, the materials and workmanship complying with equivalent Kenya Bureau of Standards (K.E.B.S.) or International Standards Organization (ISO.), for that particular material or workmanship will also be acceptable. Mixture of different Standards in one trade will not be allowed.

The Contractor may propose that the materials and workmanship be defined in accordance with the requirements of other equivalent Standards and the Contractor may execute the works in accordance with such other Standards as may be approved by the Engineer. A copy of the Standard, together with its translation into the English language if the Standard is in another language, shall be submitted to the Engineer with any request that it be adopted.

Where the dimension in one standard does not completely correspond to the dimension of the other standard, which is being used for construction of works, determination of the Engineer will be sought and any decision given by the Engineer will be final and binding upon the Contractor.

1.7 Programme for the Execution of Works

In accordance with Sub clause 8.3 of the conditions of contract, the Contractor upon receiving Engineer's order to commence shall within 28 days draw up a working programme setting out order and method in which the works are to be carried out with appropriate dates thereof, together with delivery dates for materials. The Contractor shall together with his work programme supply an expenditure chart showing monthly anticipated expenditure.

If at any time it should appear to the Engineer that the actual progress of the Works does not conform to the programme referred to above, the Contractor shall produce, at the request of the Engineer, a revised programme showing the modifications to the approved programme necessary to ensure completion of the Works within the time for completion as defined in sub clause 8.2 of the Conditions of Contract.

In addition, the Contractor shall extract from the main program and provide a 90 days' program showing works he intends to execute within every 90-day period and submit the program within the first week of each quarter.

The programme shall be deemed to have taken into account normal variations in climatic conditions to provide for completion of the works in the order and within the times specified therein.

The various operations pertaining to the Works shall be carried out in such a progressive sequence as well as will achieve a continuous and consecutive output of fully complete pipeline works inclusive of all appurtenances, treatment plants and all installations within the time limits specified in the Contract. Generally, the Contractor shall progress continuously without leaving any isolated section incomplete, provided that the land upon which the works are to be constructed has been acquired in the entirety and the encumbrances and services thereon removed.

The Contractor shall carry out the Contract in accordance with the programme agreed with the Engineer, but he shall in no manner be relieved by the Engineer's approval of the programme of his obligations to complete the Works in the prescribed order and by the prescribed completion date and he shall from time to time review his progress and make such amendment to his rate of executions of the works as may be necessary to fulfil these obligations.

Once the proposed programme is approved by the Engineer the Contractor shall not depart from the programme without the written consent of the Engineer.

In the event of unforeseen difficulties or disturbances arising, which force the Contractor to depart from the approved Programme of Works, he shall advise the Engineer in writing of such occurrences without delay and submit proposals for any necessary remedial measures, for which he shall obtain the Engineer's approval before putting such measures into effect.

The Contractor shall prepare the Programme in a CPM format and it shall include but not limited to the following requirements: The CPM program shall include as a minimum but not be limited to the following categories:

- i. Preparatory Works.

- ii. Engineering services and project management.
- iii. Manpower, equipment and machineries required for the execution of each task.
- iv. Procurement of goods.
- v. Construction works.
- vi. Operation and maintenance work.
- vii. Demolish, disconnect, dismantle and abandonment existing facilities.
- viii. Quality assurance program.
- ix. Safety precautions for the work; and
- x. Required safety equipment and materials which shall be used in conducting the work.

The Contractor shall submit the critical path management (CPM) schedule with details (colour print, (A1) size paper) in two (2) originals copies and two (2) compact discs illustrating progress of contract works for the review and comment of the Engineer.

The CPM program shall be revised and periodically updated as required by the Engineer and to his satisfaction.

The CPM program shall include but not be limited to the following detailed plans and shall be subject to Engineer review and comment:

- i. Detailed plan of management progress works such as reports, submittals, manpower categories, inspections requirements, forms and all other works specified in the contract requirements.
- ii. Detailed plan for mechanical, electrical, instrumental and civil works required by the Contract showing dates of start and completion, equipment, tools and materials needed, pumps, safety equipment, dewatering system, heavy duty mobile equipment or machinery to carry out the works, techniques, methods and procedures of executing works to the satisfaction of the Engineer as specified in the contract documents.
- iii. Detailed plan for provision, installation, test, commissioning and maintenance of preventive maintenance proposed by the Contractor and other related required works to the satisfaction of the Engineer as specified in the contract documents.
- iv. Detailed plan for maintenance and painting works of existing designated equipment, pumps, buildings, panels, substations and other related required works as specified in the contract documents.
- v. Detailed plan of rehabilitation of soil and other related works as specified in this Technical Specification.
- vi. Detailed plan of clearing the sites, landscaping, removal of all debris, waste and surplus materials off the sites. All cleaning work shall be to the Engineer's satisfaction.
- vii. Detailed safety plans, equipment and materials that shall be used in conducting the Works in accordance to specifications and standards of government regulations; and
- viii. Details of staff categories experience and curriculum vitae of all Contractor's staff. For labourers, the Contractor's may submit only a list of their names.

1.8 Method of Construction

The Contractor shall submit to the Engineer not later than 28 days from the date of award of the Contract a general description of his proposed arrangement and method for execution of the works, including inter alia temporary offices, buildings, access roads, deviations, construction plants and its intended production output, working shift arrangements, power arrangements, supply of materials, stone crushing, aggregates production and storage, cement handling, pipe handling and storage, Concrete mixing and handling, method of excavation, dealing with water, testing methods and facilities.

During execution of the works, the Contractor shall also submit to the engineer full and detailed particulars of any proposed amendments to the arrangement and method submitted in accordance with the foregoing.

In addition to providing a step-by-step description of the work (in sequential order) method statements shall also clarify the following:

- i. Scope of works covered
- ii. References (procedures or standards)
- iii. Subcontractors utilized
- iv. Products required
- v. Tools, equipment and machinery required
- vi. Plan of progress works, starting date of the activities and the Period activities to be completed
- vii. Personnel required and designated responsibilities
- viii. Safety Hazards and Precautions to be taken
- ix. Quality Control Measures
- x. Procedure (step by step sequence of work)

1.9 Normal Working Hours

The Engineer's Normal working hours shall be Monday to Friday 8.00 a.m. to 5.00 p.m. and Saturday 8am to 1pm. with all Public Holidays set aside as required. If the Contractor wishes to execute permanent work outside these hours, he shall obtain a written permission of the Engineer at least one full working day in advance to enable the engineer to make provision for supervision of such work.

1.10 Notice of Operations

No operation shall be carried out without full and complete notice having been given to the Engineer by the Contractor sufficiently in advance of the time of the operation to enable the Engineer to make arrangements as he may deem necessary for its inspection and checking.

The Contractor shall give the Engineer not less than 1 full working days' notice in writing of his intention to set out or give levels for any part of the works in order that arrangements may be made for checking.

1.11 Substantial (Practical) Completion

Substantial or Practical Completion of Works is to be understood as a state of completion, which leaves out only minor outstanding items that can be readily completed within a period of less than 1 month without interfering with the normal operation of the Works.

The work will not be considered as substantially or practically completed without the works being capable of being used by the Employer in accordance with the purpose of the works.

1.12 Nominated Sub-Contractors and Nominated Suppliers

The Contractor shall be responsible for Nominated Sub-Contractors in every respect. In particular, it shall be the Contractor's responsibility to ensure that each Sub-Contractor commences and completes the work in a manner so as to conform to the working programme, as specified above.

Sub-Contractors and Suppliers in the project area shall be given preference in sub-contracts as far as they meet the requirements for such sub-contracts.

It is also the responsibility of the contractor to ensure a satisfactory progress of the works and to ensure that the works are completed to a standard satisfactory to the Engineer.

The Contractor shall accept liability for and bear the cost of General and Specified Attendance on Nominated Sub-contractors which shall be deemed to include for: -

- i. Allowing the use of standing scaffolding, providing special scaffolding, maintenance and alteration of all scaffolding, retention of all scaffolding until such time as all relevant Sub-Contractor's works are complete and removal of all scaffolding on completion.
- ii. Providing equipment and labour for unloading and hoisting Sub-Contractor's materials.
- iii. Providing space for office accommodation, and for storage of plant and materials: allowing use of sanitary accommodation; the supply of all necessary water, power, lighting and watching and clearing away all rubbish.

Before placing any orders with nominated Sub-Contractors or nominated Suppliers, the Contractor should enter into an agreement with the nominated Sub-Contractor/nominated Suppliers to ensure that the conditions and delivery of materials to site comply with the Conditions of Contract and the working program.

Particular clause should be inserted in the agreement with the nominated Suppliers ensuring the validity of the rates for the supply of materials as per the delivery schedule.

Nominated Suppliers who are unable to meet the delivery schedule will not be given allowance for any increases in prices incurred after the delivery time agreed in the delivery schedule.

1.13 Entry upon Land, Working Site and Adjoining Lands

The Employer shall provide land, rights-of-way and way-leaves for the Permanent Works specified in the contract only.

The Employer shall make available free of charge to the Contractor all land on, under or through which the permanent works are to be executed or carried out all as indicated in the book Drawings or as detailed in the Specifications. Such land shall exclude land required by the Contractor for his own camps, Borrow sites, offices, houses, temporary works or any other purpose.

The Contractor shall give notice to the Engineer at least 30 days before he wishes to enter on to the land required to carry out the permanent works under the Contract. The Contractor shall not enter on to any land or commence any operations until such time as he receives formal confirmation from the Engineer that all necessary compensation formalities have been completed and that permission has been obtained from the land owner to enter the land and commence operations. Should the Contractor enter on to any land and commence operations without first obtaining this confirmation, he shall be liable in whole or in part, at the sole discretion of the Engineer, for all additional costs and/or legal charges which might arise there-from.

The Contractor shall on his own accord obtain rights of admission, and rights of using all other areas which are necessary for storing and manufacturing or for setting up site offices and Resident Engineer's office or whatsoever will be necessary including borrow sites. No separate payment will be made to the Contractor on account of these items and the Contractor must make due allowance for them in his rates.

The Contractor shall take care to prevent injury, damage and trespass on lands, fences and other properties near and adjacent to the works and must in this connection make all necessary arrangements with adjoining landowners, or in the case of Government Property with officers appointed for this purpose, and ensure the workmen's observance of all Government rules and Ordinances regarding game protection and other matters and provide, maintain and clear away on completion of the Works all temporary fencing which may be required for execution of the Works.

Before completion of the Works the Contractor must make good or compensate any such injury, damage or trespass on lands, fences and other properties which have not otherwise been provided for in the Contract.

1.14 Preservation of Survey Beacons

Ordinance Survey Beacons, Benchmarks, etc., on or around the site of the Works shall not be disturbed unless permission has been obtained by the Engineer from the Survey of Kenya.

In the event of unauthorized disturbance of such beacons, benchmarks, etc., in the course of the Works being carried out the Contractor shall be responsible for reporting same to the Engineer and the Survey of Kenya and for payment of any fees due to said Survey of Kenya

for replacement of such disturbed beacons, benchmarks, etc. The Contractor shall not replace such disturbed beacons benchmarks, etc. on his own accord.

1.15 Relocation of Existing Services

Drains, pipes, cables and similar services encountered in the course of the Works shall be guarded from damage by the Contractor at his own costs to safe guard a continued uninterrupted use to the satisfaction of the owners thereof, and the Contractor shall not store materials or otherwise occupy any part of the site in a manner likely to hinder the operation of such services.

If the interests of the Works shall, in the opinion of the Engineer, so require, the Contractor shall on the Engineer's direction arrange for the construction of permanent or temporary diversions of the said drains etc., together with reinstatement, if temporary, by the respective Department, Bodies, Corporations or Authorities and, the cost of such works or diversions including reinstatement shall be charged against the appropriate Provisional Sum provided in the Bills of Quantities.

It is the responsibility of the Contractor to inform the Engineer immediately any existing service is exposed.

1.16 Damage to Existing Services

The Contractor shall be held liable for all damage and interference to mains and pipes, to electric cables or lines of any kind either above or below ground caused by him or his Sub-contractors in execution of the Works, whether such services are located on the Contract Drawings or not. The Contractor must make good or report to the appropriate authorities the same without delay and do any further work considered by the Engineer or owner.

If the Contractor fails to reinstate the damaged services within the time considered as reasonable by the Engineer's Representative, then the Engineer's Representative shall be empowered to get the damaged services reinstated by any other contractor and charges thereof shall be deducted from any money due to the Contractor.

1.17 Temporary Roads and Traffic Control

The Contractor shall provide and maintain all temporary roads, bridges and other works to maintain free and efficient access to services affected by Construction of permanent works, the cost of necessary temporary traffic control signs, barricades, beacons, flagmen, lighting and watching required for the normal control of traffic. No payment shall be made for compliance of this item.

1.18 Use of Public Roads

Where a road used by the Contractor for delivery of any material used in the works is closed under Section 71 of the Traffic Ordinance Act 1962, the Contractor shall obey such closure order and use alternative roads.

The Contractor shall keep all roads used by his equipment and project vehicles in well maintained condition including watering and periodic gravelling as may be instructed by the Engineer from time to time. The items shall be provided in the Bills of quantities and the rate shall include watering, periodic grading, temporary traffic control, traffic signs, barricades, flagmen, lighting and watching required for control of normal control of traffic.

1.19 Road Crossing and Traffic Control

Wherever the water pipeline is crossing the classified roads, the Contractor will contact the relevant authorities well in advance and obtain necessary permission to dig across the road in accordance with the requirement of the authorities concerned and shall pay any royalties connected with this work, and the Contractor will provide temporary detour road together with any warning signs necessary. There will be no separate payment for this and cost of all expenses connected with road and railway crossing for which no separate items have been included in Bills of Quantities is deemed to have been covered by the unit rates included in the Bills of Quantities.

1.20 Protection from Water

Unless otherwise mentioned the Contractor shall keep the whole of the Works free from water and allow in his rates for all dams, coffer dams, pumping, piling, shoring, temporary drains, sumps, etc. necessary for this purpose and shall make good at his own costs all damage caused thereby.

1.21 Weather Conditions

The Contractor shall be deemed to take into account all normal weather conditions when preparing his tender and he shall not be entitled for extra payment by the reason of the occurrence or effect of high winds, excessive rainfall, temperature or any other meteorological phenomena occurring during normal seasons in Kenya.

1.22 Protection from Weather

All materials shall be stored on site in a manner approved by the Engineer's Representative and the Contractor shall carefully protect from the weather all works and materials which may be affected thereby.

No separate payment will be made for this and the Contractor will allow in his rates for this.

1.23 Explosives and Blasting

For works requiring the use of explosives, the Contractor shall employ men experienced in blasting, and these men must be in possession of a current blasting certificate. The purchase, transport, storage and use of explosives shall be carried out in accordance with the most recent explosives Ordinance and Rules issued by the Government of Kenya and the Contractor shall allow in his rates for excavation and quarrying for all expenses incurred in meeting these requirements, including the provision of suitable stores. Blasting operations shall be carried out with as little interference as possible to traffic or persons.

In all cases permission from the Engineer must be obtained before commencing any blasting operation. Such approval shall not relieve the Contractor from his responsibility for the damage of the works and adjoining or adjacent structures, roads, places and things, injury, loss, inconveniences and accidents to persons, animals and property consequent on the use of such explosives. The Contractor shall be entirely liable for any accident which shall occur and shall save the employer harmless and indemnified from all claims arising therefrom.

If, in the opinion of the Engineer, blasting would be dangerous to persons or property, or it is carried out in a reckless manner, the Engineer can prohibit any further use of explosives without entitling the Contractor to any extension of time occasioned by corresponding delays.

1.24 Liaison with Police and Labour office

The Contractor shall keep himself in close contact with the Police, Labour Officers and other officials of the areas concerned regarding their requirements in the control of workmen, passage through townships, or other matters and shall provide all assistance and/or facilities which may be required by such officials in execution of their duties in connection with the Works.

Any instruction given by the Traffic Police concerning fencing off of open trenches or other excavations must be followed explicitly.

1.25 Provision of Water

The Contractor shall provide water for use in the Works. He shall supply all hydrants, hose, cocks, vessels and appliances necessary for the distribution thereof and shall provide pumps, tanks, carts, vessels and appliances, transport and labour when and wherever it is necessary for water to be carted for use at the Works. All water used in connection with the Works shall if possible be obtained from a public water supply and the Contractor shall make all necessary arrangements and pay all the charges for connections to main and for water used. No separate payment will be made for this and the Contractor will allow in his rates for this.

1.26 Temporary Lighting and Power

The Contractor shall provide all artificial lighting and power for use on the Works, including all Sub-Contractors' and Specialists' requirements and including all temporary connections, wiring, fittings, etc., and clear away on completion. The Contractor shall pay all fees and

charges and obtain all permits in connection therewith. No separate payment will be made for this and the Contractor will allow in his rates for this.

1.27 Sanitation

The Contractor shall provide and maintain sufficient sanitary conveniences for all operatives and site staff engaged on the work. These shall be in accordance with any requirements and applicable regulations and subject to the approval of the Engineer. The ground shall be thoroughly disinfected at the end of the Contract.

The Contractor shall ensure that all operatives and site staff are aware that the sanitary conveniences must be used by all personnel, and the Engineer reserves the right to require the dismissal of any person committing a nuisance on or about the site by failing to use the conveniences provided.

The Medical Officer of Health or other Sanitary Authority shall be informed when Works are about to commence. The instructions of the Medical Officer or other Sanitary Authority shall be complied with by the Contractor at his own expense.

The site shall be kept in a clean and proper sanitary condition. No nuisance shall be committed on or around the work, and latrines for the workmen and staff shall be provided in accordance with the requirements of the Medical Officer or Sanitary Authorities. The Contractor shall be responsible for the sanitary discipline of his labour.

The Engineer's Representative has the right to order any labourer, who in the opinion of the Engineer's Representative does not have a satisfactory sanitary discipline, off the site with immediate effect.

The Contractor shall follow the safety rules set down by the Factories Inspectorate, Ministry of Labour. No separate payment will be made for this and the Contractor will allow in his rates for this.

1.28 Safety Officer

Contractor's attention is drawn to Legal Notice No. 79 of 22nd September 1978 by which it is mandatory that every Contractor employing more than twenty people should appoint (in writing) a safety supervisor. A safety supervisor advises the management on all matters regarding safety, hygiene and welfare of the people affected by the Contractor's undertaking on the site. The safety officer may in addition carry out other duties.

The contractor shall provide adequate first-aid equipment on the site, and ensure that at least four of his site staffs are competently trained in first-aid. No separate payment will be made for this and the Contractor will allow in his rates for this.

1.29 Signboards

The Contractor shall provide, erect and maintain signboards to the layout, colours material and dimensions shown on the drawings.

The Contractor shall erect the appropriate number of Signboards as shown on the drawings in prominent positions adjacent to the Works to the satisfaction of the Engineer. These signboards shall be erected at every site as directed by the engineer.

The signboards are to be erected within one month of the date of commencement of the contract. The Contractor shall remove the signboard at the end of the period of the maintenance

Two additional special Permanent signboards shall be erected at the end of the Contract clearly showing the project name and the Employer's name to the satisfaction of the engineer.

1.30 Setting Out

The Contractor must before commencing any construction work, make sure that levels shown in the drawings correspond with levels found on the site.

Should any discrepancy be discovered between the levels shown on the drawings and those found on the site, which may affect the levels and dimensions of any part of the Works, the Contractor shall notify the Engineer, who, if necessary, will issue drawings showing the amended levels and dimensions.

The Contractor shall clear the site and set out the Works well in advance to enable the Engineer to inspect and approve the setting out prior to commencement of the Works. The Contractor shall amend at his own cost any error due to inaccurate setting out.

Any checking or approval by the Engineer of the setting out, benchmarks, plans or schedules will not relieve the Contractor of his responsibilities under the Contract.

The Contractor shall provide a site plan showing the position of his site offices, storage sheds, accommodation, Engineer's Representative's office etc., in relation to the permanent works for the approval of the Engineer before commencing erection of his camp.

After completion of the setting out and site clearance, the Contractor shall take ground cross sections along the pipeline at 25m interval and along the centerline of all structures. These shall be submitted to the Engineer in a digital format, agreed and signed by the Engineer's Representative and Contractor prior to commencement of any excavation works and shall be used for measurement.

1.31 Drawings produced by the Contractor

Where the Contractor is to design any part of works, to the extent specified in the Contract, the Contractor shall submit seven copies of its drawings, excluding those to be returned to the Contractor.

All drawings submitted by the Contractor to the Engineer for approval shall be on ISO standard size sheets with a maximum size of A1. Every drawing shall have a title box in the bottom right-hand corner showing:

- i. Employer's name
- ii. Title of scheme
- iii. Number of Contract
- iv. Contractor's name
- v. Title of works element
- vi. Subject of drawing
- vii. Drawing number
- viii. Date
- ix. Author
- x. Signature of Contractor (to the effect that the drawing (whether his own, his sub-contractor's or from any other source) has been checked by him before submission to the Engineer).

Each drawing shall also have a separate revision box with space for up to 6 revisions, including revision number, revision date, and revision description and revision check.

Drawings shall be drawn to specified scales or to such scales as are appropriate for clearly detailing and conveying the Contractor's proposals. Scales shall generally be 1:2, 1:5, 1:10 or multiples of 10 thereof. The appropriate measuring scales used shall be shown on the drawings.

Drawings shall include cross-references where appropriate and key information such as vital levels and dimensions. All general layout plans shall show the "north" direction.

Original drawings shall be drawn in black ink. Prints of drawings shall show dark and fade-proof linework on a light and non-darkening background. Prints shall be on durable paper of good quality and 80-g/m² minimum weight. Negatives shall be on 75-micron durable plastic film.

The Engineer will not give approval to any unclear or ambiguous drawings. In addition for the DATA ACQUISITION and MONITORING systems the following shall be provided:

- i. The overview, layout diagram, single-line diagram, connection (wiring) diagram, installation and connection diagrams for control cabinets and distribution boards and devices according to DIN EN 60617, DIN EN 61346 and DIN EN 61082.
- ii. For the system, a detailed order number system shall be used.

This system shall be incorporated into the hardware and software description, so that the operator has integrated documentation of all of the systems and subsystems.

- i. Configuration overview of the hardware components
- ii. List of measuring points

- iii. Description of control programs with explanations, online documentation of the programs according to EN 61131-3 with FBD, LAD, STL in STEP7 and SFC and CFC.
- iv. Function diagrams according to DIN EN 61082, Part 9 for the controllers
- v. Information for operating and starting up the system
- vi. The original licensing key must be submitted before acceptance in the announced performance capability (tags / PO) of the respective software programs
- vii. Mimic diagrams and image objects with properties, events, actions, and direct links
- viii. Tags, properties, and communication links
- ix. Message classes, message blocks, and messages
- x. Archive tags, and configuration data for archives
- xi. User groups and users
- xii. Source text of actions/functions
- xiii. Texts of text library
- xiv. Basic Process Control configuration data

1.32 Backfilling of Holes and Trenching for Temporary Works

The Contractor shall immediately upon approval of any work at his own expense and to the satisfaction of the Engineer backfill all holes, trenches and temporary quarries which have been made, level all mounds or heaps of earth that may have been raised or made and clear away all rubbish caused by the execution of the work. The Contractor shall bear and pay all costs, charges, damages, and expenses if any kind whatsoever which may occur by reason of holes and trenches connected with the Works or materials or tools or plant being left or placed in improper situation.

1.33 Inspection of Works

No part of the Works shall be built in or covered over until it has been inspected and approved by the Engineer and the Contractor must give due notice in writing to the Engineer's Representative when any part of the Works is ready for inspection.

1.34 Cleaning up of Site

The Contractor shall keep the site clean during the entire contract performance period. And before final acceptance upon the completion of the Works the Contractor shall, at his own expense, remove and dispose of all rubbish and remove all equipment, surplus materials, camps and buildings, which the Contractor has provided, and temporary works ordered by the Engineer and shall leave the Site absolutely clear thereof and in good order and condition to the entire satisfaction of the Engineer.

1.35 Testing of Water-Retaining Structures

All water-retaining structures shall on completion be tested for watertightness in the following manner. The structure shall be filled with potable water in stages and held at each

stage for such time as the Engineer may require. Should any dampness or leakage occur at any stage the water shall be drained off and the defects made good. The procedure shall be continued and finally the structure shall after a period allowed for absorption remain full for seven days.

Within those seven days the level of the surface of the water should be recorded and measurements made at intervals of 24 hours. The total leak must not exceed 0.3% of the total volume of water in the tested structure.

If the structure does not satisfy the conditions of the test, and the daily drop in water level is decreasing, the period of test may be extended for a further 7 days, and, if the specified limit is then not exceeded, the structure may be considered satisfactory.

Should any dampness or leakages or other defects occur they shall be made good and the structures re-tested until the watertightness is approved by the Engineer.

Faces of submerged structures may not be covered before testing.

The Contractor shall allow in his rates for all expense and shall provide water and all necessary labour and materials for testing the structure.

1.36 Testing of Roofs

Where structures are used for the storage of potable water, adequate precautions should be taken to ensure that the roof is watertight in order to give protection against a potential source of pollution.

The roof should be tested by lagooning the concrete slab to a minimum depth of 75mm for a period of 3 days; the roof slab should be regarded as satisfactory if no damp patches occur on the soffit. The roof screed should be completed immediately after testing.

All water, labour and materials for the test are to be provided by the Contractor who shall allow for this in his rates.

1.37 Cleaning and Sterilizing Water-Retaining Structures

The interior of all potable water-retaining structures shall be thoroughly cleaned and washed after the water-tightness test has been approved by the Engineer in order to remove all contamination.

The structure shall then be filled to overflow level with clean water containing 50 parts per million of chlorine and left for a period of at least 24 hours. The chlorinated water shall then be drained away and the structures refilled with clear water from which samples shall be taken for bacteriological examination and for tests of residual chlorine. If any of the results of the tests are unsatisfactory when compared with those of the control sample of the supply water the sterilizing process shall be repeated until the results of the tests are satisfactory.

The Contractor shall allow for in his rates: providing water, all labour, materials, chemicals and other things necessary for cleaning and sterilizing the water-retaining structures.

1.38 Sampling and analysis of Clean Water in the System

The costs of the initial sampling, analyses and preparing reports on the bacteriological quality of the water shall be borne by the Employer, but should the initial reports be unsatisfactory the costs of any subsequent sampling analyses and preparing reports shall be borne by the Contractor.

1.39 Contractor's Superintendence

The Contractor shall give or provide all necessary superintendence during the execution of the Works and as long thereafter as the Engineer may consider necessary for the proper fulfilling of the Contractor's obligations under the Contract. The Contractor or his competent and authorized Agent or Representative approved in writing by the Engineer (which approval may at any time be withdrawn) is to be constantly on the Works and shall give his whole time to the superintendence of the same. If such approval shall be withdrawn by the Engineer, the Contractor shall after receiving written notice or such withdrawal; remove the Agent from the Site within the time stated in the notice and shall replace him by another Agent approved by the Engineer.

1.40 Transport of Workmen

The Contractor shall include in his rates for all transport of staff and workmen to and from and in connection with the various parts of the Works, and all costs incurred in recruiting and transporting labour to the site, where such labour is from outlying areas and costs of returning labour on termination of the Contract.

1.41 Normal Working Hours

These shall be taken as Monday to Friday 8.00 a.m. to 5.00 p.m. and Saturday 8am to 1pm. with all Public Holidays set aside as required. The Contractor shall allow for observance of Sabbath or any other religious days to his staff.

Where the Contractor wishes to work outside these hours he shall request the Engineer in writing at least 24 hours in advance for consideration. The Contractor shall bear the cost of overtime for all Engineers' support staff associated with such works.

1.42 Contractor's Establishment

The Contractor shall erect an office near the Works on a site to be approved by the Engineer. This office shall be kept open at all hours during which the work is in progress. Any notice to be given to or served upon the Contractor shall be deemed and taken to be effectively given or served upon by the delivery thereof at such office on the Site.

The Contractor shall provide and maintain suitable shelters and mess facilities for his workmen and supervisory staff. The facilities shall be of sufficient size and to a standard considered satisfactory by the Engineer. The Contractor shall throughout the contract provide an adequate supply of potable water for the Workmen.

Suitable temporary stores and workshops shall be erected and later removed on completion of the works. All buildings shall be adequate for protection of the equipment of materials to be kept therein and shall be constructed and located to the satisfaction of the engineer.

1.43 Communication

The Contractor shall, if so instructed by the Engineer, provide mobiles phones and airtime as necessary for the duration of the contract and, stable internet connection, post office, courier, radio communication for the exclusive use of the Engineer. The model and make of the mobiles phones shall be approved by the Engineer.

Failure by the Contractor to provide or maintain the same shall make him responsible for all costs that may be incurred as a result of the Engineer's staff using alternative means of communication, including delays in supervision and approval of the works.

Payment for complying with this requirement is included in the bill of quantities.

1.44 Houses, Office, Laboratories for the Engineer's Staff and Time for Erection

The Contractor shall supply and maintain one portable 4nr. 40ft prefabricated containerized units fully furnished as site office, for the Supervisor's staff including sanitary facilities, air conditioning, heating, electricity, refrigerator, telephone/internet connections security and watchman services. The unit rate shall include operation, maintenance, cleaning of the site office, power supply (e.g. Generator) and remove of Supervisor's site office on completion of the works. The container shall be appropriate isolated and equipped with an additional sun- roof with minimum projection (over container dimensions) of 0,5 m. The space shall be divided into three rooms and furnished as follows:

- a. Meeting room, fitted with a meeting table and (six) chairs.
- b. Office, fitted with two lockup desks, three chairs, and wooden stand with racks to hold drawings, one file locker, Celotex of fibre board 1 x 2 m fixed on wall.
- c. Kitchen, with a sink, a freshwater tank and pump, a refrigerator, clothes hooks, boot scraper and proper waste disposal facilities and glasses / cutleries etc.
- d. Toilet facility
- e. Meeting room and office shall be equipped with an appropriately sized (split case) air conditioner and sufficient lockable windows.

Furthermore, the Contractor shall install and operate and maintain for the period of the contract:

- a. Electrical power supply of appropriate rating, either from the public grid or from his own stand-by generator.
- b. Regular supply of potable water.
- c. A sufficient and regular supply of all normal stationery and consumable equipment, including notepaper (headed and plain), copy paper, carbon paper, envelopes, notebooks, duplicate and triplicate books, calendars, diaries, pencils, pens, inks, erasers, pads paper clips, pins and other like office requisites required by the Engineer's Representative and his staff.

The offices and accessories refurbished by the Contractor in accordance with this Chapter shall be approved by the Engineer's Representative and shall be maintained by the Contractor.

If the Contractor employs as communication system between office and construction sites wireless (radio) stations than the Contractor shall provide three (3) handsets capable of operating within all the project areas. The Contractor shall allow in his rates for all basic fees and costs as well as for the operation costs for operating such communication system.

The Contractor shall provide and maintain houses, offices, laboratories, survey and laboratory equipment and furniture for the Engineer and his staff including senior staff, junior staff and technicians

All houses, offices and laboratories to be provided under the contract shall be handed over to the engineer in finished and fully habitable condition not later than sixty days after Engineer's order to commence work (Clause 9.1 of the General Conditions of Contract)

No construction of any works will be permitted until the engineer's offices and laboratories have been accepted by the engineer as finished and able to function efficiently.

Should the Contractor fail to hand over the houses, offices, and laboratories within three(3) month period from the date of instruction to commence works,, the engineer will make such arrangements as he considers necessary. These arrangements may include use of hotels, rented accommodation, and the hire or purchase of caravans, port-cabins etc. the contractor will be responsible for all costs of such temporary arrangements made by the engineer, including that of additional cost of transport.

Any delays to the Contractor or the Contractor's activities caused by the Engineer being unable to perform survey work, field or laboratory tests due to the Contractor's failure to supply and/or maintain the said equipment, houses and accommodation shall be deemed to have been caused by the Contractor's own actions, and any consequences of such delays shall be interpreted as such.

1.44.1 Engineer's Staff Houses

Each Container house shall be provided with new furniture, equipment and fittings to the approval of the Engineer. All the houses and furniture mentioned below shall revert to the contractor after the completion of the contract. Contractor to include in their rates for the houses purchase of all the furniture listed below.

1.44.2 Engineer's Offices

The Contractor shall construct and maintain for the duration of the Contract, a furnished and equipped containerized office for the Engineer's Representative of durable and weather-proof construction, provided with mosquito-proof and burglar-proof windows and lockable doors and suitably insulated against heat and cold, all to the satisfaction of the Engineer in respect of the construction, design and sitting. The office shall comply with the details shown in the drawings and shall have a clear height of not less than 2.6 m. The floor shall be of floated concrete, and adequately damp- and termite-proof.

A telephone shall also be provided for the Resident Engineer's office for his exclusive use. The Contractor shall be responsible for paying all the charges and fees related to the use of the telephone and be reimbursed the same on production of proof of payment.

The office for the Engineer's Representative shall be completely separate from that of the Contractor and shall be fenced with a 2m high chain linked fence and gate with padlock and chain.

Toilets and washrooms graded to staff seniority, together with drinkable water supply and water borne sewage disposal, shall be provided for the office. The Contractor shall also provide 24 hours a day electricity supply to the offices and shall allow for any water and electricity consumed and for any statutory charges associated.

Unless the offices are accessible via an existing paved road the Contractor shall also provide an access road at least 4m wide to the office. A 100 square meters covered car parking area. Both access road and car park shall be surfaced with at least 150 mm of consolidated gravel properly graded, cambered, drained and culverted.

The offices shall be provided with day and night watchmen and security lights, the cost of which shall be deemed to have been included in the rates for the offices.

1.44.3 Laboratory

The Contractor shall construct, and maintain for the duration of the Contract, a laboratory within the ER's Main office complying with details shown on the standard drawing or equivalent, to the satisfaction of the Engineer. The building shall be of durable and weatherproof materials, provided with mosquito-proof and burglar-proof windows and lockable doors, and suitably insulated. The laboratory shall be sited adjacent to the Resident Engineer's main office.

The laboratory shall have piped potable water supply and a continuous electricity supply adequate for lighting, heating and operating the laboratory equipment.

The laboratory shall have a height from floor to ceiling of not less than 2.75 meters and all rooms shall be fitted with electric lighting and power points as instructed by the Engineer's Representative, and each door shall be fitted with a good quality mortise lock and provide with two keys.

Soaking tanks for Concrete Cubes specimens shall be provided at floor level in the laboratory. Concrete cube curing tanks of adequate size shall also be provided. The concrete cube curing shall have drainage pipes built in.

The following rooms and facilities shall be provided in the Laboratory;

(i) Office

This room shall have a total floor area of not less than 14 square meters and a total window area of not less than 2 square meters. The door and windows shall be fitted with fly screens covered with mosquito gauze. The floor shall be concrete with a float finish. The walls shall be lined up and ceiling provided.

A display board of soft-board or similar approved material shall be provided and fixed securely to the wall at a location to be indicated by the Engineer.

(ii) Laboratory room

A laboratory room shall be provided. This room shall have a total floor area of not less than 20 m² and a total window area of not less than 2 m². A door shall provide access to the main laboratory room. The floor shall be fitted out as indicated by the Engineer's Representative with two rigidly constructed workbenches constructed to the same standard of construction as the main laboratory room. The workbenches shall be at least 6 m long. A sink with waste pipe shall be connected to the water supply of the main laboratory room in addition an approved air extractor shall be fitted through an outside wall.

(iii) Store room

A separate sample store, of at least 10 m² floor area and with shelves along one wall, shall be provided in a position to be indicated by the Engineer.

(iv) Concrete slab

A concrete slab, 150 mm thick with a total area of not less than 20 m² shall be provided adjacent to the main laboratory building in a position to be indicated by the Engineer's Representative. The slab shall have a smooth finish, all to the satisfaction of the Engineer. The laboratory shall revert to the Employer at the end of the contract.

1.44.4 Engineer's housing, office and laboratory furniture

Furniture and equipment for the Engineer's Laboratory shall be as listed appendix of this specification. It shall also be the Contractor's responsibility to replenish consumables, when instructed by the Engineer. The Engineer's Housing, office and laboratory furniture will revert to the Employer on completion of the contract.

1.44.5 Engineer's laboratory and survey equipment

The Contractor shall provide, install and maintain in a good state of repair for the duration of the Contract, such laboratory, survey and other equipment as listed in the appendix of this specification. Such equipment shall be of approved manufacture, and shall be made available to the Engineer within the following time periods:

- *Survey equipment - not more than 30 days after Engineer's order to supply*

- *Laboratory equipment - not more than 60 days after Engineer's order to supply*

Any delays to the Contractor or the Contractor's activities caused by the Engineer being unable to perform survey work, field or laboratory tests due to the Contractor's failure to supply and/or maintain the said equipment shall be deemed to have been caused by the Contractor's own actions, and any consequences of such delays shall be interpreted as such.

The laboratory and survey equipment shall revert to the Employer on completion of the contract.

1.44.6 Maintenance of the Engineer's Staff Houses, Offices, Laboratories, Furniture and Equipment

The Contractor shall keep all buildings, accesses, services and facilities provided by him, for the use of the Engineer and his staff, in a well maintained, clean and fully habitable condition, 24 hours per day until the issue of the Taking Over Certificate for the whole of the Works, and if required for a period thereafter until the Contractor has completed any outstanding work.

The Contractor shall also provide constant electricity, water and an adequate refuse collection service for all houses, offices and laboratories.

The Contractor shall also maintain all furniture and equipment provided by him and/or the Employer in a reasonable state of repair and useable condition and shall replace promptly any item which becomes unserviceable or is lost.

1.44.7 Provision of Maintenance and Security

The contractor shall provide cleaners, groundmen, and day and night watchmen for housing camp and offices as directed or instructed by the Engineer on site, the cost of which shall be included in the rates for providing houses, offices and laboratory.

1.44.8 Insurance and ownership of the Engineer's Staff Houses, Offices, Laboratories, Furniture and Equipment

All buildings, furniture and equipment provided by the Contractor for the Engineer's staff shall be insured by the Contractor against loss or damage by accident, fire, theft and other risks ordinarily insured against for the duration of the Contract.

On completion of the contract the ownership of the office, laboratory and survey equipment shall revert to the employer. Unless otherwise stated ownership of all houses and laboratories shall revert to the Employer.

1.45 Provision of Vehicles

All vehicles to be supplied will be brand-new, right-hand drive, diesel powered and fitted with air-conditioner and power steering as described below.

The vehicles shall be Toyota LC 79 offroad 4x4 new Turbo diesel propelled 4WD, 4 door 5-seater Double Cabin pick up vehicle of minimum engine capacity 4164cc, with the following minimum specs: 285Nm/2200rpm torque, 96kW/3800rpm power, 130ltrs fuel tank capacity fitted with all the necessities mentioned in paragraph one of this clause for the exclusive use of the Engineer.

The Contractor shall provide vehicles as specified in the BOQ, licensed and comprehensively insured for replacement value and shall maintain and provide experienced licensed drivers, fuel, oil and replacement parts during the whole of the contract period. The vehicles shall be for the exclusive use of the Engineer and his staff during the Contract period. The Contractor shall also insure the vehicles, driver and passengers fully comprehensively at all times throughout the Contract.

The vehicles shall have diesel-driven engines with engine capacity of not less than 4200cc and shall be provided with the following optional equipment: factory installed seat belts, rear pintle hook, front hook, door mirrors, two spare wheels, toll box with necessary tools, jack, etc. If equivalent makes of vehicles are to be provided, they shall be approved by the Engineer prior to ordering. All vehicles shall have factory installed air conditioning units and power steering. They shall be printed with the address of the Resident Engineer as directed by the Engineer. This address shall be removed on reversion of the vehicles to the Employer.

The Contractor shall always service and maintain in good working order the vehicle. In the event of any vehicle being unavailable for use due to accident, damage or its being maintained or repaired, the Contractor shall immediately provide a substitute acceptable to the Engineer.

In the event of the Contractor defaulting on this obligation, the Engineer shall be authorized to hire a substitute similar vehicle for the period of non-availability of the Contractor's vehicles and the cost incurred will be recovered from the Contractor.

The Contractor shall, at the completion, bring the vehicles to the appropriate dealers for testing. The dealers shall recommend to the Engineer what repairs in addition to the ordinary service are required to be carried out on the vehicles. A certificate of roadworthiness and satisfactory mechanical condition are to be issued annually. Upon completion of the Contract the vehicles shall become the property of the Employer. They shall be handed over to the Employer in good condition, excepting fair wear and tear.

1.46 Site Meetings

Site meetings will be held monthly but will be called for whenever the progress of the works so require or when demanded by the Engineer.

The Contractor shall at all meetings be represented by a responsible representative other than the Site Agent, who has the powers to commit the Contractor in all matters concerning the contract.

In the event no responsible representative of the Contractor is present at the meetings, any decision take by the Engineer at the meeting will be binding upon the Contractor.

1.47 Miscellaneous Accounts

The Contractor may be instructed by the Engineer to make payments of general receipted accounts for such items as stationery, stores, furniture and equipment, claims and allowances for supervision personnel and any miscellaneous claims or the Engineer may direct the Contractor to purchase or pay for the above. The Contractor will, on provision of receipts, be paid under appropriate items in the Bill of Quantities

1.48 Payment of Overtime for Engineer's Junior Staff

The Contractor may be instructed by the Engineer to make payments for overtime worked by the Engineer's junior staff. The Contractor shall be reimbursed for such payments in accordance with the relevant items of the clause 1.50 of this specification except when any overtime worked by the engineer's junior staff is incurred by the need for the engineer to inspect work which, owing to earlier default by the contractor, has resulted in such work being performed outside the normal working hours as defined in clause 1.37 of this specification then the full cost of such overtime including the specified percentage for administrative overheads shall be paid by the Contractor to the Engineer.

- (i) If the Contractor wishes to execute permanent work outside the Engineer's normal working hours, as stated in Clause 1.37 of this Specification, then the payment for the overtime for Engineer's support staff shall be reimbursed in full by the Contractor to the Engineer. For purposes of this clause, in addition to the support staff provided by the contractor, the following shall also constitute part of the Engineer's junior staff
- (ii) If the Contractor wishes to execute permanent works on a regular basis outside the Engineer's normal working hour, (Clause 1.37 of this Specifications) over a prolonged period, the Engineer may, if he deems it necessary, employ additional supervisory staff for which the required salaries, plus twenty (20) percent additional amount to cover for the Engineer's overheads shall be reimbursed in full by the Contractor to the Engineer and the Contractor shall provide the required accommodation facilities for such staff at his own cost.
- (iii) Payment of Allowance on Duty Trips. The Contractor is required to pay for hotel accommodation and allowances for his staff seconded to the Engineer on official duty trips outside the base camp.

The Contractor shall not be reimbursed any of these costs (i.e. i, ii, iii)

1.49 Construction photographs

The Contractor shall take a series of photographs illustrating the progress of construction each calendar month commencing at the start of the Work. It is required that views shall be taken before commencement, during progress, and at completion, of the Work. For structures and equipment, the number of photographs taken each month shall be not less than four. For pipelines work four photographs shall be taken for each 100-metre length of pipe-one before commencement, five during progress, and one at completion. All views will be decided by the Engineer and shall include a full, clear and distinct view of each site sign.

All photographic work shall be done by a qualified photographer, which is acceptable to the Engineer. Three prints of each photograph and one electronic copy shall be furnished promptly to the Engineer. Each print shall have a glossy finish and be mounted on a stiff backing.

The dimensions of each mounted print shall be 200 mm by 250 mm with an additional 30-mm wide flexible binding margin on the short left-hand side.

Each photograph shall be neatly and legibly captioned on the rear in English as follows:

- Short description and identification of view
- Photo Number (number consecutively) and date taken
- Contractors Name
- Employer's Contract Number

1.50 Water proofing

The Consultant shall work carefully with waterproofing manufacturers and obtain constructability input from the contractor prior to giving any instructions on the type of waterproofing system and components to be used. It is recommended that the Product Performance, Application Techniques and General Condition factors listed here below be carefully considered in reviewing and selecting the appropriate waterproofing system.

The following shall be important Waterproofing Specifications factors to be considered

- (i) Qualifications of the Applicator,
- (ii) Submittals - Evidence of Applicator Qualifications,
- (iii) Manufacturer's Certificate of Conformance, Catalog,
- (iv) Application Data, and Samples,
- (v) Delivery and Storage of Materials,
- (vi) Environmental Conditions,
- (vii) Carefully review the Physical Performance, Application,
- (viii) Ensure that product materials comply with these requirements, the structural design and other design criteria.
 - Membrane should be impermeable to water but allow water vapor to pass,
 - Membrane should provide a continuous film without areas of weakness and lend itself to the design details of the structure,
 - Materials selected must be compatible,
 - Ensure that surface to be treated has been prepared to provide a positive bond to minimize the lateral migration of water,
 - Application of the waterproofing products must be specified in accordance with the manufacturer's requirements,
 - The membrane selected should maintain its physical properties, such as elasticity and durability, over wide range of environmental conditions,

- Quality control specifications should be reviewed to ensure that each phase is properly inspected and tested prior to proceeding with the next phase. Testing of the installed waterproofing system prior to and after backfilling, by the continuous application of water over extended periods of time, is essential and should be specified,
- The waterproofing system should be guaranteed for both material and performance by the installing contractor. Manufacturers' representatives should also be required by specification to be on site during the installation of their product.

1.51 Demobilization from Site

On the completion of the Contract, the Contractor shall if so requested take down and remove all structures connected with his camp, and shall take up all pipes, drains and culverts, backfill trenches, fill up all latrine pits, soak ways and other sewage disposal excavations, and shall restore the site as far as practicable to its origin condition and leave it neat and tidy to the satisfaction of the Engineer.

The demobilization includes the removal of all Site facilities and temporary installations, the demobilization of all equipment from Site, the removal of all surplus materials, the reinstatement of all damaged or worn access roads and facilities used by the Contractor and the cleaning up of the Construction Site upon completion of the Works.

1.52 Measurement and Payment

No separate measurements and payments shall be made for the cost of complying with the requirements of clauses this specification except for those detailed in the Bills of Quantities and the Contractor shall be deemed to have allowed elsewhere in his rates and price for all such costs.

No Preliminary item has been included in this Contract. All Contractor's mobilization and general costs shall therefore be included in relevant rates in the Bill of Quantities.

2 MATERIALS AND TESTING OF MATERIAL

2.1 Exploratory Borings and Test Pits

The Contractor shall incorporate within his programme and rates, the execution of exploratory borings and test pits associated with foundation works for structure and along pipeline routes, as well as the performance of tests as instructed by the Engineer. It is important to note that the completion time of the contract shall not be extended due to the duration required for the construction of trial sections and the subsequent evaluation of tests conducted on them. Additionally, no compensation shall be provided for the test pits and associated testing. The Contractor is required to reinstate the test pits in accordance with the directions given by the Engineer.

2.2 Quality of Materials and Workmanship

The materials and workmanship shall be of the best of their respective kinds and shall be to the approval of the Engineer. In reading of these Specifications, the words “to the approval of the Engineer” shall be deemed to be included in the description of all materials incorporated in the Works, whether manufactured or natural, and in the description of all operations for the due execution of the Works.

All works or parts thereof shall be in accordance with the latest edition of Kenya Bureau of Standards (K.E.B.S.), International Standards Organization (I.S.O.), EN Euro Codes and Standards, DIN standard, AWWA standards, British Standard (B.S.), and British Codes of Practice (C.P.).

All materials shall be of approved manufacturer and origin and the best quality of their respective kind, equal to sample and delivered on to the Site a sufficient period before they are required to be used in the Works to enable the Engineer to take such samples as he may require for testing or approval, and the Contractor shall furnish any information required by the Engineer as to the quality, weight, strength, description, etc. of the materials. No materials of any description shall be used without prior approval by the Engineer and any condemned as unfit for use in the Works shall be removed immediately from the Site by, and without recompense to, the Contractor.

Notwithstanding more stringent or particular prescriptions in the specific parts of these Specifications, all material, equipment and plant that shall become part of the permanent works shall be new, of first-class quality and from reputed manufacturers. Second-hand material, equipment and plant are not allowed and shall be rejected. The contractor shall submit originals of certificates issued by the manufacturers of all plant and equipment certifying date and place of origin. All plants and equipment shall bear distinct and easily legible plates of indestructible material showing manufacturer / brand, time of

manufacturing, and all relevant technical data required by the standards or in the absence of standards, as generally indicated to describe the capacity of the plant or equipment.

2.3 Trade Names

Trade Names and Catalogue References are given solely as the guide to the quality and alternative manufacturers of the materials or goods of equivalent quality will be accepted at the discretion of the Engineer.

2.4 Samples

As soon as possible after the contract has been awarded, the Contractor shall submit to the Engineer a list of the suppliers from whom he proposes to purchase the materials necessary for the execution of the Works. Each supplier must be willing to admit the Engineer or his representatives to his premises during ordinary working hours for the purpose of obtaining samples of the materials in question. Alternatively, if desired by the Engineer, the Contractor shall deliver samples of the materials to the Engineer's office without charge.

The information regarding the names of the suppliers may be submitted at different times, as may be convenient, but no source of supply shall be changed without the Engineer's prior approval once a supplier, source or material has been approved.

The samples of materials approved will be retained at the Engineer's office until the completion of the contract. Samples may be tested to destruction.

The samples of all materials shall be deposited with the Engineer and approved prior to ordering or delivery to site. The Engineer reserves his right to test any sample to destruction and retain samples until the end of the maintenance period. No payment will be made for samples and the Contractor must in the rates of prices allow for costs of samples. All materials delivered to site shall be equal or better in all respects than the samples delivered to the Engineer.

All sampling of materials on the site must be done by or in the presence of the Engineer. All other samples will be deemed not to be valid under the Contract.

Any material delivered to the site or intended for the works not equal or better than the samples approved by the Engineer shall be removed and replaced at the Contractor's expense.

2.5 Testing

As provided in Clause 7 of the Conditions of Contract and in accordance with the Specification quoted for any material used on works of this Contract, tests may be called upon by the Engineer to be carried out at the place of manufacture or on the site. The Contractor may assume that the tests will be required on soils, workmanship, and materials whether natural or manufactured to verify their compliance with the specifications. Samples of all such materials and manufactured articles together with all necessary labour, materials,

plant and apparatus for sampling and for carrying out of the tests shall be supplied by the Contractor at his own expense.

2.6 Testing at an independent laboratory

A prime cost item has been included in Bills of Quantities for testing of materials and workmanship as directed by the Engineer at an Independent Laboratory. The Contractor will be reimbursed receipted cost of testing carried out by the laboratory if the workmanship or materials pass the tests. However, if the result of tests shows that material is defective then the Contractor will bear the cost of testing.

2.7 Standards

All Design and Construction Works must be performed according to the most recent relevant international codes, standards, accident prevention regulations and the applicable national Regulations and Standards.

Wherever throughout this Specification is referred to certain standards it should be read as “or equal international standard”. It is the Contractor’s responsibility to provide sufficient evidence that any international standard the Contractor proposes will ensure an equivalent or higher standard as the one used as a reference in this Specification.

All materials and equipment supplied, and all work carried out as well as calculation sheets, drawings, quality and class of goods, methods of inspection, specific design features of equipment and parts and acceptances of partial plants shall comply in every respect with the technical codes of the International Organization for Standardization (ISO) and of the International Electrotechnical Commission (IEC).

All installations must be in accordance with the relevant international Standards and Codes of Practice. Immediately after effective date of the Contract the Contractor shall supply an indexed list of all standards, codes and associated standards to which the work is to be performed for the Engineer’s approval. The quality control systems and plans shall be according to ISO 9000 and subject to the approval of the Engineer.

2.8 Measurement and payment

Except where payment items are provided for certain materials and required tests, no separate measurement and payment shall be made for materials and tests and the cost thereof shall be included in the appropriate tendered rates.

TECHNICAL SPECIFICATIONS FOR THE CONSTRUCTION, REHABILITATION AND EXPANSION OF GROUNDWATER – BASED RURAL WATER SUPPLY SCHEMES - BATCH 1 SCHEMES IN WAJIR COUNTY

SECTION 2: CIVIL WORKS

3 SITE CLEARANCE AND TOPSOIL STRIPPING

3.1 Site Clearance and Grubbing

Site clearance shall generally be restricted to the areas under permanent works without any provision for working allowance and/or as instructed by the Engineer. No separate measurement and payment will be made for site clearance of areas cleared by the Contractor for the Storage of Construction materials, camps, housing, workshops, stores, quarries, temporary works, and working space. The contractor's rates and prices are deemed to include for this work.

Clearing shall involve the following:

- The removal of all trees and bushes (complete with roots), other vegetation, rubbish and all other material that may interfere with the construction of the Works.
- The removal of all rocks and boulders of up to 0.15 m³ in size, which are lying on the surface to be cleared or which are exposed during the clearing operations.
- The disposal of all material produced by the clearing.
- The removal and disposal of structures which encroach upon or may otherwise obstruct other work on the Site and which can be cleared by means of a bulldozer with a mass of approximately 20 t and a flywheel power of approximately 130 kW. (Structures that cannot be so cleared shall be dealt with as directed by the Engineer.)

Unless instructed, the site clearing for trenches shall only be for the width allowed for trench excavation.

The moving of a certain amount of soil or gravel may be inherent in or unavoidable during the clearing process. No extra payment will be made for the removal of such soil or gravel.

Areas that are cleared in strips for the purpose of constructing fences shall be cleared over the full length of the fence to a width as specified in the drawing and as instructed by the Engineer. Surface irregularities shall, in the case of fencing, be so graded that the fence will follow the general ground contour.

All stumps and roots exceeding 75 mm in diameter shall be removed to a depth of at least 100 mm below the original ground level. Where a construction bed or any other area has to be compacted, all stumps and roots including matted roots shall be removed to a depth of at least 200 mm below the cleared surface. All material produced by the grubbing shall be disposed of. Except in borrow areas, cavities caused by grubbing shall be backfilled with approved material and compacted to a density equal to at least that of the surrounding ground.

3.2 Cutting Trees

3.2.1 Protection of persons, animals and structures

The Contractor shall take the necessary precautions to prevent injury to persons and animals and damage to structures and other private and public property.

Where necessary, trees shall be cut in sections from the top downwards.

3.2.2 Branches overhanging boundaries

The branches of trees to be left standing shall be so trimmed as not to encroach upon the space (to a height of at least 7 m) vertically above any carriageway, railway formation, or other designated area.

3.2.3 Preservation of trees

No tree shall be cut down and no branches shall be trimmed off any of the trees to be preserved until the Engineer has given written authorization for such work to commence. Individual trees indicated and marked by the Engineer as trees to be preserved shall be left standing and undamaged.

3.3 The Disposal of Material

Any material obtained from clearing and grubbing, the demolition of structures, the re-clearing of vegetation and the cutting of trees shall be disposed off in borrow pits or other suitable places indicated by the Engineer. Where no such place for the disposal of material is indicated by the Engineer, the Contractor shall make his own arrangements to provide a suitable place which complies with the requirements laid down by the Engineer. The disposal or burning if specially permitted of combustible material on the Site may be done only with the prior written approval of the Engineer. Care shall be taken to observe the air pollution under EMCA 1999.

All tree trunks and major branches shall be sawn into transportable lengths before removal from the Site.

No haulage will be payable to the Contractor for the disposal of material obtained from clearing and grubbing, the demolition of structures, the re-clearing of vegetation, and from the cutting of trees.

Materials from stripping such as suitable topsoil shall, if instructed by the Engineer, be stacked in approved areas. All other non-combustible materials shall be buried in approved disposal area; covered with a minimum of 0.5m of excavation spoil. These disposal areas shall be left with neatly graded surfaces and stable slopes that assure drainage. Alternatively, the non-combustible material shall be removed from the area by the Contractor.

3.4 Removal of Topsoil

Topsoil shall be removed to spoil or stockpile where and as directed by the engineer. Spoil material shall be deposited in compliance with the relevant national and local laws and

regulations. Measurement shall be the net area in square metres removed as directed and shall allow for stripping topsoil to a depth of 200mm. Should the Engineer instruct that a greater depth than 200mm be removed, payment for the additional material shall be made under the item for excavation in the Bills of Quantities.

The topsoil shall be removed from over the full width of the trench to a depth of 200 mm or if rock occurs closer than 200 mm to the existing natural surface. On completion of backfilling, the topsoil shall be replaced in its original position.

Should the Contractor strip to depths greater than those instructed by the Engineer, then the Contractor shall replace the material with suitable fill material at his own expense.

3.5 Measurement and payments

a. Clause 3.1. Site Clearing and grubbing

Unit: Areas square metre (m²)

The unit of measurement for clearing and grubbing is the square metre or metre.

Only those areas or strips designated by the Engineer under Clause 3.1 of this specification shall be cleared and grubbed in accordance with the requirements of Clause 3.1 and Clause 3.3 of this specification shall be measured for payments.

The tendered rates shall include full compensation for clearing the surface, removing boulders with a size of up to 0.15 m³, cutting trees with single or multiple trunks each with a girth of 0.5 m or less, grubbing the stumps and roots of such trees, cutting trunks and branches into transportable lengths, backfilling cavities, demolishing structures, and removing, transporting and disposing of material thus cleared, grubbed, cut and demolished. Boulders exceeding 0.15 m³ in size shall be dealt with as set out in Earthworks Section of this Specification.

b. Clause 3.2 Cutting and removing large trees with a girths exceeding 0.5m

Unit: Exceeding 0.5m and up to and including 2m number (No)

Exceeding 2m and up to and including 3m number (No)

The unit of measurement shall be the number of tree trunks cut and removed in each size group. The girth of a tree trunk will be measured at the narrowest point of the trunk in the first metre of its height above ground level.

The tendered rates shall include full compensation for cutting the trees and grubbing the stumps, for cutting the trunks and branches into transportable lengths, and for removing, transporting and disposing of all such trees, stumps, trunks, branches and associated material.

c. Grubbing and the removal of the stumps and roots of large trees with a girth exceeding 0.5m

Unit: Exceeding 0.5m and up to and including 2m number (No)

Exceeding 2m and up to and including 3m number (No)

The unit of measurement shall be the number of tree stumps and associated roots of which were grubbed and removed in each size group.

The tendered rates shall include full compensation for grubbing the stumps and roots, backfilling holes, cutting the stumps and roots into transportable pieces, and removing, transporting and disposing of all such stumps and roots and associated material.

The girth of a tree trunk will be measured at the narrowest point of the trunk in the first metre of its height above ground level.

d. Clause 3.4 Removal of top soil

Unit m²

Removal of topsoil shall be measured by the square meters calculated as the plan area measured from cross-section taken in accordance with clause 1.26 of this specification.

The rate for removal of top soil shall include for the cost of all hauls as necessary and compliance with the requirements of Clause 3.3 and Clause 3.4 of this specification.

4 EARTHWORKS

4.1 General

Excavation shall be made to such lengths, depths and inclinations as may be necessary for the construction of the works or as shown on the drawings or as the Engineer may direct.

4.2 Definitions of Materials

For the purpose of these Specifications materials of earthworks are classified as follows:

- (a) Hard material: Material which can be excavated only after blasting with explosives, or barring and wedging or boulders of more than 0.5m³ occurring in soft material shall be classified as hard material.

or

Rock is defined as solid masses, layers, or ledges of such hardness that it cannot be effectively loosened or broken by ripping with a track type tractor minimum flywheel power 250KW (335 HP) equipped with a single shank ripper operating in low gear.

- (b) Soft Material: All earth materials, which do not meet the requirements of hard material as defined in above.

- (c) Overburden means soil as defined here above

Where it is impractical to prove hard material by the above method, then the quantity of hard material, if any, shall be determined by the engineer.

4.3 Scope

All the excavations covered in this section are open cut excavation also termed surface excavation in this contract:

- Excavation for cuttings (soil and rock).
This covers mainly excavations under the embankment dam, excavation for cofferdam, excavation for the spillway.
- trench excavation for the plinth (soil and rock)
This covers the excavation of the trench for the embankment dam with its adjacent filter and transition,
- Excavation for culvert (soil and rock)
This covers the excavation of the trench for the culvert, the intake tower and the downstream valve chamber.
- Small size excavation (soil and rock) See BoQ for definition
- Excavation of earth fill material in borrow area

- Excavation of overburden in rock quarry This covers the excavation of the soil cover in the quarry
- Excavation of rock fills R1, R2 (and R5 in the alternative).

4.4 Excavation

4.4.1 General

The excavations (except in the quarry and borrow area) shall be made to the lines, grades and dimensions shown on the drawings.

The Contractor shall take all necessary measures to ensure the stability and safety of excavations,

Excavations needed by the Contractor installations shall be submitted to the approval of the Engineer,

All open out excavation shall be performed in accordance with this section to the lines, grades and dimensions shown on the drawings or as directed by the Engineer.

All necessary precautions shall be taken to preserve the material below and beyond the lines of all excavation in the soundest possible condition.

Where, in the opinion of then Engineer, the surface of the excavation has become soft or unsuitable due the Contractor's method of working, the Contractor shall at his own expense remove and replace the unsuitable material with class 15 concrete or other approved material as instructed by the Engineer.

Any and all excess excavation for the convenience of the Contractor for any purpose or reason, except as may be ordered in writing by the Engineer and whether or not due to the fault of the Contractor, shall be at the expense of the Contractor. Where required to complete the work, all such excess excavation and over-excavation shall be filled with compacted concrete class 15 or as directed by the engineer, furnished and placed at the expense of and by the Contractor.

All excavations shall be kept clean and free from water, and the Contractor shall dig diversion channels, erect coffer dams or otherwise dewater the excavations

If excavations are carried out in roads, footpaths, separators, or within 5m of buildings the Contractor is required to execute the work in a way that will minimize damage and disturbances.

All open excavations shall be clearly marked or covered by the Contractor to protect the public from any damage or injury. All costs arising from injury or damage to property or persons due to the Contractor's failure to protect open excavations and shall be borne fully by the Contractor.

The Engineer's approval to the final excavated surface shall be obtained prior to the laying of pipelines or construction of structures.

The sides of pits, trenches and other excavations shall, where required, be adequately timbered and supported, and all such excavations shall be sufficient size to enable the pipe and the concrete to be laid accurately and proper refilling and compaction to be carried out.

Where instructed by the engineer, shoring and supporting timber shall be left in trenches or other excavations.

Where ground conditions are such that a satisfactory foundation cannot be achieved the Contractor shall, if instructed by the Engineer remove the unsuitable material either until a suitable material is encountered or to the depth and width instructed by the Engineer. The Contractor shall backfill the resultant excavation with approved material to the satisfaction of the Engineer. Approved material may include rock fill and/or selected backfill material as directed by the Engineer.

The Engineer reserves his right to direct the Contractor as to the lengths of trenches or parts of bulk excavations which shall be opened up at any one time.

Where trenching, pipe-laying operations and culvert construction are carried out in built-up areas, the work shall be completed as quickly as possible so as not to unduly inconvenience the public. In the case of excavations in roads, and in other places which in the opinion of the Engineer are likely to cause interference to the public, then the works shall be completed as quickly as possible so as not to unduly inconvenience the public

No permanent work shall commence until the Engineer has inspected and approved the excavation.

The Contractor shall carefully set aside the various suitable materials encountered so that they may be reused for backfilling. If the excavated materials are unsuitable the Contractor may spoil the material only after approval by the Engineer. No extra claim will be allowed for setting aside surface material or topsoil for reuse or spoil.

4.5 Ground Levels and Reconstruction Cross Sections

Before the commencement of any earthworks the sites shall be surveyed in conjunction with the Engineers Representative to establish existing ground levels and these agreed ground levels shall form the basis for the calculation of quantities of any subsequent excavation and filling.

4.6 Topographical and Geological Survey After Excavation

A topographical survey of the excavated areas (except earth fill borrow area) shall be carried out by the Contractor at his own expense under the control of the Engineer. On the topographical map obtained the Contractor shall draw any geological accident, fault, and

seams with all their details. These indications shall be reported under the control of the Engineer's geologist.

In order to facilitate the inspection of the excavation surfaces, the Engineer Is entitled to request that these surfaces shall be cleared, washed and dried in order to enable a geologist to carry out a geological survey in the best conditions. In any case the earth filling or concreting of the excavation will not be carried out before they above been inspected and approved by the Engineer.

After his inspection the Engineer is entitled to request a deeper excavation. The earth filling or concreting shall not be carried out before another inspection has been done and the excavation approved.

4.7 Tolerances

For the excavations to be covered by concrete, or adjacent filter and transition the tolerances shall be as follows: -

- for the Vertical Dimensions $\pm 100\text{mm}$
- for the Horizontal Dimensions $\pm 100\text{mm}$

4.8 Disposal of Excavated Material

In so far as they may be suitable and comply with the Specification, materials arising from excavations may be used in the Works. All surplus or unsuitable excavated materials shall be disposed to spoil banks at locations shown on the drawings or accepted by the Engineer.

4.9 Spoil Banks

All necessary measures shall be taken not to obstruct natural drainage courses with the spoil banks. Spoil banks shall be graded to a neat appearance with outer slopes not exceeding 3 H:1 V. Suitable slopes shall be given to the surface to ensure drainage.

The maximum allowable height of the spoil banks shall be fixed by the Engineer.

4.10 Use of Explosives

Permission to blast shall only be carried out on those sections of the works for which permission in writing shall above been given by the Engineer. If blasting is necessary adjacent to any structure the Contractor shall provide a seismography and demonstrate that:

- For concrete or grout in place more than four hours but less than 60 hours, the maximum particle velocity as determined by seismographic measurement shall not exceed 10 mm/s.
- For concrete or grout in place less than four hours and greater than 60 hours, the maximum particle velocity shall not exceed 60 mm/s, except that for structures with a top width greater than their height and consisting of mass concrete or concrete having

only nominal reinforcing. maximum permissible particle velocity may be increased to 80 mm/s with approval of Engineer.

On basis of measurements obtained and on basis of observation made of structures after each blast, limits specified herein may be revised by Engineer.

4.10.1 Compliance with laws and regulations

The Contractor shall at all times take every possible precaution and comply with the Explosives Laws of Kenya and regulations relating to the handling. Transportation, storage and use of explosives and shall at all times when engaged in blasting operations sufficient warning flagmen to the full satisfaction of the Engineer.

The Contractor shall at all times make liaison with and inform well in advance and obtain such supervision and permission as is required from the Police and all Government Authorities, public bodies and private parties whosoever concerned or affected by blasting operations.

The Contractor shall provide a special store for explosives in accordance with Kenyan Regulations. The Contractor shall provide experienced men with valid Kenyan blasting licenses for handling explosives to the satisfaction of the Engineer and the Authorities concerned.

4.10.2 Submittals

The Contractor shall submit to the Engineer for his approval in advance details of the intended drilling patterns, depths of holes, the amounts of explosives at each location and the method or sequence of firing that the proposes to use.

4.11 Pre-Splitting

4.11.1 General

Pre-splitting comprises drilling a line of holes of appropriate diameter, spaced on centres not more than 10 times the diameter of the drill holes diameter or 30cm whichever is the greater and charging the holes with the appropriate amount of explosives to shear the rock in a surface along the line of drill holes. Either all holes in a pre-splitting row shall be drilled, charged and detonated simultaneously prior to drilling the production holes for the excavation adjacent to the pre-split row or pre-splitting shall be accomplished by delaying the production holes to allow the presplit holes to fire first. It is to be expected that the first row of production holes adjacent to the presplit face will need to be lightly charged to ensure that no damage occurs to the pre-sheared face when the main charge is detonated.

4.11.2 Submittals

The Contractor shall submit to the Engineer for his approval the proposed detailed methodology for presplitting.

4.12 Excavations in Quarry

4.12.1 General

Excavation of the overburden in quarry

The extent of the overburden shall be defined by the Engineer after the site investigation at the beginning of construction. Excavated material shall be sent to soil bank, or if suitable and complying with the specifications can be reused as fill.

4.12.2 Submittals

The planning of exploitation for quarry and method statement shall be submitted to the Engineer one month before starting excavations in the quarry.

4.13 Change in Quarry

When exploiting quarry, the Contractor shall perform all necessary investigations to document the quantity and quality of rock which remains to be exploited and shall inform the Engineer in writing. In case of insufficient quantities use of alternative quarry shall be contemplated.

4.14 Excavation of Earth Fill Material in Borrow Area

4.14.1 Investigations

Before opening excavations in the borrow area for earthfill, the Contractor shall perform a detailed investigation which shall include 1 exploratory pit per 10,000 m² of borrow area. Depth of the pit shall be about 8m. Samples shall be taken every 1.5 m and subjected to the following laboratory tests in the contractor's laboratory:

- natural moisture content
- Atterberg limits
- grading and hydrometer
- standard compaction test

The pits shall be logged as instructed by the Engineer and results shall be submitted to the Engineer.

4.14.2 Submittals

The earthfill borrow area planned exploitation shall be submitted to the Engineer one month before starting excavations in the borrow area.

4.15 Roads

4.15.1 General

The Contractor shall construct and maintain the permanent roads comprising the embankment crest road, the access roads on the gravel surfacing on platforms and backfill as shown on the drawings. These permanent access roads are used by the Contractor for access during construction. The Contractor shall reinstate to the satisfaction of the Engineer gravel surfacing to the thickness grade and crossfall as shown on the drawings.

4.15.2 Subbase

The sub base material for access road shall be approved material compacted to 150 mm thickness at 95% of modified Proctor maximum density.

The sub base material shall comply with the following grading requirement:

- - 100% by weight passing 50 mm sieve (square mesh),
- - 75-85% by weight passing 20mm sieve (square mesh),
- - 40-50% by weight passing 5 mm sieve (square mesh).

Before placing the sub base, the foundation shall be scarified and re-compacted.

4.15.3 Gravel Surfacing

The gravel surfacing for access roads, embankment crest road, backfill and platforms protection shall be 200 mm average thickness of approved gravel rolled to a smooth even surface.

The term “gravel” used shall be any such material which might be specified for use as a wearing course, e.g. murrum, some forms of partly decomposed rock or crushed rock.

Gravel surfacing material shall be spread in a uniform layer across the full width required, spread so that the maximum size of any particle is not greater than one half the compacted thickness of the layer. It shall then be mixed, watered if directed by the Engineer, graded and compacted by at least 6 complete passes of a 10 tonne smooth wheeled roller or other equivalent and graded to final level.

The tolerances on level permitted in the final surface of the wearing course will be:

| | Variations permitted | | Camber |
|-----------------------|----------------------|-------------------|--------|
| | Thickness | 3 m straight edge | |
| Gravel wearing Course | 25 mm | 25 mm | 25 mm |

4.16 Trench Excavations

4.16.1 Timbering of Excavations

The Contractor shall supply and fix outside the limits of the permanent Works all the timber necessary for support of sides and bottoms of the excavations, for the security of adjacent structures and properties and for every other purpose for which it may be required, all to the

satisfaction of the Engineer. The Contractor shall maintain such supports until in the opinion of the Engineer, the works is sufficiently advanced to permit the withdrawal of the support. Such withdrawal shall be executed only under the personal supervision of a competent foreman.

The Engineer may order excavations to be timbered or to be close timbered or may order timbering to be driven ahead of the excavation, or may order the adoption of any other method of supporting the sides and bottoms of the excavations as may appear to be necessary, and the Contractor shall adopt and shall make no charge for executing the adopted method.

The Contractor shall be responsible for any injury to the workers and any consequential damage caused by or arising out of the insufficiency or the support he provides for his excavations or caused by or arising out of the removal of that support, and any advice, permission, approval or instruction given by the Engineer relative to that support or removal thereof shall not relieve the Contractor of his responsibility.

For the purpose of this Clause the words “timber” and “timbering” shall be construed to include trench sheeting and steel or concrete sheet piling or any other means adopted by the Contractor for supporting excavations. All the costs for compliance with the provisions of this clause shall be deemed to have been included in the Contractor’s rate for excavation

4.16.2 Trench Excavation width

The width of the trench to be excavated will depend on the size and type of pipe being laid. Sufficient width must be excavated to allow the pipe to be correctly bedded and aligned, and to allow for the joints to be correctly made. Generally, the grade of the pipe will conform to the lie of the ground, but the excavation must be deepened where necessary to avoid backfills in any section. Generally, the pipeline will slope down towards scour valves and up towards air valves. Minimum gradients are shown on the general drawings.

Width of excavations for trenches for all pipes shall be determined from the following formula or as directed by the Engineer.

$$W=nD + (n-1)0.3 + 0.6$$

Where:

W= width of the trench to be excavated in meters

n =number of pipes

D = external diameter of the pipe in meters

Trench excavation shall be carried out with great care, true to line and gradient and as near as practicable to the size required for construction of the permanent work.

Excavation for pipe trenches shall be of sufficient depth to give a minimum cover of 900 mm over the top of the pipe and 1.2m below the road crossings.

Where the pipeline is required to be laid at depth, which does not satisfy the minimum cover conditions set out above, the ground surface shall be brought up to the required level by banking the backfill or as directed by the Engineer.

4.16.3 Excavation to be Kept Free from Water

Where excavations are required below the existing water level, the Contractor shall make arrangements to keep the excavation dry and shall produce drawings and written explanations of the method to be used to enable the Engineer to determine the adequacy of the method, before commencing the excavation.

The Contractor shall give due regard to the possibility of floods and provide all pumps, timbering, coffer dams, sheet piling and other equipment necessary for keeping the excavations free from water.

Every precaution shall be taken not to diminish the bearing capacity of the soil below foundation level. Wall-points or pump pits are to be outside the foundation area to prevent flows in upward direction.

All sumps and drains are to be filled in or otherwise made good as directed by the Engineer on completion of the relevant part of the Works.

The costs of all the above precautions shall be at the contractor's expense.

4.16.4 Excavation in Hard Material

Where hard material is encountered in trenches for pipelines it shall be excavated so that no hard material protrudes within 100mm of the pipe surface. A regulating layer of 150mm sand or other approved material shall be placed on the excavated hard material surface to provide a firm but flexible bed for the pipe.

The Contractor shall notify the Engineer on each occasion when he encounters hard material prior to excavation of such materials. No payment for excavation in hard material shall be made unless the Engineer has inspected the excavation and certified in writing that the material meets the classification of hard material and the quantities involved.

The Contractor shall trim all rock faces in cutting to accord with the dimensions shown on the drawings and upon completion leave them safe from rock falls to the satisfaction of the Engineer.

The Contractor's blasting and other operations in excavation shall be such that they will yield as much suitable material as possible for the construction.

4.17 General Backfill

Backfilling materials and methods are generally subject to the approval of the Engineer. The approved materials shall be placed in layers, not exceeding 200 mm in depth before compaction and shall be well compacted as specified in the following:

- The layers of fill material shall be placed in such a manner as to maintain adequate drainage and to prevent accumulation of water.
- The timing and rate of placing of fill material around or upon any completed or partially completed structure shall be arranged in such a way that no part of the works is overstressed, weakened, damaged or otherwise endangered.

- Around structures the material shall be placed as to exert a uniform pressure and each layer shall be placed with a fall to prevent the accumulation of water.
- Where necessary, the moisture content of the backfill has to be adjusted to an optimum
- either by drying out or by adding water. After such treatment the backfill shall be thoroughly mixed until the moisture content is uniform.
- Placing the backfilling, due allowance for any settlement that may occur before the end of period of maintenance shall be made. Where necessary, the Contractor shall at the end of the period of maintenance remove any excess material or make up any deficiency of backfilling to specified levels.

The Contractor shall, when placing the backfilling, make due allowance for any settlement that may occur before the end of the Defects Liability Period. Where necessary, the Contractor shall at the end of that period remove any excess material or make up any deficiency of backfilling to specified and required levels.

4.18 Embedding of Pipes

Embedding of pipes shall be carried out in accordance with EN 1610.

4.18.1 Ductile Iron and PVC pipes

Ductile Iron and uPVC pipes shall be laid on a 150 mm compacted bed of sand or approved excavated material and shall be embedded by sand or approved excavated material to a level of 300 mm above the top of the pipes. Embedding material shall be placed by hand and compacted in layers of not more than 100 mm compacted thickness. The material shall be compacted to at least 90 % maximum density below and around the pipes as to provide firm and continuous support.

The Contractor shall ensure that the pipe is not displaced or damaged by the embedding operation.

4.18.2 HDPE pipes

HDPE pipes shall be laid on a 150 mm compacted bed of sand and shall be embedded by sand up to a level of 300 mm above the crown of the pipes. Embedding material shall be placed by hand and compacted in layers of not more than 100 mm compacted thickness. The material shall be compacted below and around the pipes as to provide firm and continuous support. The compaction grade of the embedment (30 cm above the crown of the pipe) shall be not less than 95 % proctor density and $EV2 \geq 45 \text{ MN/m}^2$. The compaction test on the embedment shall be carried out every 100 m.

The quality of material for bedding under the pipe, sidefill between pipe and trench wall and initial backfill (30 cm over the pipe) shall be approved under following requirements:

- Sand, sand/ gravel mix or crushed stone fines are allowed to be used.
- The particle size of round material shall not exceed 16 mm unless the pipeline supplier recommends a smaller size.

- The particle size of crushed stone fines shall not exceed 11 mm unless the pipeline supplier recommends a smaller size.
- The content of particles of between 8 and 16 mm shall not exceed 10 %.
- The material shall be compactable to the required value. Therefore, it shall consist of different sizes of grains.
- Polyethylene is a flexible material and can deform under load without damage. It is however, important that any deformation is minimized and that the placement of the correct sidefill and initial backfill is carried out correctly with adequate compaction.

4.18.3 Concrete Pipes

Except where concrete or granular bed is specified, the bedding material for concrete pipes shall consist of crushed stones or gravel, be free from stones and lumps and be graded 0/25 mm.

The pipe bed shall be backfilled by hand from 150 mm below the bottom of the pipes to a level of 300 mm above the top of the pipe and compacted to at least 90% maximum modified proctor density.

4.18.4 Approval of Embedding

The Contractor shall take all precautions to fix the pipes in their location. This includes the bedding of pipes and partial refilling of trenches leaving the joints exposed while awaiting pressure tests.

Formal approval of embedding shall be obtained from the Engineer prior to the testing of pipes.

4.19 Main Backfill of Trenches

Backfilling of trenches shall be carried out in accordance with EN 1610.

From the top of the bedding layer up to the finished ground level, the trench shall be backfilled with approved selected material, compacted by mechanical methods approved by the Engineer in layers with a thickness of not more than 150 mm.

Each layer shall be compacted separately. Compaction shall be not less than 95% modified proctor density. Where necessary, the Contractor shall adjust the moisture content of the refill material to assist the compaction either by drying out or by sprinkling with water.

The Contractor shall provide adequate number of power tampers or other compaction equipment subject to the approval of the Engineer and sufficient water on Site for moistening

The Contractor shall, when placing the backfill, make due allowance for any settlement that may occur before the end of Defects Liability Period. Where necessary, the Contractor shall at the end of this period remove any excess material or make up any deficiency of backfilling to specified levels.

In the event that excavated material is insufficient or unsuitable for backfilling, the Contractor shall use imported fill material from approved borrow pits.

Where directed by the Engineer, trench excavations shall be backfilled with concrete, class C8/10. Likewise, the Contractor shall use cement stabilised backfill where shown on the drawing or as directed by the Engineer.

4.19.1 Backfilling with Excavated Suitable Material

No backfilling or refilling shall commence without the Engineer's approval.

The refilling of excavations shall commence as soon as practicable after the permanent works have been tested where so required and inspected and approved by the Engineer. In particular, the backfilling of trenches shall be carried out expeditiously to reduce lengths of trenches open at any one time.

As soon as High Density Polythene pipes are laid and jointed in their final positions they should be protected from possible damage by carefully backfilling of fine granular material brought up to about 150 mm over the top of the pipe, for the full width of the trench, and well compacted.

Joints must be left open for inspection until the pressure test is completed.

Backfilling shall be executed with suitable excavated material in 150 mm layers each layer being well rammed and watered to obtain the maximum compaction. Care shall be taken to ensure that no stone or other material, which could damage pipes or other work.

Water in excess shall not be used in settling of the backfilling.

Backfilling over steel pipes shall be generally as described above, except that the initial protective filling around the pipe is not necessary.

Regardless of the means of backfilling adopted, it is the Contractor's responsibility to ensure that he satisfactorily backfills all excavations and causes no damage to permanent work or adjacent structures, and he shall at his own expense take all steps necessary to comply with this obligation.

The Contractor shall at all times be responsible for damage caused to permanent works through his backfilling operations or through the premature opening to traffic of a backfilled surface.

The minimum cover, where pipelines cross under roads, shall be 1.2 m to the top of the surrounding concrete, or such cover as may be directed by the road authorities.

Any excavated material stored on site for backfilling or other purposes shall be deposited alongside the excavation at a minimum distance of 0.5 m in such a manner that it will cause no damage and as little inconvenience as possible.

The rate for excavation shall include the costs of complying with the requirements of this clause.

4.19.2 Backfilling with sand or imported suitable material

Where shown in the drawings or instructed by the engineer, the Contractor shall provide and use approved sand or imported suitable material to backfill around pipes and structures

to the thickness instructed by the Engineer. A rate in the Bill of Quantities shall be provided for this item.

4.19.3 Reinstatement of Surfaces

Generally, all trenches and backfilled excavations shall be reinstated to equal surface as before excavation.

Trenches in any existing road shall be refilled to the level of natural soil below the road with sub-soil in 75 mm layers, each layer being carefully tamped with rammers. The remaining top layers shall be filled to the road surface with materials equal in type, quantity and compaction to materials used for the existing road.

The backfilled trench shall then be left to settle for 30 days. At the expiration of this period the surface shall be made up to level and tamped or rolled to the approval of the Engineer, who will decide on the particular surfacing employed in accordance with the existing surface of the road.

Before expiration of the maintenance period the Contractor shall make good any defaults in reinstatement. The rate for excavation shall include the costs of complying with the requirements of this clause.

4.19.4 Removal of Surplus Excavated Material

Excavated material, which is not needed either for backfilling trenches or other excavations or otherwise, shall be removed and disposed of to tipping places obtained by the Contractor. All rubbish and waste material shall similarly be removed by the Contractor. All surplus excavated material shall be spread and leveled in the tipping places in accordance with such directions as the Engineer may give, and the Contractor's rates for disposal shall include for the costs of such operations.

The Contractor shall take every practical precaution against causing any nuisance, damage, injury or inconvenience in the handling, stacking, carting or disposal of excavated materials or any other operation matter or thing in connection therewith. No excavated material shall be placed in any position where it may be washed away or may be liable to fall or spread into any private property or across a road or footpath, and should such occur, the Contractor shall forthwith remove the same at his own costs.

Should the Engineer direct the Contractor to tip certain surplus excavated materials in a particular place (other than the tipping places obtained by the Contractor) the Contractor shall abide by such instruction and shall make no charge in consequence thereof unless the place specified entails a longer haul than what would be incurred by tipping at the place or places obtained by the Contractor.

The rate for excavation shall include the costs of complying with the requirements of this clause.

4.20 Foundation for Structures

4.20.1 Soft material:

The bottom and side slope of soft material upon or against which concrete is to be placed shall be finished accurately to the established lines and grades, and loose materials on surfaces so prepared shall be moistened with water and tamped or rolled with suitable tools and equipment to form a firm foundation for the concrete structure. If, at any point in Soft material, material is excavated beyond the established excavation lines, for any reason except by written orders from the Engineer, then the over-excavation resulting voids shall be filled with concrete class 15 at the Contractor's expense.

4.20.2 Hard Materials:

The bottom and side slopes of hard material upon or against which concrete is to be placed shall be excavated to the required dimensions as shown on the drawings or established by the Engineer. No material will be permitted to extend within the neat lines of the structure. If, at any point in the hard material, material is excavated beyond the limits required to receive the structure, the additional excavation shall be filled solidly with concrete class 15.

All loose material shall be removed by the use of steel brooms and air jets.

4.20.3 Backfill Adjacent to Completed Structures

The Contractor shall start backfill only after the walls, floors and slabs have been completed and have attained their full strength. Backfill around the walls of tanks and reservoirs shall not commence before successful completion and testing and after having the Engineer's approval.

The layers of backfill material shall be placed in such a manner as to maintain adequate drainage and to prevent accumulation of water. The material shall be placed with particular care for insulation and watertight paints and all other protective or conserving surfaces and as to exert a uniform pressure around the walls of a structure and each layer shall be placed with a fall to prevent the accumulation of water.

Special attention shall be paid to the compaction of material laid immediately adjacent to concrete walls as to ensure that the material is well compacted. Hand operated vibrating plate compactors; vibro-tampers or power rammers shall be used. The compacting shall be carried out in such a way as to avoid in any case direct contact of the compacting machinery and the building.

In other cases vibrating compactors or pneumatic tyre rollers of types approved by the Engineer may be used for compaction.

4.21 Borrow Pits

No borrow pits will be allowed to be opened within the site of permanent works without the approval of the Engineer.

No separate payment will be made for acquisition, development and operating borrow sites whatsoever as the same is deemed to have been included in the Contractors rates.

All borrow sites will have to comply with national and local laws and regulations governing operations of such borrow sites. The Engineer reserves the right to order closure and reinstatement of any borrow site that might prove harmful to the public.

4.22 Rock Fill Below Structures

Where shown in the drawings or instructed by the Engineer, the Contractor shall provide and place rock fill below structures. Rockfill shall consist of clean hard broken stone or rubble with measurements not exceeding 150 mm in any one direction with sufficient lateritic gravel added to fill the interstices. The Rockfill shall be well-packed, rammed and where possible rolled with a 5-ton roller. Where rolling is impossible, compaction shall be by hand or by mechanical tampers. Before any concrete is laid on Rockfill, the rockfill shall be levelled and blinded with fine stone chippings, rolled and watered as necessary. The volume of rockfill shall be measured after compaction. A rate in the Bill of Quantities shall be provided for this item.

4.23 Ant-Proofing

Where an ant-proof course has been specified or instructed by the engineer, it should be made by application of Rentokil Termite Soil Concentrate or equal diluted one part concentrate to forty parts water (by weight) at the rate of 5 litres solution to 1 square meter to the whole area of the structure immediately before (36 hours maximum) the concrete is poured. Additionally, to all critical areas, i.e. both sides of wall foundations, piers and porches the application should be 5 litres per running metre. Treatment should not be made when the soil is excessively wet. Precautions should be taken to prevent disturbance of the treated areas before they are covered.

4.24 Stone Pitching

Where shown on the Drawings. Or directed by the Engineer the Contractor shall excavate for, trim to line and level, provide and lay stone pitching.

Stone pitching shall be formed of hard stone, roughly dressed square.

The least dimension of any stone shall not be less than 200 mm, and the volume not less than 0.01 m³. No rounded boulders shall be used.

The stones shall be set on edge and securely bedded with the largest dimensions at right angles to the flow of water, fitted closely together so as to leave only a minimum of voids between the stones which shall be filled in with suitably shaped and tightly wedged spalls. The top of the pitching shall be finished flush with the adjacent material.

Where grout is specified, a 1:4 cement: sand mortar shall be rammed into the wetted interstices and smoothed off flush with the pitched face.

4.25 Drainage Fill and Filter Materials

Free drainage fill and filter material shall be formed of hard durable grain and shall be free from clay, silt, soluble or organic matter. The particle size distribution shall be in accordance to the filter rules.

The Contractor shall provide for free drainage materials from approved sources. The Contractor may use material from excavation, provided it is suitable and processed in compliance with the specification of free drainage material.

4.26 Rip Rap

Riprap material shall be sound, un-weathered and with low water absorption capacity in order to avoid cracking, bursting and dripping as a result of weather influences.

The rock shall mainly consist of large pieces with lateral lengths from 150 to 400 mm and smaller parts to secure the boulders against sliding and to provide stability to the fill structure.

The density of riprap material shall be not less than 2.2 t/m³ (solid volume without voids) and each piece of riprap shall have is greatest dimension not large than twice its least dimension.

The dimension of the riprap material shall be 250x250x250 mm for 90 percent of the material. The material delivered shall be dumped and graded off to a uniform surface up the lines and

grades shown on approved drawings. No pockets of rocks and clusters of large blocks shall be permitted.

The Contractor shall submit full details of the proposed source, certified test results and samples for the approval of the Engineer.

4.27 Gabions

Where shown on the Drawings or directed by the Engineer the Contractor shall excavate for, trim to line and level, provide and erect gabions including providing selected rock, crushed if necessary, packed and compacted inside the gabions.

Gabions shall include gabion mattresses and gabion boxes and for the purposes of construction and method of measurement and payment no distinction shall be made between them.

Gabions shall be "Maccaferri" boxes and/or "Reno" mattresses both with diaphragms at 1 metre centres, or similar approved. The maximum mesh size shall be 100 mm x 120 mm for boxes and 60 mm x 80 mm for mattresses. The wire used for the construction of gabions shall unless otherwise instructed by the Engineer comply with the requirements of Table 4-1.

TABLE 4 – 1

| | | |
|--|---------------|------------------------------------|
| | Diameter (mm) | Galvanising (g/m ²) |
|--|---------------|------------------------------------|

| | | | |
|----------|--------------|------|-----|
| Mesh | Box Mattress | 3.4 | 275 |
| | | 2.7 | 260 |
| Binder | Box Mattress | 2.2 | 240 |
| | | 2.2 | 240 |
| Selvedge | Box Mattress | 3 .9 | 290 |
| | | 3.4 | 275 |

All wire shall be to BS 1052 having a tensile strength of not less than 40kg/mm²

Galvanizing shall comply with the requirements of BS 443.

Gabions shall be constructed to the shapes and dimensions as shown on the Drawings or given in the Special Specification or as directed by the Engineer. Gabions, as constructed shall be within a tolerance of +/- 5% on the height or width instructed and +/-3% on the length instructed.

The alignment of the gabion shall be correct within a tolerance of 100mm of the instructed alignment and the level of any course of gabion shall be correct to within a tolerance of 50mm of the instructed level. In addition, adjacent gabions shall not vary by more than 25mm in line and/or level from each other

The surface upon which gabions are to be laid shall be compacted to a minimum dry density of 95% MDD (AASHTO T99) and trimmed to the specified level or shape.

Joints in gabions shall be stitched together with 600mm minimum lengths of binder wire, with at least one stitch per 50mm, and each end of the wire shall be fixed with at least two turns upon itself.

Adjacent gabions shall be stitched together with binder wire along all touching edges.

Gabion boxes shall be laid with broken bond throughout to avoid continuous joints both horizontally and vertically. Pre-tensioning of gabions shall be subject to the approval of the Engineer.

Gabions shall be hand packed with broken rock of 150 mm minimum dimension and 300mm maximum dimension. The sides shall be packed first in the form of a wall, using the largest pieces, with the majority placed as headers with broken joints to present a neat outside face. The interior of the gabion shall be hand packed with smaller pieces and the top layers shall be finished off with larger pieces. The whole interior and to layers shall be packed tight and hammered into place.

Where instructed by the Engineer the Contractor shall place filter fabric ('Terram' or similar approved) behind gabion faces in contact with existing or backfilled ground. The Contractor shall ensure that the filter fabric is not damaged during the construction or backfilling around the gabion works and any damaged or torn fabric shall be replaced at the Contractor's expense. The filter fabric shall be installed in accordance with the manufacturer's instructions and the filter fabric shall not be left exposed to sunlight for more than 3 weeks.

At the back face and ends of completed gabion work or where shown on the Drawings or instructed by the Engineer the existing soil shall be backfilled, thoroughly compacted against the sides of the gabions and finished flush with the top surface of the gabion.

On completion of gabion construction, the exposed joints shall be painted with thick bitumen to the approval of the Engineer to discourage vandalism.

4.28 Disposal of Surplus Material

The disposal of surplus backfill material shall be deemed to be included in the rates for the respective backfilling operations.

The Contractor shall make his own arrangements to dispose off all surplus backfill and unsuitable excavated material from any part of the Work. The material shall become the property of the Contractor and shall be disposed Off-Site under his sole responsibility.

The Contractor shall clean the Site and the surrounding ground immediately after completion of works and leave the construction Sites clean and tidy to the satisfaction of the Engineer.

4.29 Backfilling Sundries

4.29.1 Backfilling under Paved Areas

When excavation is made in highways, roads, sidewalks or any other paved area, the trench shall be backfilled and thoroughly compacted up to the bottom of the sub base of the surrounding pavement.

The remaining top of the trench shall be filled with graded and well compacted aggregate up to the top of the base of the pavement.

The further reinstatement of surfaces shall comply with the existing pavements.

4.29.2 Backfilling around Manholes

Backfilling around manholes and material used for it shall meet the specifications set out for the backfilling of adjacent trenches.

In roads with a width over 3 m, the material around manholes shall be selected and compacted to meet the requirements of base and sub base.

4.29.3 Backfilling in Agricultural Land

If pipe alignments cross agricultural land, the trench shall be backfilled to the top of adjacent land; whereby the top 30-cm of the trench shall be filled with the agricultural top soil originally found before excavation.

4.29.4 Backfilling in Watercourses

In riverbeds the pipes shall be fully encased with reinforced concrete and the top of the excavation shall be covered with gabions, laid by hand and extending 1m on either side of

the excavated trench; likewise in ditches clad with masonry, the masonry shall be reinstated after completion of backfill with concrete and in small ditched without any surface cladding the trench shall be backfilled to the invert of the ditch with concrete. Concrete shall be reinforced with 80kg/m³ steel. Concrete shall be of class C20/25.

4.29.5 Field Drains

Should any existing subsoil or field drains be uncovered during general excavation, the Contractor shall either carefully replace them when backfilling, or, if this is impracticable, shall divert them to new drains or ditches, or otherwise relay them as the Engineer may direct.

4.30 Reinstatement and Maintenance

4.30.1 Reinstatement of Paved Surfaces

The Contractor shall restore all pavements or other surface structures removed or disturbed as a part of the work to a condition suitable and satisfactory to the Engineer.

No pavement shall be restored unless and until, in the opinion of the Engineer, the condition for backfill is given in such a way as to properly support the pavement.

The reinstatement of road surfaces and other pavements shall be commenced upon approval of the Engineer of the completed backfill and shall be done, if not otherwise stated, as follows:

- The top of the pipe trench (below the top of the base) shall be filled with graded aggregate (0 – 60 mm of natural stabilized material), watered, placed in layers of max.15 cm thickness and compacted to not less than 95% of maximum dry density according to modified proctor test.
- At pipeline crossings, the top 30 cm of the trench shall be filled with plane concrete C12 / 15.
- At the top of the base, the width of the trench shall be increased for 15 cm on each side.
- In order to ensure appropriate adjustment of the surfaces the Contractor shall use such methods as shall ensure the breaking of the pavement along straight lines, preferably by cutting. The face of the remaining pavement shall be approximately vertical.
- The surface shall be restored in accordance with the existing pavement and/or the direction of the Engineer.

4.30.2 Reinstatement of Unpaved Surfaces

Gravel roads and unpaved roads shall be reinstated to their original condition. If the original road construction can not clearly be applied, then 100 mm approved large gravel and 150 mm well-graded gravel compacted to 95% of maximum density shall be provided.

4.30.3 Surface Reinstatement in Agricultural Fields

After the Contractor has completely backfilled the trenches in fields and grass verges to the level specified, he shall replace all topsoil previously removed and it shall be evenly distributed and levelled over the full extent of the stripped area.

Such working area occupied by the Contractor as was originally grown with grass shall be sown with grass seed of equivalent quality and maintained until the new grass is properly established.

Other areas not originally down to grass shall be dressed with suitable fertilisers harrowed in so as to restore the original level of fertility.

4.30.4 Reinstatement of Existing Services

Where excavation is carried out close to or across the line of sewers, pipes, cables or other services, whether underground or overhead, the Contractor shall, where necessary, provide at his own cost temporary supports or slings and where such services are temporarily disturbed, they shall be replaced.

4.30.5 Reinstatement of Hedges, Fences and Walls

Where excavation disturbs features such as hedges, fences and walls, the Contractor shall, as a temporary measure, provide temporary fencing for any such parts of such barriers.

After excavation has been reinstated, the Contractor shall carry out such work as approved by the Engineer for permanent restoration of such barriers.

In case of hedges, saplings of the appropriate species and on both sides shall replace the section removed by providing an adequate post and barbed wire fence.

During the period of maintenance all hedges replanted in the above manner shall be inspected and any dead sapling replaced by the Contractor.

The reinstatement of the backfilled surface shall be done at the Contractor's own expense and include

- i. the re-excavation of the top surface, base and subbase,
- ii. compacting the backfill in the trench,
- iii. backfilling the base and sub base with graded aggregate and
- iv. reinstatement of the surface according to surface conditions met before.

4.31 Auxiliary Works

Unless otherwise specified, all and any kind of works, materials, services, safety measures, etc., as well as, and if so requested by the Engineer, all tests and samples required for the Completion of the Works shall be included in items and prices included in the bill of quantity. Hence, the auxiliary works comprise, but are not necessarily limited to, the following:

- Removing and storing of boundary stones, bench marks, etc., protection of surveying points and designation by means of boards, survey and protection of all secondary survey points, profiles, etc.;

- Difficulties to be overcome where excavation may have to be carried out in layers of by hand;
- Keeping off or diversion of water, any pumping, required, difficult work caused by water, etc.;
- Removal of any groins, buried pipes, wattle work, fascines and the like that might interfere with excavation profiles, irrespective of whether or not such structures are specified in the Price Schedules;
- Difficulties resulting from the specifications relating to fills, compaction tests, eliminating unsuitable material from fills, and, if necessary, mixing of different soil materials;
- Transport of excavated material to fill or deposit, placing and spreading in layers
- according to conditions and drawings, and careful compaction;
- Difficulties in transport due to existing subsoil conditions;
- Grading of intermediate and top fill surfaces and slopes to lines and levels required;
- Sorting of excavated material which, if necessary, is to be used for special purposes;
- Any expenditure for providing, maintaining and later removal of drive ways and roads, providing, placing, maintaining and later removal of conveying and dumping equipment that might be required.

4.31.1 Top Soil

So far as practicable, topsoil shall be obtained from material emanating from excavations and separately stored in temporary spoil tips as specified or directed by the Engineer.

If, in the opinion of the Engineer, the Contractor cannot reasonably obtain sufficient topsoil in this way, the Engineer may order the Contractor to provide extra material from an approved source off the Site.

Topsoil shall be evenly spread and trimmed over embankments and filled excavation to the slopes and levels as shown on approved drawings. The depth after spreading and trimming shall be 250 mm measured perpendicular to the surface. All clods and lumps shall be broken up and any rubbish, large stones, roots and weeds shall be removed.

Where the upper layer of natural soil is poor in organic matter, it shall be improved to a minimum depth of 25 cm by adding either clay or sand or silt to create a loamy soil texture consisting of 40% sand (size > 0.05 mm), 30% silt (size 0.05-0.002 mm) and 30% clay (size <0.002 mm).

A shallow ripping shall be required before adding clay or sand or silt which shall be mixed properly by using a disk harrow. If it shall be necessary for topographical reasons, levelling shall be carried out before mixing clay, sand or silt.

4.31.2 Grassing

Where the topsoil shall be sown with grass seed, the top 75 mm of the previously laid topsoil shall be brought to a fine tilt suitable for seeding, and sowing shall be carried out as soon as

practicable after completion of top soiling having due regard to the season and the weather conditions. If ordered by the Engineer, subsoil lime and fertiliser shall be applied in accordance with his directions.

After the seed has been sown uniformly, they shall be raked and lightly rolled into the surface. The young grass shall be kept free from weeds and any bare patches shall be re-seeded until an even close turf is established. The grass shall be watered, mown and rolled as required and maintained in good condition until the expiry of the period of maintenance.

The Contractor shall replace, at his own cost, any damaged area where the grass has dried up or has not adhered to the slope surface, which contains undesirable plants or which has an irregular or unattractive appearance in the Engineer's opinion.

4.31.3 Shrubs and Trees

Shrubs for borders and hedges shall have a minimum height of 0.6 m. Aluminium of 2 plants per m² shall be planted to create an evenly dense area.

Trees to be supplied and planted shall have a minimum height of 1.5 m.

For the plant holes vegetable soil is to be used. Stabilization of freshly planted trees against wind actions shall be provided. Shrubs and trees shall be suitable for the climatic conditions on Site.

The Engineer shall approve the species the Contractor intends to plant.

Growth of shrubs and trees shall be guaranteed for one year from the day of planting. Any shrubs and trees, which have died within the guaranteed period, must be substituted without extra payment.

4.31.4 Dressing of Topsoil

After planting of lawn, shrubs or trees, the topsoil shall receive a dressing of fertiliser. As minimum requirements, dressing of topsoil shall be done with lime, potash and super-phosphate, as applicable.

Dressing of topsoil shall only be carried out after watering and raining. The surface of the soil shall be kept wet until fertilisers have dissolved.

A rate in the Bill of Quantities shall be provided for this item.

4.32 Measurement and Payments

a. Excavation in Soft material

I) Excavation for trenches in Soft Material

Unit: m³

Excavation for trenches in soft material shall be measured in cubic meters calculated as the product of the width of the excavation given in this specification and the sectional area. The sectional area of the excavation, measured in square meters shall be calculated by the product of the average depth of the excavation and the

instructed length of the trench. The average depth shall be measured from the instructed final profile.

The rate for excavation in trenches in soft material shall include for the cost of excavation to any depth, trimming and levelling, backfilling with excavated material or removal excavated material to spoil if it is unsuitable or surplus to requirements, and complying with the requirements of this specification.

II) Excavation for Structures in Soft Material

Unit: m³

Excavation for structure in soft material shall be measured by the cubic meter, calculated as the product of the net plan area of the foundation to be excavated and the average depth of the excavation. No allowance will be made for working space. The average depth shall be calculated as the difference between the original ground level as agreed as per this specification between the engineer and the contractor, and the required level.

The rate for excavation for Structure in soft material shall include for the cost of excavation to any depth, Compaction of the foundation level of the excavation, backfilling with excavated material or removing the excavated material to spoil if it is unsuitable or surplus to requirements of this specification.

b. *Excavation in Hard Material*

Unit: m³

Hard material encountered in any excavation shall be measured by the cubic meter, calculated as the product of the average end area measured at intervals agreed with the engineer along the centreline of the excavation. No allowance will be made for the working space.

The rate for excavation in hard material shall include for the cost of excavation to any depth, Compaction of the foundation level of the excavation or trimming and levelling, backfilling with excavated material or removing the excavated material to spoil if it is unsuitable or surplus to requirements and complying with the requirements of this specification.

c. *Backfilling with sand or imported suitable material.*

Unit m³

Sand or imported suitable material shall be measured by the cubic meter, calculated as the product of the average end area (excluding any pipe or concrete surround) and the length of the suitable backfill material instructed to be placed.

The rate for suitable backfill material shall include for the cost of providing the material, backfilling at any depth, all the hauls as necessary and complying with the requirements of this specification.

d. *Rock fill below Structures*

Unit: m³

Hard-core filling shall be measured by cubic metre calculated as plan area and average depth of hard-core fill instructed.

The rate for hard-core filling shall include for the cost of providing, placing the material, compacting, all the hauls as necessary and complying with the requirements of this specification.

e. Grass planting and top soil placing

Unit: m²

Grass planting and top soil placing shall be measured as **plan area** in square meters instructed.

The rate for grass planting and top soil placing shall include for the cost of providing grass and suitable top soil, placing, planting, watering, all the hauls as necessary and complying with the requirements of this specification

f. Ant Proofing

Unit: m²

Ant proofing shall be measured as **plan area** in square meters instructed.

The rate for ant proofing shall include for the cost of providing, placing, and complying with the requirements of this specification

g. Stone pitching

Unit: m²

Stone pitching shall be measured by the. square metre calculated as the net area, measured on the slope, instructed by the Engineer.

The rate for stone pitching shall include for the cost of excavating, trimming to line and level, grouting. providing and laying the stone and of complying with the requirements of this specification. Grouting of stone pitching shall include for providing the sand, cement, mortar, wetting of the stone to be grouted, ramming the grout into the interstices and smoothing off: flush with the pitched face and complying with this Specification.

h. Gabion Boxes

Unit: No.

Gabion boxes shall be measured by the Numbers calculated as the net area of material required to construct the gabions, including diaphragms.

The rate for gabion mesh shall include for

- a. the cost of providing and fixing the mesh and the cost of complying with requirements of this Specification.
- b. the cost of excavation to any depth, compaction of the surfaces to receive the gabions, backfilling with the excavated material or removing the excavated material to spoil if surplus to requirements and complying with the requirements of other Clauses in section 4 of this Specification.

- c. the cost of providing, hauling and placing the rock and the cost of complying with the requirements of this Specification.

i. Item: Filter fabric under and/or behind gabions

Unit: m² of each weight a fabric specified

The filter fabric placed under and/or behind gabions shall be measured as the net area of filter fabric instructed.

The rate for filter fabric shall include for the cost of the preparation of the surface to receive the filter fabric, the provision, transport, storing and laying the fabric in accordance with the manufacturer's instructions, all laps and/or stitching and for complying with the requirements of this Specification.

5 CONCRETE WORKS

5.1 General

All materials and workmanship for concrete shall comply with BS EN 1992 -1-1:2006 and BS EN 1992-3:2006, where applicable.

This section covers the materials, design of mixes, mixing, transport, placing, compaction and curing of concrete and mortar required in the works. It also covers formwork and reinforcement for concrete.

5.2 Definitions

Structural concrete is any class of concrete which is used in reinforced, prestressed or unreinforced concrete construction, which is subject to stress.

Non-structural concrete is composed of materials complying with the Specification but for which no strength requirements are specified, and which is used only for filling voids, blinding foundations and similar purposes where it is not subjected to significant stress.

A **formed surface** is a face which has been cast against formwork.

An **unformed surface** is a horizontal or nearly horizontal surface produced by screeding or trowelling to the level and finish required.

A **pour** refers to the operation of placing concrete into any mould, bay or formwork, etc., and also to the volume which has to be filled. Pours in vertical succession are referred to as lifts.

5.3 Materials for Concrete

5.3.1 General

The Contractor shall submit to the Engineer full details of all materials which he proposes to use for making concrete. No concrete shall be placed in the works until the Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or substituted by other materials without the consent of the Engineer.

5.3.2 Cement

Cement shall comply with the following Kenya Standards: -

- KS1725:2001 CEM 1 42.5N for Ordinary Portland Cement.
- KS02-21 for Rapid Hardening Portland Cement plus all special conditions to its use stipulated by the manufacturer

Cement shall be free flowing and free of lumps. It shall be supplied in the manufacturer's sealed unbroken bags or in bulk. Bagged cement shall be transported in vehicles provided with effective means of ensuring that it is protected from the weather.

Bulk Cement shall be transported in vehicles or in containers built and equipped for the purpose.

Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level and shall be so constructed that no moisture rises through it.

Each delivery of cement in bags shall be stacked together in one place. The bags shall be closely stacked so as to reduce air circulation but shall not be stacked against an outside wall. If pallets are used, they shall be constructed so that bags are not damaged during handling and stacking. No stack of cement bags shall exceed 3 m in height. Different types of cement in bags shall be clearly distinguished by visible markings and shall be stored in separate stacks.

Cement from broken bags shall not be used in the Works.

Cement in bags shall be used in the order in which it is delivered.

Bulk cement shall be stored in weatherproof silos which shall bear a clear indication of the type of cement contained in them. Different types of cement shall not be mixed in the same silo.

The Contractor shall provide sufficient storage capacity on site to ensure that his anticipated programme or work is not interrupted due to lack of cement.

Cement which has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the Site.

All cement for any one structure shall be from the same source.

All cement used in the works shall be tested by the manufacturer or the Contractor in a laboratory acceptable to the Engineer. The tests to be performed shall be those set out in Section 2 of this Specification and the Contractor shall supply two copies of each certificate to the Engineer.

Each set of tests carried out by the manufacturer or Contractor shall relate to not more than one day's output of each cement plant, and shall be made on samples taken from cement which is subsequently delivered to the Site. Alternatively, subject to the agreement of the Engineer, the frequency of testing shall be one set of tests for every 200 tonnes of cement delivered to Site from each cement plant.

Cement which is stored on Site for longer than one month shall be re-tested in the laboratory of the Materials Branch of the Ministry of Transport and Communications or at the Kenya Bureau of Standards at the rate instructed by the Engineer.

Cement which does not comply with the Specification shall not be used in Works and it shall be disposed of by the Contractor.

The Contractor shall keep full records of all data relevant to the manufacture, delivery, testing and use of all cement used in the Works and shall provide the Engineer with two copies thereof.

5.3.3 Fine aggregate

Fine aggregate shall be clean hard and durable and shall be natural sand, crushed gravel sand or crushed rock sand complying with BS 882. All the material shall pass through a 5 mm BS sieve and the grading shall be in accordance with Zones 1, 2 or 3 of BS 892. In order to achieve an acceptable grading, it may be necessary to blend materials from more than one source. Fine aggregate for mortar only shall comply with BS 1200.

The fine aggregate shall not contain iron pyrites or iron oxides. It shall not contain mica, shale, coal or other laminar, soft or porous materials or organic matter unless the Contractor can show by comparative tests, on finished concrete as set out in BS 1891, that the presence of such materials does not adversely affect the properties of the concrete.

Other properties shall be as set out below:

Content passing a 75 micron BS sieve shall not exceed 3 per cent for natural or crushed gravel sand or 15 per cent for crushed rock sand.

Chlorides soluble in a 10 per cent solution by weight of nitric acid shall not exceed 0.05 per cent by weight expressed as chloride ion when tested as set out in BS 812, subject also to the further restriction given in the note on total chloride content in Sub-Clause 5.3 (d).

Sulphates soluble in a 10 per cent solution by weight of hydrochloric acid shall not exceed 0.4 per cent by weight expressed as SO₃, when tested as set out in BS 1377, subject also to the further restriction given in the note on total sulphate content in Sub-Clause 5.3.4 (d).

Soundness: After five cycles of the test in AASHTO T104 the aggregate shall not show a weight loss of more than 10 per cent.

Organic impurities: If the test described in Section 2 of this standard Specification shows that more than a trace of organic impurities is present, the fine aggregate shall not be used in the Works unless the Contractor can show by tests on finished concrete as set out in BS 1881 that the presence of organic impurities does not adversely affect the properties of the concrete.

5.3.4 Coarse Aggregate

Coarse aggregate shall be clean hard and durable crushed rock, crushed gravel or natural gravel complying with the requirements of BS 882. The material shall not contain any iron pyrites, iron oxides, flaky or laminated material, hollow shells, coal or other soft or porous material, or organic matter unless the contractor can show by comparative tests on finished concrete as set out in BS 1881 that the presence of such material does not adversely affect the properties of the concrete. The pieces shall be angular rounded or irregular as defined in BS 812 Part 1.

Coarse aggregate shall be supplied in the nominal sizes called for in the contract and shall be graded in accordance with BS 882 for each nominal size.

Other properties shall be as set out below: -

The proportion of clay, silt and other impurities passing a 75 micron BS sieve shall be not more than one per cent by weight.

The content of hollow and flat shells shall not be such as will adversely affect the concrete quality when tested as set out in BS 1881. The total shell content of aggregate shall not be more than the following:

| | |
|------------------------------|-------------------|
| 40 mm nominal size and above | 2% of dry weight |
| 20 mm nominal size | 5% of dry weight |
| 10 mm nominal size | 15% of dry weight |

Chlorides soluble in a 10 per cent solution by weight of nitric acid shall not exceed 0.03 per cent by weight, expressed as chloride ion when tested as set out in BS 812 but subject also to the further restriction under the note on total chloride content hereunder. Sulphates soluble in a 10 per cent solution by weight of hydrochloric acid shall not exceed 0.4 per cent by weight expressed as SO₃ when tested as set out in BS 1377 subject also to the further restriction given in the note on total sulphate content hereunder.

Soundness: After 5 cycles of the test in AASHTO T104, the aggregate shall not show a weight loss of more than 12 per cent.

When tested in accordance with test C289 of the American Society for Testing and Materials, the aggregate shall be non-reactive.

Flakiness Index when tested in accordance with BS 812 shall be as set out hereunder: -For 40 mm stone and above, not more than 40

For 20 mm stone and below, not more than 35

5.3.5 Testing aggregates

(i) Acceptance testing

The Contractor shall deliver to the Engineer samples containing not less than 50 kg of any aggregate which he proposes to use in the Works and shall supply such further samples as the Engineer may require. Each sample shall be clearly labeled to show its origin and shall be accompanied by all the information called for in BS 882.

Tests to determine compliance of the aggregates with the requirements of Sub-Clause 5.3 (c) and (d) shall be carried out by the Contractor in a laboratory acceptable to the Engineer. If the tested materials fail to comply with the Specification, further tests shall be made in the presence of the Contractor and the Engineer and acceptance of the material shall be based on such tests.

A material shall be accepted if not less than three consecutive sets of test results show compliance with the Specification.

(ii) Compliance testing

The Contractor shall carry out routine testing of aggregates for compliance with the Specification during the period that concrete is being produced for the Works. The tests set out below shall be performed on aggregates from each separate source on the basis of one set of tests for each day on which aggregates are delivered to Site provided that no set of tests shall represent more than 250 tonnes of fine aggregate nor more than 500 tonnes of coarse aggregate, and provided also that the aggregates are of uniform quality. If the aggregate from any source is variable, the frequency of testing shall be increased as instructed by the Engineer.

| | |
|-----------------------------|-----------------------------|
| Grading | BS 812 |
| Silt and clay contents | BS 812 |
| Moisture content | BS 812 |
| Check on organic impurities | As directed by the Engineer |

In addition to the above routine tests, the Contractor shall carry out the following tests at the frequencies stated:

- (i) Moisture content: as frequently as may be required in order to control the water content of the concrete as required by the Specification.
- (ii) Chloride content: as frequently as may be required to ensure that the proportion of chlorides in the aggregates does not exceed the limit stated in the Specification.

The Contractor shall take account of the fact that when the chloride content is variable it may be necessary to test every load in order to prevent excessive amounts of the chloride contaminating the concrete. For this purpose, the Contractor shall use the rapid field test (Quantab test). In the event of disagreement regarding the results of the field test, the chloride content of the aggregate shall be determined in the laboratory as described in BS 812 (Volhard test).

5.3.6 Delivery and storage of aggregates

Aggregates shall be delivered to Site in clean and suitable vehicles. Different types or sizes of aggregate shall not be delivered in one vehicle.

Each type or size of aggregate shall be stored in a separate bin or compartment having a base such that the contamination of aggregate is prevented. Dividing walls between bins shall be substantial and continuous so that no mixing of types or sizes occurs.

The storage of aggregates shall be arranged so that as far as possible rapid drying out in hot weather is prevented in order to avoid sudden fluctuations in water content. Storage of fine aggregates shall be arranged so that they can drain sufficiently before use in order to prevent fluctuations in water content of the concrete.

5.3.7 Water for concrete and mortar

Seawater or brackish water containing more than 1000 ppm chloride ion or 2000 ppm sulphate ion shall not be used for mixing or curing concrete.

Water shall be clean and free from harmful matter and comply with the requirements of BS 3149.

The Contractor shall carry out tests in accordance with BS 3148 to establish compliance with the Specification.

5.3.8 Admixtures

(i) General

The use of the admixtures in concrete may be required under the Contract to promote special properties in the finished concrete or may be proposed by the Contractor to assist him in compliance with the Specification.

In all cases the Contractor shall submit to the Engineer full details of the admixture he proposes to use and the manner in which he proposes to add it to the mix. The information provided shall include:

- (a) The typical dosage, the method of dosing and the detrimental effects of an excess or deficiency in the dosage.
- (b) The chemical names of the main active ingredients in the admixture.
- (c) Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a Percentage by weight of admixture.
- (d) Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage and if so, the extent to which it does so.
- (e) Details of previous uses of the admixture in Kenya.

The chloride ion content of any admixture shall not exceed 2 per cent by weight of the admixture nor 0.03 per cent by weight of the cement in the mix.

Admixtures shall not be mixed together without the consent of the Engineer.

Calcium chloride or admixtures containing calcium chloride shall not be used in prestressed concrete.

(ii) Workability agents

Workability agents shall comply with BS 5075 and shall not have any adverse effect on the properties of the concrete.

5.4 The Design of Concrete Mixes

5.4.1 Classes of concrete

The classes of structural concrete to be used in the Works shall be those shown on the Drawings and designated in Table C-1, in which the class designation includes two figures. The first figure is the nominal strength at 28 days expressed in N/mm² and the second figure is the maximum nominal size of aggregate in the mix expressed in millimeters.

TABLE C-1 Concrete Classes and Strengths

| Class of concrete | Nominal strength N/mm ² | Maximum Nominal Size of aggregate mm | Maximum water/cement ratio | | Trial mixes Target Mean Strength N/mm ² | Early works test cubes | |
|-------------------|------------------------------------|--------------------------------------|----------------------------|------|--|--------------------------------|---|
| | | | A | B | | Any one cube N/mm ² | Average of any group of 4 cubes N/mm ² |
| 10/75 | 10 | 75 | 0.60 | 0.55 | 13.5 | 9.5 | 13.3 |
| 15/75 | 15 | 75 | 0.60 | 0.50 | 21.5 | 12.8 | 20.0 |
| 15/40 | 15 | 40 | 0.60 | 0.50 | 21.5 | 12.8 | 20.0 |
| 15/20 | 15 | 20 | 0.57 | 0.50 | 21.5 | 12.8 | 20.0 |
| 20/40 | 20 | 40 | 0.57 | 0.48 | 31.5 | 17.0 | 27.5 |
| 20/20 | 20 | 20 | 0.55 | 0.48 | 31.5 | 17.0 | 27.5 |
| 20/10 | 20 | 10 | 0.53 | 0.48 | 31.5 | 17.0 | 27.5 |
| 25/40 | 25 | 40 | 0.50 | 0.46 | 36.5 | 21.3 | 32.5 |
| 25/20 | 25 | 20 | 0.52 | 0.46 | 36.5 | 21.3 | 32.5 |
| 25/10 | 25 | 10 | 0.50 | 0.46 | 36.5 | 21.3 | 32.5 |
| 30/40 | 30 | 40 | 0.48 | 0.45 | 41.5 | 25.5 | 37.5 |
| 30/20 | 30 | 20 | 0.48 | 0.45 | 41.5 | 25.5 | 37.5 |
| 30/10 | 30 | 10 | 0.47 | 0.45 | 41.5 | 25.5 | 37.5 |
| 40/20 | 40 | 20 | 0.46 | 0.43 | 51.5 | 34.0 | 47.5 |
| 40/10 | 40 | 10 | 0.45 | 0.43 | 51.5 | 34.0 | 47.5 |

NOTE: Under water/cement ratio, column A applies to moderate and intermediate exposure, and column B applies to severe exposure. See NOTE after Table C-2.

5.4.2 Design of proposed mixes

The contractor shall design all the concrete mixes called for on the Drawings, making use of the ingredients which have been approved by the Engineer for use in the works and in compliance with the following requirements: -

- i. The aggregate portion shall be well graded from the nominal maximum size of stone down to the 150-micron size.
- ii. The cement content shall be such as to achieve the strengths called for in Table C-1 but in any case not less than the minimum necessary for impermeability and durability shown in Table C-2.
- iii. The workability shall be consistent with ease of placing and proper compaction having regard to the presence of reinforcement and other obstructions.
- iv. The water/cement ratio shall be the minimum consistent with adequate workability but in any case not greater than that shown in Table C-1 taking due account of any water contained in the aggregates. The Contractor shall take into account that this requirement may in certain cases require the inclusion of a workability agent in the mix.
- v. The drying shrinkage determined in accordance with BS 1881 shall not be greater than 0.05 per cent.

Table C-2 Minimum Cement Content

| Class of Concrete | Minimum Cement Content - Kg/ m ³ of Compacted concrete | | |
|----------------------------|---|-----------------------|-----------------|
| | Moderate Exposure | Intermediate Exposure | Severe Exposure |
| 10/75; 15/75 | 200 | 220 | 270 |
| 15/40, 20/40, 25/40, 30/40 | 240 | 270 | 290 |
| 15/20, 20/20, 25/20, 30/20 | 260 | 300 | 330 |
| 40/20 | 300 | 320 | 330 |
| 20/10, 25/10, 30/10 | 300 | 340 | 390 |
| 40/10 | 310 | 340 | 390 |

NOTE: the minimum cement contents shown in the above table are required in order to achieve impermeability and durability. In order to meet the strength requirements in the Specification higher contents may be required.

The categories applicable to the Works are based broadly on the factors listed hereunder:

| | |
|------------------------------|--|
| Moderate exposure | Surface sheltered from severe rain; buried concrete, concrete continuously under water |
| Intermediate exposure | Surface exposed to driving rain; alternate wetting and drying; traffic; corrosive fumes; heavy condensation. |
| Severe exposure | Surface exposed to sea water, moorland water having a pH of 4.5 or less, Groundwater containing sulphates. |

5.4.3 Trial mixes

At least six weeks before commencing placement of concrete in the Permanent works trial mixes shall be prepared for each class of concrete specified.

For each mix of concrete for which the Contractor has proposed a design, he shall prepare three separate batches of concrete using the materials which have been approved for use in the Works and the mixing plant which he proposes to use for the works. The volume of each batch shall be the capacity of the concrete mixer proposed for full production.

Samples shall be taken from each batch and the following action taken, all in accordance with BS 1881:-

- i. The slump of the concrete shall be determined.
- ii. Six test cubes shall be cast from each batch. In the case of concrete having a maximum aggregate size of 40 mm or less, 150 mm cubes shall be used. In the case of concrete containing 75 mm or larger aggregate, 200 mm cubes shall be used and in addition any pieces of aggregate retained on a 53 mm BS sieve shall be removed from the mixed concrete before casting the cubes.
- iii. Three cubes from each batch shall be tested for compressive strength at seven days and the remaining three at 28 days.
- iv. The density of all the cubes shall be determined before the strength tests are carried out.

Subject to the agreement of the Engineer, the compacting factor apparatus may be used in place of a slump cone. In this case the correlation between slump and compacting factor shall be established during preparation of the trial mixes.

The average strength of the nine cubes tested at 28 days shall be not less than the target mean strength shown in Table C-1.

The Contractor shall also carry out tests to determine the drying shrinkage of the concrete unless otherwise directed by the Engineer.

Based on the results of the tests on the trial mixes, the Contractor shall submit full details of his proposals for mix design to the Engineer, including the type and source of each ingredient, the proposed proportions of each mix and the results of the tests on the trial mixes.

If the Engineer does not agree to a proposed concrete mix for any reason, the Contractor shall amend his proposals and carry out further trial mixes. No mix shall be used in the works without the written consent of the Engineer.

5.5 Quality control of concrete production

(i) Sampling

For each class of concrete in production at each plant for use in the works, samples of concrete shall be taken at the point of mixing and/or of deposition as instructed by the Engineer, all in accordance with the sampling procedures described in BS 1881 and with the further requirements set out below.

Six 150 mm or 200 mm cubes as appropriate shall be made from each sample and shall be cured and tested all in accordance with BS 1881, two at seven days and the other four at 28 days.

Each sample shall be taken from one batch selected at random and at intervals such that each sample represents not more than 20 m³ of concrete unless the Engineer agrees to sampling at less frequent intervals.

Until compliance with the Specification has been established the frequency of sampling shall be three times that stated above, or such lower frequency as may be instructed by the Engineer.

(ii) Testing

- (a) The slump or compacting factor of the concrete shall be determined for each batch from which samples are taken and in addition for other batches at the frequency instructed by the Engineer.

The slump of the concrete in any batch shall not differ from the value established by the trial mixes by more than 25 mm or one third of the value, whichever is the greater.

The variation in value of the compacting factor, if used in place of a slump value, shall be within the following limits:

| | |
|----------------------------------|------------|
| For value of 0.9 or more | ± 0.03 |
| For value of between 0.8 and 0.9 | ± 0.04 |
| For values of 0.8 or less | ± 0.05 |

- (b) The water/cement ratio as estimated from the results of (a) above, determined by samples from any batch shall not vary by more than five per cent from the value established during the trial mixes.
- (c) The air content of air entrained concrete in any batch shall be within 1.5 units of the required value and the average value of four consecutive measurements shall be within 1.0 unit of the required value, expressed as a percentage of the volume of freshly mixed concrete.
- (d) Until such time as sufficient test results are available to apply the method of control described in (e) below, the compressive strength of the concrete at 28 days shall be such that no single result is less than the value shown in Table C-1 under the heading 'early works test cubes' and also that the average value of any four consecutive results is not less than the value shown in Table C-1 under the same heading.

The 7-day cube result may be used as an early strength indicator, at the discretion of the Engineer.

When test cube results are available for at least 20 consecutive batches of any class of concrete mixed in any one plant, the average of any four consecutive results at 28 days shall

exceed the nominal strength by not less than half the current margin (see table below) and each individual result shall not be less than 85 per cent of the nominal strength.

The current margin shall be defined as 1.64 times the standard deviation of cube tests on at least 20 separate consecutive batches produced from one plant over a period exceeding five days but not exceeding six months or on at least 50 separate consecutive batches produced from one plant over a period not exceeding 12 months. If both figures are available, the smaller shall be taken.

The current margin shall in any case at be less than the figure given below: -

| | Minimum current margin for | | |
|------------------|----------------------------|---------------------|--------------------------------|
| | 10N/mm ² | 15N/mm ² | 20N/ mm ² and above |
| After 20 batches | 3.3 | 5 | 7.5 |
| After 50 batches | 1.7 | 2.5 | 3.8 |

(e) Failure to comply with requirements

If any one test cube result in a group of four consecutive results is less than 85 per cent of the nominal strength but the average of the group of which it is part satisfies the strength requirement, then only the batch from which the failed cube was taken shall be deemed not to comply with the Specification.

If more than one cube result in a group of four consecutive results is less than 85 per cent of the nominal strength or if the average strength of the group of which it is part fails to satisfy the strength requirement then all the batches between those represented by the first and last cubes in the group shall be deemed not to comply with the Specification, and the Contractor shall immediately adjust the mix design subject to the agreement of the Engineer to restore compliance with the Specification.

After adjustment of the mix design the Contractor will again be required to comply with sub-clause 5.4 of this Section of this Specification.

The Contractor shall take necessary action to remedy concrete which does not comply with this Specification. Such action may include but is not necessarily confined to the following:

-

- (i) Increasing the frequency of sampling until control is again established.
- (ii) Cutting test cores from the concrete and testing in accordance with BS 1881.
- (iii) carrying out strengthening or other remedial work to the concrete where possible or appropriate.
- (iv) carrying out non-destructive testing such as load tests on beams
- (v) removing the concrete

5.6 Mixing Concrete

Before any plant for batching, mixing, transporting, placing, compacting and finishing concrete is ordered or delivered to site, the Contractor shall submit to the Engineer full details including drawings of all the plant which he proposes to use and arrangements he proposes to make.

Concrete for the works shall be batched and mixed in one or more central plants unless the Engineer agrees to some other arrangement. If the Contractor proposes to use ready mixed concrete, he shall submit to the Engineer for his approval full details and test results of the concrete mixes. The Engineer may approve the use of ready mixed concrete provided that:

- a. The proposed mixes, the material to be used and the method of storage and mixing comply with the requirements of the specification; and
- b. Adequate control is exercised during mixing.

Approval to the use of ready mixed concrete may be withdrawn if the Engineer is not satisfied with the control of the materials being used and control during mixing.

Batching and mixing plants shall be modern efficient equipment complying with the requirements of BS 1305 and capable of producing a uniform distribution of the ingredients throughout the mass. Truck mixes shall comply with the requirements of BS 4251 and shall only be used with prior arrangement with the engineer. If the plant proposed by the contractor does not fall within the scope of BS1305, it shall have been tested in accordance with BS 3963 and shall have a mixing performance within the limits of Table 6 of BS 1305.

All mixing operations shall be under the control of an experienced supervisor.

The aggregate storage bins shall be provided with drainage facilities arranged so that drainage water is not discharged to the weigh hoppers. Each bin shall be drawn down at least once per week and any accumulations of mud or silt removed.

Cement and aggregates shall be batched by weight. Water may be measured by weight or volume.

The weighing and water dispensing mechanisms shall be maintained in good order. Their accuracy shall be maintained within the tolerances described in BS 1305 and checked against accurate weights and volumes when required by the Engineer.

The weights of cement and of each size of aggregate as indicated by the mechanisms employed shall be within a tolerance of plus or minus two per cent of the respective weight per batch agreed by the Engineer.

The Contractor shall provide standard test weights at least equivalent to the maximum working load used on the most heavily loaded scale and other auxiliary equipment required for checking the satisfactory operation of each scale or other measuring device. Tests shall be made by the Contractor at least once a week or at intervals to be determined by the Engineer and shall be carried out in his presence. For the purpose of carrying out these tests, there shall be easy access for personnel to the weigh hoppers. The Contractor shall furnish

the Engineer with copies of the complete results of all check tests and shall make any adjustments, repairs or replacements necessary to ensure satisfactory performance.

The nominal drum or pan capacity of the mixer shall not be exceeded. The turning speed and the mixing time shall be as recommended by the manufacturer, but in addition, when water is the last ingredient to be added, mixing shall continue for at least one minute after all the water has been added to the drum or pan.

The blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

Mixers shall be fitted with an automatic recorder registering the number of batches discharged.

The water to be added to the mix shall be reduced by the amount of free water contained in the coarse and fine aggregates. This amount shall be determined by the Contractor by a method agreed by the Engineer immediately before mixing begins each day and thereafter at least once per hour during concreting and for each delivery of aggregates during concreting. When the correct quantity of water, determined as set out in the Specification, has been added to the mix, no further water shall be added, either during mixing or subsequently.

After mixing for the required time, each batch shall be discharged completely from the mixer before any materials for the succeeding batch are introduced.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed and thereafter the first batch of concrete through the mixers shall contain only half the normal quantity of coarse aggregate. This batch shall be mixed for one minute longer than the time applicable to a normal batch.

Mixers shall be cleaned out before changing to another type of cement.

5.7 Hand Mixed Concrete

Concrete for structural purposes shall not be mixed by hand. Where non-structural concrete is required, hand mixing may be carried out subject to the agreement of the Engineer.

The mixing shall be done on a hard impermeable surface. The materials shall be turned over not less than three times dry, water shall then be sprayed on and the materials again turned over not less than three times in a wet condition and worked together until a mixture of uniform consistency is obtained.

For hand mixed concrete the specified quantities of cement shall be increased by 10% and not more than 0.5 cubic metres shall be mixed at one time. During windy weather efficient precautions shall be taken to prevent cement from being blown away during the process of gauging and mixing.

5.8 Transport of Concrete

The concrete shall be discharged from the mixer and transported to the Works by means which shall prevent adulteration, segregation or loss of ingredients, and which shall ensure that the concrete is of the required workability at the point and time of placing. The loss of slump between discharge from the mixer and placing shall not exceed 25 mm.

The time elapsing between mixing and placing a batch of concrete shall be as short as practicable as and in any case not longer than will permit completion of placing and compaction before the onset of initial set. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the Works.

5.9 Placing of Concrete

5.9.1 Consent for placing.

Concrete shall not be placed in any part of the Works until the Engineer's consent has been given in writing, and the contractor shall give the Engineer at least 1 full working days' notice of his intention to place concrete.

If concrete placing is not commenced within 24 hours of the Engineer's consent the Contractor shall again request consent as specified above.

5.9.2 Preparation of surface to receive concrete

Excavated surfaces on which concrete is to be deposited shall be prepared as set out in Section 4 of this Specification.

Existing concrete surfaces shall be prepared as set out in (clause 5.19. Before deposition of further concrete, they shall be clean, hard and sound and shall be wet but without any free-standing water.

Any flow of water into an excavation shall be diverted through proper side drains to a sump, or be removed by other suitable methods which will prevent washing away the freshly deposited concrete or any of its constituents. Any underdrains constructed for this purpose shall be completely grouted up when they are no longer required by a method agreed by the Engineer.

Unless otherwise instructed by the Engineer surfaces against which concrete is to be placed shall receive a prior coating or mortar mixed in the proportions similar to those of the fines portion in the concrete to be placed. The mortar shall be kept ahead of the concrete. The mortar shall be well worked into all parts of the excavated surface and shall be not less than 5 mm thick.

If any fissures have been cleaned out as described in Section 4 of this Specification they shall be filled with mortar or with concrete as instructed by the Engineer.

The amount of mortar placed at any one time shall be limited so that it does not dry out or set before being covered with concrete.

5.9.3 Placing procedures

The concrete shall be deposited as nearly as possible in its final position. It shall be placed so as to avoid segregation of the concrete and displacement of the reinforcement, other embedded items, or formwork. It shall be brought up in layers approximately parallel to the construction joint planes and not exceeding 500 mm in compacted thickness unless otherwise permitted or directed by the Engineer, but the layers shall not be thinner than four times the maximum nominal size of aggregate.

Layers shall not be placed so that they form feather edges nor shall they be placed on a previous layer which has taken its initial set. In order to comply with this requirement, a layer may be started before completion of the preceding layer.

All the concrete in a single bay or pour shall be placed as a continuous operation. It shall be carefully worked round all obstructions, irregularities in the foundations and the like so that all parts are completely full of compacted concrete with no segregation or honeycombing. It shall also be carefully worked round and between water-stops, reinforcement, embedded steelwork and similar items which protrude above the surface of the completed pour.

All work shall be completed on each batch of concrete before its initial set commences and thereafter the concrete shall not be disturbed before it has set hard. No concrete that has partially hardened during transit shall be used in the Works and the transport of concrete from the mixer to the point of placing shall be such that this requirement can be complied with.

Concrete shall not be placed during rain which is sufficiently heavy or prolonged to wash mortar from coarse aggregate on the exposed faces of fresh concrete. Means shall be provided to remove any water accumulating on the surface of the placed concrete. Concrete shall not be deposited into such accumulations of water.

In dry weather, covers shall be provided for all fresh concrete surfaces which are not being worked on. Water shall not be added to concrete for any reason.

When concrete is discharged above its place of final deposition, segregation shall be prevented by the use of chutes, downpipes, trunking, baffles or other appropriate devices.

Forms for walls, columns and other than sections of significant height shall be provided with openings or other devices that will permit the concrete to be placed in a manner that will prevent segregation and accumulations of hardened concrete on the formwork or reinforcement above the level of the placed concrete.

When it is necessary to place concrete under water the contractor shall submit to the Engineer his proposals for the method and equipment to be employed. The concrete shall be deposited either by bottom-discharging watertight containers or through funnel-shaped tremies which are kept continuously full with concrete up to a level above the water and which shall have the discharging bottom fitted with a trapdoor and immersed in the concrete in order to reduce

to a minimum the contact of the concrete with the water. Special care shall be taken to avoid segregation.

If the level of concrete in a tremie pipe is allowed to fall to such an extent that water enters the pipe, the latter shall be removed from the pour and filled with concrete before being again lowered into the placing position.

During and after concreting under water, pumping or de-watering in the immediate vicinity shall be suspended if there is any danger that such work will disturb the freshly placed concrete.

5.9.4 Interruptions to placing

If concrete placing is interrupted for any reason and the duration of the interruption cannot be forecast or is likely to be prolonged, the Contractor shall immediately take the necessary action to form a construction joint so as to eliminate as far as possible feather edges and sloping top surfaces and shall thoroughly compact the concrete already placed in accordance with (Clause 5.09. All work on the concrete shall be completed while it is still plastic and it shall not thereafter be disturbed until it is hard enough to resist damage. Plant and materials to comply with this requirement shall be readily available at all times during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remove all damaged or uncompacted concrete, feather edges or any other undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing without contravening the Specification and the Engineer consents to resumption, the new concrete shall be thoroughly worked in and compacted against the existing concrete so as to eliminate any cold joints.

5.9.5 Dimensions of pours

Unless otherwise agreed by the Engineer, pours shall not be more than two metres high and shall as far as possible have a uniform thickness over the plan area of the pour. Concrete shall be placed to the full planned height of all pours except during the use of Concrete pump or placers..

The Contractor shall plan the dimensions and sequence of pours in such a way that cracking of the concrete does not take place due to thermal or shrinkage stresses.

5.9.6 Placing sequence

The Contractor shall arrange that as far as possible the intervals between placing successive. Lifts of concrete in one section of the Works are of equal duration. This duration shall normally be not less than three or more than seven days under temperate weather conditions unless otherwise agreed by the Engineer.

Where required by the Engineer to limit the opening of construction joints due to shrinkage, concrete shall not be placed against adjacent concrete which is less than 21 days old.

When the drawings call for contraction gaps in concrete, these shall be of the widths and in the locations shown on the Drawings and they shall not be filled until the full time interval shown on the Drawings has elapsed.

5.10 Compaction of Concrete

The concrete shall be fully compacted throughout the full extent of the placed layer. It shall be thoroughly worked against the formwork and around any reinforcement and other embedded items, without displacing them. Particular care shall be taken at arises and other confined spaces. Successive layers of the same pour shall be thoroughly worked together.

Concrete shall be compacted with the assistance if mechanical immersion vibrators, unless the Engineer agrees another method.

Immersion vibrators shall operate at the frequency of between 7,000 and 10,000 cycles per minute. The contractor shall ensure that vibrators are operated at beginning pressures and voltages not less than those recommended by the manufacturer in order that the compactive effort is not reduced.

A sufficient number of vibrators shall be operated to the entire quantity of concrete being placed to be vibrated for the necessary period and, in addition stand-by vibrators shall be available for instant use at each place where concrete is being placed.

Where the concrete contains aggregate with a nominal size of 75mm or more, vibrators with a diameter of 100 mm or more shall be used.

Vibration shall be continued at each point until, the concrete ceases to contract, a thin layer of mortar has appeared on the surface and air bubbles have ceases to appear. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

Vibration shall not be applied by way of reinforcement nor shall vibrators be allowed to touch reinforcement or other embedded items. The vibrators shall be inserted vertically into the concrete to penetrate the layer underneath at regular spacing which shall not exceed the distance from the vibrator over which vibration is visibly effective.

5.11 Curing of Concrete

5.11.1 General

Concrete shall be protected during the first stage of hardening from loss of moisture and from the development of temperature differentials within the concrete sufficient to cause cracking. The methods used of curing shall not cause damage of any kind to the concrete.

Curing shall be continued for as long as may be necessary to achieve the above objectives but in any case for at least seven days or until the concrete is covered by later construction whichever is the shorter period.

The above objectives are dealt with in sub-clauses 5.10 (b) and (c) but nothing shall prevent both objectives being achieved by a single method where circumstances permit.

The curing process shall commence as soon as the concrete is hard enough to resist damage from the process, and in the case of large areas or continuous pours, shall commence on the completed section of the pour before the rest of the pour is finished.

Details of the Contractor's proposals for curing concrete shall be submitted to the Engineer before the placing of concrete Commences in the Works.

5.11.2 Loss of moisture

Exposed concrete surfaces shall be closely covered with impermeable sheeting, properly secured to prevent its removal by wind and the development of air spaces beneath it. Joints in the sheeting shall be lapped by at least 300 mm.

If for some reason it is not possible to use impermeable sheeting, the Contractor shall keep the exposed surfaces continuously wet by means of a water spray or by covering with a water absorbent material which is kept wet, unless this method conflicts with sub-clause 5.10 (c).

Water used for curing shall be of the same quality as that used for mixing.

Formed surfaces may be cured by retaining the formwork in place for the required curing period.

If the use of the foregoing methods is inappropriate, surfaces which will not have further concrete bonded to them and which are not to receive an application of a finish may be cured by the application of a curing compound having an efficiency index of at least 90 per cent. Curing compounds shall contain a fugitive dye to enable the extent of the spread to be seen easily.

Curing compound used on surfaces exposed to the sky shall contain sufficient finely divided flake aluminum in suspension to produce a complete coverage of the surface with a metallic finish when applied at the rate recommended by the manufacturer.

Curing compounds shall become stable and impervious to the evaporation of water from the concrete surface within 60 minutes of application. The material shall not react chemically with the concrete and shall not crack, peel or disintegrate within three weeks after application.

If instructed by the Engineer, the Contractor shall, in addition to the curing provisions set out above provide a suitable form of shading to prevent the direct rays of the sun reaching the concrete surfaces for at least the first four days of the curing period.

5.11.3 Limitation of temperature differentials

The Contractor shall limit the development of temperate differentials in concrete after placing by any means appropriate to the circumstances including the following:

- (i) Limiting concrete temperatures at placing as set out in sub-clause 5.12.2 (b);

- (ii) Use of low heat cement, subject to the agreement of the Engineer;
- (iii) Insulation of exposed concrete surfaces by insulating blankets. Such blankets shall have an insulation value at least equivalent to 50 mm of dry mineral wool;
- (iv) leaving formwork in place during the curing period. Steel forms shall be suitably insulated on the outside;
- (v) preventing rapid dissipation of heat from surfaces by shielding from wind;
- (vi) Avoiding the use of water sprays when such use would cause rapid cooling of the surface.

5.12 Protection of Fresh Concrete

Freshly placed concrete shall be protected from rainfall and from water running over the surface until it is sufficiently hard to resist damage from these causes.

No traffic shall be allowed on any concrete surface until such time as it is hard enough to resist damage by such traffic.

Concrete placed in the works shall not be subjected to any loading until it has attained at least its nominal strength as defined under the Clause Design of the Concrete Mix (Clause 5.4).

If the Contractor desire to impose loads on newly-placed concrete, he shall make at least three test cubes and cure them in the same conditions as the concrete they represent. These cubes shall be tested singly at suitable intervals in order to estimate the time at which the nominal strength is reached.

5.13 Concreting in Hot Weather

5.13.1 General

The Contractor shall prevent damage to concrete arising from Exposure to extreme temperatures and shall maintain in good working order all plant and equipment required for this purpose.

In the event that conditions become such that even with the use of the equipment the requirements cannot be met, concrete placing shall immediately cease until such time as the Requirements can again be met.

5.13.2 Concrete placing in hot weather

During hot weather the contractor shall take all measures necessary to ensure that the temperature of concrete at the time of placing in the works does not exceed 30°C and that the concrete does not lose any moisture during transporting and placing.

Such measures may include but are not necessarily limited to the following: -

- (i) Shielding aggregates from direct sunshine.

- (ii) Use of a mist water spray on aggregates.
- (iii) Sun shields on mixing plants and transporting equipment.
- (iv) Cooling the mixing water. If ice is used for this purpose it should preferably be in flake form. Lump ice shall not be allowed to enter the tank supplying the mixer drum.
- (v) Covering skips closely with polythene sheet so that the latter is in contact with the concrete.

Areas in which concrete is to be placed shall be shielded from direct sunshine and rock or concrete surfaces shall be thoroughly wetted to reduce absorption of water from the concrete placed on or against them.

After concrete in any part of an area has been placed, the selected curing process shall be commenced as soon as possible. If any interval occurs between completion of placing and start of curing, the concrete shall be closely covered during the interval with polythene sheet to prevent loss of moisture.

5.14 Finishes On Unformed Surfaces

Horizontal or nearly horizontal surfaces which are not cast against formwork shall be finished to the class shown on the Drawings and defined hereunder.

5.14.1 UF 1 finish

All surfaces on which no higher class of finish is called for on the Drawings or instructed by the Engineer shall be given an UF 1 finish.

The concrete shall be leveled and screeded to produce a uniform plain or ridged surface, surplus concrete being struck off by a straight edge immediately after compaction.

5.14.2 UF 2 finish

This is a floated finish for roof or floor slabs and other surfaces where a hard trowelled surface is not required.

The surface shall first be treated as a Class UF 1 finish and after the concrete has hardened sufficiently, it shall be floated by hand or machine sufficient only to produce a uniform surface free from screed marks.

5.14.3 UF 3 finish

This is a hard trowelled surface for use where weather resistance or appearance is important, or which is subject to high velocity water flow.

The surface shall be floated as for a UF 2 finish but to the tolerance stated below. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance

from being worked to the surface, it shall be steel trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

Table c-3 Surface Tolerances

| Class of Finish | Tolerance in mm. see notes | | |
|-----------------|----------------------------|----|-----------------|
| | A | B | C |
| UF 1 | Not applicable | 10 | + 20 or - 10 |
| UF 2 | Nil | 10 | + 20 or - 10 |
| UF 3 | Nil | 5 | + 12.5 or - 7.5 |

Notes:

1. Col A is the maximum allowable value of any sudden change of level in the surface.
2. Col B is the maximum allowable value of any gradual irregularity of the surface, as indicated by the gap between the surface and a three-metre-long straight edge or correctly shaped template placed on the surface.
3. Col C is the maximum allowable value of the difference in level or position between a three-metre-long straight edge or correctly shaped template placed on the surface and the specified level or position of that surface.
4. Where dimensional tolerances given on the Drawings or in this Special Specification they shall take precedence over those given in Table C-3.

5.15 Formwork for Concrete

5.15.1 Definitions

Formwork means the surface against which concrete is placed to form a face, together with all the immediate supports to retain it in position while concrete is placed.

Falsework means the structural elements supporting both the formwork and the concrete until the concrete becomes self-supporting.

A **formed face** is one which has been cast against formwork.

An **exposed face** is one which will remain visible when construction has been completed.

5.15.2 Construction of Formwork and Falsework

Before construction begins, the Contractor shall submit to the Engineer drawings showing details of the proposed formwork and falsework.

Formwork and falsework shall be so constructed that they will support the loads imposed on them by the fresh concrete together with additional stresses imposed by vibrating equipment and by construction traffic, so that after the concrete has hardened the formed faces shall be in the positions shown on the Drawings within the tolerances set out in Clause 5.26.

Ground supports shall be properly founded on footings designed to prevent settlement.

Joints in formwork for exposed faces shall, unless otherwise specified, be evenly spaced and horizontal or vertical and shall be continuous or form a regular pattern.

All joints in formwork including formwork for construction joints shall be tight against the escape of cement and fines. Where reinforcement projects through formwork, the form shall fit closely round the bars.

Formwork shall be so designed that it may be easily removed from the work without damage to the faces of the concrete. It shall also incorporate provisions for making minor adjustments in position, if required, to ensure the correct location of concrete faces. Due allowance shall be made in the position of all formwork for movement and settlement under the weight of fresh concrete.

Where overhangs in formwork occur, means shall be provided to permit the escape of air and to ensure that the space is filled completely with fully compacted concrete.

Formwork shall be provided for concrete surfaces at slopes of 30° to the horizontal or steeper. Surfaces at slopes less than 20° may be formed by screeding. Surfaces at slopes between 20° and 30° shall generally be formed unless the Contractor can demonstrate to the satisfaction of the Engineer that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration. Horizontal or inclined formwork to the upper surface of concrete shall be adequately secured against uplift due to the pressure of fresh concrete. Formwork to voids within the body of the concrete shall also be tied down or otherwise secured against floating.

The internal and external angles on concrete surfaces shall be formed with fillets and chamfers of the sizes shown on the Drawings unless otherwise instructed by the Engineer.

Supports for formwork may be bolted to previously placed concrete provided the type of bolt used is acceptable to the Engineer. If metal ties through the concrete are used in conjunction with bolts, the metal left in shall not be closer than 50 mm to the face of the Concrete.

Formwork shall not be re-used after it has suffered damage which is sufficient to impair the finished surfaces of the concrete.

Where circumstances prevent easy access within the form for cleaning and inspection, temporary openings for this purpose shall be provided through the formwork.

Shear keys shall be provided in all construction joints of the size and shape indicated on the Drawings.

Where precast concrete elements are specified for use as permanent formwork, or proposed by the Contractor and agreed by the Engineer, they shall comply with the requirements of the Specification. Such elements shall be set true to line and level within the tolerances prescribed for the appropriate class of finish in Clause 5.26 and fixed so that they cannot move when concrete is placed against them.

5.15.3 Preparation of Formwork

Before any reinforcement is placed into position within formwork, the latter shall be thoroughly cleaned and then dressed with a release agent. The agent shall be either suitable oil incorporating a wetting agent, an emulsion of water suspended in oil or a low viscosity oil containing chemical agents. The contractor shall not use an emulsion of oil suspended in water nor any release agent which causes staining, discoloration of the concrete, air holes on the concrete surface, or retards the rest of the concrete. In order to avoid colour differences on adjacent concrete surfaces, only one type of release agent shall be used in any one section of the works. In cases where it is necessary to fix reinforcement before placing formwork, all surface preparation of formwork shall be carried out before it is placed into position. The Contractor shall not allow reinforcement or prestressing tendons to be contaminated with formwork release agent.

Before placing concrete all dirt, construction debris and other foreign matter shall be removed completely from within the placing area.

Before concrete placing commences, all wedges and other adjusting devices shall be secured against movement during concrete placing and the Contractor shall maintain a watch on the formwork during placing to ensure that no movement occurs.

5.15.4 Removal of Formwork

Formwork shall be carefully removed without shock or disturbance to the concrete. No formwork shall be removed until the concrete has gained sufficient strength to withstand safely any stresses to which it may thereby be subjected.

The minimum periods which shall elapse between completion of placing concrete and removal of forms are given in Table 5-4 and apply to ambient temperatures higher than 10°C. At lower temperatures or if cement other than ordinary Portland is involved, the Engineer may instruct longer periods.

Alternatively, formwork may be removed when the concrete has attained the strength set out in Table C-4, provided that the attained strength is determined by making test cubes and curing them under the same conditions as the concrete to which they refer.

Compliance with this requirement shall not relieve the Contractor of his obligation to delay removal of formwork until the removal can be completed without damage to the concrete.

Table C-4 Minimum Periods for Formwork Removal

| Position of Formwork | Minimum Period for Temps over 10°C | Strength to be Attained |
|---|--|----------------------------|
| Vertical or near vertical faces of mass concrete | 24 hours | 0.2 C |
| Vertical or near vertical faces of reinforced walls, beams and columns | 48 hours | 0.3 C |
| Underside of arches beams and slabs (formwork | 4 days | 0.5 C |
| Supports to underside of arches, beams and slabs | 14 days | 0.9C |
| Arched linings in tunnels and under- ground works | 24 hours | 4N/mm2 |

NOTE: C is the nominal strength for the class of concrete used.

If the Contractor wishes to strip formwork from the underside of arches beams and slabs before the expiry of the period (or supports set out above), it shall be designed so that it can be removed without disturbing the supports. The Contractor shall not remove supports temporarily for the purpose of stripping formwork and subsequently replace them.

As soon as the formwork has been removed, bolt holes in concrete faces other than construction joints which are not required for subsequent operations shall be completely filled with mortar sufficiently dry to prevent any slumping at the face. The mortar shall be mixed in the same proportions as the fine aggregate and cement in the surrounding concrete and with the same materials and shall be finished flush with the face of the concrete.

5.15.5 Slip form for concrete face

For pouring of concrete face slab, slip form shall be used and face slab concrete should be poured in skipping sections. The initial triangle block should be poured together with the main slab.

The Slip form shall be designed according to the following principles:

1. The requirements of slab width and slip form evenness shall be satisfied.
2. Adequate strength and rigidity shall be available
3. Adequate counterweight
4. Requirements of vibration and surface compaction shall be satisfied
5. Flexible and convenient for installation, operation and removal
6. Safety measures shall be provided. Braking device on slip form shall be attached to steel net. If the hoist is used as pulling machine, ground anchor shall be safe and reliable.

Side form for face slab pouring may be wooden form or composite steel form. The height of side form shall be compatible with the thickness of face slab. Its segment length and

anchoring method shall be convenient for installation and dismantling on slope surface. If side form plays additional role as slip form support structure, it shall be designed as load bearing structure.

Side form shall be installed firmly and reliably, its inner side surface shall be smooth and even, water stops shall be fixed in position. Allowable installation tolerances are as follows:

1. Deviation from joint design line is ± 3 mm
2. The verticality is ± 3 mm
3. Height of side form shall meet design requirements

Face slab steel bars should be connected by bundling, welding, machine splicing in situ. Prefabricated bar net may be adopted also for integral assembling; they shall be connected firmly with the supporting bars. Supporting bars on cushion layer shall be set according to design requirements.

Concrete pouring shall comply with the following requirements:

1. Concrete shall be poured uniformly in blocks, and thickness of each layer is 250 mm-300 mm. Concrete around water stops shall be poured additionally by labor, and segregation is strictly forbidden.
2. Vibrating compaction shall be made in time after pouring. While vibrating, vibrators shall not strike slip form, steel bars and water stops. Vibrator shall work within scope of slip form; the vertical depth for vibrator being inserted into concrete of lower layer should be 50 mm. Vibrator with 30 mm diameter should be used to carefully vibrate concrete around waters tops.
3. During pouring, concrete adhering to forms and steel bars shall be cleaned in time. Over-poured concrete in the front face must be cleaned prior to each lifting.
4. Concrete surfaces after removal of forms shall be flattened and finished in time. The concrete surface within 1 m from the sides of joint shall be checked with 2 m ruler and unevenness shall not exceed 5 mm.
5. Distance of each lifting shall not exceed 300 mm. Time interval between lifting should not exceed 30 min. Average speed of lifting for face slab pouring should be 1.5 m/h - 2.5 m/h.

5.15.6 Surface Finishes

The surface finish to be achieved on formed concrete surfaces shall be as shown on the Drawings and defined hereunder: -

(i) Class F1 finish

This finish is for surfaces against which backfill or further concrete will be placed. Formwork may be sawn boards, sheet metal or any other suitable material which will prevent the loss of fine material from the concrete being placed.

(ii) Class F2 finish

This finish is for surfaces which are permanently exposed to view but where the highest standard of finish is not required. Forms to provide a Class F2 finish shall be faced with wrought thickness tongued and grooved boards with square edges arranged in a uniform pattern and close jointed or with suitable sheet material. The thickness of boards or sheets shall be such that there shall be no visible deflection under the pressure exerted by the concrete placed against them. Joints between boards or panels shall be horizontal and vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting, but fins, surface discoloration and other minor. Defects shall be remedied by methods agreed by the Engineer.

(iii) Class F3 finish

This finish is for surfaces which will be in contact with water flowing at high velocity, and for surfaces prominently exposed to view where good appearance is of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be faced with plywood complying with BS 1088 or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surface.

All joints between panels shall be vertical and. Horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced wrought boarding or standard steel panels will not be permitted for Class F3 finish. The Contractor shall ensure that the surface is protected from rust marks, spillages and stains of all kinds.

(iv) Curved surfaces

For curved surfaces where F2 or F3 finishes are called for, the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

Alternatively, single curvature surfaces may be faced with plastic or plywood linings attached to the backing with adhesive or with escutcheon pins driven flush. Linings shall not bulge, wrinkle or otherwise deform when subjected to temperature and moisture changes.

5.15.7 Tolerances

All parts of formed concrete surfaces shall be in the positions shown on the Drawings within the tolerances set out in Table C-5.

In cases where the Drawings call for tolerance other than those given in Table C-5 the Drawings shall rule.

Where precast units have been set to a specified tolerance, further adjustments shall be made as necessary to produce a satisfactory straight or curved line. When the Engineer has approved the alignment, the Contractor shall fix the units so that there is no possibility of further movement.

Table C-5 Tolerances

| Class of finish | Tolerances in mm (See Note) | | |
|-----------------|-----------------------------|---|---|
| | A | B | C |

| | | | |
|----|----|----|--------------|
| F1 | 10 | 10 | + 25 to - 10 |
| F2 | 5 | 10 | + or - 15 |
| F3 | 2 | 5 | + or - 10 |

Note: The tolerances A, B and C given in the table are defined as follows:

A is an abrupt irregularity in the surface due to misaligned formwork or defects in the face of the formwork.

B is a gradual deviation from a plane surface as indicated by a straight edge 3 m long. In the case of curved surfaces, the straight edge shall be replaced by a correctly shaped template.

C is the amount by which the whole or part of a concrete face is displaced from the correct position shown on the Drawings.

5.15.8 Remedial Work on Defective Surfaces

If on stripping any Formwork the concrete surface is found to be defective in any way, the Contractor shall make no attempt to remedy such defects prior to the Engineer's inspection and the receipt of any instructions which the Engineer may give.

Defective surfaces shall not be made good by plastering.

Areas of honeycombing which the Engineer agrees may be repaired shall be cut back to sound concrete to 75 mm whichever is the greater distance. In the case of reinforced concrete, the area shall be cut back to at least 25 mm clear distance behind the reinforcement or to 75 mm, whichever is the greater distance. The cavity shall have sides at right angles to the face of the concrete after cleaning out with water and compressed air, a thin layer of cement grout shall be brushed on to the concrete surfaces in the cavity and it shall then be filled immediately with concrete of the same class as the main body but with aggregate larger than 20 mm nominal size removed.

A form shall be used against the cavity, provided with a lip to enable concrete to be placed. The form shall be filled to point above the top edge of the cavity.

After seven days the lip of concrete shall be broken off and the surface ground smooth.

Surface irregularities which are outside the limits of tolerance set out in Clause 5.26 shall be ground and in the manner and to the extent instructed by the Engineer.

Defects other than those mentioned above shall be dealt with as instructed by the Engineer. '

5.16 Mortar

This clause covers mortar for use ahead of concrete placing, and other uses not covered elsewhere in the Specification.

Mortar shall be composed of fine aggregate complying with sub-Clause 5.3 (c) and Ordinary Portland Cement complying with KS02-21. The mix proportions shall be as stated on the Drawings or elsewhere in this Specification or if not stated shall be one part of cement to two parts of fine aggregate by weight.

Small quantities of mortar may be hand mixed but for amounts over 0.5 m³ a mechanical mixer shall be used.

The water content of the mortar shall be as low as possible consistent with the use for which it is required but in any case the water/cement ratio shall not be more than 0.5.

Mortar which is specified as 'dry pack' shall be mixed with sufficient water for the mix to become cohesive but not plastic when squeezed in the hand. Dry pack mortar shall be rammed into the cavity it is required to fill, using a hand rammer with sufficient force to ensure full compaction.

5.17 Concrete for Secondary Purposes

5.17.1 Non-structural concrete (NS concrete)

Non-Structural Concrete shall be used only for non-structural purposes where shown on the Drawings.

NS concrete shall be composed of Ordinary Portland Cement complying with KS02-21 and aggregates complying with BS 862 including all-in aggregate within the grading limits of Table 3 of BS 682.

The weight of cement mixed with 0.3 m³ metres of combined or all-in aggregate shall not be less than 50 kg. The mix shall be proportioned by weight or by volume. The maximum aggregate size shall be 40 mm nominal.

The concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted where required.

The concrete shall be compacted by hand or by mechanical vibration.

5.17.2 No Fines concrete (NF concrete)

No Fines concrete (NF concrete) is intended for use where a porous concrete is required and shall only be used where shown on the Drawings or instructed by the Engineer.

The mix shall consist of Ordinary Portland Cement complying with KS02-21 and aggregate complying with BS 882. The aggregate size shall be 40.0 mm to 10.0 mm only. The weight of cement mixed with 0.3 m³ metre of aggregate shall not be less than 50 kg. The quantity of water shall not exceed that required to produce a smooth cement paste which will coat evenly the whole of the aggregate.

5.18 Records of Concrete Placing

Records, in a form agreed by the Engineer, shall be kept by the Contractor of the details of every pour of concrete placed in the works. These records shall include class of concrete, location of pour, date of pour, ambient temperature and concrete temperature at time of placing, moisture contents of aggregates, details of mixes, batch numbers, cement batch

number, results of all tests undertaken, location of test cube sample points and details of any cores taken.

The Contractor shall supply to the Engineer four copies of these records each week covering work carried out the preceding week. In addition, he shall supply to the Engineer monthly histograms of all 28-day cube strengths together with accumulative and monthly standard deviations and any other information which the Engineer may require concerning the concrete placed in the works.

5.19 Construction Joints

Whenever concrete is to be bonded to other concrete which has hardened, the surface of contact between the sections shall be deemed a construction joint.

Where construction joints are shown on the Drawings, the Contractor shall form such joints in those positions. The location of joints which the Contractor requires to make for the purpose of construction shall be subject to the agreement of the Engineer. Construction joints shall be in vertical or horizontal planes except in sloping slabs where they shall be normal to the exposed surface or elsewhere where the Drawings require a different arrangement.

Construction joints shall be so arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints.

Feather edges of concrete at joints shall be avoided and any feather edges which may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal or near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 20 per cent from the horizontal.

The surface of the fresh concrete in horizontal or near horizontal joints shall be thoroughly cleaned and roughened by means of high-pressure water and air jets when the concrete is hard enough to withstand the treatment without the leaching of cement. The surface of vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

Where concrete has become too hard for the above treatment to be successful, the surface whether formed or free is to be thoroughly scrubbed by mechanical means or wet sand blasted and then washed with clean water. The indentations produced by scrubbing shall be not less than 10 mm deep and shall not extend closer than 40 mm to a finished face.

If instructed by the Engineer, the surface of the concrete shall be thoroughly brushed with a thin layer of mortar composed of one part of cement to two parts of sand by weight and

complying with Clause 5.4 all as set out in Sub-Clause 5.9.2 (b) immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete may be placed in position on or against a construction joint until the joint has been inspected and passed by the Engineer.

5.20 Expansion and Contraction Joints

Expansion and contraction joints are discontinuities in concrete designed to allow for thermal or other movements in the concrete.

Expansion joints are formed with a gap between the concrete faces to permit subsequent expansion of the concrete. Contraction joints are formed to permit initial contraction of the concrete and may include provision for subsequent filling.

Expansion and contraction joints shall be formed in the positions and in accordance with the details shown on the Drawings or elsewhere in the Specifications.

5.21 Water-stops

All references to water-stops include grout stops.

Water stops shall be of the material and form shown on the Drawings. No water-stop material shall be brought onto site until the Contractor has submitted full details of the materials he proposes to use, including samples, and these have been approved by the Engineer. All samples shall be of adequate length for testing.

Water stops shall be made of material which are resistant to chlorides, sulphates, or other deleterious substances which may be present in the environment of the Works.

Rubber water stops may be of natural or synthetic rubber and shall have an elongation at breaking stress of at least 500 per cent at 25°C and shall allow a joint movement of at least 50 mm.

Polyvinyl chloride (PVC) water stops shall be extruded from unfilled plasticized PVC polymer or copolymer which does not contain any reclaimed or scrap PVC. PVC water stops shall have an elongation at breaking stress of at least 225 per cent at 25°C and shall allow a joint movement of at least 10 mm.

Low modulus water stops shall be of rubber or PVC as described above but shall have an elongation of at least 200 per cent at 25°C under a tensile stress of 6 N/mm² and shall allow a joint movement of at least 50 mm.

Water stops shall be supplied in lengths as long as possible consistent with ease of handling and construction requirements.

In rubber or plastic materials joints other than butt joints shall be supplied ready made by the manufacturer. Butt joints shall be made on site in accordance with the manufacturer's instructions and with equipment supplied for the purpose by the manufacturer.

Water stop material shall be stored carefully on Site to avoid damage and contamination with oil, grease, or other pollutants. Rubber and plastic water stops shall be stored in cool well ventilated places away from direct sunlight.

Rubber and plastic water stops which are embedded in one side of a joint more than one month before the scheduled date of placing concrete on the other side shall be protected from the sun.

Water stops shall be firmly fixed in the formwork so that they cannot be displaced during concrete placing and shall be completely free of all dirt, grease, oil, etc. before placing concrete. Where eyelets are provided these shall be fully wired to the reinforcement and this will be the only means whereby the water stop is fixed. In no circumstances shall a water stop be punctured with nails etc. as a means of fixing.

Concrete shall be placed carefully round water stops so as to avoid distortion or displacement and shall be fully compacted. Where water stops lie in a horizontal or nearly horizontal plane the Contractor shall ensure that no voids are left on the underside of the water stop.

Formwork round water stops shall be carefully removed to avoid damage. If water stops suffer any damage which cannot be properly repaired in situ the Engineer may require a section of concrete to be removed and the water stop replaced.

5.22 Grouting of Pockets and Holes and Underpinning of Base plates

Pockets and holding-down bolt holes shall be thoroughly cleaned out using compressed air and water jet. Holes drilled by a diamond bit shall be roughened. The pockets and holes shall be filled with grout consisting of cement and clean fresh water mixed in proportion of two parts by weight of cement to one part by weight of water. The pouring of liquid grout shall cease as soon as each hole is filled and any excess grout on the surface of the concrete foundation shall be completely removed and the surface dried off before the next operation proceeds.

The space between the top surface of foundation concrete and the underside of base plates shall be filled with a special mortar made up in the following proportions: -

- Portland cement... .50 kg
- Fine aggregate . . 50 kg

An additive acceptable to the Engineer to counteract shrinkage in proportions recommended by the manufacturer

The special mortar shall be mixed with -the lowest water-cement ratio which will result in a consistency of mix of sufficient workability to enable maximum compaction to be achieved.

The special mortar shall then be well rammed in horizontally below the baseplate and from one edge only until it is extruded from the other three sides. The mortar which has extruded shall then be rammed back to ensure complete support without voids.

5.23 Reinforcement for Concrete

Reinforcement which shall comply with the following British Standards and or latest edition of each of the standards, covers plain and deformed bar reinforcement and steel fabric to be cast into concrete in any part of the works but does not include prestressing tendons or any other embedded steel.

- BS 4449 for hot rolled plain bar and high yield deformed bar
- BS 4482 for hard drawn mild steel wire
- BS 4461 for cold worked steel bar
- BS 4483 for steel mesh fabric

All reinforcement shall be from an approved manufacturer and, if required by the Engineer, the Contractor shall submit a test certificate from the manufacturer.

All reinforcement for use in the Works shall be treated for compliance with the appropriate British Standard in a laboratory acceptable to the Engineer and two copies of each test certificate shall be supplied to the Engineer. The frequency of testing shall be as set out in the British Standard.

In addition to the testing requirements described above, the Contractor shall carry out additional tests as instructed by the Engineer.

Any reinforcement which does not comply with the Specification shall be removed from Site.

5.23.1 Storage of Reinforcement

All reinforcement shall be delivered to Site either in straight lengths or cut and bent. No reinforcement shall be accepted in long lengths which have been transport bent over double.

Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. All reinforcement which has become corroded or pitted to an extent which, in the opinion of the Engineer, will affect its properties shall either be removed from Site or may be tested for compliance with the appropriate British Standard in accordance with Clause 5.28 of this Specification at the Contactor's expense.

5.23.2 Bending Reinforcement

Unless otherwise shown on the drawings, bending and cutting shall comply with BS 4466.

The Contractor shall satisfy himself as to the accuracy of any bar bending schedules supplied and shall be responsible for cutting, bending, and fixing the reinforcement in accordance with the Drawings.

Bars shall be bent cold by the application of slow steady pressure. At temperatures below 5°C the rate of bending shall be reduced if necessary to prevent fracture of the steel.

After bending, bars shall be securely tied together in bundles or groups and legibly labelled as set out in BS 4466.

Reinforcement shall be thoroughly cleaned and all dirt, scale, loose rust, oil and other contaminants removed before it is placed in the Works.

5.23.3 Fixing Reinforcement

Reinforcement shall be securely fixed in position within a dimensional tolerance of 20 mm in any direction parallel to a concrete face and within a tolerance of 5 mm at right angles to a face, provided that the cover is not thereby decreased below the minimum shown on the Drawings, or if not shown shall be not less than 25mm or the diameter of the bar, whichever is the greater. Cover on distribution steel shall not be less than 15mm or the diameter of whichever is the greater.

Unless otherwise agreed by the engineer, all intersecting bars shall either be tied together with 1.6 mm diameter soft annealed iron wire and the ends of the wire turned into the body of the concrete, or shall be secured with a wire clip of a type agreed by the Engineer.

Spacer blocks shall be used for ensuring that the correct cover is maintained on the reinforcement. Blocks shall be as small as practicable and of a shape agreed by the Engineer. They shall be made of mortar mixed in the proportions of one part of cement to two parts of sand. Wires cast into the block for tying in to the reinforcement shall be 1.6 mm diameter soft annealed iron.

Alternatively another type of spacer block may be used subject to the Engineer's agreement.

Reinforcement shall be rigidly fixed so that no movement can occur during concrete placing. Any fixings made to the formwork shall not be within the space to be occupied by the concrete being currently placed.

No splices shall be made in the reinforcement except where shown on the Drawings or agreed by the Engineer. Splice lengths shall be as shown on the Drawings.

Reinforcement shall not be welded except where required by the Contract or agreed by the Engineer. If welding is employed, the procedures shall be as set out in BS2640 for gas welding or BS 5135 for metal arc welding. Full strength butt welds shall only be used for steel complying with BS 4449, and if used on high yield deformed bars complying with BS 4449 the permissible stresses in the vicinity of the weld shall be reduced to those applicable to plain bars complying with that specification.

Mechanical splices shall not be used unless the Engineer agrees otherwise.

The Contractor shall ensure that reinforcement left exposed in the Works shall not suffer distortion, displacement or other damage. When it is necessary to bend protruding reinforcement aside temporarily, the radius of the bend shall not be less than four times the

bar diameter for mild steel bars or six times the bar diameter for high yield bars. Such bends shall be carefully straightened before concrete placing continues, without leaving residual kinks or damaging the concrete round them. In no circumstances will heating and bending of high yield bars be permitted.

Bars complying with BS 4461 or other high tensile bars shall not be bent after placing in the Works.

Before concrete is placed in any section of the Works that includes reinforcement, the reinforcement shall be completely clean and free from all contamination including concrete, which may have been deposited on it from previous operations.

5.24 Precast Concrete

Precast concrete covers all precast units for use in the Works, whether instructed under the Contract or proposed by the Contractor, and includes prestressed units where applicable.

5.24.1 Moulds for Precast Units

Moulds shall be so constructed that they do not suffer distortion or dimensional changes during use and are tight against loss of cement grout or fines from the concrete.

Moulds shall be set up on firm foundations so that no settlement occurs under the weight of the fresh concrete.

Moulds shall be constructed so that units may be removed from them without sustaining any damage.

Release agents used for demoulding shall not stain the concrete or affect its properties in any way.

5.24.2 Reinforcement for Precast Units

Reinforcement in precast units shall comply with the requirement of relevant sections of this specification. When preformed cages are used, the cages shall be made up on jigs to ensure dimensional accuracy and shall be carefully supported within the mould in such a way that they cannot move when concrete is placed. Reinforcement complying with BS 4449 may be tack welded where bars cross to provide rigidity in the cage but reinforcement complying with BS 4461 shall not be welded.

Cover to main reinforcement shall be as shown on the Drawings, or if not shown shall be not less than 25 mm or the diameter of the bar, whichever is the greater. Cover on distribution steel shall not be less than 15 mm or the diameter of the bar whichever is the greater.

Bars shall be spaced so that the minimum clear distance between them is the maximum nominal aggregate size plus five millimeters but in any case not less than the diameter of the bars.

Bars may be placed in pairs provided that there are no laps in the paired lengths.

5.24.3 Casting of Units

Concrete for precast units shall comply with relevant sections of this specification using the class of concrete specified on the Drawings.

If lightweight aggregates are specified, they shall comply with BS 3797.

The area in which the units are cast shall be adequately protected from weather so that the process is not affected by rain, sun or drying winds.

5.24.4 Curing Precast Units

Requirements for curing shall be generally as set out in relevant sections of this specification. The Contractor shall ensure that units do not suffer any loss of moisture or sudden changes of temperature for at least four days after casting. If a water spray is used for curing, the water shall be at a temperature within 5°C of the temperature of the unit being cured.

If the Contractor proposes curing at elevated temperature, the method shall be subject to the agreement of the Engineer and shall include means whereby units' are heated and subsequently cooled evenly without sudden changes of temperature.

5.24.5 Dimensional Tolerances of Precast Units

Units shall be accurately formed to the dimensions shown on the Drawings and within the tolerances set out in BSCP 110 unless closer tolerances are called for in the Special Specification or on the Drawings

5.24.6 Surface Finish of Precast Units

The formed faces of precast units shall be finished to Class F3 as set out in relevant sections of this specification unless another class of finish is specified on the Drawings.

Free faces shall be finished to Class UF2 unless another class of Finish is specified on the Drawings.

In cases where a special finish is required a trial panel shall be constructed by the Contractor which after approval by the Engineer shall be kept available for inspection at the place of casting and production units shall thereafter match the approved pattern.

Those parts of the unit which are to be joined to other units or to in situ concrete shall be brushed with a stiff brush before the concrete has fully hardened. Alternatively, if the concrete has been allowed to harden, the surfaces shall be roughened by sand blasting or the use of a needle gun.

5.24.7 Handling and Storage of Precast Units

Precast units shall be handled in a manner which will not cause any kind damage and of shall be stored on a hard impermeable base.

Prestressed units and large precast normally reinforced units shall be handled and stored so that no stresses shall be induced in excess of those which they will incur in their final positions in the Works unless they have been designed to resist such stresses.

Units shall be provided with adequate lifting holes or loops, placed in the locations shown on the Drawings or agreed by the Engineer and they shall be lifted only by such holes or loops. Where it is not possible to provide holes or loops, suitable sling positions shall be indicated in paint on the units.

Units shall be marked indelibly with the reference number and date of casting and shall be stacked on suitable packers which will not damage the concrete or stain the surfaces. Not more than two packers shall be placed under each unit and these shall be located either at

The positions of the permanent support points or in positions such, that the induced stresses in the unit will be a minimum.

5.24.8 Testing Precast Units

Precast units shall be capable of safely sustaining the load which they have been designed to carry. The Contractor shall subject units selected by the Engineer to load tests simulating the working conditions. Details of such tests shall be agreed between the Engineer and the Contractor.

In the case of units subject to bending loads the test piece shall be supported at full span and a loading equivalent to 1.25 times the sum of the live and dead loads which were assumed in the design shall be maintained for one hour without the appearance of any signs of distress. The recovery one hour after the removal of load shall be not less than 75 per cent of the full load deflection.

If the unit fails to meet the above requirements, further tests shall be carried out on two more units. If either of these fail, the whole batch of units will be rejected.

If the Engineer so requires, a test to destruction shall also be carried out which on unit's subject to bending shall be as follows: -

The units shall be supported at full span and a load applied in increments instructed by the Engineer up to 95 per cent of the designed ultimate load. This load shall be held for 15 minutes without failure of the unit. The deflection at the end of this period shall be not more than 1/40th of the span. The load shall then be further increased until failure occurs.

If the unit fails to sustain the required load for the prescribed period or if the deflection exceeds the specified amount, the Engineer may order two further tests, and if either of these fails, the batch of units which they represent may be rejected.

5.25 Measurement and payment

5.25.1 Item : Concrete

Unit : m³ of each class

Concrete shall be measured by the cubic metre of each class calculated from the dimensions given on the Drawings or instructed by the Engineer. No deduction shall be made in the measurement for:

- (i) bolt holes, pockets, box outs and cast in components provided that the volume of each is less than 0.15 cubic metres;

- (ii) mortar beds, fillets, drips, rebates, recesses, grooves, chamfers and the like of 100 mm total width or less.
- (iii) Provision and transport of cement aggregates and. water.
- (iv) Admixtures and workability agents including submission of details unless specified.
- (v) Hatching, mixing, transporting, placing, compacting and curing.
- (vi) Class UF1 finish.
- (vii) Laying to sloping outfaces not exceeding 15° from the horizontal and to falls.
- (viii) Formwork to blinding concrete.
- (ix) Placing and compacting against excavated surfaces where required including any additional concrete to fill over break or working space.
- (x) Complying with the requirements of the relevant Clauses of this Specification.

5.25.2 Item: Blinding concrete

Unit: m³

Blinding concrete shall be measured by the cubic metre calculated as the product of the plan area of the foundation as shown on the Drawings and the instructed thickness. No deduction shall be made for openings provided that the area of each is less than 0.5 square metres. Blinding concrete over hard material shall be measured as the volume used provided that the maximum thickness of 150 mm allowed for over break is not exceeded.

The rate for blinding concrete shall include for all costs itemized in Clause 5.41.1 (a) of this Specification.

5.25.3 Item: No fines concrete.

Unit: m³

No fines concrete shall be measured by the calculated cubic metre from the dimensions given on Drawings or instructed by the Engineer.

The rate for no fines concrete shall include: for all costs stated in Clause 5.41.1 (a) of this Specification.

5.25.4 Item: Unformed surface finishes

Unit m² of each class of finish

Unformed surface finishes shall be measured by the square metre from the dimensions given on the Drawings or instructed by the Engineer.

The rate for concrete in Clause 5.41.1 (a), 5.41.2 (b) and 5.41.3 (c) shall include for class UFI finish.

The rate for unformed surface finishes shall include for the cost of complying with Clause 5.13 of this Specification.

5.25.5 Item: Formed surface finishes

Unit: m² of formed Surface for each class of finish for each range of inclinations.

Except as stated below, formed surfaces shall be measured by the square metre of the finished face of the concrete. No deduction shall be made in the measurement for openings, pipes, ducts and the like, provided that the area of each is less than 0.50 square metres.

Formed Surfaces less than 300 mm high to edges of slabs shall be measured by the linear metre in accordance with the relevant Clauses of this Specification.

Formed Surfaces required for blinding concrete, to form construction joints and shear keys for future concrete and other construction surfaces shall not be measured and the costs shall be included in the rates for other work.

Formed Surfaces to contraction and expansion joints shall be measured by the square metre on one face only. The rates shall include for the costs stated below and for forming recesses for sealant and channels for grout.

The rates for formed Surface shall include for the cost of submission of details providing and transporting all materials for formwork and falsework, erection including provision of supports, fillets and chamfers 75 mm and less in width, bolts, ties, fixings, cutting to waste, drilling or notching the formwork for reinforcement where required, working around pipes, ducts, conduits and water stops, temporary openings, cleaning, dressing, stripping, filling bolt holes and any remedial work and for complying with the relevant Clauses of this Specification.

The rate shall also include for costs of constructing formed surfaces to any inclination, shape or curvature as shown in the drawing or as instructed by the Engineer.

5.25.6 Item Formwork to edges of slabs

Unit: m of each class of finish

Formwork less than 300 mm high to edges of slabs shall be measured by the linear metre.

The rates for formwork shall include for the cost of submission of details providing and transporting all materials for formwork and falsework, erection including provision of supports, fillets and chamfers 75 mm and less in width, bolts, ties, fixings, cutting to waste, drilling or notching the formwork for reinforcement where required, working around pipes, ducts, conduits and water stops, temporary openings, cleaning, dressing, stripping, filling bolt holes and any remedial work and for complying with the relevant Clauses of this Specification.

5.25.7 Item: Water stops

Unit: m of each type

Water stops shall be measured by the metre run of each type.

The rate for water stops shall include for the provision installation, jointing, any sealants required at the face of the concrete and for placing and compacting concrete around the water stop.

5.25.8 Item: Mortar

Unit: m²

Mortar used for bedding base-plates and the like shall be measured by the square metre as the area of the base plate at the specified nominal thickness of bedding.

Mortar used in filling bolts pockets and the like shall not be measured separately and the costs shall be included in the rates for the bolts. The rates for mortar shall include for the cost of providing and placing the mortar and of complying with the requirements of Clauses 5.14 and 5.20 of this Specification.

5.25.9 Item: Admixtures, workability and hardening agents

Unit: as per instruction of the Engineer

Where required by the Special Specification admixtures, "Workability and hardening agents will be measured and paid for in accordance with the Engineer's Instructions.

5.25.10 Item: Reinforcement

Unit: tonne of each type for each range of diameters. Reinforcement shall be measured separately for each of the following ranges.

- i. of diameter equal to or less than 16 mm.
- ii. of diameter greater than 16 mm.
- iii. Steel fabric reinforcement shall be measured in accordance with relevant clause of this Specification.

Steel plain and deformed bar reinforcement shall be measured by the tonne and shall be the calculated weight of the steel required including splice lengths shown on the Drawings. No allowance shall be made in the measurement for rolling margin or cutting waste. The density of Steel shall be taken as 7,850 kilograms per cubic metre.

The rates for reinforcement shall include for the cost of providing, cutting to length, splice lengths additional to those shown on the Drawings, laps, bending, hooking, waste incurred by cutting, cleaning, spacer blocks, provision and fixing of chairs or other types of supports, welding, fixing the reinforcement in position including the provision of wire or other material for supporting and tying the reinforcement in place, bending reinforcement aside temporarily and straightening, placing and compacting concrete around reinforcement and for complying with the requirements of relevant clauses of this Specification.

5.25.11 Item: Fabric reinforcement

Unit: m² of each type

Steel fabric reinforcement shall be measured by the square metre and shall be the calculated area excluding any allowance for laps.

The rate for steel fabric reinforcement shall include for the costs stated in Clause 5.41 (j) of this Specification.

5.25.12 Item: Precast Units

Unit: no. of each type

Precast units shall be measured by the number of each type instructed unless otherwise specified in the Special Specification.

The rate for precast units shall include the cost of all the materials, forming and placing units, complying with the requirements of Clauses 5.33 to 5.40 inclusive and with the relevant Clauses of the Special Specification.

No separate measurement or payment will be made for formwork reinforcement or prestressing tendons to precast units.

6 BUILDING AND MASONRY WORKS

6.1 BUILDING WORKS

6.1.1 General

This sub-section covers the requirements for the construction of buildings and includes all building works, except earth and concrete works. The work required under this sub-section shall include all labour, materials, equipment, remedy of deficiencies, Site clearance and all other appurtenant works required to complete all building works specified herein.

6.1.2 Standards and Rules

The Contractor shall carry out the works described in this Section in accordance with the appropriate BS EN standards or equivalent standards. The main standards are, but are not limited by, the following:

BS EN 1996-1-1 (Eurocode 6 - Design of masonry structures)
BS EN 1992-1-1 (Eurocode 2 - Design of concrete structures)
BS EN 1469 (Natural stone products)
BS EN 13369 (Precast concrete products) or other concrete product standards
BS EN 1995-1-1 (Eurocode 5 - Design of timber structures)
BS EN 14891 (Liquid-applied water impermeable products)
BS EN 1254-1 (Waterproofing products for building structures)
BS EN 1304 (Clay roofing tiles) / BS EN 1297 (Concrete roofing tiles) / BS 5534 (Slating and tiling)
BS EN 806 (Specifications for installations inside buildings conveying water for human consumption)
BS EN 13914-1 (Gypsum plasterboards) / BS EN 13279-1 (External rendering)
BS EN 14411 (Ceramic tiles)
BS EN 13813 (Screed material and floor screeds)
BS EN 13108-1 (Bituminous mixtures)
BS EN 14220 (Windows and external pedestrian doorsets)
BS EN 12150 (Glass in building - Thermally toughened soda lime silicate safety glass)
BS EN 1062-1 (Coating materials and coating systems for exterior masonry)
BS EN 13329 (Laminate floor coverings) / BS EN 14041 (Resilient floor coverings)
BS EN 13141-1 (Ventilation for buildings - Performance testing of components/products)
BS EN 1451-1 (Sanitary appliances - Washbasins) / BS EN 997 (WC suites)

6.1.3 Works Included

The Contractor shall, unless otherwise specified herein, supply all materials, equipment, temporary works and labour necessary to perform, maintain and complete the building works.

6.1.4 Works to be Measured

Building works under the present Contract shall be quoted as a lump sum for the various sections of work. Payments for the completed sections of work will be made in accordance to the provisions made in the Particular Conditions of Contract.

6.1.5 Approval of Materials and Workmanship

The supply of all materials and items shall be subject to the approval of the Engineer. The Contractor shall provide such samples as the Engineer may require in advance for the approval and, when approved, the quality of materials and workmanship shall be at least equal to the approved samples.

6.2 MASONRY WORKS

6.2.1 Bricks and Blocks

First Class Bricks shall be made from good brick earth free from saline deposits and shall be sand molded. They shall be thoroughly burnt by coal without being vitrified, of uniform and good color, shall be regular and uniform in size, shape and texture with sharp square edges and parallel faces. They must emit a clear metallic ringing sound when struck one against another. They shall be free from flaws, cracks, chips, stones, and nodules of lime or canker. A First-Class Brick shall not absorb more than 1/6th of its weight of water after being soaked for one hour.

The quality of bricks shall correspond to BS EN 1496. Compressive strength class shall be not less than 12 N/mm² for solid bricks for general use and 20 N/mm² for fair faced masonry or hollow bricks.

Blocks shall be solid or hollow concrete blocks, as indicated, in accordance to BS EN 13813 with a compressive strength not less than 8 N/mm² for solid block and 12 N/mm² for hollow blocks or fair faced masonry.

The Contractor shall submit samples of each type of bricks and blocks used in the works and obtain the Engineer's approval before placing orders with suppliers. Strength test certificates performed on the basis of appropriate DIN standards shall also be submitted on request of the Engineer.

6.2.2 Fixings for Brickwork

Fixings shall be, if not otherwise specified by the Engineer, of stainless steel for sheet, strip, plate and bars in accordance to DIN 17440.

6.2.3 Sand

Sand shall be clean and sharp course grit, freshwater river or pit sand conforming in all respects to DIN 1053 and DIN 18550 and shall be re-washed on Site if the silt, loam or clay content exceeds the limits prescribed in DIN 4226. The sand shall be obtained from a source approved by the Engineer.

6.2.4 Cement

Cement shall be sulfate resisting Portland cement as specified in BS EN 14213-2004. The source of cement is subject to the approval of the Engineer and shall not be changed without his prior approval.

6.2.5 Water

For the mixing of mortar and plaster the Contractor shall provide tap water, if not otherwise directed or approved by the Engineer.

6.2.6 Mortar Mix

Masonry mortar for setting blocks and bricks shall be of the quality group III set out in BS EN 998-1-2016. The proportion shall be 1 part cement to 4 parts sand or as otherwise directed or approved by the Engineer. Mortar shall be added to the mix in an amount compatible with workability. Mortar constituents shall be measured by volume using clean gauge boxes.

Mortar shall be mixed in a mechanically operated mortar mixer for at least three minutes after all ingredients are in the drum. The mixing by hand will only be permitted when the quality of hand mixing is comparable to mechanical mixing.

Mortar shall be used within 2 hours after discharge from the mixer at normal temperatures. No mortar shall be used after the initial set has taken place. Reconstitution of mortar will not be permitted.

6.2.7 Workmanship

All masonry shall be laid plumb and true to lines and built to the thickness and bond required. Masonry shall be carried up in a uniform manner. No one portion shall be in raise more than one meter above adjacent portions, except with the approval of the Engineer.

Sample panels of 1 m² size shall be prepared for each type of facing brickwork or blockwork, including jointing or pointing, and the Contractor shall not commence facework without the approval of the Engineer. Facework shall be kept clean during construction and until completion of the Works.

Under hot and dry weather conditions, bricks and blocks shall be stacked on a hard standing level so as to prevent the absorption of water. Suitable shading shall be provided to prevent high temperatures within the brick and block stacks. Clay brickwork and blockwork shall be kept wet to the minimum extent required to prevent mortar drying out prematurely.

Freshly laid brickwork / blockwork shall be protected during interruption through rain and at the completion of each day's work.

Facework shall be kept clean during construction and until practical completion. Scaffold boards shall be kept clear of the building at night and during heavy rain. Rubbing to remove stains will not be permitted.

All bricks shall be wetted before being laid.

Clay bricks shall not be used until completely cold from the kiln.

Facing bricks of varying colour shall be distributed evenly throughout the work so that no patches appear. Different deliveries, which vary in colour, shall be mixed to avoid horizontal stripes.

Brickwork and blockwork abutting concrete columns, walls and beams shall be tied with stainless steel ties in accordance with the relevant references and as directed by the design. Additional ties shall be supplied at openings. Fair-faced walls shall have selected bricks and blocks with perfect arises and flat surface structures and with faces in line

6.2.8 Exposed Concrete Blocks

Concrete blockwork shall be laid in stack bond and, unless otherwise directed, with joints not exceeding 1 cm and uniform throughout. All blocks shall be laid in a full bed of mortar applied to shells only. Intersecting bearing walls shall be tied together with stainless steel ties at one meter vertical spacing.

Where directed, concrete blocks shall be reinforced and concrete blocks lintel type shall be built in above wall openings.

Control joints shall be installed at the intersection with structural concrete and elsewhere where joints are useful. Joints not detailed otherwise shall be racked out to a depth of 2 cm for the full height of the wall and be caulked. Joints shall be examined to locate cracks, holes or other defects and all such defects shall be remedied with mortar and pointed.

6.2.9 Concrete Blocks to Receive Plaster

Concrete block walls to be plastered may be laid with bonds described above. Joints shall be left rough to assist in bounding of plaster. Control joints in plastered block shall be carried through the plaster. The joint shall not be plastered.

6.2.10 Brickwork

Solid brick walls shall be laid in common bond with all joints filled solidly with mortar and backs fully purged to form solid masonry structure. Joints of walls to receive plaster shall be lightly raked to provide a bond for plaster. Control joints in brick walls shall be carried through the plaster. The joint shall not be plastered.

6.2.11 Lintels, Miscellaneous

The Contractor shall build in or provide all miscellaneous items to be set in masonry including lintels, frames, reinforcing steel, electrical boxes, fixtures, sleeves, grilles, anchors and other miscellaneous items. All anchorage, attachments and bonding devices shall be completely covered with mortar.

6.2.12 Cleaning

Masonry work to be exposed shall be thoroughly cleaned. Mortar smears and droppings on concrete block walls shall be dry before removal with a trowel. Masonry work may be cleaned using a mild muriatic acid solution.

6.2.13 Damp-proof Courses

As a minimum requirement, damp-proof courses shall be in accordance with DIN 4117 and DIN 4122.

Bituminous sheet damp-proof courses shall be laid on a level bed of cement mortar with a minimum lap of 75 mm at angles and joints and neatly pointed in matching mortar on exposed edges. Horizontal and sloping damp-proof coursing over door openings shall be in single pieces of material of a length to extend 225 mm at both sides beyond the width of the frame.

6.2.14 Waterproof Building Paper

Waterproof building paper shall be laid beneath structural concrete. The paper shall be laid with 150 mm lapped joints, which shall be treated and sealed with an approved bituminous solution. The weight of the paper shall not be less than 0.3 kg/m².

6.3 PLASTERING

6.3.1 Sand

Sand shall be clean and sharp course grit, freshwater river or pit sand conforming in all this specification BS EN 14213-2004 and shall be re-washed on Site if the silt, loam or clay content exceeds the limits prescribed in BS EN 14213-2004. The sand shall be obtained from a source approved by the Engineer.

6.3.2 Cement

Cement shall be sulphate resisting Portland cement as specified in BS EN 14213-2004. The source of cement is subject to the approval of the Engineer and shall not be changed without his prior approval.

6.3.3 Water

For the mixing of mortar and plaster the Contractor shall provide tap water, if not otherwise directed or approved by the Engineer.

6.3.4 Plaster Mixing

Plaster shall be mixed with proportions according to BS EN 13279-1:2017. The constituents shall be measured by volume and water added in an amount compatible with workability.

Plaster shall be mixed in a mechanically operated plaster mixer for at least long enough to make a thorough, complete intimate mix of the materials. The mixing of plaster by hand shall not be permitted, unless otherwise directed. The mixer, bunker, gauge boxes and all tools

shall be kept clean, and care shall be taken to ensure that fresh plaster is not contaminated with set plaster.

6.3.5 Workmanship

Plaster shall be of 2 or 3 coats. If plaster is to be applied to smooth surfaces, a dash coat shall be applied as a bonding surface. The dash coat shall be of mush consistency, composed of 1 part Portland cement and 1.5 parts of sand. The plaster coats shall be applied with the thicknesses given below, notwithstanding additional thickness being required in case of unevenness in the masonry surface

| Location: | Ceiling | Interior wall | Finish |
|---------------------------------|---------|---------------|--------|
| Thickness of first coat: | 15 mm | 10 mm | 10 mm |
| Thickness of intermediate coat: | -- | 6 mm | 9 mm |
| Thickness of finish coat: | 10 mm | 6 mm | 6 mm |
| Total thickness: | 25 mm | 22 mm | 25 mm |

6.3.6 Preparation of Surfaces

The Contractor shall carefully examine surfaces that are to receive plaster and any unsatisfactory surface shall be repaired as directed by the Engineer. Where fixtures have to be installed prior to plastering they shall adequately be protected from damage during plastering. Concrete masonry and brick surfaces shall have sufficient roughness to provide proper bond and shall be dumped by brushing or spraying with water followed by plastering.

6.3.7 Plastering

The dash coat shall be applied with a whisk broom or fibre brush and be kept moist for 48 hours before the first coat is applied to the dash coat.

Before the first coat hardens, the surface shall be scratched to provide bond for the intermediate coat. This coat shall be kept moist for not less than 24 hours and be allowed to set for not less than 14 days before application of the intermediate coat.

The surface of the intermediate coat shall be brought to a true and even surface, then roughened with a wood float before setting to provide a bond for the finish coat.

The finish coat shall be applied while the intermediate coat is moist and if the intermediate coat dries out it shall be wetted evenly. The finish coat shall be first floated to a true and even surface and then trowelled to a smooth and even finish.

6.3.8 Completion of Work

Completion of work includes curing (moisturizing for at least 3 days) and removal of deficiencies (at the Contractor's expense). Upon completion of the work, all plaster surfaces shall be cleaned and all rubbish, debris and excess material and equipment shall be removed.

6.3.9 Waterproof Plaster

Waterproof plaster shall consist of waterproofing compound, cement and sand mixed in strict accordance with the manufacturer's specification. The water proofing compound shall be a mass product of a repudiated manufacturer and shall be approved by the Engineer.

6.3.10 Tolerances

All surfaces shall be true to line, level, plumb and all junctions, angles and arrises truly square. On two or three coat work, the plaster surface shall not show any deviation greater than specified in DIN 18202 for accuracy class B.

6.4 SCREEDS

6.4.1 General

Workmanship and construction shall generally conform to DIN 18353 and DIN 18560 or equivalent standards.

Materials used for mortar shall be measured in gauge boxes. All concrete surfaces shall be adequately prepared and keyed to receive screeds. The screeds to be carried out have to be placed within buildings and shall be dense aggregate cement screeds.

6.4.2 Floor Screeds

Floor screeds in operation buildings shall be laid monolithically to a thickness of 2.5 cm and be laid separately.

The preparation of base concrete shall include the removal of laitance from the concrete surface to receive screed and the removal of all loose concrete, dust and dirt by thorough washing with water.

The screed mix shall be prepared in accordance to DIN 18550 and shall be thoroughly and efficiently be mixed dry by mechanical means until a uniform distribution is obtained prior to adding the water. The water content shall be kept as low as it is necessary to allow for sufficient workability for laying and compacting. Where only small quantities are required, mixing might be carried out by hand on clean watertight surface with the approval of the Engineer.

The screed mix shall be placed between forms, rigidly fixed on a firm foundation and set true to level within ± 3 mm, and shall be fully compacted by means of a screed board providing laitance is not brought to the surface. The screed wearing course shall be tamped with a wood float and trowelled with a steel trowel to produce a smooth finish.

The screed mix shall be placed between the forms (and or other bays) worked around the penetrations, duct covers, manhole covers, gutters, balustrade standards, pipes, etc., and shall be fully compacted by means of a screed board, or other suitable compacting equipment, providing laitance is not brought to the surface.

6.4.3 Joints

All edge joints of floor screeds shall be simple butt joints without filler. Screeds laid over construction joints in concrete shall be separated by 10 mm impregnated oakum strips or the like. Joints in wearing courses shall be 10 mm polysulphide

6.4.4 Tolerances

Floor screeds shall be free of all defects and any work which shows signs of bond failure, hollow patches, crazing, cracking or any other defects will not be accepted and shall be removed and replaced with acceptable work by the Contractor.

The extent of the work to be removed and the method to be used in the removal and replacement of this work shall be to the approval of the Engineer. The Engineer shall approve all surfaces before continuation of works.

6.5 FLOORING

6.5.1 General

All materials and structural components not covered by ISO or EN standards or equivalent may be used subject to the Engineer's consent only. The floorings shall be such as to provide a cover surface that can well be walked on and must not give any rise to any unreasonable inconvenience.

6.5.2 Materials

Concrete paving slabs shall be 50 mm thick, hydraulically pressed pre-cast concrete slabs in accordance with BS EN 14991:2006+A2:2012.

All fillers and levelling compounds shall have a firm and durable bond to the base, provide a good bonding surface for the adhesive and be of suitable property so as to give an adequate support to the covering. They must have no adverse effect on base, adhesive, underlay, or covering.

6.5.3 Workmanship in General

The Contractor shall examine the base to verify whether it is in suitable condition to carry out his work. He shall communicate any doubts the Contractor may have in this connection, to the Engineer immediately in writing.

All materials and structural components whose processing is subject to manufacturer's instructions shall be processed accordingly. The Contractor shall clean the flooring and treat it in accordance with the manufacturer's instructions for flooring materials.

The Contractor shall furnish the Engineer with the written instructions for the care and the maintenance of the flooring.

6.5.4 Preparation of Surfaces

The surfaces must be cleaned prior to flooring. The base for covering to be placed without underlay shall be smoothed with filler compound. In the case of major unevenness a suitable levelling compound shall be used.

Any filler or levelling compound shall be applied so that it will bond firmly and durably to the base, will not crack and will adequately withstand pressure. Any screeds such as magnesia and anhydride screed to which the filler or levelling compound will not sufficiently bond, shall receive a priming coat.

6.5.5 General Requirements for Application

Workmanship generally shall be in accordance with DIN 18352 and DIN 18365. Floorings shall be placed without underlays unless otherwise specified. The courses shall be laid towards the main window wall, in halls and corridors, however, in a longitudinal direction, unless otherwise specified.

6.5.6 Precast Concrete Slabs

All pre-cast concrete slabs shall be laid in bays not exceeding 10 m in length, the bays being separated by an expansion joint 10 mm wide.

6.6 ROOFING

6.6.1 General

The work shall consist of supplying, laying and finishing complete insulation and roof coverings and shall include the provision of all necessary skirtings, copings, flashings etc. On completion, all roofs shall be left sound and watertight and in neat and clean condition. All roof finishes shall be carefully worked or fitted around pipes and openings.

Roofing systems shall be in general the “inverted roof” or “protected membrane roof system” where the waterproof membrane is laid directly onto the structural slab and the insulating layer is then laid on the membrane and protected by a layer of files. Any special working details prepared by the Contractor must be submitted to the Engineer for approval.

6.6.2 Waterproofing and Insulation

The structural slab or surface screed on it shall be primed before application of the membrane in accordance to the manufacturer’s instructions. The insulation layer shall have a minimum density of 35 kg/m².

6.6.3 Workmanship

Workmanship shall be carried out in accordance with BS EN 1304 (Clay roofing tiles) / BS EN 1297 (Concrete roofing tiles) / BS 5534 (Slating and tiling). The roof surfaces shall be uniform, compact and free from debris.

Waterproof membranes shall be 1.5 mm thick self adhesive rubber bitumen applied strictly in accordance to the manufacturer’s instructions. The membrane shall be continuous and take

up abutments and pipes to above the insulation layer. Exposed membrane shall be solar protected. The waterproof membrane shall be dressed and bonded into rainwater outlets and under flashings.

The insulation board shall be not less than 50 mm thick closed cell extruded polystyrene loose laid in a single layer with tight staggered butt joints in accordance with the manufacturer's instructions. The board shall be trimmed to fit any fillets used under the waterproof membrane.

Flashings shall be sheet aluminium neatly cut to the width and length required. The aluminium shall be carefully bent using a slightly rounded former so as to avoid surface cracking. Where surface fixing is required, the sheet shall be pre-drilled and fixed with inoxidisable screws to proprietary fixings or hardwood grounds let into the surface of the base concrete or brick work.

Lightweight screeds shall be laid in accordance with the manufacturer's instructions and to falls not less than 1:40 with a thickness of 100 mm.

The screed shall be laid in two courses and in bays not exceeding 15 m², laid alternatively and finished with a mortar topping of 1:4 cement/sand mortar. Immediately after laying, the screed shall be protected from wind and sunlight and cured for 7 days.

6.7 HVAC Systems

This Section includes a general description of Heating, Ventilation and Air Conditioning systems, smoke ventilations system and the mechanical support for the generator system.

6.7.1 General Requirements

- i. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- ii. Energy-Efficiency: Equal to or greater than prescribed by ASHRAE standards.
- iii. Conform to the requirements of the following:
 - a. Latest issue of American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Handbooks on "Fundamentals", "Systems & Equipments" and "Applications"
 - b. National Fire Protection Association (NFPA), USA
 - c. Air-Conditioning and Refrigeration Institute (ARI), USA
 - d. ASHRAE Energy Standard
 - e. ASHRAE Ventilation Standard
 - f. American Society for Testing and Materials (ASTM)
 - g. All Applicable DIN Standards
 - h. OSHA standards and regulations.
 - i. EPA standards and regulations.

6.7.2 Equipment installation – common requirements

- i. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.
- ii. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.
- iii. Install HVAC equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
- iv. Install equipment to allow right of way for piping installed at required slope.

6.7.3 Piping systems – common requirements

- i. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
- ii. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- iii. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- iv. Install piping to permit valve servicing.
- v. Install piping at indicated slopes.
- vi. Install piping free of sags and bends.
- vii. Install fittings for changes in direction and branch connections.
- viii. Install piping to allow application of insulation.
- ix. Select system components with pressure rating equal to or greater than system operating pressure.
- x. Install escutcheons for penetrations of walls, ceilings, and floors according to the following:
- xi. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
- xii. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece or split-casting, cast-brass type with polished chrome-plated finish.
- xiii. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass type with polished chrome-plated finish.
- xiv. Bare Piping in Equipment Rooms: One-piece, stamped-steel type with set screw or spring clips.
- xv. Bare Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.
- xvi. Install sleeves for pipes passing through concrete and masonry walls and concrete floor and roof slabs.
- xvii. Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
- xviii. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.

6.7.4 Refrigerant Piping

- i. Quality assurance
 - a. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure
 - b. Vessel Code: Section IX, "Welding and Brazing Qualifications."
 - c. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."
 - d. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."
- ii. Copper tube and fittings
 - a. Copper Tube: ASTM B 88, Type K or L or ASTM B 88M, Type A or B
 - b. Wrought-Copper Fittings: ASME B16.22.
 - c. Wrought-Copper Unions: ASME B16.22.
 - d. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.
 - e. Brazing Filler Metals: AWS A5.8.
- iii. Flexible Connectors:
 - a. Body: Tin-bronze bellows with woven, flexible, tinned-bronze-wire-reinforced protective jacket.
 - b. End Connections: Socket ends.
 - c. Offset Performance: Capable of minimum 20-mm misalignment in minimum 180-mm- long assembly.
 - d. Pressure Rating: Factory test at minimum 3450 kPa.
 - e. Maximum Operating Temperature: 121 deg C
- iv. Flexible Connectors:
 - a. Body: Stainless-steel bellows with woven, flexible, stainless-steel-wire-reinforced protective jacket
 - b. End Connections:
 - DN 50 and Smaller: With threaded-end connections.
 - DN 65 and Larger: With flanged-end connections.
 - c. Offset Performance: Capable of minimum 20-mm misalignment in minimum 180-mm- long assembly.
 - d. Pressure Rating: Factory test at minimum 3450 kPa.
 - e. Maximum Operating Temperature: 121 deg C.

6.7.5 Insulation

Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, NFPA 255, UL 723; by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing and inspecting agency.

- a. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
- b. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

6.7.6 Vibration isolators

Vibration isolators shall be generally used where the vibrating force is transmitted directly to ground or the vibrating force is very small compared to the absorption capacity of the structural slab at higher levels.

- i. Flexible duct connections
 - a. Flexible duct connections shall be fabricated from coated fabric (or loaded vinyl as called for on the drawings). The clear space between connected parts shall be a minimum of 75-mm (3-inch) and the connection shall have 38-mm (1 1/2-inch) minimum of slack material.
 - b. UL Listed fire retardant, Neoprene coated (Silicon rubber for smoke extract duty / Hypalon or equal for outdoor use), woven, glass-fibre fabric of 750 gm/M2 (30 Oz/yard2) average weight: tailored to suit requirements.
 - c. Pressure Rating: 500 Pa (2 inch WG) positive and 375 Pa (1.5 inch WG) negative.
 - d. Maximum Velocity: 20.3 m / Sec.
 - e. Continuous Temperature Range: -40 grad C to 93 grad C for normal air moving equipment and 260 grad C for smoke extraction units.
 - f. Galvanised steel edging strips, crimped on to the duct fabric shall be provided at the ends of flexible connections to equipment / metal ducts.
- ii. Flexible pipe connections
 - a. Flexible pipe connections shall be fabricated of multiple plies of nylon cord, fabric, and neoprene, vulcanised so as to become inseparable and homogeneous. Straight connections shall be formed in a double sphere shape. Elbow connections shall have a single sphere shape at the curve of the unit. Flexible connections shall be able to accept compressive, elongative, transverse, and angular movements.
 - b. The flexible connections shall be selected and specially fitted, if necessary, to suit the system temperature, pressure, and fluid type.
 - c. Use bellow type metal flexible connectors with braided steel wire armour when they are located in outdoor areas where the type described above will be damaged due to sun radiation.
 - d. Connectors for pipe sizes 50 mm (2 inch) nom. dia. or smaller shall have threaded female union couplings, made up of compatible material like cast iron for steel and bronze for copper piping, on each end. Larger sizes shall be fitted with metallic flange couplings.

6.7.7 Inspection, testing , adjustment and balancing

During installation and after completion of works; the system, sections of the system or its components shall be tested by the Contractor/Specialist Subcontractor in the presence of the Engineer as directed below or elsewhere. The Contractor shall procure all testing instruments and accessories and bear all costs in connection with the same:

- a. Basic materials for conformity with the specified standards.
- b. Supports and anchors for ability to withstand required loads.

- c. Heat transfer equipment for full load capability, controls, safety interlocks, and alarms and operation of safety valves.
- d. Control system for operating ranges, tolerances, cut-out, alarms etc.

Carry out the testing, adjusting and balancing of the HVAC Equipment and systems as directed by the Engineer.

Provide additional volume dampers in all branch ducts and as required (whether shown on drawing or not) to completely balance air quantities on supply, return and exhaust ducts.

6.7.8 Refrigerants

- i. ASHRAE 34, R-22: Monochlorodifluoromethane.
- ii. ASHRAE 34, R-134a: Tetrafluoroethane.
- iii. ASHRAE 34, R-407C: Difluoromethane/Pentafluoroethane/1,1,1,2-Tetrafluoroethane.
- iv. ASHRAE 34, R-410A: Pentafluoroethane/Difluoromethane.

6.7.9 Ductworks

This Section includes metal, pre-insulated and non-metal ductworks for supply, return, outside, and exhaust air-distribution systems. Ductworks include the following:

- Rectangular ducts and fittings.
- Round and flat-oval spiral-seam ducts and formed fittings.
- Duct liner.
- i. Sheet metal materials
 - a. General: Non-combustible or conforming to requirements for Class 1 air duct materials, or UL 181.
 - b. Steel Ducts: ASTM A527 galvanized steel sheet, lock-forming quality, having zinc-coating designation of G90 in conformance with ASTM A525. Mill phosphatized for exposed locations
 - c. Stainless steel ducts: ASTM A167 stainless steel sheets; Type 304, sheet metal gauge and construction shall conform to recommendations in SMACNA duct construction standards, metal and flexible, latest edition.
 - d. Flexible Ducts
 - UL 181, Class 1, aluminum-polyester composite film with latex adhesive, supported by helical wound spring steel wire; fiberglass insulation; aluminized vapor barrier film and PVC jacket, K value of 0.23 maximum @ 75 °F mean temperature.
 - Pressure Rating: 2,500 Pa (10 inch WG) positive.
 - Maximum Velocity: 25 M / Sec.
 - Temperature Range: - 30 °C to 140 °C (-22 °F to 284 °F).
 - e. Fasteners: Rivets, bolts, or sheet metal screws.
 - f. Sealant: Non-hardening, water resistant, fire resistive, compatible with mating materials; liquid used alone or with tape, or heavy mastic.
 - g. Hanger Rod: Galvanized; continuously threaded.
 - h. Fire Resistant Duct Work

- Fire Resistant ductwork shall meet BS 476 part 24 (1987) and ISO 6944(1985) up to temperature of 1130°C.
- The ducts shall be constructed from reinforced degreased galvanized steel sheets and factory fire sprayed with specially formulated water based compound. The fire resistive compound shall contain selected mineral fillers in a low permeability elastomeric binder to thickness of approximately 1mm to give cellulosic fire conditions resistance in excess of 4 hours duration.
- The ductwork shall be produced in sections and assembled on site utilizing approved fire stop gaskets/sealants.

ii. Fabrication

- a. Fabricate and support in accordance with SMACNA HVAC Duct Construction Standards and ASHRAE handbooks, except as indicated. Provide duct material, gauges, reinforcing, and sealing for pressure classes indicated.
- b. Size round ducts installed in place of rectangular ducts in accordance with ASHRAE table of equivalent rectangular and round ducts. No variation of duct configuration or sizes permitted except by written permission.
- c. Construct T's, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows are used, provide [airfoil] turning vanes. Where acoustical lining is indicated, provide turning vanes of perforated metal with glass fiber insulation.
- d. Increase duct sizes gradually, not exceeding 15 degrees divergence. Divergence upstream of equipment shall not exceed 30 degrees; convergence downstream shall not exceed 30 degrees.
- e. Provide easements where ductwork conflicts with piping and structure. Where easements exceed 10 percent duct area, split into two ducts maintaining original duct area.
- f. Connect flexible ducts to metal ducts with adhesive plus sheet metal screws.
- g. All duct supports should be fabricated from hot dipped galvanized angles and channels.
- h. The welding joints and the cut ends should be protected with zinc rich paint before installation.
- i. Use double nuts and lock washers on threaded rod supports.
- j. Provide standard 45-degree lateral wye takeoffs unless otherwise indicated where 90 degrees conical tee connections may be used.
- k. Duct access doors
 - General: Provide where indicated or required, factory fabricated duct access doors of size indicated. Provide gasketed access doors for future duct cleaning as approved by the Engineer.
 - Construction: Construct of same or greater gauge as ductwork served, provide insulated doors for insulated ductwork. Provide flush frames for uninsulated ductwork, extended frames for externally insulated duct. Provide one side hinged, other side with one handle-type

latch for doors 300 mm high and smaller, two handle-type latches for larger doors.

iii. Pre insulated ductwork

- a. Pre Insulated Duct Systems: Aluminium / Polyurethane foam sandwich panel, as per Class 0 British Standard 476 Part 6 & 7, & Class B1 DIN 4102 – Zulassungsnummer Z- PA-111 2.2984 U-Zeichen LGA Nurnberg. (ALP Noise-Off, Noise Absorption Sandwich Panel)
- b. Construct as per Manufacturer Specifications and SMACNA HVAC Duct Construction Standards.
- c. Construct tees, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows are used, provide [air foil] turning vanes.
- d. Construct and use fittings, sealants and gaskets etc. as per manufacturer's recommendations.
- e. Pre insulated ductwork shall be fabricated using panels as the following:

| Pre-Insulated Panels | Internal Use and Mechanical Areas | External Use (Expose to Weather) |
|--------------------------------------|-----------------------------------|----------------------------------|
| Thickness | 20 to 30 mm | 30 mm |
| Density | 45 to 50 kg/m ³ | 50 kg/m ³ |
| Thermal conductivity | 0.022 W/mk | 0.022 W/mk |
| Minimum Thickness of Aluminum sheets | 200 Micron (inner & outer sides) | 200 Micron inner side 500 Micron |
| Finishing of inner aluminum sheet | Smooth | Smooth |
| Finishing of outer aluminum sheet | Smooth | Smooth or embossed |

- f. Pre insulated duct installation, fabrication & fixation required specialized labors (trained and qualified staffs), shall be employed by the A/C contractor under the supervision of the pre-insulated duct supplier.

6.7.10 Dampers

- a. Low Pressure Manual Dampers: Provide dampers of single blade type or multiblade type as per duct size constructed in accordance with SMACNA "Low Pressure Duct Standards".
- b. Control Dampers: Provide dampers with parallel blades for 2 - position control, or opposed blades for modulating control. Construct blades of 16 gauge steel, provide heavy-duty molded self-lubricating nylon bearings, 13mm diameter steel axles spaced on 225mm centres. Construct frame of 50mm x 13mm x 3mm steel channel for face areas 2.25 sq.m and under; 100mm x 32mm x 16 gauge channel for face areas over 2.25 sq. M. Provide galvanised steel finish with aluminium touch-up. Equipped dampers with motors with proper rating for each application.

- c. Secure blades to 13 mm diameter zinc-plated axles using zinc-plated hardware. Seal off against spring stainless steel blade bearings. Provide blade bearings of nylon and provide thrust bearings at each end of every blade. Construct blade linkage hardware of zinc-plated steel and brass. Submit leakage and flow characteristics, plus size schedule for controlled dampers.
- d. Operating Temperature Range: From -0 to 93°C.
- e. For standard applications as indicated, provide parallel or opposed blade design (as selected by manufacturer's sizing techniques) with optional closed-cell neoprene edging.
- f. For low-leakage applications as indicated, provide parallel or opposed blade design (as selected by manufacturer's sizing techniques) with inflatable seal blade edging, or replaceable rubber seals, rated for leakage at less than 3.04 cubic metre per minute/Sq.m of damper area, at differential pressure of 100 mm when damper is being held by torque of 50 inch-pounds.

6.7.11 Fire and smoke dampers

- a. Fire Dampers: Provide fire dampers, of types and sizes indicated. Construct casings of 16 gauge galvanized steel with bonded red acrylic enamel finish. Provide fusible link rated at 71-74°C unless otherwise indicated. Provide damper with positive lock in closed position, and with the following additional features:
 - Damper Blade Assembly: Multi-blade or curtain type.
 - Blade Material: Steel, match casing.
- b. Fire/Smoke Dampers: Provide fire/smoke dampers, of types and sizes indicated. Construct casings of 16 gauge galvanized steel with bonded red acrylic enamel finish. Provide fusible link rated at 71-74°C unless otherwise indicated. Provide additional fire stat electrically connected and in series with fusible link. Provide stainless steel spring loaded leakage seals in sides of casing, and 900mm long wire leads for connecting smoke link to smoke detector, and the following additional features:
 - Damper Blade Assembly: Multi-blade type.
 - Blade Material: Steel, matching casing.
 - Provide reusable, resetable fusible link.
 - Provide smoke indication of open or closed position.
- c. Motor-Driven Fire/Smoke Dampers: Provide motor-driven fire/smoke dampers in types and sizes indicated, with casing constructed of 16 gauge galvanized steel with bonded red acrylic enamel finish, resetable, reusable fusible link 71-74°C, unless otherwise indicated, and multiblade aerofoil blades, with electric motor equipped with instant closure clutch, stainless steel cable damper blade linkage, motor mounting bracket, and 800mm (32") long wire leads for connecting to smoke detector, and with the following construction features:
 - d. Motor: Motor mounted outside air stream. Motor shall be capable to open/close damper in response to remote signal from controller.
- iv. Turning vanes

- a. Fabricated Turning Vanes: Provide fabricated turning vanes and vane runners, constructed in accordance with SMACNA “Low Pressure Duct Standards”.
- b. Manufactured Turning Vanes: Provide turning vanes constructed of 38 mm wide curved blades set at 19 mm O.C., supported with bars perpendicular to blades set at 50 mm O.C., and set into side strips suitable for mounting in ductwork.
- c. Acoustic Turning Vanes: Provide acoustic turning vanes constructed of aerofoil shaped aluminium extrusions with perforated faces and fiberglass fill.

6.7.12 Acoustical linings for ducts

- a. General: Provide acoustical duct linings as indicated or covered under these Specifications.
- b. Construction
 - Provide board type acoustical duct liner complying with NFPA-90-A, UL 181, Class 1 requirements. Lining, coating and adhesives shall have a flame spread rating of 25 or less and a smoke developed rating of 50 or less as determined by ASTM E84. Pretreat acoustic lining with fungicidal.
 - Provide 25mm thick liner, for ductwork and 13mm thick for supply plenums.
 - Coat liner on the airflow side with a fire resistant coating to resist erosion of the glass fiber. Adhesives conforming to Adhesive and Sealant Council “Standards for Adhesives for Duct Liner” ASC-A-7001 Latest Publication.
 - Mechanical fasteners shall conform to “Mechanical Fastener Standard” MF-1 Latest Publication.
 - All acoustical linings shall be spray coated as per manufacturers recommendation with Foaster 40–20 or approved equal fungicidal protective coating to improve the indoor air quality by guarding against the re-growth and spread of odour causing bacteria and mold in the HVAC system. Fungicidal protective coating should be EPA registered with a registration number on the product label and specifically formulated for long term fungicidal activity with no loss of activity on aging.

6.7.13 Roof exhausters

- a. Centrifugal Fan Unit: V-belt or direct driven with two speed motor, with spun aluminum impeller and shall have weatherproof spun aluminum housing incorporating an integral weather shield; resilient mounted motor; 13mm mesh, 16 gage (2mm) aluminum birdscreen; square base to suit roof curb with continuous curb gaskets; secured with cadmium plated bolts and screws. Provide polyester or equivalent anti corrosion protection cover for impeller, housing and all components.

- b. Roof Curb: 250 mm high concrete up-stand built-in situ with 50mm wood block fasten to it as per standard details.
- c. Disconnect Switch: Factory wired, non-fusible, in housing for thermal overload protected motor.
- d. Backdraft Damper: Gravity activated, aluminum multiple blade construction, felt edged with nylon bearings. Back draft damper may not be used (at the descretion of site Engineer) if excessive static pressure is encountered.
- e. Sheaves: cast iron or steel, dynamically balanced, bored to fit shafts and keyed, variable and adjustable pitch motor sheave selected so required rpm is obtained with sheaves set at mid-position; fan shaft with self-aligning pre-lubricated ball bearings.
- f. All fans shall have their static pressure calculated by the Contractor and the calculations shall be submitted to the Engineer for his approval before ordering the fans. The required fan and motor HP shall be provided without additional costs.

6.7.14 Ceiling air diffusers

- a. General: Except as otherwise indicated, provide manufacturer's standard ceiling air diffusers where shown; of size, shape, capacity and type indicated; constructed of materials and components as indicated and as required for complete installation.
- b. Performance: Provide ceiling air diffusers that have, as minimum, temperature and velocity traverses, throw and drop, static pressure drop and noise criteria ratings for each size device as listed in manufacturer's current data.
- c. Ceiling Compatibility: Provide diffusers with border styles that are compatible with adjacent ceiling systems and that are specifically manufactured to fit into ceiling module with accurate fit and adequate support.
- d. Types: Provide ceiling diffusers of type, capacity and with accessories as listed on diffuser schedule.
- e. Finish: To be manufacturers standard factory applied matt, baked on enamel in colours to be selected by Engineer's Representative to match architectural finishes.

6.7.15 Linear diffusers

- a. Provide linear diffusers with internal damper vanes, adjustable from face of diffuser without removing or disturbing installation. These variable vanes shall provide 180 degree discharge pattern, left, right or vertical adjustable in each slot.
- b. Connect diffuser frame to acoustically lined plenum. Connect plenum to supply duct or supply branch takeoff with flexible duct. Provide damper at takeoff from supply branch duct.

- c. Where continuous strips are required, provide strip diffusers with blank off covers for dummy diffusers.
- d. Where linear diffusers are used for return air, the appearance from the room shall be identical to supply diffusers.
- e. Provide similar finish as described above for ceiling air diffusers.

6.7.16 Register, grills and perforated floor panels

- a. General: Except as otherwise indicated, provide manufacturer's standard products where shown; of size, shape, capacity and type indicated; constructed of materials and components as indicated, and as required for complete installation.
- b. Performance: Provide products that have, as minimum, temperature and velocity traverses, throw and drop, static pressure drop and noise criteria ratings for each size device as listed in manufacturer's current data.
- c. Wall/Floor Compatibility: Provide registers and grilles with border styles that are compatible with adjacent wall/ floor systems, and that are specifically manufactured to fit into wall/floor construction with accurate fit and adequate support.
- d. Types: Provide registers, grilles and perforated floor panels of type, capacity, and with accessories as listed on register and grille schedule or as shown on drawings.
- e. Provide all supply grilles and registers with adjustable front and rear bars with front bars parallel to the short dimension and rear bars parallel to the long dimension. Provide registers with an opposed blade damper behind the bars, to be key operated from the register face.
- f. Provide all return grilles or registers with fixed face bars set at a 45 degree angle and parallel to the long dimension. Provide registers with a key operated opposed blade damper operable from the register face.
- g. Provide perforated floor tiles specially designed for computer centre floor system.
- h. Provide volume damper operated from the face of floor tile. Limit discharge velocity to 300 FPM.
- i. Provide finish as described for ceiling air diffusers.

6.7.17 Particular air filtration

Air filters shall comply with DIN-EN 779, EIN-EN 1822 for manufacturing, filters classes, and testing of coarse dust (pre-filters), fine filters and HEPA filters.

Filters Classification:

- Pre-filters : G1 to G4 according to DIN-EN 779
- EU1 to EU4 according to EUTOVENT 4/5
- Fine filters : F5 to F9 according to DIN-EN 779, EU5 to EU9 according to EUROVENT 4/5
- High efficiency particulate air filters (HEPA), H10 to H14 according to DIN-EN 1822

- Ultra-low penetration air filters U15 to U17 according to DIN-EN 1822

The pressure loss of a filter section loaded with dust shall not exceed the values given in Table below. Lower final pressure drops can be also specified where appropriate.

Table: Maximum final pressure drop for filters

| Filter Class | Final Pressure Drop |
|--------------|---------------------|
| G1 – G4 | 150 Pa |
| F5 – F7 | 200 Pa |
| F8 – F9 | 300 Pa |

The final pressure drops tabulated in Table above are typical maximum values for air-handling units in operation and lower than those used in EN 779 for classification purposes, for reasons of energy saving, and the performance obtained from tests according to EN 779 are not necessarily met at these lower pressure drops.

- a. Provide temporary rolled disposable filters of Class 4 used as a pre-filters for AHU's and FCU's to protect the units and ductwork from dust during start up period of the HVAC system.
 - Media : Glass fiber or synthetic or treated foam
 - Separation efficiency of G4 to DIN-EN 779
 - Temperature 80°C
 - Humidity 100% RA
- b. Filters Installed in Air Handling Units:
 - Fresh air intake side : 2" thick cleanable washable pre-filter class G2.
 - Filter section : 4" thick replaceable throw away pre-filter class G4 plus fine filter class F9.
 - Install carbon filter where is indicated in the drawings.
- c. Filters Installed in Fan Coil Units: Provide replaceable throw away panel filter in rigid frame class G4 with 50mm (2") thick as specified.

6.7.18 Self-contained air conditioners (Package A/C Units)

- i. Type
 - a. Provide units having electric refrigeration and that will be suitable for control by the zoning system.
 - b. Units shall be self-contained, packaged, factory assembled and prewired, consisting of cabinet and frame, supply fan, control, air filters, refrigerant cooling coil and compressor, condenser coil, electric heater and fans.
 - c. All exposed parts to ambient weather shall be protected with corrosion resistant paint technicoat 10-1 phenolic coating or approved equal.
- ii. Performance
 - a. Performance characteristics of unit shall be as indicated on the drawings.

- iii. Fabrication
 - a. Cabinet: Steel with baked enamel finish, Structural members shall be minimum 18 gauge (1.20mm). Provide corrosion resistant paint.
 - b. Insulation: 1 inch thick neoprene coated glass fibre on surfaces where conditioned air is
 - c. handled. Protect edges from erosion.
 - d. Supply Fan: Centrifugal type rubber mounted adjustable variable pitch motor pulley, and rubber isolated hinge mounted motor.
 - e. Air Filters: 51 mm thick viscous metallic, cleanable media in metal frames arranged for easy replacement in accordance with air cleaning requirements.
- iv. Evaporator coil
 - a. Provide copper tube aluminium fin coil assembly with stainless steel drain pan and connection, capillary tubes, and expansion valve.
- v. Compressor
 - a. Provide semi-hermetic compressors, 3000 rev/min maximum, resiliently mounted with positive lubrication, crankcase heater, high and low pressure safety controls, cylinders unloaders, motor overload protection, service valves, and filter drier. Provide single phase operation prevention. Provide at least 2 compressors per unit. Hermetic compressors will also be approved provided that the number of compressors will be four per unit to allow for four unloading steps.
 - b. Timed off circuit shall limit number of compressor starts to 12 per hour.
 - c. Provide maximum step capacity control by cylinder unloading (minimum steps).
- vi. Condenser
 - a. Provide copper tube and anticorrosion factory / workshop-coated aluminium fin coil assembly.
 - b. Provide direct drive axial fans, resiliently mounted with fan guard, motor overload
 - c. protection, wired to operate with compressor.
 - d. Provide refrigerant pressure switch to cycle condenser fans.
- vii. Supply/return casing
 - a. Dampers: Provide manual outside and return air dampers for fixed outside air quantity.
 - b. Gaskets: Provide tight fitting dampers with edge gaskets.
- viii. Operating controls
 - a. Provide low voltage, adjustable thermostat to control compressor and condenser fan, and supply fan to maintain temperature setting.
 - b. Include system selector switch fan control switch (on-auto).
 - c. Provide the thermostat in architecturally approved casing.
 - d. The units shall be controlled from the zone control system.

6.7.19 Split system air conditioner

- i. Concealed evaporator-fan components
 - a. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.

- b. Insulation: Faced, glass-fiber duct liner.
- c. Drain Pans: Galvanized steel, with connection for drain; insulated.
- d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
- e. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 2.5 mm; leak tested to 2070 kPa underwater; and having a two-position control valve.
- f. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow proving device; and one-time fuses in terminal box for overcurrent protection.
- g. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
- h. Washable Filters: 25 mm thick.
- i. Wiring Terminations: Connect motor to chassis wiring with plug connection.
- ii. Floor-mounting, evaporator-fan components
 - a. Cabinet: Enameled steel with removable panels on front and ends in color selected by Engineer.
 - b. Discharge Grille: Welded steel bars forming a linear grille and welded into supporting panel.
 - c. Insulation: Faced, glass-fiber, duct liner.
 - d. Drain Pans: Galvanized steel, with connection for drain; insulated.
 - e. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
 - f. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm); leak tested to 300 psig (2070 kPa) underwater; and having a 2- position control valve.
 - g. Fan: Direct drive, centrifugal, with power-induced outside air.
 - h. Filters: Permanent, cleanable.
- iii. Wall-mounting, evaporator-fan components
 - a. Cabinet: Enameled steel with removable panels on front and ends in color selected by Engineer, and discharge drain pans with drain connection.
 - b. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
 - c. Special Motor Features: Multitapped, multi-speed with internal thermal protection and permanent lubrication.
 - d. Filters: Permanent, cleanable.
- iv. Ceiling-mounting, evaporator-fan components
 - a. Cabinet: Enameled steel with removable panels on front and ends in color selected by Engineer, and discharge drain pans with drain connection.
 - b. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
 - c. Fan: Direct drive, centrifugal fan, with power-induced outside air, and integral condensate pump.
 - d. Filters: Permanent, cleanable.
- v. Air –cooled, compressor-condenser components

- a. Casing: Steel, finished with baked enamel in color selected by Engineer, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
 - b. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - c. Compressor Type: Reciprocating or Scroll.
 - d. Two-speed compressor motor with manual-reset high-pressure switch and automatic- reset low-pressure switch.
 - e. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with
 - f. ARI 210/240, and with liquid sub-cooler.
 - g. Fan: Aluminum-propeller type, directly connected to motor.
 - h. High Ambient Kit: Permits operation up to 50 deg C.
 - i. Mounting Base: Polyethylene.
- vi. Accessories
 - a. Control equipment and sequence of operation are specified in Division 23 Sections "Instrumentation and Control for HVAC" and "Sequence of Operations for HVAC Controls."
 - b. Thermostat: Low voltage with sub-base to control compressor and evaporator fan.
 - c. Thermostat: Wireless infrared functioning to remotely control compressor and evaporator fan, with the following features:
 - Compressor time delay.
 - 24-hour time control of system stop and start.
 - Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
 - Fan-speed selection, including auto setting.
 - d. Automatic-reset timer to prevent rapid cycling of compressor.
 - e. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.
- vii. Installation
 - a. Install units level and plumb.
 - b. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.
 - c. Install ground-mounting, compressor-condenser components on 100-mm-thick, reinforced concrete base; 100 mm larger on each side than unit. Coordinate anchor installation with concrete base.
 - d. Install ground-mounting, compressor-condenser components on polyethylene mounting base.
 - e. Install roof-mounting compressor-condenser components on equipment supports with removable, cadmium-plated fasteners.
 - f. Install compressor-condenser components on restrained, spring isolators with a minimum static deflection of 25 mm.

- g. Install and connect pre charged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.
- viii. Connections
- a. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
 - b. Install piping adjacent to unit to allow service and maintenance.
 - c. Duct Connections: Drawings indicate the general arrangement of ducts. Connect supply and return ducts to split-system air-conditioning units with flexible duct connectors.
- ix. Field quality control
- a. Perform the following field tests and inspections and prepare test reports:
 - Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - b. Remove and replace malfunctioning units and retest as specified above.
- i. Installation
- a. General: Assemble and install ductwork in accordance with recognized industry practices which will achieve airtight and noiseless systems, capable of performing each indicated service. Install each run with minimum 7mm misalignment tolerance and with internal surfaces smooth. Support ducts rigidly with suitable ties, braces, hangers and anchors of type, which will hold ducts true-to-shape, and to prevent buckling.
 - b. Seal ductwork, after installation, in accordance with recommendations of SMACNA.
 - c. Supply concrete inserts for installation by others during casting for support of ductwork, as required to avoid delays in work.
 - d. Complete fabrication of work at the Project site as necessary to match shop fabricated work and accommodate installation requirements.
 - e. Locate ductwork runs, except as otherwise indicated, vertically and horizontally and avoid diagonal runs wherever possible. Locate runs as indicated by diagrams, details and notations or, if not otherwise indicated, run ductwork in shortest route which does not obstruct usable space or block access for servicing building and its equipment. Hold ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building. Limit clearance to 115mm where furring is shown for enclosure or concealment of ducts, but allow for insulation thickness, if any. Where possible, locate insulated ductwork for 25mm clearance outside of insulation.

Wherever possible in finished and occupied spaces, conceal ductwork from view, by locating in mechanical shafts, hollow wall construction or above suspended ceilings. Do not encase horizontal runs in solid partitions, except as specifically shown. Co-ordinate layout with suspended ceiling and lighting layouts and similar finished work.

- a. Where ducts pass through interior partitions and exterior walls, conceal space between construction opening and duct or duct-plus-insulation with sheet metal flanges of same gauge as duct. Overlap opening on 4 sides by at least 40mm.
- b. Co-ordinate duct installations with installation of accessories, dampers, coil frames, equipment, controls and other associated work of ductwork system.
- c. Support ductwork in manner complying with SMACNA.
- d. Provide openings in ductwork where required to accommodate thermometers and controllers. Provide pilot tube openings where required for testing of systems, complete with metal can with spring device or screw to ensure against air leakage. Where openings are provided in insulated ductwork, install insulation material inside a metal ring.
- e. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.
- f. Set plenum doors 150 to 3300mm above floor. Arrange door swings so that fan static pressure holds door in closed position.
- g. Connect terminal units to ducts directly or with 300-mm maximum length of flexible duct. Do not use flexible duct to change direction.
- h. During construction provide temporary closures of metal or taped polyethylene on open ductwork to prevent construction dust from entering ductwork system.
- i. Provide air leakage tests for high pressure supply, return, fresh air, exhaust ducts and submit data for approval.
- j. Utilize sealants in the construction of low pressure supply, return, fresh air exhaust ducts to the best international standards, do as to minimum air leakage.
- k. Clean ductwork internally, unit-by-unit as it is installed, of dust and debris. Clean external surfaces of foreign substances, which might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.
- l. Strip protective paper from stainless ductwork surfaces, and repair finish wherever it has been damaged.
- m. Clean duct system and force air at sufficient velocity through duct to remove accumulated dust. To obtain sufficient air, clean half the system at a time. Protect equipment, which may be harmed by excessive dirt with temporary filters, or bypass during cleaning.
- n. Clean duct systems with high power vacuum machines. Protect equipment, which may be harmed by excessive dirt with filters, or bypass during cleaning. Provide adequate access into ductwork for cleaning purposes.

6.8 CORROSION PROTECTION AND PAINTING

6.8.1 General

This Specification covers the general requirements and standards of workmanship and the painting and protective coatings required to be carried out by the Contractor of the works,

except where particularly redefined in individual specification clauses or as necessary due to a particularly corrosive local environment, the possible reaction of escaping chlorine on the works or on the structures or the reaction of chlorine residuals on phenolic paints (e.g. inside pipelines), harmful or toxic paint in contact with process liquids, or other special requirements, in which case the Contractor submit his own special specification along with his Bid.

No alternative or substitute painting standard or specification will be accepted unless it is specifically required for the above stated reason. No painting or protective coating will be accepted by the Engineer unless it is at least to the standard and of the quality specified herein.

6.8.2 Contractor's Responsibility

The Contractor shall be responsible for the complete cleaning, preparation, priming, painting and protection of the works carried out by him.

6.8.3 Appropriate Standards

Where no explicit instruction is given standards in the Specification or by the manufacturer concerning any particular aspect of the workmanship, materials or procedures in connection with anti-corrosion protective systems in the works for iron and steel structures, the relevant recommendations of the following standard or code of practice shall apply:

- BS EN ISO 8044:2015 (Corrosion of metals and alloys)
- BS EN ISO 12944 (Paints and varnishes — Corrosion protection of steel structures by protective paint systems)
- BS EN 1090 (Execution of steel structures and aluminium structures)
- BS EN ISO 1461:2009 (Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods)
- BS EN ISO 2063:2017 (Thermal spraying — Zinc, aluminium and their alloys — Coatings on steel)

All coatings shall be suitable for the long term protection of the plant under operational conditions at the Site of installation.

The Contractor's attention is specifically drawn to the extremes of temperature and humidity recorded in the region and he shall take into account possible abrasions, restricted ventilation, and the various potentially corrosive environments within the works buildings and structures.

6.8.4 Colour code

The colouring of piping for various media, moving parts, etc., shall be in accordance with DIN

2403. Pipework, tanks and ducting shall be colour coded by totally painting with the appropriate code colour as specified. The principal code colours shall be as follows:

| | | |
|-------|---|--------------|
| i. | Potable water | Blue |
| ii. | Hot water | Crimson |
| iii. | Raw water | Light green |
| iv. | Firefighting water (including sprinkler systems and hydrants) | Signal red |
| v. | Oil and fuel oil | Brown |
| vi. | Gas for fuel | Yellow ochre |
| vii. | Chlorine liquid and gas | Yellow |
| viii. | Compressed air | Light blue |
| ix. | Air (ventilation and air conditioning ducts) | Silver |

All pipes and tanks shall also bear stenciled labels to indicate the contents. Lettering shall be in both Swahili and English. Labels on pipework shall incorporate arrows showing the direction of flow within the pipework.

Black lettering shall be used on orange, yellow and green background and white lettering shall be used on red and blue. Sufficient labels shall be used to ensure adequate identification throughout the length of the pipe runs. These shall be located at least adjacent to each flange or disconnecting joint, where pipework passes through walls, floors, crosses doorways and other access ways and at intervals in long runs of pipework.

6.8.5 Application of Protective Coating and Paint System

Unless specifically specified elsewhere, the protective systems shall be applied in accordance with the manufacturer's instructions to the full thickness range specified, particular note being taken of the requirements for the time interval between successive coats of the system.

The coating thickness for painting on concrete or plaster surfaces shall be in accordance with the manufacturer's instructions or proposals.

6.8.6 Paint Thickness and Continuity

The Contractor shall provide and maintain, during manufacture and on Site, gauges and measuring equipment of an approved type to ensure that the specified film thickness are achieved, paint holidays are avoided, and adhesion is to the satisfaction of the Engineer.

Wet film thickness gauges shall be provided to and used by each painter to check the rate of paint application.

The thickness of the built-up dry film after each paint coat applied to steel or other magnetic surfaces shall be measured systematically with a dry film thickness gauge.

The Contractor shall adopt holiday detection on concrete, steel and iron surfaces and shall use a suitable method of detecting pinholes in the coating system after trials on test plates, which shall be notified in advance to the Engineer.

The sweep voltage on high voltage DC equipment shall not exceed half the voltage required to spark through the complete paint system specified.

Gauges, instruments and meters shall be maintained in an accurate working condition and shall be made available to the Engineer for checking when requested.

The following instruments, with the manufacturer's operating instructions, shall be provided, maintained and used by the Contractor's inspector. In addition, under the Contract a separate set shall be provided and maintained for the Engineer's sole use for the duration of the Contract:

- i. 1 adhesion tester, cover 0 to 280 kg/cm²;
- ii. 1 DC high voltage holiday detector, 20 kV, with rechargeable batteries;
- iii. 1 paint inspection gauge, 0 to 500 microns;
- iv. "wet-check" moisture meters with suitable concrete and timber scales;
- v. 1 dry film thickness gauge, 0 to 500 microns;
- vi. wet film gauges, up to 500 microns;
- vii. 1 steel temperature gauge, up to 50°C;
- viii. 1 air humidity gauge;
- ix. 1 air Thermometer (maximum and minimum);
- x. surface profile gauge, up to 150 microns.

Daily checks shall be carried out and recorded on Site in accordance with the provisions of DIN 55928.

6.8.7 Dry Film Thickness

References in the Specification to dry film thickness (DFT) shall mean the minimum dry film thickness measured with a suitable instrument, either of individual coats, or the total system, as specified in microns (um). The maximum permissible coat tolerance shall be + 15%, - 0% over the DFT.

6.8.8 Knotting and Stopping

Knotting shall comply with DIN 4062.

Stopping for concrete or sand/cement plastering shall be of similar material to the background and shall have a similar surface finish.

Stopping for woodwork, hardboard and plywood shall be a proprietary spirit-based wood filler, tinted to match the woodwork.

Parts to be subjected to manufacturer's shop testing shall not be stopped or surface treated prior to satisfactory completion of the testing. Thereafter the specified treatment shall be applied.

6.8.9 Systems to be Compatible and Complete

All coatings, stoppings, primers, compatible and undercoats and finishing paints of any one complete protective system shall be compatible with each other and the completed system

shall provide continuous, pore-free coatings resistant to physical and chemical disintegration in the environment.

As far as is practicable, materials, forming any one protective and/or decorative system used in the permanent works, shall be obtained from one manufacturer.

i. Bitumen Coating

Bitumen coatings shall be to DIN 18195, 18336 and DIN 18337.

Suitable grades shall be selected where the coating will be in contact with potable water.

ii. Waste

The Contractor shall provide on Site suitable moveable receptacles for the collection of all the liquid, slops, washings, etc. All solid refuse or inflammable residues shall be removed from Site or carefully burned. No refuse shall be deposited on any soil or disposed down any permanent sanitary fittings, sinks or drains. The Contractor shall immediately clean up any unauthorized deposition and remove from the Site any employee found to be responsible.

6.8.10 Application

i. Spray application

The equipment to be used for spray application shall be in strict accordance with the paint manufacturer's instructions for each coating material. Any runs shall be immediately brushed out.

ii. Brush Application

The shape and quality of the brushes shall be suitable for the work to be carried out. Extension handles to brushes shall not be permitted.

6.8.11 Primers

Except if otherwise specified, primers for steelwork shall comply with the relevant DIN standards and contain corrosion-inhibiting pigments, adhere firmly to the substrate and form suitable bases for the subsequent coats.

6.8.12 Surface Preparation by Sand Blasting

All surfaces to be coated shall be free of scale, rust, grease, oil, dust and other deleterious materials.

The surface finish of sand blasted steel shall be in accordance with the relevant DIN standard and to a visual standard in accordance with SIS 05 59 00 at the time of painting. The blast profile shall be within the limits 50 - 75 microns.

Abrasives shall be restricted to reusable iron or steel (grit and shot) or copper slag. The type and grades of abrasive shall be selected in accordance with the appropriate DIN standard.

Within four hours of completion of surface preparation, and before surface re-rusting occurs, a coating of primer shall be applied to avoid deterioration of the prepared base metal. No contamination shall be permitted to occur between blast cleaning and primer coating.

6.8.13 Metal Coatings, general

Metal coatings required for protective purposes on any item of metalwork shall be applied as shop coats after fabrication of the items is completed, including all punching, welding, drilling, grinding, screw tapping and cutting, and after the removal of surface defects. Tapped holes shall be blanked off before the metal coating is applied.

Except if specified otherwise, all steelwork shall be galvanised either by hot dip or by zinc spray both not less than 100g/m².

6.8.14 Coatings of steel structures, general application

Coatings of general steel structures shall be multi-layered and as follows:

- a) Sand blasting to SA 2 ½ acc. to EN ISO 12944 part 4 and free of dirt, oil, grease
- b) 1 shop coat of 1-component high-pigmented rich zinc polyurethane primer, of low solvent content, 80micron as primerc)field coat of 1-component high-pigmented mica- filled polyurethane paint, of low solvent content, 80micron d) 1 finish coat of 2- component epoxy resin, low solvent content, 80 micron

6.8.15 Coatings of steel pipes and tanks for water

Coatings inside and outside on steel tanks and their pipework shall be multi-layered and as follows:

- a) Sand blasting to SA 2 ½ acc. to EN ISO 12944 part 4 and free of dirt, oil, grease
- b) 1 shop coat of 2-component high-pigmented rich zinc epoxy primer of low solvent content, 20micron as primer, weldable
- c) 1 Site coat of the same primer, 60 micron, spray application
- d) 2 finish coats of solvent-free 2-component epoxy resin, 225 micron
- i. Classification of Painting

Lettered classification of surfaces shall be used for the purpose of identifying the protective coating specified herein:

"A": Surfaces above process liquid level and not liable to splashing thereby, in non- aggressive atmosphere.

"B": Surfaces in contact with untreated or treated water for potable use.

"C": Surfaces below process liquid level or liable to splashing thereby in non-aggressive solutions and/or atmospheres.

For the Contractor's convenience the painting requirements are summarised in the table at the end of this section.

ii. Embedded Steel

Steel which is to be totally embedded in concrete shall be cleaned to Swedish Standard St2 and shall not be primed.

iii. Plain Surfaces

The only surfaces of iron or steelwork or non-corrosion resistant materials, which shall be left, unprotected by paint or metals coating are the following:

The internal surfaces of boxes or hollow sections which are of dimensions too small to permit access for painting either at the fabrication stage or for maintenance during the operation life of the steelwork and which shall be hermetically sealed by welding;

- a) Those surfaces of built-in iron or steel members which are to have concrete cast against them;
- b) Machine plain parts and bearing surfaces which shall be thoroughly cleaned, polished and protected from corrosion by painting with one coat of a mixture of white lead and tallow or other similar approved material before dispatch. The Contractor shall provide solvent for removing the treatment;
- c) Parts which are specified to include corrosion allowances instead of protective coatings.

Surfaces of iron or steel members, which are to have concrete cast against them, shall be clean and free of deleterious matter and loose rust at the time of concreting.

The paint protection system, to be applied to the permanently exposed faces of these members before the members are built in, shall be continued for 50 mm as marginal strip along the contact surface.

No paint containing Aluminium in metallic form shall have direct contact with concrete.

iv. Repair of Defective Work

Unless specified elsewhere, areas of paint on steelwork, which have been damaged, shall be cleaned to sound material and the edges of the undamaged paint smoothed with sand-paper to a gentle bevel. Thereafter, the specified paint system shall be applied in accordance with manufacturer's instructions to bring the damaged area up to the same state of protection as the surrounding paintwork, with each coat of new paint overlapping the corresponding existing coat of paint by at least 50 mm.

Where epoxy coatings are damaged, suitable repair supplied by the manufacturer of the original coating shall be applied in accordance with the manufacturer's instructions.

v. Fastenings

Bolts, nuts and washers and other demountable fastenings of all galvanised parts and also aluminium alloy parts shall be in stainless steel to the appropriate DIN standard and shall remain unpainted. P.T.F.E. washers shall be fitted beneath bolt-head and washer when fastening galvanised and aluminium alloy parts.

Fastenings, except high tensile, of all ferrous parts shall be steel prepared and galvanised to or sherardised to the relevant DIN standards, primed and painted in accordance with location.

Unless specifically approved and required for superior protection, electro-galvanising, nickel, cadmium or any other plating process, except chromium plating, will not be acceptable, and shall not be offered.

vi. Painting and Protection of Bolted Connections

Joint areas of bolted connections shall be masked to maintain the surfaces free from any paint applied prior to making the connections. Masking shall be removed before erection.

After installation and after all bolts have been tightened, the area of the connection shall be cleaned to remove all dirt, dust, oil or other contaminant. Particular care shall be taken to ensure that all traces of oil and grease are removed from bolts, nuts and washers.

Bolts, nuts and washers and any exposed at bolted connections shall also be primed as specified, particular care being taken to ensure that any crevices are fully sealed.

The remaining coats of the paint system shall then be applied.

Following painting and where the bolted connections are in an area to be backfilled (pipe trench flanges, etc.) the bolts, nuts and washers and the entire joint assembly shall be carefully packed with an approved purpose made water proof protective paste (non solvent) and finally wrapped with an approved protective paste impregnated tape to completely encase the assembly. Pipe joint protection shall continue along the length of the barrel for a distance of 200 mm.

vii. Copper and Brass

Copper pipes and brass fittings shall be painted where they are located in aggressive locations, or to colour code the function.

viii. Plaster and Concrete Protection

Where specified or required for the protection of the work or the containment or storage of chemical solutions, concrete or rendered surfaces shall be protected with paint systems accordingly to the table at the end of this section.

ix. Preparation of Concrete and Rendered Surfaces

Concrete and rendered surfaces shall be thoroughly cured in accordance to the manufacturer's instructions before the application of any painting system is begun.

x. Minimum Thickness and Adhesion Tests for Painting Systems, Concrete and Plaster

The total dry film thickness of any used paint system shall have a minimum value of tests for 0.75 mm. In order to restore the coating integrity and plaster thickness whenever the paint inspection gauge is used or wherever the coating has been otherwise damaged, the surface shall be abraded for 50 mm around such damage and the area touched in with not less than two thick applications.

6.8.16 Preparation of Plaster, Brickwork and Concrete Surfaces

Efflorescence present on the surface of internal plaster, brickwork and concrete shall be removed by scraping and brushing before any surface paint is applied. When fluorescence has been removed surfaces shall be left for at least three days before priming. Painting shall be deferred where further salt deposits form on the surface during this period.

Plaster surfaces to be painted shall be cleaned down, smoothed as necessary, and all cracks shall be filled with stopping for plaster. All fittings shall be carried out before paint is applied to the surface.

Brickwork, blockwork and concrete surfaces shall be cleaned of all contaminating matter before being primed. Subject to the approval of the Engineer large holes which would cause a break in the paint film shall be filled with mortar, the surface being rubbed down to match the surrounding areas.

6.8.17 Paint Schedule for Plaster and Concrete Protection

The following schedule for Plaster and Concrete painting shall apply:

Table P-04: Paint schedule for plaster and concrete

| Surface | Environment | Primer | Final Treatment |
|---------------------------------------|---|--|---|
| Concrete and cement plaster | High humidity | 1 coat of a highly weather resistant resin, thinned to manufacturer's instruction | 2 coats of a highly weather resistant synthetic resin-based paint |
| Concrete | Exposed to oil | 1 coat with a plastic modified hydraulic mortar | 3 coats with an oil-resistant synthetic resin-based paint |
| Concrete | Exposed to mechanical and chemical attack | 1 coat of colorless 2-pack epoxy-based paint, thinned to manufacturer's instructions | 2 coats of a 2-pack epoxy-based paint |
| Concrete flooring | Exposed to mechanical wear and oil | 1 coat of colorless rubber-based paint, thinned to manufacturer's instructions | 2 coats of a 2-pack epoxy-based paint |
| Internal concrete and plastered walls | Exposed to minor abrasion | 3 coats of an oil-free synthetic resin-based dust-binding paint | |
| Concrete flooring | Exposed to minor mechanical wear | 2 coats of an oil-free synthetic resin-based dust-binding paint | |
| Internal plastered | Exposed to normal | 1 coat of polyvinyl-2 coats of polyvinyl- | |

6.9 Building Stone

All building stone shall be capable of withstanding when wet a crushing stress of 1.4 kg./sq.mm. the source of stone shall be approved by the Engineer and stone supplied therefrom shall be free from Magadi, overburden, mudstone, cracks, sandholes, veins, laminations or other imperfections.

The stone shall be chisel dressed into true rectangular blocks, with each surface even and at right angles to all adjoining surfaces, to the size specified. For exposed stonework the maximum permissible variation of any of the specified dimensions shall be 6mm provided that cut stone, supplied as 'rock face' stone may be hammer dressed on one face only, or on one face and one end, if in other respects it conforms with this specification. Stones shorter than 375mm will not be accepted.

Unless the Engineer allows otherwise the Contractor shall at his own expense provide and dress four 100mm cubes of stone for testing.

The stone shall be sound when tested in accordance with SRN 870 except that:-

- i) The treatment shall be repeated for 10 cycles only; and
- ii) The second criterion of failure shall be amended to allow for a loss of weight of not more than 20% of its original weight.

6.10 Stone Dust

Stone dust for blinding shall be blacktrap screened to the following grading:-

| | |
|-----------------------|------------|
| Passing 10mm sieve | 100% |
| Passing No. 4 sieve | 85% - 100% |
| Passing No. 100 sieve | 5% - 25% |

6.11 Murram

Murram shall be from an approved source quarried so as to exclude vegetable matter, loam, top soil or clay. The California Bearing Ratio of the murram, as determined for a sample compacted to maximum density (as defined under SRN 601) and allowed to soak in water for four days, shall not be less than 30%. This C.B.R. is a guide to quality only and the compaction in the work will be judged by density.

6.12 Water For Cement Treated Materials

If water for the works is not available from the Employer's supply the Engineer's approval must be obtained regarding the source of supply and manner of its use. Water to be used

with cement or lime shall be free from salt, oil, alkali, organic matter, and other deleterious substances. If the water is required to be tested, this shall be done in accordance with SRN 114: Tests for Water for Making Concrete, all to the cost of the Contractor.

6.13 Cement Mortar

Cement mortar shall consist of proportions by volume as specified of Portland Cement and natural sand or crushed natural stone or a combination of both as specified in SRN 135 and SRN 136: Building Sands from Natural Sources. The constituent materials shall be accurately gauged and mixed in an approved manner.

Cement mortar shall be made in small quantities only as and when required, and any mortar which has begun to set or which has been mixed for a period of more than one hour shall be rejected.

6.14 Hydrated Lime

Hydrated lime shall comply with SRN 801 : Building Limes, and shall be of the semi-hydrated type.

6.15 Calcium Chloride

Calcium chloride shall be of good industrial grade, and shall be obtained from an approved source.

6.16 Lime Mortar

Lime mortar shall consist of proportions by volume as specified of hydrated lime and naturals and/or crushed natural stone or a combination of both as specified for cement mortar in Clause 5-16. The constituent materials shall be accurately gauged and mixed in an approved manner.

6.17 Cement-Lime Mortar

Cement-lime mortar shall consist of Portland Cement, hydrated lime and natural sand or crushed natural stone or a combination of both, as specified for cement mortar in Clause 5-16. The constituent materials shall be accurately gauged and mixed by volume in an approved manner in the proportions specified.

Cement-lime mortar shall be made only in small quantities as and when required. Any mortar which has begun to set or which has been mixed for a period of more than two hours shall be rejected.

6.18 Cement Grout

Cement grout shall consist of Portland Cement and water mixed in the proportion of one part by volume of cement and one and a half parts by volume of water. The grout shall be used within one hour of mixing.

6.19 Cast Stone

Cast stone shall be manufactured by an approved manufacturer to the shapes and dimensions shown on the drawings, and shall conform to the requirements of SRN 871 : Cast Stone. It shall have a dense and even surface of the texture and colour detailed on the drawings or required by the Engineer. Where indicated the exposed faces of the stone shall be formed of a specially graded mix. Metal bond ties of approved manufacture shall be cast in with the stone as shown on the drawings. Samples of the completed stone shall be submitted for the Engineer's prior approval.

All stones shall be protected from damage during transport and erection by means of cement slurry coatings or by other approved methods.

6.20 Structural Steel for Welded Work

Structural steel for riveted and welded work shall comply with the requirements of SRN 125 : Structural Steel, SRN 126 : The Use of Structural Steel in Building and for Welded Work, SRN 125 : High Yield Stress and High Tensile Structural Steel, High Tensile (Fusion Welding Quality) Structural Steel for Bridges, etc. and General Building Construction.

6.21 Waterproof Underlay

Waterproof underlay shall consist of either waterproof paper complying with SRN 856 : Waterproof Building Paper, containing approved fibrous reinforcement, or 500 gauge polythene sheeting as stated in the Bill of Quantities.

6.22 Preformed Joint Filler

Preformed joint filler shall be of the thickness shown on the drawings or as stated in the Bill of Quantities.

The material comprising joint filler shall be as stated on the drawings or approved by the Engineer.

6.23 Joint Primer

Joint priming compound shall be entirely in accordance with the manufacturer's recommendations for the joint sealant to be used.

6.24 Joint Sealing Compound

Poured joint sealing material shall consist of an approved rubber-bitumen compound, complying with the requirements of SRN 879, or a two component, cold applied compound complying with SRN 879 as stated in the Bill of Quantities. Test Certificates, prepared by an approved testing laboratory, shall be supplied by the Contractor to show that the material does in fact comply in respect of cone penetration, flow and bond with the under-mentioned requirements:

6.24.1 Test Cone Penetration

- i. 0.15 kg. for 5 secs. at 25o centigrade using standard grease cone Hot-poured Materials
- ii. Penetration not to exceed 9mm Cold-poured Materials
- iii. Penetration to be not less than 5mm not more than 27.5mm

6.24.2 Flow

- i. On a plane inclined at 75o to the horizontal, 5 hours at 60o centigrade
- ii. Flow not to exceed 5mm
- iii. Flow not to exceed 20mm

6.24.3 Bond

25mm wide joint extended 12mm at rate of 4mm per hour at 18o centigrade. No more than one specimen in three to develop a crack separation or other opening more than 4mm deep. Five cycles of extension and recompression. Three cycles of extension and recompression

Approved hot-poured materials shall also comply with a requirement whereby when heated for a period of 6 hours at a temperature of 80 degrees centigrade above recommended pouring temperature or 30 degrees centigrade below the safe heating temperature whichever is the greater shall still comply with the flow requirements of this clause.

In addition to materials complying with SRN 879, the Engineer may approve the use of alternative materials provided that they meet the requirements of this clause relating to cold-poured joint sealing compounds.

6.25 Concrete Slabs For Open Drains

Precast concrete slabs for lining open drains shall be manufactured to the detail drawings supplied from concrete Class 20/10 using maximum 12mm size aggregates. If required, cube test certificates shall be supplied by the manufacturer.

6.26 Timber

Timber shall be sound, well-seasoned and entirely free from worms, beetle, warps, shakes, splits, and all forms of rot and deadwood. Where required, all timber shall be treated with creosote, as specified in SRN 872: Coal Tar Creosote for the Preservation of Timber or an alternative approved timber preservative.

6.27 Water Bars

Water bars shall be “Dumbell” type and be of natural or synthetic rubber or extruded PVC. They shall be flexible, tough, elastic and durable and of dimensions detailed. They should be unaffected on contact with dilute acids or alkalis. Joints and junctions shall, when possible, be prefabricated by the manufacturer, but if made at site the manufacturer’s instructions including recommended adhesives shall be followed and used. Samples shall be submitted for approval of the Engineer before use of any material.

6.28 External Works

All materials and workmanship not described in this section are deemed to comply to the relevant specifications of the work in hand contained in other sections of these specifications

6.29 Fencing

All fencing shall be erected in exact vertical position and to straight lines as shown on the drawings. The materials and workmanship shall comply with the recommendations in BS 1722.

6.30 Concrete Posts

Precast concrete posts shall be cast of concrete Grade 20 as specified in Section 4, to the sizes shown on the drawings.

The posts shall be securely placed in performed holes and cast in concrete to depth as shown on the drawings.

Bracings shall be provided at all corners, and at intervals of not more than 50 metres on straight lines of fencing. Maximum distance between posts is 4.5m concrete posts and bracings are measured in numbers, and the rate shall include for supply, excavation, erection and backfilling.

6.31 Chain Link

The chain link fencing shall be supplied in rolls of 2130mm (7 feet) width and shall be with 65mm mesh of 12 ½ gauge, fitted to 4 rows of line wires with binding wire at 130mm centres.

The cranked top of the posts shall be fitted with 3 strands of 12 ½ gauge barbed wire with four-point barbs at 150mm centres. All members of the fencing shall be hot dip galvanized.

Fencing is measured in linear metres and the rate shall include all waste and cutting, as well as fixings to posts and all line wires, barbed wires and binding wires.

6.32 Gates

If not otherwise stated gates shall be 4 metres wide double leaf gates, made from 40mm galvanized steel tube frame (medium class) with 8 gauge galvanized weldmesh welded to the frame. Bracings, hinges, towerbolts and locking arrangement shall be as shown on the drawings or of other approved type. The top of the gates shall be fitted with 3 strands of 12 ½ gauge barbed wire. The price for the gate shall include for the manufacture, installation, all bolts and padlocks etc. and painting all as shown on the drawing. Gate posts made of rolled hollow square sections as shown on the drawings are measured separately.

6.33 Masonry Works

All masonry work shall be constructed from building stone as specified in Clause 6.1.

For culvert headwalls and other small works, the stone shall, unless otherwise specified, be rough dressed. For walls, facing and other exposed works the stone shall unless otherwise specified, be medium chisel dressed.

6.33.1 Workmanship

The Contractor shall provide and use proper setting out rods for all work.

Stones shall be well soaked before use and the tops of walls shall be kept wet as the work proceeds. The stones shall be properly bonded so that no vertical joint in a course is within 115mm of a joint in the previous course. Alternate courses of walling at angles and intersections shall be carried through the full thickness of the adjoining walls. All perpend, reveals and other angles of the walling shall be built strictly true and square.

The stones shall be bedded, jointed and pointed in mortar 1 to 3 in accordance with Clause 5.16 with beds and joints 9mm thick flushed up and grouted solid as the work proceeds.

All masonry work shall be cured in accordance with the relevant requirements of Clause 5.

6.33.2 Cast Stonework

Cast stone shall be as specified in Clause 6.11. Facing stones shall be brought up in courses to a height not exceeding 1 metre at a time, the concrete backing being then brought up and well incorporated into and round the backs of the stones and the projecting metal ties to ensure a complete bond. The stones shall be bedded and jointed as shown on the drawings.

All materials, moulds, mixing, casting and surface treatment, setting, jointing and pointing, and all centering, scaffolding and labour required to complete the cast stonework specified or as shown on the drawings, shall be included in the rates for such work.

6.34 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

7 DRAINS AND CHAMBERS

7.1 Excavation for Drains and Chambers

The ground shall be excavated to the lines and depths shown on the drawings or to such other lines and depths as the Engineer may direct. Excavations taken out to a greater depth than is necessary shall be filled to the required level with approved material as specified for the pipe bed at the Contractor's own cost. Trenches shall be of sufficient width to enable the pipes to be properly laid and jointed. In case of pipes of greater diameter than 300mm, the width of trench shall be external diameter of pipe, plus 400mm.

When any excavation has been taken out and trimmed to the levels and dimensions shown on the drawings or as directed by the Engineer, the Engineer shall be informed accordingly so that he may inspect the completed trench and no excavation shall be filled in or covered with concrete until it has been so inspected and the Contractor has been authorised to proceed with the work.

All surplus materials from such excavations not required for refilling shall be carted away to tips, or otherwise disposed of, as directed. All excavations shall be kept dry, and all bailing and pumping, timbering, shoring and supporting of sides that may be required, and any refilling, ramming and disposal of surplus materials necessary in carrying out the excavations and backfilling of trenches shall be taken to provide a solid and even bed for barrels of the pipes and, where a concrete bed is not specified, the floor of the trench shall be properly shaped to receive the sockets and the backfill must be thoroughly rammed along the sides of the pipe.

The rate of excavation in the Bill of Quantities shall include for keeping trenches dry and for all bailing, pumping, timbering, shoring and supporting of sides that may be required.

7.2 Supports for Pits, Trenches and Other Excavations

The sides of pits, trenches and other excavations shall, where necessary, be adequately supported to the satisfaction of the Engineer, and all such excavations shall be of sizes sufficient to enable the pipes and bedding to be laid accurately, and proper refilling and compacting to be carried out.

The Contractor shall take all precautions necessary for the safety of adjoining structures and building by shoring, opening in short lengths or otherwise, during the time the trenches are open.

7.3 Rock Cutting In Trenches For Pipes

Where solid rock is met within trenches, it shall be cut out to a depth of 100mm below the intended level of the bottom of the pipes, and replaced with 100mm of approved material as

specified. In measuring such rock excavation the Contractor will be allowed a width of 400mm more than the external diameter of the pipes to a level of 100mm below the bottom of the pipes. The price inserted in the Bill of Quantities shall be held to cover all expenses in connection with excavating the rock, backfilling after laying of pipes and disposing of surplus material as directed by the Engineer.

7.4 Water In Trenches for Pipelines

Trenches shall be kept free from water at all times during construction of works until, in the opinion of the Engineer, any concrete or other works therein are sufficiently set, and the Contractor shall construct any sumps or temporary drains that the Engineer may deem necessary.

The Contractor shall be responsible for the removal and disposal of all water entering the excavations from whatever source and shall deal with and dispose of such water in a manner approved by the Engineer so as to ensure that excavations are kept dry while ensuring that the disposal of this water does not cause a nuisance to adjacent plot holders or works.

The Contractor shall provide all plant, labour and materials required for such work and all costs incurred shall be deemed to be included in his rates for excavation.

7.5 Laying And Jointing Rigid Jointed Concrete Pipes

Concrete pipes shall be laid true to line and level, each pipe being separately boned between sight rails.

For spigot and socket joints, the spigot of each pipe shall be placed home in the socket of the one previously laid, and the pipe then adjusted and fixed in its correct position with the spigot of the pipe accurately centred in the socket. A ring of tarred rope yarn shall next be inserted in the socket of each pipe previously laid and driven home with a wooden caulking tool and wooden mallet, such yarn when in position shall be 25mm in depth. The socket shall then be completely filled with cement mortar 1 to 2 and a fillet of the same worked all round the side. The fillet shall be levelled off and extend for a length of not less than 50mm from the face of the socket.

For 'Ogee' jointed pipes, the joints shall be thoroughly cleaned before laying, and cement mortar, as shall be applied evenly to the ends for jointing so as to completely fill the joint. The pipes shall then be neatly pointed with a band of cement mortar approximately 125mm wide and 20mm thick. The inside of each joint shall also be pointed up as the work proceeds.

Special care shall be taken to see that any excess of cement mortar etc. is neatly cleaned off while each joint is being made and any earth, cement or other material cleaned out of the pipes by drawing a tight-fitting wad through them as the work proceeds, or by other approved means. A properly fitting plug shall be well secured at the end of the last laid pipe and shall be removed only when pipe laying is proceeding. The trenches, pipes and joint holes shall be kept free from water until the joints are thoroughly set.

Where shown on the drawings or directed by the Engineer, concrete pipes shall be bedded and haunched or surrounded with concrete as specified.

The price inserted in the Bill of Quantities shall include for providing, laying and jointing of pipes.

7.6 Pipes Laid With Open Joints

O.G. porous concrete pipes as specified herein shall be laid unjointed with a space of 12mm between the spigot and the inner end of the socket.

All pipes shall be packed and surrounded as directed by the Engineer with approved broken stone, sand or gravel aggregate, to the gradings as shown on the drawings or stated in the Bill of Quantities. The prices inserted in the Bill of Quantities shall include the trench excavation, providing and laying pipes, supplying and placing graded packing material, refilling trench and disposing of surplus all as specified.

7.7 Cast Iron Pipes

Cast iron pipes and special castings, shall be as specified herein and shall be supplied, laid and jointed with lead wool properly caulked to form perfectly uniform and watertight joints, and when laid and jointed they shall be true to line and level.

Where cast iron pipe drains are laid on unstable ground or ground which is likely to settle appreciably over a period of years they shall be pointed by means of an approved self adjusting or screwed gland joint as directed by the Engineer.

7.8 Drains To Be Left Clean On Completion

On completion, all drains, chambers, etc. shall be flushed from end to end with water from an approved source and left clean and free from obstructions.

7.9 Refilling Trenches

Trenches shall be refilled with suitable excavated material of 100mm surround but not before the work has been measured and approved by the Engineer. For pipes which are not surrounded with concrete, the first layer of filling material shall be free from stones and shall not be thrown directly on to the pipes, but shall be placed and packed with care all round them. All filling shall be deposited and compacted in layers, not exceeding 225mm loose depth, to a dry density not less than that of the adjoining soil. The last 450mm of filling must be returned in the order in which it has been removed. Timber and framing shall be withdrawn ahead of the layer to be compacted, care being taken to keep the sides of the trenches solid and to fill all the spaces left by the withdrawn timber.

7.10 Connections Of Existing Lines

Where shown on the drawings, existing lines shall be properly extended, connected and jointed to new lines or channels. All such connections shall be made during the construction of the main line or other work and a record of their positions kept for future use or reference.

7.11 Inspection Chambers

Inspection chambers shall be constructed in accordance with the drawings and in the position shown on the drawings or directed by the Engineer. Foundation slabs shall consist of concrete of the appropriate classes as specified on drawings. The side walls shall consist of similar concrete or building stone as specified in Clause 703 in accordance with the drawings.

The side walls shall be fair faced or rendered internally as specified on drawings. They shall be brought up vertically to receive a precast slab formed of concrete of the appropriate classes specified and reinforced all as shown on the drawings. Cast iron manhole covers and frames as specified in Clause 726 shall be provided and frames shall be bedded in cement mortar 1 to 3 and so set that the tops of the covers shall be flush at all points with surrounding surface of the footway, verge or carriageway, as the case may be. Any slight adjustment of the slab level which may be necessary to accomplish this shall be effected by topping the side walls with concrete integral with the slab.

If required, half channel pipes, bends and junctions as specified in Clause 718 and Clause 719 shall be laid and bedded in cement mortar 1 to 3 to the required lines and levels, and both sides of the channel pipes shall be benched up with concrete of the appropriate class and finished smooth to the slopes and levels as shown on the drawings or directed by the Engineer. The ends of all pipes shall be neatly built in and finished flush with cement mortar 1 to 3. Where the depth of the invert exceeds 1 metre below the finished surface of the carriageway or the adjacent ground, iron steps as specified in Clause 730 shall be built in with alternate steps in line vertically and with such additional hand irons as the Engineer may direct.

The prices inserted in the Bill of Quantities shall include for excavation, provision of all materials, construction, refilling and disposal of surplus.

7.12 Gully Connections

Connections from gullies to sewers and surface water drains or ditches shall consist of concrete pipes and fittings as specified in Clause 718 jointed with cement mortar 1 to 3 as specified in Clause 707. All pipes, bends and junctions shall be laid to the lines and levels shown on the drawings or as directed by the Engineer.

7.13 Surface Boxes, Covers Etc.

Surface boxes, manholes and other covers lying within the site of the works, shall be raised, lowered, altered or removed as directed by the Engineer.

7.14 Gullies

Gullies complete with gratings and with rodding eyes where necessary all as specified in Clause 727 shall be supplied and laid in accordance with the drawings. Where directed by the Engineer, precast concrete gullies shall be laid on and surrounded with 100mm of concrete of the appropriate grade specified in Table 4.2. The concrete surround is to be brought up to the underside of the frame or flush with the top surface as the case may be. Masonry gullies shall be constructed from 225mm building stone and rendered internally. The rates included in the Bill of Quantities shall include for excavation, provision of all materials, construction, making junctions with connections to main drains, accurate setting of frames to line and level, refilling and disposal of surplus materials. Gullies shall be trapped where leading into foul sewers or into combined foul and surface water sewers.

7.15 Completion Of Drainage Works

All sub-soil and surface water drains shall be completed in advance of the construction.

7.16 Temporary Stoppers

Junction pipes which are laid but not immediately connected to gullies shall be fitted with temporary stoppers or seals, and the position of all such junctions shall be clearly defined by means of stakes or training wires properly marked and labelled.

7.17 Provision For Future Connection To Chambers

Inlet pipes of the required diameters shall be built into the walls of chambers and elsewhere for future use and shall be of the diameters shown on the drawings. The external ends of all such connections shall be sealed off with temporary stoppers, approved by the Engineer. The pipes shall be laid and jointed as specified in Clause 1005 and during the placing of the concrete they shall be adequately supported.

7.18 Surrounding Or Haunching Of Pipes With Concrete

Surrounding or haunching of pipes shall be carried out using concrete of the appropriate grade specified in Table 4.2. In carrying out this work the Contractor shall take care to pack the concrete under and around the pipes to ensure even bedding and solidity in the concrete and the concrete shall not be thrown directly on to the pipes. The upper surface of the concrete shall be struck off with a wooden screed or template and neatly finished off. The rates shall include for any formwork that the Contractor requires to use under this item.

7.19 Invert Block And Stone-Pitched Drains

Precast concrete invert blocks and side slabs shall be formed of concrete of the appropriate grade specified in Table 4.2 to the dimensions shown on the drawings. Each course of side

slabs required in the Bill of Quantities shall be interpreted as one complete row of side slabs to one side of the channel concerned. Stone used for channels shall be 225mm x 100mm building stone. Drains should not normally be laid to a radius of curvature less than 10 times the actual width of the drain.

Invert block and stone-pitched drains shall be constructed in the positions and to the levels and dimensions shown on the drawings and laid to true line and even fall. Where under-filling is required it shall be in 100mm maximum thickness layers of compacted murrum. The earth sides to such channels shall be neatly finished to a slope of 1 to 1 or such other slope as the Engineer may direct.

Invert blocks and side slabs shall be laid on a 100mm minimum thickness of compacted murrum and be neatly jointed with cement mortar 1 to 3 as the work proceeds. The excavation, murrum bedding, providing, laying and jointing invert blocks or stone, backfilling and disposal of surplus shall all be as specified and all in-situ connections shall be in concrete of the appropriate grade specified in Table 4.2.

7.20 Testing Of Jointed Pipes And Valve chambers

Sealed jointed drains, up to and including 600mm diameter shall be tested in sections (e.g. between manholes) by filling with water under a head of not less than 1 metre. Drains found to be water-tight after a period of 30 minutes will be passed as satisfactory but the water must be retained in the pipes until a depth of at least 450mm of filling has been deposited and compacted on top thereof. Drains failing to stand the test shall be taken out and the pipes re-laid and re-jointed until completely water-tight.

Drains exceeding 600mm in diameter shall be tested by means of a smoke test before they are covered up. Both ends of the lengths of drain to be tested shall be sealed to the satisfaction of the Engineer, and smoke shall then be pumped into the section from an approved machine. Should any joint in the section show an escape of smoke, the section shall be taken out and the pipes re-laid and re-jointed until there is no further escape of smoke.

Should the Engineer so direct, manholes shall be tested by completely filling with water, and there shall be no appreciable loss over a period of 2 hours.

On completion of the works, or at suitable intervals during construction, infiltration tests will be carried out. The permissible amount of infiltration shall be 1 litre per hour per linear metre of nominal internal diameter.

The Contractor shall provide all labour and apparatus for the above tests.

All testing will be done in accordance with the procedure of the British Standard Code.

7.21 Pipes With Rubber Ring Joints

Rubber rings complying with SRN 308 will be provided by the Contractor. They will be laid in the socket and the pipes then jointed as specified. The jointing of pipes shall be carried out in accordance with manufacturer's instructions and in conformity with any modifications proposed by the Engineer.

7.22 Laying, Jointing And Backfilling For Flexible Jointed Pipes

The Contractor shall ensure that any hard spots and loose stones are removed from the formation prior to laying of bedding materials. The Contractor shall lay a bed of thickness 100mm consisting of granular material i.e. sand, gravel, or approved soil of friable nature.

After laying of pipes the Contractor shall lay bedding material on the sides of the pipe compacted by tamping into soffit of sewer.

After completion of this operation the Contractor shall lay the bedding material on top of the pipe in 150mm layers to a thickness of 300mm. The material is to be compacted by tamping. However, precautions are to be taken to avoid excessive tamping on top of the pipe. The remaining trench excavation is to be backfilled to comply with Clause 1009 of specification.

The pipes shall be laid with flexible ring seal joints provided that solvent cement joints could be used for fittings where necessary subject to the approval of the Engineer. Pipes and fittings shall be checked for deformities prior to laying. Deformed pipes and fittings shall not be accepted.

7.23 Flexible Rubber Ring Joints

The Contractor shall ensure that the spigot end is free from grit, dust or dirt and sealing rings should be seated evenly in the socket groove. Pipe lengths and fittings are supplied with a chamfer on the spigot. Where pipes are to be cut or are supplied without a chamfer on the spigot end the Contractor shall ensure that the pipe is cut square and then form a chamfer on the spigot end with a medium file to an angle of 15 degrees. Remove saw flashing by scraping with a pen-knife.

7.24 Expansion Gap

It is necessary to leave a gap between the edge of the spigot end and the base of the socket to allow for expansion. Moulded fittings are supplied with an embossed line indicating the correct depth of insertion. In other cases where the marking is not done, the Contractor shall ensure that an expansion gap of at least 3mm per metre length of pipe or at least 15mm per pipe length is provided. This can be done by marking spigot ends or by pushing spigot fully home, making a small mark on pipe and then withdrawing the pipe by 15mm.

After completing jointing the pipe shall be laid on the prepared bed making sure that a suitable depression is created in the bed for the socket.

7.25 Solvent Cement Joints

For solvent cement joints make sure that mating surfaces are clean and free of grease and dirt. Roughen mating surface with sandpaper, clean both surfaces with cleansing fluid using a clean cloth. Apply solvent cement on both mating surfaces. Without delay bring mating surfaces together and hold in position firmly for a few seconds. A layer of cement should be visible at the edges. Joints should not be disturbed for at least 10 minutes after assembly.

7.26 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

8 STRUCTURAL STEELWORK

8.1 General

The fabrication and erection of all structural steelwork shall be under the constant supervision of competent and experienced personnel. All workmanship shall be in accordance with the best modern workshop practice and only skilled workers trained and experienced in steel fabrication and erection shall be employed.

8.2 Applicable Standards

The supply, fabrication and erection of structural steelwork shall be in accordance with the provisions of the relevant clauses of the following British Standards: -

- BS 4 Structural steel sections.
- BS 4848 Hot rolled structural steel sections.
- BS 153 Steel girder bridges,
 Part 1 - Materials and workmanship and
 Part 2 - Weighing, shipping and erection.
- 8S 4360 Weldable structural steels.
- BS 4395 High strength friction grip bolts and associated
 Parts 1&2 nuts and washers for structural engineering (metric series).
- BS 4604 The use of high strength friction grip bolts in structural steelwork.
- BS 2708 Unified Black Square and hexagon bolts, screws and nuts (UNC and UNF threads).
- BS 4190 ISO metric black hexagon bolts screws and nuts.
- BS 3692 Isometric precision hexagon bolt screws and nuts.
- BS 4320 Metal washers for general engineering purposes.
- BS 5135: Metal arc welding of carbon and manganese steels.
- BS 638 Arc welding plant, equipment and accessories.
- BS 639 Covered electrodes for the manual metal-arc welding of mild steel and medium tensile steel
- BS 4870 Approval testing of welding procedures, Part 1 Fusion welding of steel.
- BS 4871 Approval testing of welders working to approved welding procedures, Part 1-Fusion welding of steel.
- BS 5493 Protective coating of iron and steel structures against corrosion.

8.3 Materials

All structural steel shall be to the Grade as defined on the Drawings and shall comply with the requirements of BS 4360 in every respect.

Mill certificates shall be supplied to the Engineer in duplicate to confirm the mechanical and chemical properties.

Steel for headed stud shear connectors shall have a minimum yield stress of 385 N/mm² and a minimum tensile strength of 495 N/mm².

8.4 Storage of Materials

Structural steelwork whether plain or fabricated shall be stored above ground on platforms, skids or other supports and in such a way as to prevent pools of water forming on the ground. It shall be kept free from dirt, grease and other deleterious material and shall be protected as far as is practicable from corrosion. The time limits for outside storage of unpainted or primed steelwork shall be as detailed in the Special Specification.

8.5 Fabrication

Fabrication shall generally be in accordance with the requirements of BS 153 Part 1, Workmanship. Rolled material, before being processed, must be straight or flat. Straightening or flattening, where required and where permitted by the Engineer, shall be accomplished by a process not harmful to the material.

The Contractor shall submit to the Engineer for his approval two sets of shop drawings with calculations as appropriate and the Contractor shall not commence fabrication until written approval has been given by the Engineer. The Engineer will give comment or approval within 28 days after receipt of the shop drawings and calculations. Such approval shall not relieve the Contractor of any of his responsibilities under the Contract.

Following approval of the shop drawings the Contractor shall supply to the Engineer a further four copies of each drawing for the use of the Engineer and the Employer.

The components of various members of the structure shall be placed in jigs of approved design and all welding shall be carried out in accordance with Clause 6.7 of this specification. Every precaution shall be taken to prevent distortion.

8.6 Preparation of Edges and Ends of Plates

Edges and ends shall be either:

- (a) left as rolled, sawn, machine cut, machine flame cut;
- (b) hand flame cut and ground to a smooth profile; or
- (c) for stiffeners and gussets not exceeding 12 mm thick, sheared and subsequently ground to a smooth profile.

Where ends of stiffeners are required to be fitted, they shall be ground to be in contact with the flanges over 80% of the area of stiffener.

After shearing or flame cutting of plates, one of the following requirements shall be satisfied:

- (a) The hardness of the out edge shall not exceed 350 HV 30 of BS 427;
- (b) the cut edge is incorporated in a weld;
- (c) the material from the edge is removed by machining or grinding to demonstrate that the hardness of the edge is less than 350 HV 30 of BS 427;
- (d) the edge is softened by an approved heat treatment and is shown to be free from cracks by crack detection procedures; or
- (e) the material is Grade 43 steel and is not greater than 40 mm thick and the edge preparation is by machine flame cutting.

8.7 Welding

Welding will be permitted only where shown on the Drawings and the agreed shop drawings.

All welding operations shall comply with the requirements of BS 5135. The details of all welds shall be arranged to achieve the most satisfactory welding procedure. The details of the welding procedure shall be submitted to the Engineer for his approval and no welding may commence without the prior approval of the Engineer. No departure from an approved procedure may be made without the prior approval of the Engineer. Welding procedure details to be submitted to the Engineer shall include the following: -

- Welding position.
- Fusion face preparation. Pre-heating.
- Electrode make, type and size and mechanical properties. Number and arrangement of runs.
- Welding current.
- Arc energy.
- Method of back gouging and sealing.
- Proposed methods of quality control and testing of welds.
- Welding shall be carried out under the supervision of an experienced and competent supervisor in accordance with the requirements of BS 5135. The welders shall be tested in accordance with the requirements of BS 4871 prior to the commencement of the work.
- The Contractor shall carry out trials of the welding procedure in accordance with the requirements of BS 4870.

Welding plant and accessories shall comply with the requirements of BS 638 and shall be used in accordance with the manufacturer's instructions. The welding plant shall be capable of maintaining at the weld the current and voltage specified by the manufacturer and in accordance with the welding procedure.

The electrodes shall be selected with regard to the quality of the material to be welded and the optimum performance with the welding procedures and shall comply with the requirements of BS 639. All electrodes shall be stored in their original packets in a dry and preferably heated place adequately protected from the weather and shall be handled with care and in accordance with the manufacturer's instructions. Electrodes and fluxes that show signs of moisture, damage or deterioration shall not be used.

Welds shall be subject to non-destructive examination and testing as specified in the Special Specification.

Welded fabrications and weld quality shall comply with the requirements of the American Welding Society Specification ANSI/AWS D1.1.81., section 9, PART D

Stud shear connectors shall be subjected to the following tests: -

- a) (a)The fixing of studs after being welded in position shall be tested by striking the side of the head of the stud with a 2 kg hammer and shall pass such test if no part of the weld shows fracture or is dislodged thereby.
- b) Any stud selected by the Engineer shall be capable of being bent by striking the side of the head of the stud with a 6 kg hammer until its head is displaced laterally a distance of approximately 0.25 times the height of the stud from its original position. The stud weld shall not show any signs of cracking or lack of fusion. Satisfactory studs shall not be bent back again.

Studs whose welds have failed the tests given in (a) and/or (b) above shall be replaced according to a procedure to be agreed with the Engineer.

8.8 Bolting

8.8.1 Black Bolts

All mild steel bolts, washers and nuts shall be of the grade as specified on the Drawings and shall comply with the requirements of BS 4190, BS 2708 or BS 3692 as appropriate.

All holes shall be drilled or drilled small and reamed and shall be clean cut without torn or ragged edges. The holes shall be perpendicular to the member and not more than 2mm larger than the nominal diameter of the bolt.

In all cases where the full bearing area of the bolt is to be developed the bolt shall be provided with a steel washer under the nut to avoid any threaded portion of the bolt being within the parts bolted together. Tapered washers of the correct angle of taper shall be provided under all bolt heads and nuts bearing on bevelled surfaces.

8.8.2 High Strength Friction Grip (HSFG) Bolts

HSFG bolts shall comply with the requirements of BS 4395 Parts 1 and 2 and shall be used in accordance with the provisions of BS 4604 Parts 1 and 2.

HSFG bolts, nuts and washers shall be supplied cadmium plated to BS 3382 to a thickness of 5 microns and shall be stamped or otherwise marked with a suitable and permanent mark

and the Contractor shall obtain the written approval of the Engineer to the proposed marks before commencement of the work.

Each HSFG bolt shall be supplied complete with its nut screwed on. washers may be supplied on the bolt or separately and bolts and washers shall be packed in the manufacturers works and delivered to site in waterproof containers and stored under cover in these until required: for use.

The method of tightening HSFG bolts shall be either the part turn method, the torque control method or with the use of load indicating washers in accordance with the following: -

| HSFG bolts complying with standard | Permissible methods of tightening. |
|------------------------------------|---|
| BS 4604 Part 1 and 2 | 1) Part turn for bolts M16 and above 2) Torque control. 3) load indicating washers. |
| BS 4604 Part 2 | 1) Torque control. 2) load indicating washers. |

Whatever method of tightening is adopted, the Contractor shall supply to the Engineer full details of the procedures to be adopted which shall be in accordance with the requirements of BS 4604, together with details of the tools and equipment he will be using at Site and the tests to be carried out to determine the tension characteristics of the tools, bolts and the load indicating washers. No bolting shall commence until the Contractor has carried out sufficient site tests to confirm the load/torque/shank tension characteristics of the tools and bolts.

In the case of torque control tightening methods, calibration of the equipment shall be carried out daily before commencing bolting operations in accordance with the requirements of BS4604.

Where load indicating washers are used they shall be of a type approved by the Engineer and used in accordance with manufacturer's instructions.

The general requirements of BS 4604 shall apply to the assembly and use of HSFG bolts with indicating washers including check testing to confirm minimum shank tension is being achieved.

HSFG bolts that have been slackened off after final tightening by any method shall be removed, discarded and replaced.

8.9 Transportation Handling and Erection

Erection shall be in accordance with BS 153 Part 2, Weighing, Shipping and Erection. Structural steel shall be handled with due care at all times and in such a manner as not to cause damage to the steelwork or its protective coatings.

The Contractor shall submit to the Engineer for his approval two sets of drawings and calculations and details showing his proposed methods for transport, handling and erection of structural steelwork including all plant, temporary supports and bracings required to ensure stability and safety during erection. The Contractor shall erect the steelwork, remove the temporary supports and do all the work required to complete the Works in accordance with the Drawings and this Specification. The work shall be carried out in such a manner as will not injure, overstress or disfigure any part of the structure or the foundations and any part injured, overstressed or disfigured shall be removed and replaced or rectified to comply with the requirements of this Specification.

The steelwork shall be temporarily erected at the fabrication works and be subject to inspection by the Engineer before being dispatched to Site.

Drift pins will be allowed only for bringing together the several parts of the structure, and shall not be used in such a way as to distort the work or enlarge the bolt holes.

Bolts in site connections shall not be finally tightened until sufficient of the structure is properly plumbed, aligned and levelled and no subsequent straining into position will be allowed. Finally, all bolts and connections shall be systematically checked and tightened.

8.10 Surface Preparation of Steelwork

Surface preparation of steelwork shall be by blast cleaning in accordance with the requirements of BS 4232, second Quality. The maximum amplitude of the blast cleaned surface shall not exceed 0.1mm.

Manual cleaning of structural steelwork including mechanical wire brushing, chipping hammers, vibratory needle guns and the like shall not be permitted except for small parts and then only with the prior written permission of the Engineer.

Surfaces shall be painted with the specified primer paint within four hours of having been blast cleaned.

As soon as the first undercoat has dried, a further stripe coat of paint shall be applied by brush to all edges, corners, crevices, exposed parts of bolts, rivet heads and welds. The stripe coat should have the same specification as the undercoat but be a contrasting shade.

Painted surfaces shall be cleaned of dust immediately prior to the application of further paint. All loose paint, dirt and grit shall be removed and areas contaminated with oil and grease shall be cleaned with emulsion cleaners followed by washing and rinsing with clean fresh water and followed to dry thoroughly before paint is applied.

In the case of painted steelwork where the interfaces of HSFG bolts are bare steel, the primer coat shall be taken between 100mm and 20mm inside the perimeter of the joint area.

Where paints are to be applied to parent surfaces before making of a joint they shall be stepped back at 30mm intervals commencing at 80mm from welded joints and 100mm from the perimeter of all other joints.

All bolted joints shall be sealed against the ingress of water. Gaps at joints shall be plugged with approved filler and the perimeter of all joints shall be sealed with subsequent coats of paint.

All joints, welds and surfaces affected by welding shall receive the same protective system as applied to the parent surfaces.

Within 14 days of a joint being made and accepted by the Engineer, the parent material, exposed parts of bolts, nuts and washers, weld and affected areas shall be prepared and painted.

8.11 Painting

All paint used in the Works shall be subject to the approval of the Engineer.

All paint shall be supplied from the store to the painters ready for application. Any addition of thinners must be made in the store under the supervision of the Engineer and only as permitted by the manufacturer's data sheet. All the requirements of the manufacturer's data sheet shall be strictly complied with.

Paint shall be applied only to surfaces which have been prepared and cleaned in accordance with the requirements of Clause 6.10 of this specification.

The use of rollers shall not be permitted for the application of paint.

Paint shall not be applied under any of the following conditions: -

- a. When the ambient temperature is less than 4°C.
- b. When the relative humidity is greater than 90%.
- c. During fog, rain or mist.
- d. When any moisture is present or likely to condense on the steel. Each coat of paint shall be free from surface defects.

Successive coats of paint shall have different shades for identification.

The Contractor shall ensure that the proposed application rates shall enable the specified minimum dry film thickness to be achieved. If the total dry film thickness is less than the specified minimum, an extra finishing coat or coats shall be applied until the specified dry film thickness is obtained.

8.12 Paint Systems

The paint system to be used on structural steel work shall be as specified in the Special Specification.

8.13 Damaged Surfaces

Any areas of paint which have been damaged following application shall be cleaned down to bare metal and the full specified painting system shall be re-applied. The new paint shall overlap the existing paint by at least 50mm all-round the affected area.

Galvanized surfaces damaged shall be repaired either by the use of low melting point zinc alloy repair rods or powders made specifically for this purpose or by the use of at least two coats of a good quality zinc rich paint to BS 4652.

8.14 Internal Bracings and Brackets:

Internal bracings and brackets shall be designed to ensure the strength, rigidity and absolute uniformity of each tank depending on sizes.

8.15 Fasteners:

All bolts used in the assembly of the tank shall be of High Tensile Grade 9.8 for rigid holding. They shall be zinc coated to protect against any rust forming.

8.16 Joint Materials:

A non-toxic strip joining material shall be used between the flanges of tank plates, under the internal brackets and for sealing the cover plates to make all joints completely leak proof.

8.17 Fittings:

The steel structure shall be provided with suitable standard nozzles either threaded or flanged depending on the requirements. Sizes and orientations are to be provided by the time of ordering.

The steel structure shall be provided with Inlet, Outlet, Overflow, Drain Vent, Level Indicators and Internal & External Ladder. Any other additional fittings shall be provided on request.

8.18 Pressed Steel Tanks and Towers

The pressed steel tanks (or similar approved), towers and associated materials and fittings shall comply with SRN 909 and SRN 863.

Detailed drawings of the steel tank should be submitted to the Engineer for approval prior to acceptance.

The pressed steel tank to SRN 909 (B.S. 1564 Type A (2) or similar approved) shall be supplied complete with: -

- a. All stays, cleats, bolts, nuts, washers, jointing compound and associated materials and fittings.
- b. Connections for inlet, outlet, washout and overflow.
- c. Galvanized access ladder 450mm wide.
- d. Steel roof cover to fit the tank complete with access manhole and mosquito-proof cowl ventilators.
- e. Water level indicator.

Jointing material to the tank to be a non-toxic plastic compound which does not impart taste, colour nor odour to the water.

Connections to the tank shall be welded to the outside of the tank plate and drilled and tapped to suit flanges to SRN 207, NP 16 unless otherwise stated.

The cover to the tank shall be of mild steel cambered for external use and adequately supported by rolled steel or pressed steel bearers or trusses.

The tank tower shall be supplied complete with: -

- a. Anchor bolts.
- b. Bolts, nuts, washers and associated materials and fittings.
- c. Access ladder 450mm wide extending from ground level to the top of the tank.
Safety rings shall be at 1.2m centres.

The supports to the tank shall consist of steel joints designed to carry imposed load under each transverse joint and the two ends of the tank.

The columns of the tank shall consist of rolled steel joist sections or similar. Four such columns shall be provided with adequate bracing.

Internal surfaces of the tank shall be painted with approved non-toxic primer and non-toxic bituminous paint.

External surfaces of the tank and tower shall be painted with approved primer and approved bituminous aluminium paint.

8.19 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

9 PIPEWORKS

9.1 Materials

All pipes, couplings, gaskets, lubricants, seals, coupling machinery etc., necessary for the proper construction of the pipe works as detailed in the Bill of Quantities and drawings shall be supplied by the Contractor.

The Contractor shall be responsible for ensuring that the pipes, couplings and other fittings laid or installed on each section of the work are of the standard and pressure classification specified as appropriate to the circumstances, and are manufactured of the specified materials.

The Engineer reserves his right to refuse any materials that in his opinion is inferior.

The Engineer has the right to test any material upon delivery, and materials found defective shall be replaced forthwith by the Contractor.

If the Contractor procures materials of different specifications in respect of flanges and threads etc. (imperial units-metric units), he shall at his own cost provide all adaptors and other fittings necessary to make connections to the satisfaction of the Engineer.

All materials shall be marked as specified in the relevant current British or ISO Standards for easy identification on site.

Pipes shall be supplied in standard lengths unless otherwise shown on the Drawings.

Specials shall be fabricated to the details shown on the Drawings, using, where applicable, the same materials, welding procedures and protective linings and coatings as are specified for the corresponding straight pipes.

Satisfactory temporary end covers shall be provided for the protection of threads, flanges and the prepared ends of pipes, fittings and specials, and for the prevention of damage to internal linings during transportation and during handling on Site.

9.2 Handling and Storing Materials

The method of transportation, handling and storing of pipes and fittings shall be in accordance with the manufacturer's recommendations.

Pipes, valves, specials and other materials shall be handled, moved, lifted or lowered with the least possible impact. Handling equipment shall be of approved type. In slinging pipes only flat slings shall be used and the use of chain slings, hooks or other devices working on scissors or grab principles shall not be permitted. Pipes shall be slung from two or more points as the engineer may direct and the slinging, lifting and lowering shall be in the hands of a competent and experienced man.

Subject to the requirements of inspection before acceptance, protective bolsters, caps or discs on the ends of flanges or pipes or specials shall not be removed until the pipes or specials are

about to be lowered into the trench. Every precaution shall be taken to prevent damage to internal Linings or external coatings.

Pipes in storage shall be supported clear of the ground on approved supports and adequately braced to prevent rolling. They shall not be stacked more than four tiers high without the approval of the engineer. Materials of different classification shall be stored separately.

All pipes and associated material shall at all times be protected from sun and weather to the satisfaction of the Engineer.

The spindle shall not be used lift the valves.

No valves, fittings or specials shall be stacked more than one tier high without the permission of the Engineer, and they shall not be stored in a dirty place or condition and shall not be allowed to become embedded in earth, sand, stone, aggregate, water, fuel, or any other deleterious matter. Great care shall be taken at all times to keep the faces and seats of all valves clean and free from dirt and grit of any kind. No valve shall be closed without at first wiping the faces with a clean cloth dipped in clean oil. The cavity beneath the valve doors shall be thoroughly cleaned by hand. In the event of accidental spilling of bitumen, cement or other matter, they shall be either dissolved or carefully removed by methods that do not involve scraping of the faces.

Valves and their ancillary equipment shall be protected before and after erection against collapse of earthworks, falls of materials, concrete and cement droppings, wood and other matter.

Shortly before laying or fixing any valve, pipe or fitting the Contractor shall in the presence of the Engineer or his representative carefully examine each valve, pipe and fitting to ascertain damage or defect occasioned to the valves, pipes and fittings during loading, unloading, handling, storage and transportation. All damage and all defects revealed by this examination shall be repaired and remedied by the Contractor.

9.3 Pipes and fittings

9.3.1 Flanges

Where flanged joints are used, flanges shall be in accordance with the requirements of BS 4504: part I or BS 4622 or BS 4772.

The minimum pressure rating shall be for a working pressure of 1.0N/mm^2 (approximately 100 meters head) corresponding to NP 10 flanges. The hydraulic test pressure shall not exceed 3.0N/mm^2

The number of holes shall be as follows:

| Diameter(mm) | No of holes |
|--------------|-------------|
| 80 – 150 | 8 |
| 200 – 250 | 12 |

Flanges in pipelines with higher pressure rating shall be for a working pressure of 3.0 N/mm² (approximately 300 meters head) corresponding to NP 30 flanges. The hydraulic test pressure shall not exceed 4.0 N/mm².

Bolts, nuts and washers shall comply with the requirements of BS 4190 and BS 4320. Gaskets shall fulfil the requirements of BS 2494 and shall have a minimum thickness of 2 mm.

9.3.2 Ductile Iron

Ductile iron pipes and fittings shall comply with BS 4772 or ISO 2531, and pipeline distribution network shall be as per CP 2010 Part 3. The pressure rating of the pipes shall be for a minimum working pressure of 2.5 N/mm² (approximately 250 metres head) and a hydraulic test pressure of 3.0 N/mm². Care should be taken when the pressure test is carried out not to exceed the permissible test pressure for the fittings installed.

Joint shall be either "Tyton", "Stanlock", "Viking Johnson" of flanged joints as specified in the drawings and the Bills of Quantities. Before any other joint is used written approval of the Engineer must be obtained.

Pipes and fittings shall be coated inside and outside with a hot material complying with the requirements of BS 4147, type 1, grade-d, or with a cold applied material complying with BS 3416: Type II material.

9.3.3 Grey-Iron or Cast Iron

Grey iron or cast iron pipes and fittings shall comply with BS 4622 or ISO/R 13. The pressure rating of the pipes shall be for a minimum working pressure of 1.0N/mm² (approximately 100 meters head) and a hydraulic test pressure of 1.6 N/mm². Joints, internal and external coatings to be as specified in under the clause of Ductile iron.

9.3.4 Steel pipes

The steel pipe shall conform to B.S. 534 1981, B.S 1387, BS 3600 and BS 3601 and pipeline distribution shall be as per CP 2010 part 2, 1970 and unless otherwise stated specials shall be made from pipes that have been manufactured and tested in accordance with B.S. 3601. Joints shall be screwed and socket for nominal diameters up to 50 mm and flanged or socketed for nominal diameter above 50 mm unless otherwise stated. The type of joint used shall be to the approval of the engineer. The Pipes and specials shall be protected from corrosion internally and externally complying with the requirements of BS 539. The type of protection used shall be to the approval of Engineer.

Welds shall be inspected by radioactive non-destructive testing and tensile and weld bend tests as per BS EN 10224.

Steel Tubes and tubulars with screwed and socket joints shall be covered by the requirements of BS 1387.

Flanges shall be as specified in Clause 7.4.1 and threads as specified in BS 21.

9.3.5 Plasticized Polyvinyl Chloride Pipes

All PVC pipes and fittings shall comply with KS 06-149:1981, ISO 161/1-1976 (E) or BS 3505.

Pipes indicated with a pressure class shall conform to the following minimum working pressures

Class 0.6 MPa- 0.6 N/mm² (marking: red) (KS classification: A)

Class 0.9 MPa- 0.9 N/mm² (marking: blue) (KS classification: B)

Class 1.2 MPa- 1.2 N/mm² (marking: green) (KS classification: C)

Class 1.5 MPa- 1.5 N/mm² (marking: brown) (KS classification: D)

All fittings shall be of pressure class 1.5 MPa and be manufactured of cast iron, PVC or steel.

Joints to be Solvent Cement Joints for nominal sizes equal to or smaller than 50mm and mechanical joints (rubber ring) for nominal sizes equal to or bigger than 80 mm.

For both types of joints, the manufacturer's jointing instructions, shall be strictly adhered to.

For solvent cement joints it is essential that the solvent cement used is the correct type, i.e. it shall be purchased from the same factory which delivers the pipes.

The rubber ring joints can be either the Polva type, which incorporates only one rubber ring or loose couplers with two rubber rings. In any case the fittings used shall be purchased from the same factory which delivers the pipes.

If the joint is difficult to fix the manufacturer should be consulted immediately. No cutting or scraping in any of the joints components shall take place.

PVC pipes and fittings shall be stored under cover, which fully protects the material from sunlight.

Acceptable nominal pipe diameters for PVC pressure pipes are 75 mm, 90 mm, 110 mm, 160 mm and 200 mm, 75 mm diameters shall only be allowed when a network analyses shows that the water demand for firefighting is satisfied.

All PVC pipes and fittings shall, prior to delivery, be factory-tested to 1.5 times the specified working pressure, and a certificate to this effect shall accompany all deliveries. PVC products shall be stored away from sunlight and shall be backfilled as soon as practicable after having been laid.

9.3.6 Precast Concrete

Precast concrete pipes and fittings shall comply with BS 556: Part 2.

The laying and jointing of the pipes shall comply with CP 301.

The Contractor shall adopt such measures as may be approved by the Engineer to ensure that every newly laid pipe is concentric with previously laid pipes with which it joins.

Unless otherwise approved by the Engineer pipes shall be laid in an upstream direction and the socket ends shall point upstream.

Before commencing the laying operation, the Contractor shall ensure that the parts of pipe which will come into contact with the jointing material are perfectly clean.

Cement mortar joints for spigot and socket pipes shall be made as follows: -

- (1) Before commencing the jointing operation, the socket of the previously placed pipe and the spigot of the new pipe shall be cleaned and thoroughly soaked with water.
- (2) The spigot shall be wrapped one complete lap with tarred hempen spun yarn and the new pipe shall be carefully drawn towards the previously laid pipe so the spigot enters tie full depth into the socket of the previously laid pipe. The new pipe shall then be adjusted and fixed in its correct position in line, level and gradient and the tarred yarn shall be sealed tightly into the socket.

On completion of this operation, the yarn shall not fill more than one quarter of -the total depth of the socket.

- (3) The remainder of the socket shall be completely filled with cement mortar consisting of one part of cement to three parts of sand. The mortar filling shall terminate flush with the socket and shall be neatly troweled to a smooth finish around the pipe.

To assist the curing of the mortar the contractor shall cover the joints immediately after they are made with a layer of Hessian cloth which shall be kept continuously wet during daylight hours and he shall further adopt such other measures as the Engineer may direct

Provided the Contractor has the Engineer's written consent other means of jointing may be adopted, e.g., rubber ring-joints. The Engineer's instructions in regard to other jointing materials must be strictly complied with.

9.3.7 Glass Reinforced Polyester Pipes (GRP)

The GRP pipes shall be of International Standards Organization ISO 10639 and EN 1796 for potable water transfer. Joint testing shall meet ASTM D4161 AND EN 119 Standards. Long Term Stiffness shall meet ISO 10468 and Long Term Bending shall meet ASTM D5365 Standards. Production of GRP pipes shall be through controlled manual process to ensure high quality pipes.

9.3.8 High Density Polyethylene Pipes (HDPE)

The (HDPE) pipes shall be of International Standards Organization ISO 4427 and BS 6437 & 6730 for Potable Water Stress Regression Tests to comply with ASTM D 2837. Density 955kg/ m³, pipe classes and markings shall correspond to those of uPVC pipes. Pressure testing shall be as per manufacturer's recommendation and as approved by the Engineer. All

transitions from HDPE pipe to GI, Steel, uPVC or Cast Iron shall be as per manufacturer's recommendation and to the approval of the Engineer

Acceptable nominal pipe diameters for HDPE high pressure pipes are 25 mm, 40 mm, 50 mm, 63 mm, 75 mm and 90 mm. Under no circumstances may saddles be used with PE pipes. Welded adaptors may also not be used with PE pressure pipes.

9.3.9 Piping with Accessories

The scope of works includes all pipes, fittings, valves, connecting and fixing materials with installation. The connecting material (screws, nuts and gaskets) as well as the fixing material (supports, clamps and suspenders) for the equipment which is to be installed in or on the pipes (e.g. valves, dismantling pieces, measurement and control devices) are to be included. Furthermore, the pressure test, the flushing and the disinfection of the pipes is to be quoted with the relevant items of the B.O.Q. (Bill of Quantities).

Further all parts to be embedded in concrete shall be placed according to the drawings or as instructed by the Engineer at site with written approval.

9.3.10 Design Requirements:

The maximum internal pressure of the collecting well piping is the test pressure. The design pressure shall be PN 10 all parts shall be made of steel.

9.4 Protection of Pipes

The concrete used for bedding, haunching and surrounding the pipes shall be concrete class 15 unless otherwise ordered by the Engineer. The concrete protection shall have total dimensions not less than those given below.

The various types of concrete protection to pipelines are detailed below:

- (i) Bedding concrete shall have a width of at least 300 mm bigger than the external diameter of the pipe and shall support at least the bottom quarter of the pipe circumference. It shall have a minimum depth of 100mm measured under the pipe throughout the cross-section.
- (ii) Bedding and haunching shall comprise a concrete bed with a minimum width of 300mm more than the external diameter of pipe and a minimum thickness of 150mm below the pipe, and haunching with a minimum thickness of 150 mm on both sides the pipe. The top of the haunching to be flush with the top the pipe.
- (iii) Surrounding concrete shall comprise a concrete bed as described above together with 150 mm concrete on both sides and on to the pipe, giving a pipe protection of at least 150 mm concrete everywhere around the pipe.

Concreting of bedding, haunching or surround shall not be done until the pipes have been jointed, inspected and tested. The concrete shall be placed on one side of the pipe only until the flow of material under the weight placed ensures that the concrete is in full contact with

underside of the barrel of the pipe throughout its length. The concrete shall be placed in one operation and shall be well worked to a homogeneous mass. The pipe shall be carefully anchored against floatation. All anchorage, haunches, surrounds, etc. shall be placed on and against undisturbed earth or rock as directed by the Engineer.

PVC pipes are laid in suitable bedding material as per drawings. Protection against e.g. load from traffic is carried out by laying of concrete slabs as detailed on the drawings. Special care shall be taken regarding compaction of fill below the concrete slabs.

9.5 Valves and Specials

Unless otherwise directed all valves, flowmeters, fittings and specials shall be individually supported and their weight shall not be borne by the pipeline, joints or couplings etc.

All supports for valves and fittings shall be of concrete Class 20 or as specified on the drawings.

Where air valves are to be placed the Contractor shall ensure that the highest point in the main is determined by levelling instrument.

Air valves shall be checked before the main is charged to ensure that the balls and faces are not scored or split, and that there is no dirt or other deleterious materials in the cavities of the body. All air nozzles shall be probed to see that they are clear. No air valve shall be stored before erection in the open in sunlight, or upside down to expose the balls and air cavities.

Scour valves shall be installed at low points in the pipelines as shown on the Drawings. The Contractor shall be in agreement with the Engineer on the exact position of scour valves in particular situations.

Scour valves shall, where possible, discharge in the direction of natural drainage and at such a distance from the Works as to preclude erosion effects.

Unless otherwise directed the controlling valve for a scour shall be installed not more than 1.5 m from the main pipeline.

Ends of all scours shall be protected from intrusion of animals and other foreign matter by suitable screening securely fixed to the pipe end.

All valves shall be supplied with remote controlled actuator including valve penstocks and other fittings which shall be securely fixed and where required extension spindles and headstocks shall be properly aligned and fixed in a vertical position unless otherwise directed. They shall be tested for ease of operation and water tightness and valve lands shall be repacked where necessary. Any damaged protective coating shall be made good and they shall be left clean in all respects.

Before each valve is put into service all gears, bearings and spindles shall be oiled with approved oil as recommended by the valve manufacturer. Oil baths shall be topped up to the appropriate levels and all grease nipples charged with grease of approved manufacturer. No deleterious matter shall be allowed to come into contact with the working faces and oil sumps shall be maintained clean.

All valves, fittings, specials shall be fixed with proper sealing tube, gaskets, washers etc. as necessary to the satisfaction of the Engineer.

The rates in the Bills of Quantities shall cover for the supply, storing handling installation and Jointing, together with all bolts, washers, gaskets and lubricants etc.

Where flanged joints are used, flanges shall be in accordance with the requirements of BS 4504: part I or BS 4622 or BS 4772. Where screwed joints are used, thread shall be complying with BS 21.

Joints shall be flanged for sizes equal to or bigger than nominal diameter 80mm and screwed for small sizes. The names of manufacturers and the specifications of the products offered shall be provided at the time of tender.

All flexible couplings shall be supplied complete with rubber gaskets, bolts, nuts and washers. All couplings shall be coated with red oxide primer and bituminous composition suitable for use with potable water.

9.5.1 Valves and Accessories

The Contractor shall furnish all valves and other accessories for pipe installation as specified herein and as shown on the drawing and in the Bill of Quantities. All valves and other accessories shall be of the size specified and, as far as possible; all valves of the same type shall be of one manufacturer.

All valves and accessories shall have cast on the body the name of the manufacturer, working pressure, diameter, and direction of flow.

All flanges for pipes, fittings, valves shall comply with DIN 28604 for PN 16. or equivalent

Stuffing boxes shall be of the “O” ring or packing type, unless otherwise specified.

The Supplier shall submit shop drawings to the Engineer for approval. Shop drawings shall include:

- lists and schedules of materials
- details of joints (and adaptors if necessary)
- Names of manufacturers, size, details, materials, and thickness of all items.

All valves and accessories shall be designed for a working pressure of not less than PN 10, unless otherwise specified. The Supplier shall submit a certificate from the manufacturer certifying that each valve meets the requirements of the specifications.

Valves shall be equipped with hand lever, hand wheel, or as specified. Valve ends shall be flanged, Screws and rubber ring gaskets shall be provided to joint to the valve with the piping.

9.5.2 Gate Valves and Sluice Valves

Gate valves are to be provided according to DIN 3352 for water up to 40 degrees Celsius with fixed, non-rising hand-wheel. The body shall be of cast iron GG-25 or ductile iron.

9.5.3 Butterfly-Valves

Butterfly valves shall comply with BS 5155. The valves shall be of the "Tight shut-off type" and shall be of either the double flanged or the wafer types with metal-to-metal seating.

The minimum service rating shall be PN 2.5. Care shall be taken when installing wafer type butterfly valves to ensure that the door when open does not foul the connecting pipe bore or any other- adjacently connected valve or fitting.

The valves shall be lever operated and shall be marked with arrows showing "Open" and "Closed" positions.

Where the valve is mounted in a horizontal pipe with the shaft horizontal, it should be fitted in the pipeline so that the lower portion of disc moves in the same direction as the flow when opening the valve.

9.5.4 Non-Return Valves (Reflux or Check Valves)

The valves shall comply with BS 5153 and shall be of the swing pattern type.

The pressure rating shall be NP 10 corresponding to a working pressure of 1.0 N/mm² (100 metres head). Material to be Mechanite Iron or Cast Iron for sizes equal to or bigger than 40mm, and Bronze or Brass for smaller sizes.

The valves shall be installed, on horizontal parts of the pipelines, and shall have an external indication of the direction of flow.

Non-return device with silent action tight sealing designed for a pressure of PN 10 for streamlined flow and minimum head loss.

9.5.5 Air-Valves (Small-Orifice)

Air release valves shall have high strength cast or ductile iron bodies. The valves shall contain an integral shut-off valve for use during maintenance.

All moving parts shall be stainless steel.

A complete unit with gate valve connection of the single and double type shall be provided as shown on the drawings and wherever necessary.

9.5.6 Float-Valves

Float-operated level control valve, angle-type body for water reservoirs. Closing with rising water level and opening with sinking water level. Balanced valve piston shall ensure

minimum operating forces. A long piston guiding shall prevent canting. Closing action shall be shock-free.

9.5.7 Constant Flow Valves

Constant Flow Valves or flow regulators are to be of flexible orifice type or other approved type with an accuracy of discharge flow of plus or minus 10% of the nominal flowrate, at least up to a pressure of 1 N/mm² flow rates to be as shown on drawings,

9.6 Butterfly Valves

Each valve shall consist, essentially, of a cast-iron or ductile iron body with a rubber seat, a disc, a valve shaft, and an operating mechanism.

It shall conform in all respects to DIN 3354, part 2.

9.7 Safety Valve

The safety valve shall be a spring-loaded type with adjustable pressure range as shown in the Bill of Quantity. The safety valve shall be manual releasable by a lever arm.

9.8 Dismantling Piece

The dismantling piece shall be rigid type and provided with steel middle ring, steel followers, gas and necessary bolts and nuts of galvanized steel. They have to be installed in their medium length.

9.9 Pipe Compensator

The pipe compensator shall be of rubber type and provided with flange as specified in the Bill of Quantity. The pipe compensator shall contain anchor sturdy of strength adequate to hold the pipe together under a pull equal to the longitudinal strength of the pipe.

9.10 Wall Duct

The wall duct shall be of steel body and provided with rubber/solid gasket, bolt and nuts, and loosed flange according to working pressure as specified in the Bill of Quantity. The length of wall duct shall be suitable of the concrete wall width specified in the Bill of Quantities. The connecting pipe to be inserted in the wall duct shall have four degrees' deflection without any leaks.

9.11 Fire Hydrants

Fire hydrants shall be in accordance with SRN 509. They shall be for installation underground and shall be in accordance with SRN 509.

The spindle shall be provided with a cast iron cap conforming to dimensions under “Spindle Cap” in SRN 501.

The spindle of the fire hydrant shall be of the non-rising type and screwed so as to close the hydrant when rotated in a clockwise direction viewed from above. The direction of closing shall be clearly cast on the valve cap.

The flanged outlet of the outlet bend shall have a Bayonet Joint Outlet for a 63mm standpipe. The outlet of the hydrant shall be of the hooked type with hooks 112mm apart.

The outlet shall have a gun metal standpipe seating and be covered by a loose cast iron cap which shall be attached to the hydrant by means of a chain.

Both flanges shall be 63mm drilled to requirements of SRN 207.

The outlet bends shall be subject to a hydrostatic test in accordance with procedure set out in SRN 509 and shall be water-tight against a test pressure of 1.85 Pa. head of water.

9.12 Marker and Indicator Posts

Marker posts shall be erected at changes in direction of water mains as directed by the Engineer. Indicator posts shall be erected at valves and other fittings as directed

Marker and indicator posts shall be embedded in concrete as shown on drawings and shall be vibrated precast reinforced concrete as per dimensions shown on drawings. They should be painted in colours as indicated on the drawings.

9.13 Main-Water meters

The water meters shall be approved electromagnetic type.

9.14 Penstocks or Sluice Gates

Penstocks shall be single faced cast iron gates with non-rising spindle complete with extension spindle and removable hand wheel all of approved manufacture.

9.15 Draw-off taps and Stop valves

All draw-off taps (bib-taps, hose-taps etc.) shall comply with BS 1010, and shall be made of brass.

If specified in the drawings or Bills of Quantities, the taps shall be chromium plated.

9.16 Auxiliary Works

All works specified in this clause shall be with materials and workmanship as specified in Section 3: Builders Works.

9.16.1 Valve Chambers

Unless otherwise directed or detailed all valves, meters and other mechanical fittings shall be housed in chambers with lockable covers.

Valve work shall be so placed in chambers as to facilitate operation, meter reading etc. through the cover opening.

Chambers are measured in numbers and shall be priced as lump sum items covering all composite work as specified on the drawings inclusive of excavation in excess of trench excavation, concrete supports or valves, anchoring walls and backfilling around the chambers.

The depths stated on the drawings are normal depths. Actual depths depend on depth of pipes.

9.16.2 Thrust blocks and Anchors

If not instructed to do otherwise the Contractor shall provide thrust blocks at all bends, tees, ends and wherever shown on the drawings.

Enlargements shall be excavated in sides and bottom of the trench to accommodate anchorages and thrust blocks.

Concrete thrust and anchor blocks shall be formed in accordance with the typical sections shown on the Drawings or as directed by the Engineer. The additional excavation shall be made 'after the bends etc. have been jointed and the concrete shall be placed immediately after the completion of the excavation.

The back of supports and blocks shall abut on to solid ground, all loose material being removed before Concreting.

The concrete used for thrust and anchor blocks shall be of Grade 20 and shall after Placing be kept in view for not less than six hours. No pressure shall be applied in any section of mains until the concrete has cured at least three days.

All PVC material shall be wrapped with two layers of bituminous felt for the entire length in contact with concrete. Thrust blocks are measured in numbers and shall be priced as lump sum items covering all necessary works and materials together with excavation, backfilling and formwork.

Anchoring walls for valves are parts of the valve chambers and are included in the lump sum for valve chambers.

9.16.3 Road-Crossing

When the contractor encounters a road where a road crossing is indicated on the drawings or where to his opinion, such a crossing is required, he shall immediately inform the Engineer. On receipt of the above information, the Engineer will issue appropriate instructions.

9.16.4 Painting

Painting and other protection of the external and internal surfaces shall be in accordance with, manufacturer's recommendations or as specified in Section 5 of these Specifications.

9.17 Testing of Pressure Mains

Pressure pipelines (together with all specials and valves incorporated in the mains) shall, before being covered, be tested with water as specified in CP 310.

At least two days' notice must be given in writing to the Engineer before pressure testing is commenced.

9.18 Cleaning and Sterilization of Water supply pipes

The Contractor shall before be handing over and during the Maintenance period clean pipelines, chambers and manholes for all dirt and rubbish.

All pipes shall be thoroughly cleaned and washed out to remove all contamination, and all water from these operations shall be removed and drained away.

Sterilization should be carried out in accordance with CP 310.'

Following the satisfactory cleansing the Contractor shall with the use of a portable dosage system - or by some other approved method introduce a solution of a sterilizing chemical containing chlorine into the pipeline. The solution shall be introduced at a very slow rate and shall be of such strength as to give a chlorine concentration of not less than 50ppm (parts per million) throughout the Length of the pipelines.

All taps on the distribution pipes shall be opened successively, working progressively away from the Place where the solution is introduced. Each tap shall be closed when the water discharged begins to smell of chlorine. The whole system shall then remain charged for 24 hours, after which a test shall be made for residual chlorine. If no residual chlorine is found, the sterilization process will have to be carried out again, until a satisfactory result is obtained. Finally, the pipes shall be thoroughly flushed out and recharged with supply water.

On completion of the sterilization process the pipes shall be left full of water.

The Contractor shall in his rates for pipe laying include all costs of labour, transport, materials, equipment, chemicals and water necessary for the satisfactory completion of the cleansing and sterilization operations.

9.19 Laying of Mains and Pipe Installation

9.19.1 General

Contractors have a responsibility to comply with all national legislation and standards, the provisions of which take precedence over this Specification. Contractors and their employees are expected to be competent in the basic elements of designing and constructing water systems such as water main and service pipe laying; service connections; health and safety; understanding materials selection; regulatory requirements; principles of water supply hygiene; customer care and environmental issues. This specification refers to watermains up to and including 600mm in diameter.

All pipes and specials shall be laid in accordance with the alignment, levels and gradients shown on the working drawings approved by the Engineer, adjusted in the field by the Contractor as may be required from time to time and as finally authorized by the Engineer. The completed main shall run straight between the bends or any curved alignment and a uniform gradient shall be accurately maintained between changes of gradient as shown on Drawings or otherwise instructed by the Engineer.

The Contractor at his own expense shall repair any injury of the protective coating of the pipes from any causes during the construction of the pipeline to the satisfaction of the Engineer.

At the end of each day's work a strong wooden plug or iron disk shall be firmly fixed in each open end in order to prevent any foreign material to enter the laid pipe.

9.19.2 Routing of Mains

Before setting out any section of a main, the Contractor shall make an inspection on Site together with the Engineer. The Contract Drawings show the approximate lines and levels to which the main is to be built however such alignments are subject to the amendments made by the Engineer on Site. He may vary or abandon any part or parts of the route of mains indicated on Drawings and issue the respective instructions to the Contractor.

The Contractor shall prepare the working drawings and shall lay the pipes in accordance with any such variation the Engineer may issue.

9.19.3 Inspection

The Engineer may inspect works from time to time to ensure that:

- Watermains have been laid in accordance with this Specification. Pressure, chlorination and bacteriological tests have been carried out and approved. Specific testing requirements may be specified for individual works.

9.19.4 Materials

No materials shall be used without the prior approval of the Engineer. It is the responsibility of the Contractor to ensure that all materials/fittings to be used on the site have been approved for use by the Engineer in advance of work commencing. In the event that ground conditions in any part of the site prove to be anything other than inert material, the Contractor shall inform the Engineer accordingly and take whatever precautions are deemed necessary by the Engineer to deal with the situation. These precautions may include, but not be restricted to, the laying of watermain

9.19.5 Depth and position of pipes

All pipes shall have a minimum depth of cover of 800mm measured from the top of the pipe to the finished ground surface. There shall be a minimum clear horizontal distance of 300mm between the distribution watermain and other utilities, cabinets, poles, junction boxes or chambers. No other service shall be laid over the line of the watermain. There shall be a minimum vertical clearance of 100mm where other services cross over the watermain. Pipes/ducts, cabinets, poles, junction boxes or chambers shall not be constructed on top of a watermain.

Before being positioned, each pipe shall be thoroughly examined to ensure that it is free from defects and shall have all dirt removed from the inside thereof. The Contractor shall lay the pipe in accordance with professional practice and install all fittings, specials and adaptors as may be required for the proper execution of the works.

9.19.6 Trench width

The trench should be kept as narrow as possible, but must allow adequate room for pipe jointing and placing and compaction of backfill, a width of 300mm greater than the outside diameter of the pipe being laid will normally be found adequate for these purposes. The trench width should normally not exceed the diameter by more than 500mm.

The bottom of the trenches shall be graded and prepared to provide a firm and uniform bearing throughout the entire length of each pipe; bell holes shall be provided as required.

The Contractor shall inform the Engineer sufficiently in advance when a section of trench has been prepared ready for inspection. No pipe shall be laid until the trench bottom has been inspected and approved by the Engineer.

9.19.7 Thrust blocks

Appropriate thrust blocks shall be designed and installed on the main. Except where selfanchoring joints are used, thrusts from bends and branches in mains shall be resisted by concrete thrust blocks cast in contact with undisturbed ground. Concrete support blocks shall be cast to hydrant tees and valves installed in pipelines in order to resist the torque forces imposed on the fittings during operation. Support blocks shall be cast in such a manner so as not to interfere with the operation or maintenance. In general, support blocks should not cover any pipe or fitting joints. Thrust blocks shall be allowed composition to develop adequate strength for at least 7 days before any internal pressure is applied to the pipeline.

Where it is not possible to brace against undisturbed soil, suitable fitters shall be arranged as directed by the Engineer.

Thrust forces and shaping of the thrust blocks and collars shall conform to the field test pressure (STP) and be calculated by the Contractor for each individual thrust block considering the actual soil bearing capacity. Where large abutments are required, the bearing plate and the transmitting prism shall be of reinforced concrete B20/25. The dimensions, classes of concrete and steel reinforcement given in standard drawings are approximate only.

9.19.8 Warning mesh

All pipework shall have a 400mm wide water warning mesh, laid directly over the centreline of the pipeline and tied to valves, at a depth of 350mm below the finished ground surface. Supply pipes shall have a mesh 200mm wide laid at the same depth.

The tape shall be blue in colour and of 200 mm overall width and contain an aluminium strip throughout its length and shall have warning signs “Caution Water Main below” along the top section of the pipe. Samples of the tape shall be submitted to the Engineer for his approval.

9.19.9 Cleaning of pipes

All pipes shall be examined internally for dirt, stones, or any foreign matter and shall be thoroughly cleaned before laying in final position. To prevent foreign matter or vermin entering the main as it is being laid, all open ends of laid pipes shall be plugged until the next pipe is ready for insertion.

9.19.10 Location of other utilities

Any available records and proprietary cable locators shall be used prior to excavations taking place. Due diligence shall be used when making excavations for water mains and services and care shall be taken to protect and support all existing services (water, gas, telecommunications, drainage and electricity mains) and other works so as not to interfere with the working arrangement of same.

9.19.11 Tests

After the pipes have been laid and jointed, the main shall pass the following tests:

i. Pressure Test

DI Mains shall be subjected to 1.3 times the operation pressure but at least 16 bar for 24 hours and shall be increased to 1.5 times the operation pressure but maximum 40 bar for at least 1 hour in the presence of a representative of the Engineer. Testing shall be carried out between suitably supported blank end pieces. Testing between “live” shut valves will not be accepted.

Note: DI pipes shall under no circumstances be exposed to a test pressure of more than 40 bar .

ii. Chlorination Test

All mains shall be swabbed and disinfected before being put in to supply. The pipelines shall be disinfected as described in this Technical Specification. Chlorine residual tests shall be taken at the end of the main furthest from the point of injection.

iii. Bacteriological Test

The main shall then be refilled and a sample of the water shall be taken for bacteriological analysis. Great care shall be taken when obtaining samples for testing and only sterile containers shall be used. This sampling shall be carried out in the presence of the Engineer and/or his/her representative. Samples shall be tested within 6 hours of collection. Water samples may be tested in the following centre or in any approved or accredited laboratory.

The requirement for startup bacteriological quality is no positive bacteriological test result. A positive bacteriological result means a test result indicating unacceptable levels of bacteria per 100 ml of sample volume in accordance with the following criteria:

- 1 or more total coliforms (TC); or
- 1 or more faecal coliforms (FC); or
- overgrowth (OG) or >200 colonies of background bacteria; or presence of *Escherichia coli*.

Note: Engineer will not connect the new main to the existing network until a copy of a satisfactory bacteriological test report has been submitted to the Engineer for approval.

9.19.12 Flushing

The mainline system must contain the ability for routine and emergency flushing through fire hydrants, blow-offs, yard hydrants or other similar measures. Pigging facilities are to be considered where pipe deposits and biological growth are evident. Flushing of laterals and service lines may be by service connections. Substantial flush devices such as yard hydrants or large diameter hose connections may be used at pipe service connection entrances. Water pipelines without adequate flushing flow must also have access to pumps, the ability to connect the pumps and a water source to accommodate flushing.

9.19.13 Laying of Pipes

A number of general directions for pipe laying are as follows:

- i. Before a pipe is lowered into the trench, it should be inspected for damage and any unsatisfactory lengths must be rejected for use. The inside of each pipe length should, if necessary, be washed with clean water and, where particularly dirty, brushed out with a strong solution of bleaching powder. Precautions should be taken to prevent further contamination.

- ii. The Contractor shall cut pipes exclusively with the cutting tools recommended by the manufacturer for the particular pipe material and approved by the Engineer. Cuts shall be smooth and perpendicular to the axis of the pipe. Damages to coatings or linings (if any) shall be repaired. Spigot ends to be joined to sockets shall be chamfered.
- iii. Matching pieces required in any section of a main or to terminate the main in manholes or other parts of the works shall be cut only after all adjacent pipes have been installed and jointed.
- iv. The serviceable life of ferrous metal pipes or steel pipes, particularly those used in the salt water distribution system, depends mainly on the internal lining. Before laying, it is most important to ensure that the lining and external protection of the pipes, especially for steel pipe fittings fabricated by the Contractor, is sound and that all damaged spots are repaired. After laying, all joints must be made good and any damage to the external protection repaired or protected by anticorrosion tapes prior to backfilling.
- v. Flow disturbance will cause inaccurate readings of flowmeters. If any repair is made to the internal lining of a pipe in the vicinity of an installed flowmeter, the repaired lining should be made to the same thickness as the original and that the finished surface and profile are free from any irregularities.
- vi. External protection to steel flange joints, slip-on type couplings and flange adaptors should be provided using petroleum type anticorrosion tapes with primer and mastic filler. External protection to buried steel pipe body should be provided with epoxy or bituminous anticorrosion tapes as appropriate.
- vii. Whenever possible, full length pipes should be used instead of cut length pipes to reduce the number of joints in the pipeline. When cut length is required such as at position of bends or tees, it is preferable to check whether ready-to-use cut length pipes can be used instead of cutting from a full length pipe.
- viii. Pipes should never be pushed off the bank or allowed to fall into the trench.
- ix. When pipelaying is not in progress, the open ends of installed pipes should be temporarily closed by wooden stoppers or appropriate means to prevent entrance of dirt and trench water.
- x. Pipe lengths should never be deflected in the joint to any greater degree than recommended by the manufacturer.
- xi. Pipe should have adequate support along their whole length or should be bedded, haunched or surrounded as shown in the drawings or advised by the Engineer. The use of timber or other means to save forming socket holes must not be permitted. All objects on or in the surface on which the pipe is to be laid which may cause damage to the pipe should be removed.
- xii. Pipelaying should follow closely upon the progress of trench excavation.
- xiii. All necessary precautions should be taken to prevent floatation of pipes. For pipelaying near deep sump gullies, it is necessary to ensure that there is adequate clearance between the pipeline and the drainage connection.
- xiv. When handling asbestos cement pipes, special precautionary measures must be taken in accordance with "Asbestos Work Manual for Maintenance of Asbestos Cement Water Pipes" regarding their cutting and disposal.

- xv. For pipelaying in a new bridge the pipes should be located in a trough accessible from above or supported on concrete/steel works cantilevered from the side of the bridge
- xvi. When handling polyethylene pipes, special precautionary measures should be taken in accordance to manufactures recommendations
- xvii. Particular care shall be applied to ensure that the spigot end of the pipe does not damage or displace the rubber ring joint. The pipe shall be secured in place with approved backfill material tampered around it, except at the socket.
- xviii. When laying pipes in reclaimed areas or at locations that are susceptible to differential settlement, special attention should be given to position appropriate and sufficient flexible joints to prevent leakage or even pipe burst due to uneven settlement. Surrounding the pipes with concrete under this condition must only be made with extreme care especially for steel pipe with welded joints. In the event that ground settlement has induced sufficient stress to open up the welded joints, the surrounding concrete will become an obstacle to the repair operation.

9.19.14 Protection of pipeline

In pipeline sections where the pipeline is aligned parallel to existing roads (except the road is only a designated service road for the pipeline) the pipe shall be protected by the arrangement of boulders or additional marker posts which shall be allocated in a distance of not more than

50m. Boulders shall have a minimum weight of 300 kg. The Contractor shall agree with the Engineer the details of the execution and it shall be the discretion of the Employer to select the applied protection method (boulders or additional marker posts).

9.19.15 Bedding and Backfilling

All pipes shall be laid on a 150mm bed of rounded single sized pebble of 10mm nominal diameter or sand and haunched and covered to a depth of 150mm above the crown with similar material. The bedding directly underneath and directly over the pipe shall be lightly compacted while the sidefill shall be well compacted.

Pipes shall not be supported by stone or rock at any point. Rock shall be excavated to a depth of 150mm below the actual depth of trench required and backfilled with appropriate material before laying the pebble bed. All pipes shall be examined

internally for dirt, stones, or any foreign matter and shall be thoroughly cleaned before laying in final position. To prevent foreign matter or vermin entering the main as it is being laid, all open ends of laid pipes shall be plugged until the next pipe is ready for insertion. In ground that contains ashes or chemicals or material that could accelerate corrosion or deterioration of the pipe, the material to be used and method of laying shall be agreed in writing with the Water Section prior to laying.

9.19.16 Restrained joints

The Contractor shall lay sections with restrained joints strictly according to the manufacturer's instructions. Lengths of anchoring tails shall be computed by the Contractor

acc. to the field test pressure (STP) for each individual bend or tee considering the actual soil parameters. Adjacent to the respective bend, upper bedding and side fill shall be of concrete B8/10. Anchoring tails shall be completely backfilled prior to the pressure test.

At least three self-anchored flexible joints shall be used at each bend ≥ 45 degree deflection at each side of the bend also at locations where trust blocks are used. Where no trust blocks are used the number of anchored joints the manufacturers recommendations shall be strictly observed.

The following table provides a general guidance for the Length of the tails for the use of restrained joints

Table B4-02: Tail length for the application of restraint joints at deflection points

| Deflection X in degree | Minimum tail length in m for DN UPTO 800 pipe |
|------------------------|---|
| $X \leq 22.5$ | 12 |
| $22.5 < X \leq 45$ | 24 |
| $45 < X \leq 67.5$ | 30 |
| $X > 67.5$ | 42 |

Self-anchored flexible joints shall be used as an alternative to the traditional concrete anchor block especially in difficult circumstances such as:

- soft ground or ground prone to subsidence
- steep inclines where the inclination is $> 20\%$
- where space is limited
- at river crossings

Application of self-anchoring joints shall be in full compliance with manufacturer's recommendations.

For all locations where the site conditions are different from the made assumptions for the design of the trust blocks included in this Technical Specification the Contractor shall be obliged to recalculate the specified trust blocks in accordance with the effective soil conditions at the particular location and submit to the Engineer two sets of the design documents for each trust blocks including the statical calculations and the effective soil conditions for approval.

Further the Contractor shall be obliged to install the pipeline components in accordance with the suppliers recommendation particularly with regard to the application of restrained joints.

9.19.17 Laying of Steel Pipes

If ordered steel pipes shall be used as directed by the Engineer, the procurement, laying and measurement of steel pipes shall be in accordance with the rules outlined for DI pipes.

However the specific requirements for the jointing and handling of black steel pipes are summarised as follows:

•Steel pipes shall be jointed together by electric butt-welding. Welding shall be in accordance to approved standards and Manufacturer's prescriptions. The electrodes used shall be suitable for overhead welding and shall be subject to the Engineer's approval. Pipes shall be joined beside the trench.

- The Contractor's welders shall have passed welding tests as prescribed by the Engineer and no welder shall work on the pipes before passing the test and being approved by the Engineer in writing.
- After passing the prescribed pressure test, external coating of all joints shall be completed in accordance with the Engineer's instructions and to his satisfaction.
- After inspection of the joints, the pipes shall be lowered into the trench. Steel pipes shall be joint together by electric butt-welding. Welding shall be in accordance to approved standards and Manufacturer's prescriptions. The electrodes used shall be suitable for over head welding and shall be subject to the Engineer's approval. Pipes shall be joined beside the trench.
- The Contractor's welders shall have passed welding tests as prescribed by the Engineer and no welder shall work on the pipes before passing the test and being approved by the Engineer in writing.
- After passing the prescribed pressure test, external coating of all joints shall be completed in accordance with the Engineer's instructions and to his satisfaction.
- After inspection of the joints, the pipes shall be lowered into the trench.

9.19.18 Laying of HDPE Pipes

Straight pipes: The pipes shall be cut to the required lengths, positioned and bedded in the trenches on the compacted and finished bedding and jointed with the appropriate fittings.

Rolls: The pipes shall be taken from the roll, straightened, cut to the required lengths, positioned and bedded in the trenches on the compacted and finished bedding and jointed with the appropriate fittings.

9.19.19 Laying of Galvanised Iron Pipes

If ordered by the Engineer, the installation of GI pipes, diameters ranging from ½" to 1", from behind the water meter to the consumer's house piping system shall be executed by the Contractor.

Piping shall include all fittings, connecting materials, supports, earthwork chiselling, mending and pressure tests for the complete installation of GI pipes in every respect.

Payment shall be according to linear meters of pipes laid from behind the water meter to consumer's house connection point.

9.19.20 Marker Posts

The Contractor shall supply and erect approved reinforced concrete marker posts for all valves chambers, vent and drain valve chambers, hydrants and along the pipeline in a distance of not more than 500m, at any angle point, and at the entrance to an easement. Marker posts

shall be set vertically against the property line (or elsewhere as directed) so that a line from the centre of the post to the position/ fittings to be indicated is at right angles to the principal face of the post.

Figures and letters on the plate shall show the following information on the valves: number of valve, DN and offsets; for hydrants: number of hydrant and offsets. Figures and letters shall be placed by the Contractor.

9.19.21 Reinforced Concrete Chambers

Reinforced concrete chambers shall be located as indicated on Drawings or directed by the Engineer. In-situ concrete chambers shall comply with the applicable specified requirements for Earth works and Concrete works.

Reinforced concrete chambers shall be quoted for, without the various pipeline appurtenances as valves, meters, dismantling joints etc. These items shall be paid separately as extra over for pipeline installations.

All external pipework before entering and after exiting a reinforced concrete chamber shall be fitted with flexible joints at a minimum distance of 300 mm from the external face of the chamber. The following types of chambers shall be applicable:

- Air valve chamber
- Washout chamber
- Water meter chamber in main lines

The structures shall be built into the pipelines in accordance with Standard Drawings. Given dimensions on the drawings shall be verified by the Contractor so as to suit the pipe installation and the prevailing condition on Site.

Cast iron covers with frames shall be installed for all valve chambers as specified or shown on drawings. The wording on each cover shall be agreed with and approved by the Engineer prior to ordering. Covers to be used in surfaces, which are subject to vehicular traffic, shall be Class D, according to EN 124.

Two pairs of keys for use with each type of cover shall be handed over by the Contractor after completion of works at no extra cost. All valve chambers shall be equipped with step irons as indicated in drawings or as directed by the Engineer. Step irons shall be malleable cast iron according to DIN 1211, galvanised iron or as directed by the Engineer.

All valve chambers shall have pump sumps installed as shown on the Standard drawings or as instructed by the Engineer.

9.20 PIPEWORK IN CHAMBERS AND PUMPING STATIONS

9.20.1 Preparation of Pipes

The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before it is placed into commission.

Cleaning shall include the removal of all dirt, rust, scale and welding slag due to Site welding. All small bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment.

9.20.2 Installation of Pipes

Care shall be taken during the erection of pipework to ensure that no loads of any kind are transmitted through to the pump flanges or the flanges of any other equipment. Care shall also be taken that pipe flanges are accurately aligned to prevent distortion of flanges and/or pipework when bolting together. Bolts of flanged connections shall be tightened uniformly, so that the gasket pressure is evenly distributed around the circumference.

9.20.3 Support of Pipework and Valves

All necessary supports including structural steel work foundations, hangers, saddles, sliding, expansion pieces, fixing bolts, foundation bolts, fixing and anchor points and all attachments shall be supplied to support the pipework and its associated equipment in an appropriate manner.

Valves, meters, strainers and other devices mounted in the pipework and its associated equipment shall be supported independently of the pipe to which they connect.

9.20.4 Supports and Passage of Pipes through Walls

Whenever pipework passes through walls, the Contractor shall provide block outs and install the pipes only after the structure has been completed and grout the pipes in secondary concrete after the pipes have been accurately positioned. Where axial thrust is to be transmitted, puddle flanges shall be grouted and reinforcement be placed in such manner that the thrusts shall be safely transmitted into the structure.

In exceptional cases the Engineer may accept to incorporate the pipes into primary concrete provided that all pipe elements and appurtenances are completely wrapped into PE-sheets.

9.20.5 Disinfection of Mains

Disinfection of mains shall be carried out in accordance with EN 805.

EN 805 recommends several disinfectants. The disinfectant may be selected by the Contractor and submitted to the Engineer for approval together with the method of application. It is recommended to use a hypochlorite solution; the process for the hypochlorite solution is given hereinafter.

After a section of the mains has been hydraulically tested successfully and before being commissioned, the Contractor shall proceed with the disinfection.

Firstly, the mains section shall be flushed with clean water to remove foreign matter.

Then the mains section shall be disinfected with a chlorine solution at a rate as to obtain 50 mg/l of active chlorine at the point of introduction. The line shall be blown-off until a residual of 5 mg/l chlorine is obtained at the point of blow-off.

If a residual of 5 mg/l chlorine is obtained, the blow-off shall be closed and the water allowed to remain in the pipe for a minimum of 24 hours (static method). After this period the water shall be tested for residual chlorine at the point of blow-off. If no residual chlorine remains, the process shall be repeated until satisfactory results are obtained.

After completion of the disinfection process the main shall be flushed with 0.5 mg/l chlorinated water until effluent concentration at the point of blow-off is less than 0.5 mg/l.

Any effluent from the disinfectant shall be duly neutralised.

9.21 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

**TECHNICAL SPECIFICATIONS FOR THE
CONSTRUCTION, REHABILITATION AND
EXPANSION OF GROUNDWATER – BASED
RURAL WATER SUPPLY SCHEMES - BATCH 1
SCHEMES IN WAJIR COUNTY**

**SECTION 3: ELECTRO-MECHANICAL
WORKS**

10 MECHANICAL WORKS

10.1 SCOPE OF WORK

The work to be performed under this section consists of the assembling and installation of supplied equipment and piping material as shown on the drawings or specified or directed by the Engineer like pumps, vessels, hoists, process equipment, station piping, etc. It shall include transportation, testing, assembling, furnishing, first filling with all needed operation means, of all materials, equipment and accessories required for completing the specified equipment. It shall include, but shall not be limited to, the following parts: All field screws and bolts, electrodes for welding, anchor bolts, protective painting against corrosion, etc.

The Contractor shall strictly observe the related specifications and shall carry out all work in a skilled and workmanlike manner in keeping with modern methods of construction. The Contractor has particularly to observe all instruction for installations defined by the manufacturer/supplier of the equipment.

Only materials approved and accepted by the Engineer shall be supplied and installed. Materials which are rejected shall immediately be removed from the Site at the cost of the Contractor.

The equipment shall be delivered fully cleaned and flushed for immediate service. The equipment shall be properly preserved for transport and storage.

A complete set of pipe work, fittings and jointing materials shall be provided as necessary for all equipment, and unless otherwise specified shall terminate 250 mm outside the building or at the pumping main or other suction or discharge systems with a plain end suitable for connection.

Where the equipment is manufactured to require special tools for maintenance other than those normally available commercially, the Contractor shall supply one complete set of special wrenches or other special tools necessary for the assembly, adjustment, and dismantling of the equipment. All tools shall be of best quality hardened steel forgings with bright, finished heads and with work faces dressed to fit nuts. The set of tools shall be neatly mounted in a labelled tool box of suitable design provided with a hinged cover.

The Contractor shall obtain and submit from the manufacturer a list of suggested spare parts for each piece of equipment which are required for two years of operation. After approval, Contractor shall furnish such spare parts suitably packaged, identified with the equipment number, and labelled. Contractor shall also furnish the name, address, and telephone number of the nearest distributor for each piece of equipment. All spare parts are intended for use by the Employer, only, after expiration of the guarantee period. Any spare parts which the Engineer permits the Contractor to use for start-up activities shall be replaced by the Contractor prior to the Employer's acceptance of beneficial use of the equipment.

Further to the above, auxiliary works to be included in the tender for mechanical and process equipment including associated pipework shall comprise, among others, the following works and commitments:

- i. establishment of shop drawings and all details for any components.
- ii. transportation from manufacturing plant to Site including packing, handling, off-loading, adequate storing and protection against damage and spoiling;
- iii. all erection equipment for assembling the steel structure;
- iv. all connecting components, such as bolts, rivets, nuts, washers, shims, welding rods, etc., required for completing the job;
- v. all drilling, welding, wedging, plumbing, levelling, alignment etc., required for completing the work;
- vi. training of welders, if required;
- vii. provision of all instruments, gauges and other appliances for inspection and testing of the structures by the Engineer or any assigned authority including all ancillary access supports; and
- viii. All data plates shall be of stainless steel suitably attached to the equipment. Data plates shall contain the manufacturer's name, main data as e.g. pump size and type, serial number, speed, impeller diameter, capacity and head rating, and other pertinent data.

10.2 MANUFACTURER AND SUPPLIER REQUIREMENTS

Equipment of similar design shall be from the same manufacturer. If applicable, the Contractor shall verify local representative for chosen equipment with full name, contact person, address and telephone. Also the representative's experience, service and spare parts organisation etc. shall be provided. All equipment shall be designed for ease of installation and maintenance.

Special required tools and equipment shall be supplied. Flow and rotation direction shall be permanently marked. Renewable sleeves under seals shall be removable on site without the application of heat.

Material for external bolting of 10mm and smaller shall be corrosion resistant steel. Larger bolting shall as a minimum be hot dip galvanized low alloy steel. Sub-merged bolting shall be compatible with the base metal. Bolts shall be in accordance with ISO 262. All equipment shall have a material handling procedure. When manhandling cannot be expected, handling and lifting devices shall be provided or clearly defined.

Couplings shall not contain wear parts and shall use forged steel. Dampering couplings can be differently designed. All rotating couplings shall be shielded by structurally strong non coupling guards. Non-sparking guard is required in classified zones 0, 1 and 2. Limitation of the noise emission from the equipment shall be specified.

All submerged moving parts of the equipment, or equipment in humid areas, or the pins and spindles of the submerged moving parts or the faces in contact with them, shall be of

corrosion resistant materials. All parts in direct contact with various chemicals shall be completely resistant to corrosion, or abrasion by these chemicals.

Particular attention shall be given to the prevention of seizure by fretting where two corrosion resistant metals are in contact, by the selection of materials of suitable hardness and surface finish and the application of lubricants. All instrument indicator scales shall be in the English language with units in the international SI-System.

10.2.1 Identification Plates of Equipment

All parts to be delivered under the Contract shall be labelled with permanent identification plates in readily visible locations. The identification plates shall be protected during erection and especially during painting. Damaged or illegible identification plates shall be replaced. The identification plates shall be of non-corroding, non-disintegrating material and shall be labelled in English language.

Printed or stencilled inscriptions shall be waterproof, oil-proof and wear resistant.

The following data shall be shown in accordance with the relevant standards:

- i. Manufacturer's name and address;
- ii. Manufacturer's type, serial number and date of manufacture;
- iii. Parameters describing rated capacity.

Small, standardized components may bear the manufacturer's standard nameplate only. Warning signs and plates for designations or instructions for operation, safety and maintenance shall have a uniform design and shall be inscribed in English language.

10.2.2 Inspection at the place of the manufacturer

All materials shall be inspected prior to shipment by an internationally recognized Third Party

Agency (TPA) such as Bureau Veritas subject to the approval of the Engineer.

The Third Party Agency shall inspect the equipment and materials in accordance with the Technical Specifications and conduct tests. For any clarifications, Third Party Agency shall contact the Engineer. The Third Party Agency shall submit the detailed inspection report along with observation data sheets directly to the Engineer.

The Engineer shall hold the final inspection upon arrival of the material on site.

The Engineer shall reserve the right to reject the supplied material during final inspection or at later date, if found not as per the Technical Specifications.

The Engineer shall reserve the right to inspect the materials in the factory.

The manufacturer shall allow access to the Engineer and / or Third Party Agency at all times during manufacture and testing to the premises in which the material being manufactured and / or tested.

10.3 CONTRACTOR SUBMITTALS

10.3.1 Shop Drawings

The Contractor shall prepare shop drawings of all essential piping and installation details for approval by the Engineer. The preparation of these drawings and the structural computations for them shall not be sublet without the Engineer's permission.

These drawings shall give all necessary information for the installation, erection and painting of the equipment and pipes on the basis of the accepted standards. Vents and drains are to be arranged where needed.

All parts of the works shall be designed and manufactured in accordance with the latest recognized rules of workmanship and modern engineering practice. The regulations, standards and guidelines listed in these specifications shall be respected in the design, calculation and execution.

Where additionally shop drawings are to be prepared by the contractor, no pre-fabrication or installation shall be conducted until the shop drawings together with the structural analysis have been approved by the Engineer. A specified number of sets of finally approved drawings shall be furnished to the Engineer.

Scale of shop drawings shall not be smaller than 1:20; for details from 1:10 to 1:1.

The Contractor shall not be released of its responsibility and guarantee because the drawings and structural computations have been approved by the Engineer.

The structural calculations to be submitted shall contain at least the following details:

- i. Loads and horizontal thrust on which the calculation is based
 - a. Dead weight
- ii. Type of material of the main structural parts and means of jointing
 - a. Measurements and cross-sections of all essential elements
- iii. Maximum stresses as well as maximum pressures on supports and moments of all individual structural elements and of their joints
 - a. Evidence of stability

10.3.2 Manufacturer's Certificates

The Contractor shall submit all the required written certifications from manufacturer showing that the equipment is in compliance with all applicable codes and standards.

10.4 TRANSPORTING AND STORAGE REQUIREMENTS

10.4.1 Protection and packing for dispatch

Before sending from manufacturer all equipment should properly protected with painting or other approved mean for all transporting, storage and installation period against corrosion and accidental damages.

All equipment and equipment as necessary shall be packed in first quality containers or packing; no second-hand timber shall be used. The material shall be packed to withstand rough handling in transit and all packages shall be suitable for several stages of handling via sea or air freight, inland transport and movement on Site and for storage including possible delays in delivery. Packing cases shall be of the fully boarded type, slated cases will not be allowed. Precautions shall be taken to protect shafts and other unprotected surfaces where they rest on wooden or other supports likely to contain moisture. At such points wrappings impregnated with antirust composition or vapour phase inhibitors shall be used of sufficient strength to resist chaffing and indentation due to any movement which is likely to occur in transit. Shape and size of the protective wrappings and impregnation shall be suitable for a minimum period of twelve months.

Lids and internal cross battens of all packing cases shall be fixed by screws and not nails. Hoop metal bindings of cases shall be sealed where ends meet and if not of corrosion resistant material, shall be painted. Contents of such cases shall be bolted securely or fastened in position with struts or cross battens and not with wood chocks, unless they are fastened firmly in place. All struts or cross battens are preferably to be supported by cleats fixed to the case above and below to form ledges on which the battens may rest. Cases shall be upended after packing to prove that there is no movement of contents.

Where parts are required to be bolted to the sides of the cases, large washers shall be used to distribute the pressure and the timber is to be strengthened by means of a pad.

Waterproof paper and felt linings are to overlap at seams by at least 12 mm and the seams secured together in an approved manner, but the enclosure is to be provided with screened openings to obtain ventilation.

The flanges of pipes, valves and fittings shall have their open ends protected by adhesive tape or jointing and then be protected by wooden discs secured by means of service bolts (which shall not be used on Site) or by other approved means. The sleeves and flanges of flexible couplings shall be bundled by wire. Cases containing rubber rings, bolts and other small items shall not normally weigh more than 500 kg gross.

All relays, instruments, etc. shall be shipped with transport screws and/or clamps, clearly marked and painted red, to prevent movement of moving parts. Reference shall be shown in the operating and maintenance instructions, detailing the removal of these temporary fixings prior to setting the equipment to work.

Unless stated otherwise in the specifications, pumps (pump, motor, check-valve (if any), tail cable) shall be supplied completely assembled in a strong and suitable case / crate / wooden box suitable for shipment to the place of ultimate installation.

Structural steel work, pipes, valves, uncased fittings and metalwork shall be similarly marked. In addition, one in every ten repeated articles shall bear the dispatch marks in suitable paint or other approved medium. When in the opinion of the Engineer the dispatch marks cannot be applied satisfactorily to any item they shall be stamped on a metal label attached to the item or part by means of a piece of wire passing through holes at either end of the label and secured so that it lies flat with the item.

Indoor items such as electric motors, switch and control gear, instruments and panels, machine components, etc., shall be 'cocooned' in aluminium or polythene sheeting, sealed at the joints and the enclosures provided internally with an approved desiccate.

All items shall be clearly marked for identification against the packing list, English language. All cases, packages, etc., shall be clearly marked on the outside with a waterproof material to show the weight, where the weight is bearing, and where the slings shall be attached and shall also have an identification mark relating them to the packing lists and to the appropriate shipping documents. Cases shall bear the Contractor's name and the name of the particular Site. These shall be marked in stencils or legible letters and shall be in red or black waterproof paint or protected by shellac or varnish to prevent obliteration in transit.

Each crate or package is to contain a packing list in a waterproof envelope and copies in duplicate shall be forwarded to the Engineer, prior to dispatch. All items of material shall be clearly marked for ready identification against the packing list.

The Contractor shall be deemed to have included in the Contract Price for all materials and packing cases necessary for the safe conveyance and delivery of the Equipment.

The Engineer may require to inspect and to approve the packing before the items are dispatched but the Contractor is to be entirely responsible for ensuring that the packing is suitable for transit, and such inspection will not exonerate the Contractor for any loss or damage due to faulty packing.

The Contractor shall send advice of dispatch to the Engineer so that this information is received not less than two weeks before the anticipated delivery of the goods.

10.4.2 On site storage and safekeeping

The Engineer shall agree machinery delivery dates with the Contractor within 60 days of the award of the Contract, and these shall be in accordance with the Contract. In case of delay to the Implementation programme, to prevent delay to the shipment of equipment or the deterioration of equipment stored at Site, the Contractor shall either:

- 1) Adequately package all items of equipment to enable the equipment to be stored in the open on Site without any deterioration whatsoever.
- 2) Provide an approved store, complying with the following minimum requirements on Site which will also prevent any deterioration of the Equipment:
- 3) Electrical equipment: covered, air conditioned, dust proof and vermin proof area.
- 4) Rotating mechanical machinery: covered area.

- 5) Pipes, valves, steelwork, etc.: sheeted on open hard standing area.

Contractor should provide storage and loading area for intermediate equipment storage. Required room for devices will be provided on site.

Storage rooms should be protected against environment condition effect, with good ventilation and firm floor covering. Storage room floors should be designed in order to cope with stored detail weight.

The sheeting to be used shall be of a type that will not deteriorate in ultra-violet light. The machinery shall be ready for erection at Site by the end of the Manufacturing and carriage periods but if the machinery is complete and ready for erection before the agreed date, the Contractor shall arrange on Site storage as defined herein, at his own expense within the Contract Price. The Contractor shall provide insurance and shall be entirely and solely responsible for the security of all such equipment stored at the Site for the period until erection. The Contractor shall be responsible for inspecting all equipment prior to storage and he shall arrange for any damaged equipment to be rectified prior to delivery to store. The Contractor shall remove the machinery from storage and deliver to the final point of installation upon receipt of the Engineer's instruction. The Contractor shall be responsible for the operation, safe keeping and maintenance of all equipment on Site during and after erection up to the issue of the Completion Certificate.

10.4.3 Unloading, erection and running-in of equipment

The Contractor shall make his own arrangements for the unloading of the Equipment supplied at Site or store and be responsible for any damage occasioned. The Contractor shall at his own expense provide all equipment, tools, meters, gauges, temporary accommodation, all skilled and unskilled labour, for the erection of the whole of the Equipment and apparatus so that it can be installed complete and left in good working order.

Before commencing this work the Contractor shall examine the structure and make arrangements with the Engineer so that the Equipment may be installed without interfering with the

works and the running of the equipment in course of construction and shall deliver to Site items required to be "Built-in" prior to delivery of the main equipment. The Contractor must expect erection at Site to be discontinuous to suit the continuous running of the existing equipment and the Contractor shall be deemed to have included a suitable allowance for this. Any special erecting tackle required shall be provided by the Contractor and be left at Site after the completion of the Contract. The Contractor shall provide adequate protection for the equipment from the time it is delivered to Site until the Maintenance Certificate is issued. In particular, the Contractor shall provide and fix adequate sheeting, etc., to prevent the ingress of dust and dirt both during erection and whilst the building finishes are carried out after erection.

Upon the complete erection of the whole of the equipment and auxiliary apparatus, the Contractor shall set the Equipment to work in conjunction with arrangements to be made with

the Engineer. The date of commencement of the twelve months maintenance period shall be on receipt of a notice in writing from the Engineer to the Contractor intimating that the entire Equipment has been satisfactorily tested, has obtained the guarantees and that the Maintenance Certificate has been issued. The Contractor shall instruct the Employer's employees who may be appointed to take charge of the equipment in all matters and things relating to the proper running, adjusting and maintaining of the equipment in efficient condition.

The Contractor shall provide a suitably qualified and authorised Engineer to act as Site manager to co-ordinate the activities of the various sub-contractors for the whole period covered by the Contract. The Contractor shall also provide suitably qualified and competent specialist personnel employed for:

10.5 GENERAL REGULATIONS AND REQUIREMENTS

The specifications of this section details design, supply and erection of equipment and shall be valid for all mechanical equipment, except such equipment specified in Section 4 – Civil Works. For certain standard elements of this section references is made to Section 3 – Materials and Piping Equipment which in such case shall be applicable.

All parts of the equipment shall be sized for and be suitable in every respect for continuous operation at rated output plus 10% overload under the climatic and operating conditions of the Site.

The Contractor shall safeguard compatibility of all elements particularly when originating from different manufacturers

10.5.1 Design Loads

The equipment shall be designed taking account of all relevant loads listed in codes and data sheets, and include the effect of field hydrostatic tests, wind, explosion blast pressure, acceleration, connected piping, transportation and installation.

All loads used in the design, including those of equipment and components, shall be clearly indicated in the design calculations.

Equipment nozzles shall wherever possible not be charged with static or dynamic forces or moments by the connection pipes. If equipment nozzles will be charged with static or dynamic

forces or moments it shall not exceed the figures defined by the manufacturer and evidence thereof must be provided to the Engineer.

10.5.2 Functionality of elements

All equipment shall be designed, manufactured and arranged in a logical manner to easy operation and maintenance and also to give an appealing appearance.

All elements shall be rugged and of proven quality through long-lasting operation and from internationally reputed manufacturers.

10.5.3 Protection / safety

All moving and rotating parts shall be provided with appropriate effective protection to avoid danger to the operating staff. Drive Guards shall be used for all power transmission, prime movers, machines, shaft extensions, and moving machine parts and shall be guarded to conform with DIN EN Standards and ISO 14120.

All metal parts shall be electrically grounded. Equipment shall be encapsuled to prevent the ingress of dust and dirt into any sensitive equipment (such as bearings, relays, control and measuring equipment, etc.). Large or heavily loaded balls and roller bearings shall be protected against deformation and vibration during transport. Any bearing deformed during transport shall be changed at Site against new ones free of charge.

Suitable lifting eyes and backing-out bolts shall be provided for erection and dismantling. No pockets are allowed that may hold water.

Equipment shall be arranged so that no part remains out of regular operation. Safety devices shall be included in the regular operational schedule.

10.5.4 Allowable noise levels

The noise level definition and measurement shall be in accordance with the relevant ISO and IEC standards. The noise level caused by the installed operating equipment shall not exceed the following values, if not otherwise stated:

- i. In the pump house, at any place 1m from operating equipment max. 80 dB(A)
- ii. In offices, control rooms, etc. max. 55 dB(A)
- iii. In residential areas (daytime) max. 50 dB(A)
- iv. In residential areas (night time) max. 35 dB(A)

The Contractor shall furnish to the Employer one calibrated noise-measuring instrument during the commissioning period of the equipment.

10.5.5 Colour code

The colouring of piping for various media, moving parts, etc., shall be in accordance with DIN 2403. Pipework, tanks and ducting shall be colour coded by totally painting with the appropriate code colour as specified. The principal code colours shall be as set forth in this Technical Specification

All pipes and tanks shall also bear stencilled labels to indicate the contents. Lettering shall be in both English. Labels on pipework shall incorporate arrows showing the direction of flow within the pipework.

Black lettering shall be used on orange, yellow and green background and white lettering shall be used on red and blue. Sufficient labels shall be used to ensure adequate identification throughout the length of the pipe runs. These shall be located at least adjacent to each flange or disconnecting joint, where pipework passes through walls, floors, crosses doorways and other access ways and at intervals in long runs of pipework.

10.5.6 Allowable stress

Except where standardized pressure ratings are used, design of all parts of equipment shall be based on the severest exceptional conditions to which they will be exposed during operation and testing. The stresses which occur in that section of the part when exposed to the severest exceptional operating conditions or test pressure, shall not exceed 70 % of the yield point of the material of the respective part, unless otherwise specified.

When exposing complicated steel castings or welded parts to the pressure test, the maximum allowable stress limit of 70 % of the yield point may be exceeded locally in limited zones, if these zones are small in extent and do not endanger the overall strength of the part. To check these stresses in the critical zones, the Engineer may require strain gauges to be mounted during pressure tests.

In the design of the equipment, the maximum stresses due to normal operating conditions shall not exceed one-third of the yield point or one-fifth of the ultimate strength of the material. Increased size or thickness, i.e. at least 1mm, shall be required for members subject to corrosion or erosion and for members mainly designed for rigidity. The dimensions of the parts which are exposed to repetitive and alternating stresses as well as to impacts and vibrations shall take into account the safety measures approved in practice.

The computations performed by the Contractor when dimensioning the main parts of the equipment shall be submitted to the Engineer at his request.

10.6 Spare parts and tools

10.6.1 General requirements

All spare parts to be supplied shall be interchangeable with the corresponding parts of all the equipment supplied and shall be of the same material and workmanship. Spare parts will not be accepted before the Contractor has submitted the complete list of all spare parts.

All spare parts shall be protected against corrosion and provided with identification labels in English language. All spare parts shall be delivered in marked boxes of sufficiently sturdy construction to withstand five years of storage.

10.6.2 Required amount of spares

At least the quantity of general spare parts listed below shall be included as a minimum in the scope of supply of the Contract.

For a number of identical assemblies or items, general spare parts as indicated below shall be delivered, one set of which shall be defined as the total quantity of one assembly. The quantity "X" to be supplied is a function of the number "N" of supplied assemblies, subassemblies, or items identical in type and size:

- i. $N < 3 \quad X = 1$
- ii. $N < 10 \quad X = 2$
- iii. $N > 10 \quad X = N/10 + 1$ rounded to the next higher whole number

10.6.3 General spare parts to be supplied

X sets of packing, seals, gaskets, bushings, springs, wearing parts of couplings, drive belts, etc., for each identical element such as motors, pumps, compressors, blowers, etc.;

- i. X sets of seals, gaskets and packing, plus X complete spare units for valves and gates;
- ii. $X + 1$ of identical gaskets for pipe work but at least three;
- iii. $X + 1$ assemblies or subassemblies of all filter elements;
- iv. $X + 1$ assemblies or subassemblies of all measuring / control instruments, limit switches, relays, etc.;

5 % but at least two pieces of all bolts (except foundation bolts), screws, nuts, washers, etc.; the quantity may be taken from the surplus material at completion;

5 % of the quantity of painting material but at least one litre, in unused sealed containers, for repair work other than the Contractor's.

If any additional spare parts are recommended by the Contractor, these shall be stated in quantity and description in the Technical Data Sheets for each item. Prices for additional recommended spare parts shall be included in the Bid Price. Orders for additional recommended spare parts shall be optional for the Employer for a period of five years after the date of Contract award at the price indicated in the Tender.

10.6.4 Tools

The Contractor shall include in his supply all customary and special tools as well as special devices including lifting devices, ropes, etc., necessary for total assembly, disassembly and maintenance of all parts of the supplied equipment.

The costs for spare parts shall be included in the unit prices.

The standard set of maintenance tools shall comprise, if not otherwise directed or specified:

- a. 1 set of chrome vanadium spanners to fit each size of nut and bolts used throughout the installation;
- b. 1 set of screwdrivers to fit each size and kind wrench;
- c. 1 set of star screwdrivers to fit each size and kind of screws used throughout the installation

- d. 1 no. grease gun
- e. 1 no. lantern ring extractor if required
- f. 1 set insulated pliers
- g. 1 set keys
- h. 1 set of hammers (0,5-2kg);
- i. 1 no. adjustable Stilton
- j. 1 no. packing extractor

The use of special tools and devices for erection shall be allowed but must be approved by the Engineer in each case. Special tools and devices shall be provided with means for ready identification. Special tools and devices shall not be accepted before the Contractor has submitted the complete list of special tools and devices.

The total price for tools and devices, as required by this clause, shall be included in the bid price.

10.6.5 Requirements for lubrication

Where lubrication is effected by means of grease, preference shall be given to a pressure system, which does not require adjustment or recharging more than once weekly.

For accessibility grease nipples shall be placed at the end of extension piping, and when a number of such points can be grouped the nipples shall be brought to a conveniently mounted battery plate. "Hydraulic" Button head nipples in accordance with DIN standards shall be used for normal grease. Arrangements shall be provided to prevent bearings being overfilled with either grease or oil.

Oil filling/emptying plugs shall be situated so that maintenance can be done from ground level or gangway.

The Contractor shall supply permanently labelled grease guns for each type of nipple and type of grease provided.

Oil containers shall be supplied complete with oil level indicators of the sight glass type, or where these are not practicable with dipsticks. The indicators shall show the level at all temperatures likely to be experienced in service. The normal maximum and minimum levels shall be clearly visible in sight glass type indicator from the normal access floor to the particular item of equipment, and the indicators shall be easily dismantled for cleaning.

The Contractor shall supply flushing oil for each lubrication system when an item of equipment is ready, together with sufficient quantity of the approved lubricants for the commercial operation of the equipment.

10.6.6 Connection nozzles for equipment

All flanges on equipment and appurtenances provided under this Section shall conform to DIN EN 1092-1, unless otherwise shown. All pipe threads shall be in accordance Whitworth-

Thread and Pipe-thread (BS 84/BS919, DIN-ISO 228, DIN 2999, DIN 3835), and this Technical Specification.

10.6.7 Relevant standards

The Contractor shall carry out works described in this Technical Specification in accordance with the appropriate international standards. These are, but are not limited by, the following:

- EN 3 Portable Fire Extinguishers
- EN 294 Safety of machinery. Safety distances to prevent danger zones being reached by the upper limbs
- EN 593 Industrial valves - Metallic butterfly valves
- EN 773 General requirements for components used in hydraulically pressurized discharge pipes, drains and sewers
- EN 837-1 Pressure gauges. Part 1: Bourdon tube pressure gauges. Dimensions, metrology, requirements & testing.
- EN 1171 Industrial valves - Cast iron gate valves
- EN 1452 Plastics piping systems for water supply - Unplasticized polyvinyl chloride(PVC-U)
- EN 1561 Founding. Grey cast irons
- EN 1563 Founding. Spheroidal graphite cast irons
- EN 1676 Aluminium and aluminium alloys. Alloyed ingots for remelting. Specifications.
- EN 1706 Aluminium and aluminium alloys. Castings. Chemical composition and mechanical properties.
- EN 1982 Copper and copper alloys - Ingots and castings
- EN 10083 Steels for quenching and tempering
- EN 10088 Stainless steels
- EN 10216 Seamless steel tubes for pressure purposes
- EN 10217 Welded steel tubes for pressure purposes
- EN 10255 Non-alloy steel tubes suitable for welding and threading
- EN 10293 Steel castings for general engineering uses
- EN 12334 Copper and copper alloys - Ingots and castings
- EN 12540 Corrosion protection of metals
- ISO 898 Mechanical properties of fasteners made of carbon steel and alloy steel
- ISO 1217 Displacement compressors. Acceptance tests
- ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
- ISO 3046 Reciprocating internal combustion engines
- ISO 7005 Metallic Flanges
- ISO 8528 Reciprocating internal combustion engine driven alternating current generating sets
- ISO 9905 Technical specifications for centrifugal pumps
- ISO 5199 Technical specifications for centrifugal pumps - Class II
- ISO 9908 Technical specifications for centrifugal pumps - Class III

- ISO 9906 Rotodynamic pumps - Hydraulic performance acceptance tests
- DIN 2403 Identification of pipelines according to the fluid conveyed
- DIN 2501 Flanges; Connecting Dimensions
- DIN 2642 Loose flanges
- DIN 3230-4 Technical Conditions of Delivery for Valves; for Potable Water Service, Requirements and Testing
- DIN 4100 Welded Steel Structures
- DIN 4114 Steel structures stability
- DIN 4132 Crane ways, steel structures, computations and design
- DIN 4056 Water pipelines; valve boxes for stop valves; DVGW code of practice
- DIN 8974 Polyethylene (PE) pipes - Dimensions
- DIN 15018 Cranes, steel structures, stress analysis
- DIN 15020 Lifting applications basic principles for Rope Receiving components
- DIN 15030 Cranes, acceptance testing of cranes

The Contractor may carry out the works or provide materials in accordance to international standards (BS, ISO and others), provided their requirements are superior or equal to the requirements set forth below.

10.7 Materials

10.7.1 General

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

- - Grey-iron DIN1691
- - Ductile iron DIN1693
- - Carbon steel DIN1681-85
- - Copper and copper alloy DIN1714, DIN1705, DIN1709

10.7.2 Stainless steel

Where stainless steel is specified or used it shall have resistance to atmospheric corrosion not less than that provided by 18 % chrome / 8 % nickel steel, DIN17445 (AISI 316).

Higher corrosion resistance grades shall be provided as required for particular duties.

10.7.3 Cast iron

CI Shall be of standard grey close-grained quality to DIN1691 or better. The structure shall be homogeneous and free from excessive non-metallic inclusions and other injurious defects. Un- furnished surfaces shall be treated to remove all foundry irregularities.

10.7.4 Ductile iron

DI Shall be of standard grey close-grained quality to DIN1693 or better. The structure shall be homogeneous and free from excessive non-metallic inclusions and other injurious defects. Un- furnished surfaces shall be fettled to remove all foundry irregularities.

Materials shall be standardised as far as possible. Materials and structural parts which are not standardised shall comply with the relevant site requirements and shall only be used with the approval of the Engineer.

All materials shall be the best of their respective kinds, free from all imperfections that might impair their strength, durability and appearance. All materials shall meet the current applicable specifications.

10.7.5 Bolts and screws

Generally the material shall comply to DIN EN ISO 898-1 and DIN EN ISO 898-2 for the mechanical properties of screws and DIN EN 20898-2 for nuts. All screws and bolts for submerged installations, in areas which are endangered to be flooded or generally in all areas with an increased corrosive ambient air shall be stainless steel including anchor bolts for the mounting of equipment.

- **Bolts:** Connection bolts may be raw or galvanized unfinished machine bolts as specified in the detailed description. When galvanized, the depth of threads shall be sufficient to give a free fit. Semi-finished machine bolts may be used in lieu of unfinished bolts, if required to obtain the fit as specified.
- **Locknuts:** shall be galvanized locknuts of the auxiliary type to be used with standard nuts.
- **Nuts and washers:** Steel for nuts and washers shall be made according to the relevant standards meeting the requirements pertinent to the bolts.

10.8 EXECUTION OF WORKS

10.8.1 Installation

The Contractor shall liaison with the Engineer', Statutory Authorities and other Contractors as required for compliance with applicable laws and standards. The Contractor shall supervision during the safekeeping, site testing, commissioning and maintenance periods.

At the end of the programme, the Contractor shall commission the equipment to the satisfaction of the Engineer who will then issue the Maintenance Certificate. Until such certificate is issued, the Contractor shall be responsible for the making good of any damage occasioned, however caused.

The Contractor shall ensure that the positions of foundations for machinery plinths, holding-down bolts and the setting of machinery are positioned in accordance with the approved machinery drawings.

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

The machinery shall be mounted on flat steel packing of thickness selected to take up variations in level of the concrete foundations. The packing shall be bedded by chipping or grinding of the concrete surface. One packing only of selected thickness shall be used at each location which shall be adjacent to each holding down bolt. The number of shims shall not exceed two at each location and the thickness of each shim shall not exceed 3mm.

The machinery shall be aligned, levelled and pulled down by nuts of the holding down bolts with a spanner of normal length. Only grouting of holding down bolts to the approval of the Engineer shall be carried out before the machinery has been run and checked by the Supervisor for stability and lack of vibration. Final grouting of shims, etc., shall be carried out only after the aforementioned run and check by the Engineer has been completed, approval given, and the grouting area clean and suitable in every way.

10.8.2 Alignment

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

10.8.3 Machinery finish

All covers, flanges and joints shall be clean, properly faced, bored, fitted, hollowed, moulded or chamfered as the case may be, according to the approved practice and all working equipment and other apparatus shall in like manner be well and accurately fitted, finished, fixed and adjusted.

10.8.4 Lubrication

All bushes and ball or roller bearings shall be arranged for grease gun lubrication. Grease nipples shall be standardised. Provision shall be made in the design to prevent the over-lubrication of any part. It is preferable that routine lubrication of the equipment shall be kept to a minimum.

Grease lubrication systems shall preferably be of the pressure type designed so that adjustment or recharging is not required more than once per nine days under normal operating conditions. Grease application points shall be easily accessible and, where needed, extension piping shall be provided. When a number of such points can be grouped, they shall be brought to a rigidly constructed battery plate and each point shall be clearly labelled. A permanently

la- belled grease gun shall be supplied for each type of grease required and each standard type of nipple fitted.

Oil lubrication shall preferably be of the re-circulating reservoir type, which automatically maintains the correct oil level and shall be designed for continuous normal operation for long periods. Sight glass level indicators shall be fitted on all oil reservoirs and the levels shall be easily read over the maximum operating range. Re-circulating oil lubrication systems shall be provided with an external replaceable filter element.

The level indicators shall be simple to dismantle for cleaning, clearly marked, with the minimum, normal and maximum oil levels at normal running temperatures and shall show the normal filling level at design ambient temperature. The sight glass shall be positively protected against mechanical damage. Particular care shall be taken in arranging lubrication points to protect the works and the process water from accidental contamination. Catch trays, drip trays, screens and the like shall be generously provided throughout the works.

The type of lubricants and intervals of lubrication for each individual item of equipment shall be entered on a working schedule, which shall form part of the operating and maintenance instructions. A complete schedule of recommended lubricants with their trade names, their purposes, viscosity, etc., container size and life and the name of the manufacturer (preferably one only) and his local supplier shall be stated in the Bid and is subject to written approval of the Engineer. The number of different lubricants shall be kept as small as possible.

Unless otherwise stated, the first oil or grease filling for bearings, transformers, etc., including the necessary quantity for flushing and for the first oil change, shall be included in the Bid Price.

10.9 Pipework for equipment and plant

10.9.1 General requirements

It shall be the responsibility of the Contractor to furnish and install all piping systems specified herein and shown on the contract drawings. Each system shall be installed complete with all applicable fittings, hangers, supports, anchors, expansion joints, flexible connections, valves, and accessories to provide a functional system as designed. In addition, all insulation, lining and coating, heat tracing, testing, disinfection, excavation, backfill and encasement shall be the responsibility of the Contractor.

The Contractor shall provide all tools, equipment, materials, and supplies necessary and shall perform all labour necessary to complete the work specified herein and indicated on the drawings. The Contractor shall provide all testing apparatus necessary to perform testing as required by the contract documents. The Contractor shall provide any equipment necessary for inspection of and testing of piping systems specified.

Piping shall be routed in an orderly fashion to facilitate operation and maintenance. Attention shall be paid to access to valves, instruments, etc. The layout of the piping shall also take into

account space requirements for conduits, cables, cable trays, isolators, etc. for the Electrical Contractor with a view to providing an integrated layout.

When installing piped services the following clearances shall be provided:

- walls 25 mm
- ceiling 100 mm
- floors 150 mm
- adjacent 25 mm (between finished surfaces including insulation where applicable)
- Cables and conduits 150 mm

No joint of any type shall be made in the thickness of walls, solid floors, etc. of any other position where access for maintenance is difficult.

Piping connected to Mechanical Equipment which will require dismantling e.g. pumps, vessels, etc. will be provided with flanges or couplings to allow easy removal of piping without cutting out piping. Piping around Mechanical Equipment will be adequately supported so that equipment can be removed/dismantled without the need to install temporary supports on piping. All piping must be installed without springing or forcing.

All necessary pipe supports shall be included either in the form of hangers, brackets or stub joints, and pipe work shall be adequately clamped to support by “U” bolts or similar approved fixings.

Pipe work shall be designed and installed so that no hydraulic thrust or dead-weight loads are transmitted to the pump flanges, castings or other machinery. Puddle flanges shall be provided on iron pipe work passing through walls. HDPE or other flexible pipe materials shall be provided with neoprene rubber sleeves.

The Contractor shall use end caps or plugs to prevent the entrance of dirt, water and other foreign matter into pipes, valves or fittings. Plates, plugs or caps may not be attached to the pipes by means of welding or any other method, which will damage the pipe ends. The caps or plugs shall be installed after finishing daily work or whenever work is interrupted for other than very short duration.

Flexible joints shall be provided for all piping connections to and from the skid mounted equipment.

The hydraulic test pressure applied at the manufacturer's works shall be twice the OP, or 1,5 x PN, whichever is the greater, unless otherwise specified. After completion of manufacture, all pipes shall be hydraulically tested. If any alterations involving additional fabrication are made after dispatch, a further hydraulic test will be required on the pipe or piping assembly concerned.

The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly clean before and during erection and before commissioning. Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. All small bore

pipes shall be blown through with compressed air before connection is made to instruments and other equipment.

The Contractor is obliged to determine the material and exact diameter of any existing pipe, to which a new pipe will be connected and shall submit to the Engineer a proposal for the intended transition pieces for approval before ordering the respective accessories. (The temporary excavation for searching / inspecting existing pipe will be paid as set forth in the Particular Specification and in the Bill of Quantities).

10.9.2 Internal cleaning for all water pipes

The Contractor shall ensure that the internal surfaces of all pipelines, valves, in-line-installed equipment and vessels are thoroughly clean before being placed into commission. The cleaning steps shall include, as a minimum the following:

Cleaning of internal surfaces prior to erection to remove dirt, rust, scale, and welding slag.

Prior to and during erection all parts shall be inspected to make sure they are clean and adequate steps taken to prevent entry of foreign matter both during and after erection. Each section erected shall be cleaned prior to the next section being connected. All headers shall be cleaned before closing up.

All pipework and vessels shall be thoroughly cleaned by blowing through, to atmosphere, with flushing water. The contractor shall provide all the necessary facilities including temporary pipework and valves.

The flushing medium shall in general be fresh water. When flushing stainless steel lines, the chloride ion content shall be less than 200ppm.

10.9.3 Additional disinfection for drinking water pipes

All pipework and vessels shall be thoroughly disinfected in accordance with the applicable DIN EN Standards.

10.9.4 Pipe connections

The following connections only shall be used for joints in piping:

- Butt Welds
- Flanges
- Pipe thread
- Couplings

In general piping will be all welded except as required on equipment or valves or for maintenance on equipment or valves.

Flanges for pipes and pipeline fittings shall comply with DIN 2642, BS 4504 Section 3.1 and 3.2, or equivalent for PN10 nominal pressure rating. Flanges for PN 6 shall be acc. to DIN

2631, for PN 10 to DIN 2632, for PN 16 to DIN 2633, for PN 25 to DIN 2634 and PN 40 DIN 2635 or equivalent

The nominal pressure rating for flanges in pressure systems shall be at least equal to the highest pressure rating of the pipes or fittings to which they are attached, but with a minimum nominal pressure of PN 10.

Flanges shall have flat faces and shall be attached with bolt holes straddling the vertical axis of the pipe unless otherwise shown. Flanges for miscellaneous small pipes shall be in accordance with the standards specified for these pipes.

10.9.5 Insulation flanges

Insulating flanges shall be used for joining flanged piping of dissimilar metals and for piping systems where corrosion or cathodic protection are involved. Insulated flanges shall have bolt holes 7 mm diameter greater than the bolt diameter.

10.9.6 Insulation flange sets

Insulating flange sets shall be provided where shown and where necessary to prevent contact between dissimilar metals. Each insulating flange set shall consist of an insulating gasket, insulating sleeves and washers and a steel washer. Insulating sleeves and washers shall be one piece when flange bolt diameter is 1-1/2-inch or smaller and shall be made of acetal resin. For bolt diameters larger than 1-1/2-inch, insulating sleeves and washers shall be 2-piece and shall be made of polyethylene or phenolic. Insulating gaskets shall be full-face.

All Witworth pipe threads shall be in accordance with BS 84/BS919, DIN-ISO 228, DIN 2999, DIN 3835

10.9.7 Gaskets

Gaskets shall be treated in accordance with manufacturers' instructions. Gaskets shall be replaced after opening or dismantling of flange connections.

Geometrical data of flat gaskets according to DIN 2690/2691/2692/2697, gasket characteristics according to DIN EN 1591-2. Gaskets shall be as stated below:

- Flat gaskets according to DIN 2690 for flanges with plane face PN 1 to PN 40, DN 10 to DN 4000
- Flat gaskets according to DIN 2691 for flanges with tongue and groove, PN 10 to PN 160, DN 10 to DN 1000
- Flat gaskets according to DIN 2692 for flanges with male and female face, PN 10 to PN 100, DN 10 to DN 1000
- Grooved metal gaskets according to DIN 2697, PN 64 to PN 400, DN 10 to DN 400, material PTFE, graphite or silver on several steels.

Generally, non-asbestos filler with neoprene or nitrile binder, 2 mm minimum thickness for plain finished surfaces and 3 mm minimum thickness for serrated surfaces. For drinking water gasket material has to be in compliance with German's KTW-Certification or Great Britain's WRAS Certification or equal.

10.9.8 Flexible connections

Piping connections on to positive displacement type equipment e.g., air-operated pumps, rotary gear pumps, etc., will be fitted with hygienic type flexible connectors. Corrugated type connectors shall not be used on product lines. End connections on connectors shall be fitted with flanges or couplings.

10.9.9 Pipe support & brackets

Pipe racks, pipe supports and pipe brackets will be fabricated from stainless steel only. Pipe racks and pipe supports will be adequately designed using stainless steel box section 50 x

50mm, 80 x 50mm, 100 x 50mm or a combination of such sections. Scaled Stainless Steel will generally be used except where polished is required or requested. Distance between brackets will be in accordance with static requirements. A detailed drawing of the pipe racks and supports must be submitted for approval prior to installation on site.

10.10 Welding works

10.10.1 General

All welding works shall be applied under most convenient working conditions, utilising modern, effective equipment and techniques and latest welding technologies. All welding shall be performed by welders qualified and experienced in the particular type of welding required. It shall be the responsibility of the Contractor to ensure that all welding operators are properly qualified and competent to carry out all required field welding.

Records of the welding procedures and welder performance qualification tests for work done shall be maintained by the Contractor for review by the Engineer. The method and procedure adopted for welding in workshops and at Site shall be approved by the Engineer before production starts.

For any welding work, only the appropriate welding rod, either arc or gas, shall be used. The tensile properties shall conform to the material to be welded as specified in the respective standards.

The electrodes for arc-welding shall be classified on the base of mechanical properties of the as-welded deposited weld-metal, type of covering, welding position of the electrodes and type of current.

No welding, burning, filling or plugging of defective castings or any other components shall be carried out without the Engineer's approval in writing.

All welds shall be shown in the detailed drawings as well as the welding sequence to minimise residual shrinkage stresses. For the various structures and plates to be welded, the Contractor shall submit adequate information concerning the proposed:

- a. Weld profiles for each type and size of weld type required, shop and field welds;
- b. Extent to which automatic and manual welding techniques will be applied;
- c. Use of pre-weld heat treatment, post-weld stress relieving, full anneal stress relieving or normalising;
- d. Weld electrodes, welding wire and flux to be used (also to be stated on drawing); and
- e. Standard tolerances for the deviations of mating weld profiles and the root gap tolerances.

10.10.2 Preparative works

Pieces to be joined by welding shall be cut accurately to size including the allowances. Welding edges shall be sheared, flame-cut or machined. The faces to be welded shall be free of all visible defects, such as laminations, surface defects caused by shearing or flame-cutting operations and free of rust, mill scale, grease, oil paint or any other foreign matter. Freedom from laminations shall be checked with ultrasonic or dye penetrate methods.

Welding over zinc primers shall be permitted subject to submission of a certificate of recognized institution, stating the limiting pertinent parameters for this welding procedure. In all other cases, welding over paint shall be prohibited; all painting materials next to the joint to be welded shall be removed for a distance 6 times the plate thickness, subject to 80mm minimum and 150mm maximum in the case of automatic welding.

Temporary or permanent welding shall not be permitted on areas where the welding will damage paint or other protective coatings, unless the areas of coatings which would be damaged thereby, are accessible for repair and inspection.

10.10.3 Welding process

Welding procedure specifications shall be furnished to the Engineer for approval prior to the welding of pipe. The specifications shall be in compliance with DIN EN 288 or BS EN ISO

15614 (Specification and qualification of welding procedures for metallic materials). The welding procedure form shall include the type of plate edge preparation, welding method, arc-voltage, arc-amperes, travel speed, wire size and type, flux type, and all other procedures necessary to make the weld.

Welding, when required and approved by the Engineer, shall be done by qualified welders, who have been previously tested according to approved standards to do this type of work. All techniques pertaining to welding shall conform to approved standards for arc and gas welding in pipeline construction.

All welds shall be made in such a manner that residual shrinkage stresses will be reduced to a minimum and that no stress relieving treatment will be required.

A welding procedure specification (WPS) shall be established for all welding which will be used in the fabrication of piping systems. The WPS shall contain the information listed in DIN EN 288 or BS EN ISO 15614. Prefabrication of stainless steels, Copper, Titanium and Nickel based alloys should be performed in a workshop, or parts thereof, which is reserved exclusively for those types of materials.

10.10.4 Welding consumable standard

All welding consumables shall have individual marking. All extra low hydrogen consumables for carbon steels and all consumables for welding of stainless steel Type 6Mo, Type 22Cr or

25Cr duplex, Nickel and Titanium alloys shall be delivered according to manufacturer data

sheets and with certification according to EN 10204 Type 3.1B. Certificates should contain chemical analysis of weld metal including C, Si, Mn, P, S and any other intentionally added element stated in the data sheet. Level of impurities maximised in the data sheet or classification code should be stated, but may be given as guaranteed maximum. The data sheets should contain guaranteed values on mechanical and impact test results as long as the welding is carried out within the recommended range. If the consumables shall be used for welds in Post Weld Heat Treatment (PWHT) condition, then the properties shall also be documented in Welding Procedure Qualification Record (WPQR) condition. Batch testing of the welding consumables is also acceptable. The welding and testing shall be carried out as required for a WPQR for the actual material. Consumables for other materials and fluxes for submerged arc welding processes shall be delivered with certification according to EN 10204 Type 2.2.

10.10.5 Welder and welding operator qualification

All bracers, welders and welding operators shall be qualified in accordance with ASME IX, EN287, ISO 9606, EN 1418 as applicable or equivalent codes.

10.10.6 Inspection and testing

Inspection of welds during production welding shall be carried out according to EN 970 by a qualified inspector. All pipework systems will undergo the following inspections/tests:

- 1) Radiography of 10% of all welds. Half of these shall be taken as early as possible to identify potential problems. The welds for examination will be selected by the Engineer. Radiographic techniques shall be in accordance with BS 2600 Parts 1 & 2 & BS 2910.
- 2) Wet systems will undergo a 12-hour pressure test at 1.50 times maximal operating pressure. Pressure shall not drop by more than 5% over this period. The contractor will be responsible for carrying out the test and supplying all necessary equipment, including certified calibrated pressure gauges.

- 3) Dry systems will undergo a 12-hour pressure test at 1.50 times maximal operating pressure. Pressure shall not drop by more than 5% over this period. The contractor will be responsible for carrying out the test and supplying all necessary equipment, including certified calibrated pressure gauges. During this period a soapy water leak test of all joints will also be carried out.

All systems will undergo a visual inspection to ensure all supports have been correctly installed, and that all paintwork or other coatings have been properly applied. Should deterioration of paintwork or coatings become evident at a later stage this inspection shall not remove the obligation from the contractor to rectify the defect.

The critical item to be checked is the finish on the inside of the weld. The following defects in the welding will result in the weld being rejected.

- Over-penetration resulting in root concavity
- Occlusions in the internal weld surface
- Lack of fusion resulting in an incomplete weld
- Inadequate gas purging results in oxidation on the internal weld surface.

All welding (except welding of thin plates or piping of small sizes) shall be performed by the electric-arc method and where practical, under procedure control using automatic machines. For any welding work, only the appropriate welding rod, either arc or gas, shall be used. The properties shall conform to the material to be welded as specified in the respective standards. The electrodes for arc-welding shall be classified on the basis of mechanical properties of the as-welded deposited weld-metal, type of covering, hydrogen absorption, welding position of the electrodes and type of current.

Electrodes shall be used only in the positions and under the conditions of intended use in accordance with instructions for each type and with all safety precautions. Electrodes for manual welding shall preferably be the heavily coated type and shall be suitable for welding in any position. Tacks should be removed before welding. Electrodes shall be dried in electric ovens before use.

After being cooled and deposited, welds shall be cleaned of slag and shall show uniform sections, smoothness of weld metal, feather-edges without overlap, and freedom from porosity and clinker. Visual inspection of the ends of welds shall indicate good fusion with the base metal.

Where weld metal is deposited in successive layers, each layer shall be thoroughly preened before the next layer is applied, unless otherwise approved by the Engineer. Particular care shall be taken in aligning and separating the edges of the members to be joined by butt-welding so that complete penetration and fusion at the bottom of the joint shall be ensured. All pinholes, cracks and other defects shall be repaired by chipping or grinding the defects to sound metal and re-welding. Where fillet welds are used, the members shall fit closely and shall be held together during welding.

The ignition of weld electrodes shall not be started at the plate beside the weld, but at the seam flanks to prevent detrimental increments of local hardness. Where ignition points of electrodes are discovered, they shall be ground appropriately.

Where auxiliary structural members are welded to components for the purpose of assembly or installation, the connecting welds of these shall be given particular care. The auxiliary structural members shall be removed not by knocking them off, but by burning, followed by grinding the affected areas flush with the plate, without producing additional thermal stresses.

10.10.7 Welding of carbon steel

Manual, shielded metal-arc, submerged arc, gas metal-arc, flux-cored arc, gas tungsten arc, and other applicable welding processes and methods may be used in the construction and fabrication of welded carbon steel equipment. Prefabrication in workshop shall as far as possible be used.

10.10.8 Welding of stainless steel

The welding method which shall be used, shall be the tungsten inert gas method (TIG) or the metal inert gas method (MIG) for both workshop welding and Site welding. For workshop welding the metal arc, plasma method is also approved. Irrespective of the method chosen, the inner surface of the welds shall be protected by clean inert gas.

In order to guarantee high quality welded joints, piping and other quality stainless steel equipment shall as far as possible be prefabricated in the workshop. Furthermore, for stainless steel welding the following shall be noted:

- 1) Only butt weld jointing of the pipes is allowed during the erection work
- 2) Where butt welds are used, the penetration shall be completed, if necessary, with root run
- 3) Backing rings shall not be used
- 4) No surface defects reducing the corrosion resistance or discoloration of the surface will be accepted
- 5) After welding, the welds shall be carefully pickled and passivated
- 6) The welds must be thoroughly washed in clean water after pickling and passivation
- 7) Sand blasting will not be permitted for stainless steel.

10.10.9 Heat treatment

All weld-fabricated parts and castings except minor parts, parts where stress is not important or parts which are specifically exempted from stress relieving shall be designed, fabricated, stress relieved and inspected in accordance with an approved "Boiler and Pressure Vessel Code". All such parts shall be stress relieved as a unit prior to final machining.

Heat treatment of field erection welding seams shall be performed according to the specifications for the welding procedure for the corresponding parts, which shall be submitted to the Engineer for approval.

10.11 Corrosion protection of equipment

10.11.1 Coating

To ensure the proper execution of cleaning and preservation processes, under conditions of prescribed temperature and permitted air humidity and with employment of the correct drying times, the Contractor shall maintain close contact with the paint supplier during the execution and shall adhere stringently to the suppliers' instructions. The preservation operations shall be executed, as far as possible, in a covered space, prior to the dispatch of components to the site of their installation.

Components to be cast in with concrete shall be preserved prior to their being cast in by means of the galvanisation or equal of all their surfaces that will lie external to the concrete or internal to the concrete up to a depth of approximately 100 mm; surfaces internal to concrete shall not be painted.

Cleaning of steel components shall incorporate thorough stripping-off of grease, good drying and subsequent thorough de-rusting and abrasive-blast or pickle cleaning; All non-stainless equipment should be shot blasted to degree of cleanliness after blasting, as defined by relevant DIN standard, as given below:

- i. degree Sa 2 for red-lead primer etc.;
- ii. degree Sa 2½ for zinc-epoxy and zinc-polyurethane coatings;
- iii. degree Sa 3 for metallized coatings.

Painting shall be made as specified in the following. The paintwork must be free of drips, runs and blisters.

This specification shall be used for the corrosion protection of steel structures, components, piping and equipment in general which are installed in confined areas (indoors) or outdoors.

Paint shall be delivered to the shop and the Site in original sealed containers, which shall be clearly marked with the manufacturer's name and the identifying brand number or name. The paint shall be used as prepared by the manufacturer without thinning or other admixtures. Steel encased in concrete shall not be painted.

Surface preparation, as well as protective coatings and coating systems are based on this specification in order to assure that structural parts of different suppliers will get a corrosion protection of similar and high quality.

Regarding maintenance work (storage), application and supervision of coating work, choice of coating suppliers should be minimized. At any rate, similar parts of structures/components (such as structural steel, containers, piping, etc.) shall only be coated with products of one individual manufacturer.

The materials and equipment used, the methods of application and the quality of work shall at all times be subject to the inspection and approval of the Engineer.

Applicable standards are:

- i. Product data of coating manufacturer
- ii. DIN 2403, Indication of pipe-lines according to flowing material
- iii. DIN 4762, Surface roughness
- iv. ISO 8503, Surface roughness
- v. DIN 8201, Part 1-9 tight blasting agents
- vi. DIN 50976, Corrosion protection, hot dip batch galvanizing of single parts, requirements and testing
- vii. DIN 55928, Part 1-9 corrosion protection of structural steel work through protective coatings and topcoats
- viii. ISO 8501, Preparation of steel substrates before application of paints and associated products
- ix. ISO 12944, Paints and varnishes – corrosion protection of steel structures by protective paint systems
- x. RAL, Colour card
- xi. SIS 05 5900, Swedish standard
- xii. SSPC Vol. 1 and 2, Steel structure painting council.

Surface preparation and cleaning of surfaces in the shop prior to blasting, areas have to be cleaned from

- i. oil
- ii. grease
- iii. paint residues
- iv. splatters
- v. mill scale
- vi. welding splashes and
- vii. welding slag.

Sharp edges have to be rounded off. Contamination caused by salts, acids and alkali solutions shall be eliminated by rinsing with water up to a pH value of 6-8.

The preparation of substrates shall be carried out on the basis of the specifications of DIN 55928 part 4 and ISO 8501.

After blasting, an anchor profile of 25-50 μ shall be achieved. Blasted surfaces have to be provided with a prime coat of the considered coating system immediately after blasting.

10.11.2 Cleaning to be performed on site

Steel work protected by shop primer after arrival on site must be cleaned of salt, sand, oil, etc. before the first coat of paint is applied on site. Shop primer damaged during transport must be rectified by blast-cleaning and coating before application of the site coats.

Wood surfaces shall be sanded clean. All nail holes shall be puttied and sanded before priming.

If a protective coating of concrete is required, concrete shall be allowed to cure before painting.

Transport and erection damages, as well as damages which result out of additional welding have to be repaired as soon as possible. The damaged areas have to be de-rusted with rotating or steel brushes, abrasive wheels, abrasive blasting according to Standard CST3, DIN-ISO8501-1.

i. Cleaning Of Prime and Intermediate Coats (If Required)

To prevent contamination by mineral oil products, areas with prime and intermediate coat have to be treated with suitable cleaning agent. Cleaning has to be done free of residues, e.g. with alkaline detergents and thorough washing done with fresh water. Rusty spots have to be removed according to required purity. Metallic areas which are provided with temporary corrosion protection have to be cleaned. No oxidation products shall remain on the surface. Furthermore it has to be taken care that on hot components no destructive or reaction products will be released when heating which could injure insulation.

ii. Application Procedure

When using the provided coating material, strict adherence to all application instructions given in product data of coating manufacturer is necessary. To obtain the maximum performance, technical data as well as application instructions for the individual coating material have to be strictly followed.

For a multi-layer coating system each layer has to have a different colour shade in order to clearly identify number of coats applied. The last finish coat has to be applied in the specified colour shade.

The interval between applying the different coats has to follow according to supplier's precautions. Each layer has to be cleaned and released from spray dust before the next layer will be applied. Prior to applying a further layer, the last one has to be repaired. All coatings have to be applied without retarding. Following application procedures are allowed:

- prime coats by airless spray areas like disconnection, angles, corners, etc. which are difficult to be reached can be applied by brush or roller
- repair of prime coat by brush
- finish coats
- at works by airless spray, roller or brush
- at site by roller or brush or airless spray.

When applying coating systems by roller, rollers have to be of kind and quality which make an appropriate application possible.

Control areas in accordance with the coating supplier's instructions have to be applied. For this procedure, a schedule for control areas has to be prepared by

the Contractor and coating supplier which corresponds with the requirements of the warranty agreement.

Number and performance of the control areas have to be done in accordance with DIN 55928 part 7 and have to be documented in writing.

No application may take place either when the relative humidity will not be within the given limit or in case of fog, dust, rain or hail or when it can be assumed that such conditions of poor weather within 2 hours after application can arise.

All specified dry film thickness (DFT) are minimum thickness.

Welding seams mounted at site have to be taped with an adhesive tape of about 30-50 mm after surface preparation (blasting or manual de-rusting) and prior to application in the manufacturing plant and to be coated with stripping coat.

Chequered plates, nap plates, etc. have not to be covered with adhesive tape, but have to be coated with stripping coat in a dry film thickness of at least 150 µm.

Edging lines on steel structure have to be taped prior to application and after blasting in sufficient width or have to be protected with varnish before application. Thickness of prime coat may be 50 µm max.

During repairing works at site on shop-primed structures, it is important that different coats will have different colour shades. Numbers of layers have to be the same as the original coating system to be used.

Application of temporary primer on structures which have to be insulated has to be in accordance with sufficient corrosion protection for the period of storage respectively erection time.

iii. Coating Warranty

The general guarantee and maintenance periods as stated in the Conditions of Contract shall not apply to protective coatings work.

The guarantee period for all paintings shall be five years, commencing from the issue of the Certificate of Completion. These protective coatings guarantee period shall be effective regardless of any other guarantee periods for the project or parts of the project, or any Certificate of Maintenance, issued prior to the elapse of the painting guarantee period. The Contractor shall perform requested painting repair work at no charge to the Client if the painting quality guarantee is not met during the guarantee period.

iv. Galvanising

Galvanising work shall conform in all respects to DIN 50976 or BS 729, BS 3083 and BSCP 2008 and shall be performed by the hot dip process unless otherwise specified.

It is essential that details of steel members and assemblies which are to be hot-dip galvanised should be designed to suit the requirements of the process. They should be in accordance with BS 4479 and DIN 55928.

Vent holes and drain holes shall be provided to avoid high internal pressures and air locks during immersion and to ensure that molten zinc is not retained in pockets during withdrawal. Careful cleaning of welds is necessary before welded assemblies are dipped.

All defects of the steel surface including cracks, surface laminations, laps and folds shall be removed in accordance with BS 4360. All drilling, cutting, welding, forming and final fabrication of unit members and assemblies shall be completed, where feasible, before the structures are galvanised.

The minimum average coating weight shall be as specified in Table 1 of BS 729. Structural steel items shall be first grit-blasted to BS 4232, second quality, (SA 2.5) or pickled in a bath, and the minimum average coating weight on steel sections 5 mm thick and over shall be 900 g/m², on steel sections 2 – 5 mm thick 600 g/m².

Galvanised contact surfaces to be joined by high-tensile friction-grip bolts shall be roughened before assembly so that the required slip factor (defined in BS 3294 part 1 and BS 4604 part (1) is achieved. Care shall be taken to ensure that the roughening is confined to the area of the mating faces.

Table B5-01: Coating Systems

| System- No. | Surface location | Temp. °C | Surface Preparation | Coating systems | No. of coats | Generic type | Dryfilm thickness (DFT) per coat µm | Total DFT µm |
|-------------|---|-----------|---------------------|-----------------|--------------|----------------------|-------------------------------------|--------------|
| 1 | Structural steel works, piping, vessels, tanks INDOOR | up to 120 | SA 2.5 | Primer | 1 | Zinc-Epoxy | 80 | 80 |
| | | | | Finish | 1 | Epoxy High Solid | 80 | 80 160 |
| 2 | Structural steel works, piping, vessels, tanks OUTDOOR | up to 120 | SA 2.5 | Primer | 1 | Zinc-Epoxy | 80 | 80 |
| | | | | Intermediate | 1 2 | Epoxy High Solid | 160 | 160 |
| | | | | Finish | 1 | 2-Comp. Polyurethane | 50 | 50 290 |
| 3 | Piping, tanks, etc. | up to 120 | SA 2.5 | Primer | 1 | Zinc-Epoxy | 50 | 50 |

Additional 1 x Finish Coat 2-Comp. Polyurethane, 50 µm, when exposed to UV and colour retention is required or when exposed to weathering.

Protected slings must be used for off-loading and erection. Galvanised work to be stored at the works or on site shall be stacked so as to provide adequate ventilation of all surfaces to avoid wet storage staining (white rust).

Small areas of the galvanised coating damaged in any way shall be restored by: Cleaning the area of any weld slag and thorough wire brushing to give a clean surface. The application of two coats of zinc-rich paint, or the application of a low melting point zinc alloy repair rod or powder to the damaged area, which is heated to 300°C.

Connections between galvanised surfaces and copper, copper alloy or aluminium surfaces shall be protected by suitable tape wrapping.

v. Chromium plating-

All chromium plating shall comply with EN 12540.

10.12 Materials incorporated.

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

10.12.1 Wrought steel

Where not otherwise specified, wrought steel parts shall be selected from appropriate grade of EN 10083 and be free from blemishes, shot or hammer marks. The Contractor shall submit for the approval of the Engineer, the grade number selected for the various components.

10.12.2 Cast molybdenum.

Cast Molybdenum steel shall be supplied to EN 10293.

10.12.3 Cast iron

All grey iron castings supplied shall be to the appropriate grade in EN 1561. All castings shall be free from blowholes, flaws and cracks.

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

10.12.4 Bronze

Except if specified otherwise, bronze shall be strong, durable and free of zinc acc. to EN 1982.

10.12.5 Aluminium and aluminium alloys

Due to the corrosive atmosphere, the use of aluminium or aluminium alloys requires the approval of the Engineer in all cases. Alloys shall be of types used for marine applications where magnesium is the main addition. Castings shall be manufactured according to EN 1676 and EN 1706.

Full details of the composition of each alloy shall be supplied to the Engineer for approval, before commencing manufacture. Immersed structures or structures that are periodically immersed shall not be constructed from aluminium or aluminium alloys.

10.12.6 Stainless steel

Stainless steel shall be provided in accordance with Grade 316S13 to EN 10088 if not specified otherwise.

10.12.7 Finish

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

10.13 Foundations

Base shall be designed to support the assembled weight of the equipment. Base shall safely withstand all stresses imposed thereon by vibration, shock and all possible direct and eccentric loads. Base shall have adequate horizontal dimensions foundation contact area, anchorage facilities and shall be of sufficient height. Base shall be made of reinforced concrete. Bolts for installation shall be firmly keyed and grouted into concrete foundation blocks. Height shall be minimum 100 mm.

If applicable, set and level equipment, grout under equipment base with non-shrink grout (preferable resin based grout), minimum thickness 15 mm.

Vibration Level: All equipment subject to vibration shall be provided with restrained spring-type vibration isolators or pads per manufacturer's written recommendation.

Shop Drawings: Shop drawings shall be submitted to the Engineer for review. Shop Drawings will be considered incomplete unless clear, concise calculations are presented showing equipment anchorage forces and the capacities of the anchorage elements provided by the Contractor.

10.14 Appurtenances

10.14.1 Screw, bolts and nuts

All bolts, screws, anchor bolts, etc., including sleeves, nuts, washers, locking devices, etc., required for all equipment and accessories to be supplied under this Contract shall be furnished. Except for those consisting of stainless materials, they shall be adequately treated against corrosion before dispatch from the works. All threads shall be greased carefully during installation except where otherwise specified. Split pins or other approved locking devices generally shall be provided for nuts which may become loose due to vibration, etc.

All bolts, nuts, screws and other devices used to fix, clamp or adjust any parts, which are of stainless steel, or exposed to water or high humidity, or subjected to frequent adjustment or frequent removal shall be of corrosion resisting steel or bronze. All other bolts and pins shall be of carbon steel.

When in position, all bolts or screwed rods shall project through the corresponding nuts, but this projection shall not exceed three threads, unless more length is required for adjustment.

The Contractor shall supply the net quantities plus 5 % of all permanent bolts, screws and other similar items and materials required for installation of the works at the Site. Any such rivets, bolts, screws, etc., which are surplus after the installation of the equipment has been completed, shall become spare parts and shall be wrapped, marked and handed over to the Engineer.

10.14.2 Anchor bolts for equipment

Equipment suppliers shall furnish suitable anchor bolts for each item of equipment. Anchor bolts together with templates or setting drawings shall be delivered to permit setting the anchor bolts when the structural concrete is placed. Two levelling nuts shall be furnished for each bolt. Unless otherwise shown on the Drawings or specified, anchor bolts for items of equipment mounted on baseplates shall be long enough to permit 4.0 cm of grout beneath the baseplate and to provide adequate anchorage into structural concrete. Bolts shall extend with at least two threads over the nut after final alignment.

Unless otherwise specified or approved by the Engineer, anchor bolts, nuts, and washers shall be stainless steel.

10.14.3 Vibration dampers

Vibration dampers comprising steel springs shall be used for the installation of generators.

The isolation mountings shall consist of malleable cast iron top and bottom housings incorporating one or more steel springs and shall be provided with built-in leveling bolts, elastomer pad and built-in resilient chocks to control oscillation and withstand lateral forces in all directions. They shall be pre-sized and installed in accordance with the recommendations of the generator set manufacturer.

10.14.4 Bearings

Bearing Life: Except where otherwise specified or shown, all bearings shall have a minimum B-10 life expectancy of 5 years or 20,000 hours, whichever occurs first. Where so specified,

bearings shall have a minimum rated B-10 life expectancy corresponding to the type of service, as follows:

Table M -02: Design life for bearings

| Type of Service | Design Life | B-10 Design Life (hours) |
|-----------------|-------------|--------------------------|
| 8-hour shift | 1 | 20.000 |
| 16-hour shift | 1 | 40.000 |
| continuous | 1 | 60.000 |

All lubricated-for-life bearings shall be factory-lubricated with the manufacturer's recommended grease to ensure maximum bearing life and best performance.

- i. All bearings shall be according to DIN standard, S1 unit dimensions where practicable.
- ii. Bearings shall be wherever applicable arranged external and be removable with the rotating element.
- iii. Bearings shall be wherever applicable adequately rated ball or roller type and shall be arranged to take all radial and axial loads during start-up and running conditions.
- iv. Bearings shall be mounted in dust-proof housing and provided with accessible lubricating points for grease gun greasing.

10.14.5 Gearboxes

Standard enclosed gearboxes for machines shall be obtained from an approved manufacturer where necessary. The gearbox shall be designed to operate with the output shaft tilted to the required angle of inclination without lubricant leakage. The input shaft shall be horizontal where possible and appropriate.

All gearboxes shall be suitable for outdoor installation and shall be derated considering continuous operation and heavy shock loads. Service factor shall not be less than 2. The thermal horsepower rating of the gear reducer shall exceed the motor horsepower after derating for 50°C ambient temperature. The gearbox selection shall be checked for momentary over-loads and overhung of radial and thrust loads. Gearbox housings shall be of rigid high-strength close grained cast iron with provisions for:

- i. proper closing inspection cover,
- ii. ventilation opening,
- iii. oil level gauge,
- iv. gauge window protection.

The ingress of moisture into the gearbox shall be prevented and splash and leakage water, etc., must be able to drain off easily. The transmission of power shall be achieved by means of precision gears. Helical gears shall be used. Cylindrical gears having helical or herring-bone teeth shall be precision ground for close tolerance operation.

All gears shall be amply designed, both with regard to surface durability and bending strength, guaranteeing a life span of at least 100,000 hours running.

The gearbox shafts shall be solid forging of the parallel type, precision ground and made from heat-treated hardened and tempered chrome-molybdenum alloy steel. Gearbox shafts shall be mounted on tapered roller bearings of double row anti-friction self-aligning spherical roller bearings (or as recommended by the gearbox manufacturer) capable of handling radial and thrust loads simultaneously and guaranteeing a life of at least 50,000 hours running.

Lubrication of the gear teeth surfaces shall be achieved by being immersed in the oil contained in the gearbox housing. For this purpose the gearbox shall be oil-tight and shall be such as to prevent the total loss of oil from the gearbox in the event of the failure of the oil seals. The whirling oil and the oil dripping from the surfaces shall lubricate the bearings.

Where immersion or splash lubrication is not effective, gears and bearings shall be lubricated automatically by a forced lubrication system. Lubricants shall be as or equal to that recommended by the manufacturer of the gearbox. Provision shall be made in the design of gear-boxes for oil filling and drainage. If the drain is not easily accessible, the gearbox shall be equipped with an outlet hose and small hand pump.

The gearbox shall be provided with a flexible overload coupling (including safety guards) between the motor and the input shaft of the gearbox. Parts subject to wear must be easily replaceable without disassembling the motor.

Particular care shall be taken in designing gearbox arrangements to protect the works or water under treatment from contamination arising from accidental overflow, any future leakage due to excessive wear, seal failure, or poor filling or drainage practices. Drip and catch trays and the like shall be generously provided throughout the works.

10.14.6 Couplings

Couplings shall be generously rated to cover the full range of duties. Couplings liable to impregnation by oil shall be of the all metal flexible type. General service couplings shall be of the flexible multi-pin and bush type, having not less than six bushes and each bush shall have an inner sleeve to allow rotation on the pin (bushes shall not be in direct contact with the pin). All pins shall have shoulders to allow positive location and securing to the bosses. Bosses shall be a tight fit on the shafts and secured with hand fitted keys.

Couplings shall be supplied in matching balanced sets and shall be machined, balanced and marked before leaving manufacturer's works. All couplings shall be fully checked for alignment and all necessary equipment for checking alignment shall be supplied by the Contractor. Particular attention shall be paid to achieving accurate alignment of solidly bolted couplings and the Contractor's proposed alignment procedure shall be to the approval of the Supervisor. In particular, alignment procedures which involve rotating only one half coupling will not be accepted. The coupling alignment procedure shall include a final check in the "bolted-up" condition for "cranking".

Where flexible couplings are used, the Contractor shall fully describe the arrangements proposed for ensuring that the desired freedom of relative movement between the shafts is

obtained, when transmitting a torque corresponding to the continuous maximum rating. Final alignment shall be checked by the Contractor in the presence of the Engineer.

10.15 Centrifugal pumps

10.15.1 General requirements

These rules and regulations define the requirements for single and multi-stage centrifugal pumps with axial, semi-axial and radial flow, and for dry or submersible installation.

Pumps shall be capable of satisfying the performance requirements as specified; be quiet in operation and free from vibration. Pumps shall be mounted on base plates or suction stools manufactured of cast iron or steel plate or suspended on the riser pipe. The pumps shall be accurately aligned and fixed by dowels or machined spigots. Holes shall be provided in the base plates or stools for foundation bolts.

Pumps shall be driven by electric motors except if stated otherwise in the Contract.

Production of pumps shall conform to current standards such as ISO 9905, ISO 5199 and ISO 9908, and IEC standards.

A label made of non-deteriorating material shall be attached to each pump and motor in a place where it can be easily read and shall show the following information:

- i. Manufacturers, serial numbers and types of both pump and motor
- ii. Nominal flow in m³/h (Qopt)
- iii. Manometric head in m (Hman opt)
- iv. Efficiency Eta opt in %
- v. Net positive suction head (NPSH req opt) in m
- vi. Power consumption, voltage, start-up mode in kW, V.
- vii. Speed of rotation 1/min

Pumps shall withstand continuous operation at full load (8000 hours/year).

Except if specified otherwise elsewhere in the Contract Documents pump shall be designed in such a way that the main duty point shall be set as near as possible to the optimum. The duty point(s) shall be guaranteed according to ISO 9906 Class 1. If one or several pumps are installed in parallel the characteristics shall be identical.

The maximum output of the pump shall be related to the maximum allowable performance of the motor.

The regime of the pump shall be stable within the range defined for each particular pump. In the absence of such definition of range, the regime shall be stable and permissible up to 130% of the nominal flow.

Pump and motor material shall be suitable for the liquid they are to propel (aggressiveness, abrasion, shape of impeller and comply with detailed regulations. Ambient temperature and pumped water temperature shall be as set forth in Sec. VI C of the ISO standard.

The documentation for each pump shall include, all three-fold:

- i. Manufacturer's declaration / certificate of conformity
- ii. ISO certificate
- iii. Type test report to EN 10204
- iv. Test report of electric motor
- v. Technical data sheets of pump and electric motor
- vi. Dimension sheets for pump and electric motor
- vii. Sectional drawings showing all parts of pump and electric motor
- viii. Installation and operating manual in English language for pump and electric motor
- ix. Foundation drawings / installation plan
- x. Connection diagram
- xi. Certificates of material and all tests mentioned above
- xii. Standard centrifugal pump

10.15.2 Pump

Pumps shall be standardised single stage volute casing low pressure pumps according to EN 773, for horizontal installation, rotating part statically and dynamically balanced, with bearing bracket in back pull-out design. Bearings shall be grease-lubricated, maintenance-free, deep groove ball bearings, sealed for life, shaft seal shall be uncooled soft-packed stuffing box packing, suitable for potable water, asbestos-free, flanges drilled to ISO 7005/2 (DIN 2501).

10.15.3 Motor

Motors shall have 2 or 4-pole rotors; motors between 1.1 kW and 90 kW and shall comply to CEMEP Voluntary Agreement (European Committee of Manufacturers of Electrical Machines and Power Electronics) and / or EPACT (Energy Policy Act, USA) requirements for energy saving, be squirrel cage induction motors, efficiency class EFF1 "high efficiency", and bear the corresponding values on the rating plate, protection class IP 55 (TEFC) and IK 08 for mechanical protection, continuous duty class S1, basic design, normal rated output for ambient temperature up to 40°C at altitudes up to 1,000 m above sea level, de-rating at higher altitude and higher temperature as may be set forth in Sec. VI C. Larger electric motors shall be similar to the "high efficiency" motors, the efficiency at 4/4-load has to be at least 95.0% for ratings above 90 kW and below 200 kW, and has to be at least 95.5% for ratings of 200 kW and above.

Thermal class shall be according to International IEC and EN standard, fabricated to ISO 9001 quality standard, electrical standards IEC 60034, IEC 60038 and IEC 60085, and mechanical standards IEC 60072 and IEC 60034, dynamic balancing to ISO 8821. However, all motors shall be designed acc. to thermal class F, but the temperature rise shall be allowed

to class B only, allowing a service factor of 1.15. Permissible temperature rise to IEC 34-1. Rated voltage shall be 400 Volts +5/- 20%, exceeding IEC 60038 standard, winding 400 V /690 Volt Y, frequency 50 Hertz.

Number of starts shall be not less than 5 per hour, 3 minutes between restart. Scope of supply of a standard pump unit. Pump and motor completely mounted, painted, c/w soft-packed stuffing box, with strong type plate of corrosion-resistant material properly secured to the casing

Common base plate / base frame for pump and electric motor in torsion-resistant design, including foundation bolts and nuts.

i. Materials

Materials of pump and motor shall be as follows:

- | | |
|-----------------------------|--|
| • Volute casing: | Grey cast iron JL 1040 (GG-25) |
| • Bearing bracket: | Grey cast iron JL 1040 (GG-25) |
| • Discharge cover: | Grey cast iron JL 1040 (GG-25) |
| • Impeller: | Bronze CC480K-GS (G-CuSn10) |
| • Pump shaft: | Steel C45 or chromium steel 1.4021 |
| • Wear rings: | Bronze CC495K-GS (G-CuPb10Sn) or equivalent |
| • Shaft protecting sleeves: | Stainless steel 1.4122 or equivalent |
| • Outside coating: | after surface treatment, 2-pack zinc-rich primer and top |
| | coat of epoxy resin, layer thickness of not less than 100 micron in ultra- marine blue |
| • Inside coating | after surface treatment, 2-pack zinc-rich primer and top |
| | coat of epoxy resin, layer thickness of not less than 125 micron in black |

ii. Accessories of a standard pump unit

All necessary accessories as specified below shall be provided by the Contractor:

- Flexible coupling with spacer sleeve allowing dismantling of impeller without loosening of pipework or motor
- Coupling guard as per EN 294
- Flushing / sealing water pipe
- Pressure gauges of CrNi-steel, 0 to 10 / 16 bar at discharge, –1 to 1.5 bar at suction side, muting, cocks, vents
- Drain, horizontal
- Spare parts for 5 years' service for the pump and the electric motor
- Packing and Shipment of a standard pump unit

Unless stated otherwise in the specifications, the pump unit shall be supplied completely assembled and mounted on the common base plate / base frame in a strong and suitable case / crate / wooden box suitable for shipment to the place of ultimate installation.

10.16 Pressure vessels

All vessels shall be designed in accordance with the applicable international manufacturing and safety standards and regulations. The Contractor shall only supply and install proven brands and types of vessels.

All necessary connections shall be provided for all pipe work, together with connection and tapping points for instrumentation. Manholes, vents, drains, air valves, safety devices and any platforms necessary for safe operation and easy maintenance shall be included in design and supply. Air valves shall be sized to prevent pressure below atmospheric pressure under any possible transient or permanent status of operation.

The welding factor for all vessels shall be $v = 1.0$. The minimum wall thickness shall not be less than 7 mm, and an appropriate corrosion allowance based upon the particular material, but not less than 1 mm.

Instrumentation and control equipment shall be provided to assure safe operation. As a minimum all vessels shall be equipped with a local analogue level indicator and a manometer. Where the fluid is other than cold water a thermometer shall be installed.

- Manholes shall be provided as follows:
- Manhole (minimum clear diameter 600 mm) for vessels of 1.0 meter diameter and above
- Hand holes (minimum clear diameter 200 mm) for vessels below 1.0 meter diameter.

All nozzles shall be provided with flanges and shall be so arranged that pipe connections are easily accessible. The stub length for all stub pipes shall be not less than 200 mm, measured from the tank wall to the flange sealing surface. In the case of insulated vessels, the length shall be chosen so that there will be a clear space of at least 100 mm between the cover of the insulation and the underside of the flange. Nozzles of nominal bore DN 50 and less shall be reinforced by stiffeners. Nozzles shall not have a diameter less than DN 25.

For insulated vessels, provision shall be made for fixing and supporting of insulation. Manhole covers of nominal weight more than 20 kg shall be provided with hinged arms. All elements inside the tanks shall be replaceable through the manhole.

Prefabricated vessels shall have complete coating inside and not less than a coat of primer outside applied before shipment. The inside of vessels shall be cleaned and dry. All openings shall be firmly closed with blank flanges or caps shipment.

10.17 Air blower and compressor

Air blowers and compressors shall be oil-free and air-cooled suitable for use in potable water process. Air blower and compressor units shall be complete and shall include, motors, pressure switches, gauges with pressure snubbers and isolating cocks, pressure tanks with hand- holes, relief valves, drain cocks from tanks with pipe taken to nearest gully, line pressure regulators, oil separators and all other necessary controls, pipework, etc.

The units shall have suction filters, suction and discharge silencers and be mounted on vibration isolators on a common rigid mild steel base plate on top of the receiver. The pipework connections to the compressors shall be flexible to avoid vibrations being transferred to the pipes or to any structures.

The units shall be manufactured in accordance with the respective EN and DIN standards and specifications for design and construction of reciprocating type compressors. The acceptance tests for the compressors shall be carried out in accordance with ISO 1217, Methods for simplified acceptance testing of air compressors.

10.18 Drain pumps

Drainage pump units shall be suitable for installation in wet well and shall have non-clogging impellers.

The motor and the pump shall form a complete integral unit suitable for operation in submerged condition. The stator casing, pump housing, impeller and discharge connection shall be manufactured of cast iron. The pump shaft shall be made from stainless steel and the bearings shall be of metal carbide resistant to sand.

The pump shall be equipped with a complete level control system with automatic start and stop of the pump. The discharge pipe, of same diameter as the pump discharge, shall be included and routed as shown on the drawings. The pipe shall be of galvanised steel and shall have an additional outside and inside protection of two layers of bitumen.

10.19 Generators

10.19.1 General

The power generating system shall supply electrical prime power to the equipment as required to maintain basic system functions in the case of shutdown of grid. It shall consist of one generating set, operated by a diesel engine driving a 3-phase synchronous alternator with 1500 rpm. The rating of the generating set shall be as indicated elsewhere in the documents.

Prime Power shall be available for an unlimited number of annual operating hours in variable load applications, in accordance with ISO 8528-1. A 10% overload capacity shall be available for a period of 1 hour within each 12-hour period of operation, in accordance with ISO 3046-1. The standby power rating shall be applicable for supplying emergency power in variable

load applications in accordance with ISO 8528-1. For stand-by power no overload shall be applicable.

The power generator shall fulfil the following standard features:

- i. Water cooled diesel engine
- ii. Oil and fuel filter fitted, water separator
- iii. Electric starter and charge alternator 24V DC
- iv. Lube-oil drain valve
- v. Normal dirty air filter
- vi. Single bearing alternator , class H/H, IP23
- vii. Anti vibration mounts
- viii. Single sheet metal fuel tank , capacity of 8 hours
- ix. 70% standby load
- x. Welded steel base frame with A/V mounting
- xi. Set mounted starting battery
- xii. Standard voltage 400/230 V, 50 Hz
- xiii. Loose silencer
- xiv. Low fuel level shutdown
- xv. Exhaust silencer – Industrial (9dB), in line
- xvi. Flexible and fixing kit for industrial silencer
- xvii. Warranty – 5 years extended standby Application
- xviii. Battery charger
- xix. Packing export box
- xx. Heavy duty air filter
- xxi. Oil temperature shutdown
- xxii. Engine

The diesel engine shall fulfil the following requirements:

- | | | |
|-------|---------------------------|---------------------------------|
| i. | Operation method: | four-stroke cycle, turbocharger |
| ii. | Combustion method: | direct fuel injection |
| iii. | Valves per cylinder: | two valves per cylinder |
| iv. | Engine mounting: | resilient to base skid |
| v. | Starter Battery voltage : | 24 VDC |
| vi. | 6) Air cleaner: | Dry element and restriction |
| | indicator | |
| vii. | Governor: | Electronic |
| viii. | Exhaust System: | Exhaust temperature 565°C |
| | [1049°F] | |
| ix. | Max back pressure: | 750mm CE [30in. WG] |
| x. | Fuel System | complete, pump, filter, |
| | line from tank, | |
| xi. | Oil System | complete, pump, filter |
| xii. | Air intake | heavy duty filter |
| xiii. | Coolant System: | Max water temperature 105°C |
| xiv. | Outlet water temperature | 93°C |

- xv. Electric fan
- xvi. Permissible restriction on air flow: 20mm CE [0.8in. WG]
- xvii. Type of coolant: Gen-cool
- xviii. Thermostat: 82-94 °C

The engine shall be rated for continuous operation. Radiation heat shall not be higher than 3-4% of rated engine power. All components of the engine shall be free of asbestos. The engine shall be suitable for operation with fuel of high sulphur content. The engine shall be painted with two coats of alkyd-resin paints, colour as instructed by the Engineer. Data and instruction plates shall be written in English language

The Diesel Generator shall have a 3-phase 50KVA or as applicable in the design, power output with 415 V at 50 Hz. It should include a highly corrosion resistant enclosure, control panel and monitoring, fuel tank and circuit breaker protection. The diesel generator shall be suitable for outdoor installation and perform accordingly with the inverter and the system design. The diesel generator shall work in a fully automated manner with the above stated component. A concrete plinth to be constructed for the generator placement plus a shed of steel hollow sections and IT 4 sheets to engineer's approval to house the generator

10.19.2 Alternator

The alternator shall be a 3-phase, synchronous, brushless single bearing, self-exciting, self-ventilating alternator with damping equipment for unbalanced load up to 30%.

The alternator shall be operated star connected. Both ends of each winding have to be brought out to terminals in the alternator's terminal box. Each terminal shall be equipped with a suitable current transformer for differential protection and over current/short circuit protection. At the outgoing terminal of the current transformer auxiliary busbars to connect the power cables have to be installed. The size of the alternator's terminal boxes shall be sufficient to allow maintenance work and refastening of all bolt connections without hindrance or requirement for special tools. The alternator shall be delivered with the correct star-point reactor, which shall be installed in the alternator's switchgear cabinet.

The Contractor shall note that the generator must be suitable to be switched to the unloaded transformer in case of power failure. In this situation, initially high currents may be required to demagnetize the transformer. The windings and the mechanical components of the generator have to be manufactured to these criteria. The characteristics of the alternator shall be as follows:

- i. Voltage: 400/230 V
- ii. Frequency: 50 Hz
- iii. Speed: 1500 rpm
- iv. Site rating: according basic operation needs
- v. Degree of protection: IP 65
- vi. Insulation class: F, tropicalized with anti-humidity insulation
- vii. Setpoint adjustment: +/- 5%

- viii. Cooling air temperature: 40°C if not set forth otherwise in Sec. VI C
- ix. Fully interconnected damper winding
- x. AC exciter and rotating rectifying unit
- xi. Epoxy coated stator winding
- xii. Rotor and exciter impregnated with tropical grade insulating oil and acid resisting polyester resin.
- xiii. Control panel

The following functions shall be available for monitoring, and protecting the generator set:

- i. Frequency meter, Ammeter, Voltmeter
- ii. Alarms and faults low Oil pressure, high water temperature,
- iii. Overcrank, overspeed (>60 kVA), Min/max alternator,
- iv. Low fuel level, Emergency stop.
- v. Engine parameters Hours counter, Engine speed,
- vi. Battery voltage, Fuel level, Air preheating
- vii. Anti condensation heater
- viii. Heat shield protection
- ix. Enforced impregnation

Unless stated otherwise the generating set shall be delivered with all required fuel, cooling, air and exhaust systems, the required instrumentation for operation control, all genset accessories required for appropriate maintenance and testing (tool and test kits) and spare parts for one year operation.

Name Plates:

For the engine as follows:

- i. Manufacturer,
- ii. Type, serial number
- iii. year of manufacture
- iv. Nominal power in kW, as stand-by and prime power
- v. Speed of rotation 1/min

10.20 Major overhaul of existing generators

10.20.1 Quality assurance requirements

All work shall be performed by OEM Diesel Certified Technician(s), and shall be performed in such a manner that the Manufacturer's warranty on parts and labor is not voided.

10.20.2 Statement of work required.

- i. Provide all labor, material, equipment, tools, staging, shop facilities, rigging, transportation, required to accomplish work in this item.

- ii. All engine and generator mounted components that are required for removal as interferences to accomplish work in this specification are to be removed/reinstalled by the contractor with new gaskets, seals, etc.
- iii. The Contractor is responsible and shall drain the engines of lube oil and jacket water prior to commencement of work. Lube oil shall be drained to the waste oil tank.
- iv. Completely disassemble the generator engine and components in their entirety for cleaning, inspection, and overhaul.
- v. Thoroughly clean and conduct a thorough visual inspection of all disassembled parts for
- vi. cracks, scoring, chipping, pitting, signs of overheating, excessive wear, signs of distress, and other defects which could affect serviceability of the engine.
- vii. After inspections and measurements, submit a typed report of all inspection findings and
- viii. a record of all measurements and readings taken, to the Engineer. Include in the report recommendations for any additional repairs, inspections, tests, and part renewals not already covered by this specification that are needed to insure continued reliable service of the engine. Do not proceed with any additional (not covered by scope of previously required work) repairs, inspections, tests, part renewal, or reassembly until authorized by the Engineer.
- ix. After submittal of report, provide for an inspection of all engine components by the Engineer, the OEM or a nominated third party expert. Provide 48 hours notice for the inspection.
- x. Renew all of the following "mandatory-renewal" parts and components in the proper quantities for the engine specified. Where "rebuilt" is added in parenthesis after a component, an OEM rebuilt component may be provided in lieu of a new component. In addition to the components listed below, the Contractor shall furnish compounds and sealants as required in performance of the overhaul.
 - a. All Seals, "o"-rings, and gaskets of all removed and dissembled components and parts.
 - b. All Bearings and bushings. To include but not limited to crankshaft bearings, connecting rod bearings, accessory drives bearings, camshaft bearings.
 - c. Cylinder Kits, to include liners, pistons, connecting rods, piston rings, piston pins, retainers, and associated parts.
 - d. Cylinder Head Assemblies, to include all valves, seats, guides, springs, retainers, rocker arms, push rods, etc. to provide a complete operational head assembly. (rebuilt) Also to include new cylinder head bolts.
 - e. Lube oil
 - f. Hoses
 - g. Thermostats and water temperature regulators
 - h. Coolant and non-chromate corrosion inhibitor
 - i. Filter elements
 - j. Crank Shaft Seals
 - k. Air starters (rebuilt)
 - l. Fuel injectors (rebuilt)
 - m. Fuel pumps (rebuilt), to include shutoff solenoid

- a) Fresh water pumps (rebuilt)
- b) Sea water pumps (rebuilt)
- c) Lube oil pumps (rebuilt)
- d) Turbochargers and blowers (rebuilt), to include new clamps.
- e) Governor Actuator (rebuilt) and fuel rack linkages.
- f) Piston Cooling Oil spray nozzles and bolts.
- g) Gear Drive components, to include all gears, bearings, stub shafts, and retaining bolts.
- h) Camshafts, cam followers
- i) Lube oil pressure switches.
- j) jacket water temperature switch.
- xi. Completely disassemble, clean, visually inspect, test as indicated, reassemble with new seals/gaskets, and calibrate the following components, parts, and subassemblies:
 - a) Cylinder block. Inspect dimensionally and inspect for wear, fatigue, cracks.
 - b) Manifolds, to include oil filter manifold, water filter manifolds, exhaust manifolds, in- take manifolds. Accomplish dye penetrant test on the exhaust manifold welds as applicable.
 - c) Lube Oil Coolers. Accomplish hydrostatic test to 125%
 - d) After Coolers. Accomplish hydrostatic test to 125% operational pressure. e) Dampeners.
 - e) Other components to the extent required to perform the required inspections, tests, and repairs, and to the extent required to renew parts and components.
 - 1) Conduct visual and dimensional inspections of the crankshaft journals.
 - 2) After all reports have been accepted and all additional work has been completed, reassemble and reinstall all components that were previously disassembled or removed in accordance with the manufacturer's instructions. Perform all tests and measurements required for freedom of movement, backlash, clearances, etc.
 - 3) Accomplish tune up of engine to factory specifications (adjusting valves and injectors).
 - 4) Accomplish the following for the generators while they are separated from the engines.
 - a) Disconnect the generator leads for generators and accomplish megger testing.
 - b) Submit as found condition report.
 - c) Test PMG diodes, submit as found condition report.
 - d) Temporarily remove the permanent magnetic Exciter (PMG) rotor and stator assemblies.
 - e) Renew the generator bearing.
 - f) Accomplish in place cleaning of the generator windings. Solvent wipe clean all traces of grease using a lint-free cloth and solvent, ZEP SOLV, ZEP product No.
 - g) 4240 or similar type solvent.
 - h) Conduct an inspection with the Engineer to prove cleanliness.
 - i) Reassemble the generator in accordance with OEM instructions.
 - j) Accomplish megger and PMG diode testing. Submit as released condition report.
 - k) Align the generator with the engine. Measure final alignment of generator to engine in the presence of the Engineer. Final alignment is to be within OEM specifications. Submit as released condition report.

- 1) Make all electrical connections.
- 5) Tests. Conduct the following tests of the engine after all components have been reassembled.
 - a) Test all alarm and shutdown systems prior to starting the engine. To include but not limited to high jacket water temperature, low lube oil pressure, over speed, and reverse power.
 - b) Monitor engine operations as the Engineers start the engine. Check all joints for leaks.
 - c) Provide the services of a controls contractor to calibrate the control system for proper load sharing and performance. The controls contractor is to accomplish an initial calibration pier side after the overhaul and then a final calibration during trials in item e).
 - d) Operate each engine for one hour with half load, monitoring engines for leaks.
 - e) Provide personnel to test the generator for a 8 hour trial during which each engine will be loaded as much as possible and the generator controls will be adjusted for proper load sharing.

10.21 Air filter for drinking water reservoirs

Air Filters for Drinking Water Reservoirs and Tanks according to EN 1508:1998. Fine filter (F7) or Micro filter (H13). The filters shall protect against vacuum and positive pressure inside the reservoir/tank. Filter shall be installed in vent pipes. The filter shall prevent undesirable particles, insects from getting into the water storage vessel and deteriorating the quality of the water. Pending from the application the filter shall be designed either for interior and exterior vent openings. When the water level in the reservoir/tank sinks, air shall be sucked in through the vent openings as it is designed to do.

The filter material of the filter element shall be available as fine filter (F7) or as micro filter (H13). The casing shall be designed to accommodate either F7 or F13 filter cartridges.

i. Filter for outdoor storage facilities

The protective hood shall enclose the actual filter material. It shall be possible only to open using a special tool. If vandalism proof design is required the hood shall be secured using a pad- lock.

ii. High and low pressure protection.

The secured pressure membrane shall be designed as diaphragm that will break when a sudden drop (or increase) in pressure of 3 kPa or more occurs. If this diaphragm ruptures, the air- flow area is bigger than the area of the air vent pipe and the reservoir shall be protected against structural damage.

10.22 Valves and accessories

i. General

All valves and sluice gates shall be best water works quality and suitable for use with water or water works sludge at all fluid temperatures up to 40°C. Valve parts to be in contact with potable water shall meet the relevant provisions of EN standards. Small valves and gates shall conform to DIN 3230-4.

Generally, valves shall be leak-proof in either flow direction except for check (non-return) valves, when the nominal pressure is applied. All valves with design pressures larger than PN 10 and larger than DN 100 shall be workshop-tested to DIN 3230 for tightness and soundness of materials. All pressure reduction valves, safety valves and similar components shall be workshop-tested and provided with a works certificate. Valve bodies shall bear the following information:

- Manufacturer's name,
- DN,
- PN ,
- Flow-direction arrow.

The operating gear of valves and sluice gates shall be such that one man can open and close the valve against an unbalanced head 15% in excess of the maximum to be encountered in service. Where necessary, arrangements shall be provided with gearing to achieve this requirement. The maximum couple which can be exerted by one man shall be taken as 130 N, and the maximum force as 250 N. Where specified, valves 300mm nominal bore and over shall be fitted with bypasses with isolating valves. Valves above 250 DN shall be complete with a spur gear unit.

Gate valves shall be provided with renewable seats and it shall be possible to remove the gates without removing the valve body from the pipe work. The operation of all valves shall be such that turning the hand wheel or tee-key in a clockwise direction closes the valves.

All materials shall comply with the appropriate EN or DIN standards and shall be subject to the

Engineer's approval. All castings shall be free of blowholes and other defects. Gate valves and butterfly valves shall be suitable for flow in either direction.

All standard valves shall be suitable for frequent operation and for infrequent operation after long periods in the open or closed condition. Packed glands shall be arranged for easy replacement of the packing, which shall be accessible without removal of the valve from the pipe. Precautions shall be taken to prevent corrosion of the valve spindles in contact with the gland packing.

Each valve or sluice gate or its operating equipment shall bear an approved brass nameplate stating its function in English. Valves, cocks and operating spindles which are for submerged operation, shall be independent of external lubrication.

ii. Spindle operation

Unless otherwise specified, all valves shall be located and orientated in readily accessible positions with hand wheels conveniently arranged for ease of operation. Where this requirement is impracticable or would lead to undue complication in the works, operating spindles shall be taken vertically to penstocks for manual operation.

Chain operated wheels shall not be incorporated in the arrangements. Knuckling of spindle extensions and remote operation through mitre geared linkages shall be avoided wherever possible.

Tee-key operation of valves and sluice gates shall only apply where specified elsewhere in the documents. In such case, spindles shall be fitted with a cast iron detachable cap included in the Manufacturer's supplies and sized acc. to DIN 4056.

Sluice gates and valves of and exceeding DN 50 shall be fitted with mechanical position indicators.

iii. Hand wheels

Hand wheels for valves and penstocks shall be cast iron. All hand wheels on valves over 50 mm diameter shall be fitted with a circular inscribed brass disc with an arrow indicating the clockwise direction of opening and closing and the words "OPEN" and "CLOSE", respectively in English.

External hand wheels shall be fitted with a purpose made integral locking device to prevent operation by unauthorised persons. A padlock and chain will not be acceptable.

iv. Nozzle type check valves

Nozzle-type check valves shall have a concentric, spring loaded obturator, length shall comply with EN 558-1 series 14-short (DIN 3202-F4), flange dimensions and drilling to EN 1092-2 PN16 (DIN 28605 / DIN 2501). Head loss factor zeta shall not exceed 0,7 when fully open and closure time not 0,15 sec. For DN>250 and 0,1 sec. for DN<300.

Check valves shall be double flanged conforming to EN 12334. Check valves shall be suitable for operating in the horizontal or vertical position unless otherwise specified.

v. Swing check valves

Swing check valves shall have an eccentric, lever-and weight loaded obturator, length shall comply with EN 558-1 series 48 (DIN 3202-F6), flange dimensions and drilling to EN 1092-2 PN 16 (DIN 28605 / DIN 2501).

Check valves shall be double flanged conforming to EN 12334. Check valves shall be suitable for operating in the horizontal or vertical position unless otherwise specified.

- body ductile iron EN-JS-1030 acc. to EN 1563 (GGG 40.3 - DIN 1693)

- obturator (swing check valve) ductile iron EN-JS-1030 acc. to EN 1563 (GGG 40.3 - DIN 1693)
- obturator (nozzle-type valve) stainless steel 1.4404
- shaft stainless steel AISI 410
- seats stainless steel 1.4404
- all other elements stainless steel or zinc-free bronze. Float Valves:
- Body Cast iron with guide brass
- Valve seal Soft seal on metal
- Piston seal Guide ring brass / O-ring seal
- Float lever Welded steel
- Float ball Copper sheet, tinned or stainless Steel

vi. Flap valves

Flap valves shall be round or rectangular, single door bitumen coated, double hung tidal type flap valves, with the clear opening dimensions designed to pass the required discharge. Flap valves shall be fitted with phosphate or bronze or stainless steel or similar approved corrosion-resistant metal faces and hinge pins and shall have a galvanised mild steel lifting eye.

Flap valves shall be designed to withstand a working pressure equivalent to 8.0m of water and shall be tested after installation with a feeler gauge to a non-acceptance of 0.05mm between sealing faces when closed.

Materials used in the manufacture of the flap valves shall be as specified above.

vii. Pressure control or flow control valves

Pressure or flow control valves used for pressure reduction, pressure sustaining or pressure relief or flow control shall be of the double flanged type and shall operate by use of an integral auxiliary pilot circuit suitable for the fluid and shall be actuated by the integral spring and the differential pressure on the diaphragm. For DN less than DN80 diameter a direct spring controlled valve may be used. Flow control valve shall have a downstream orifice installed and incorporated into the pilot circuit. Valves shall inherently close at backflow. All valves shall have an indicator showing degree of aperture.

Length shall comply with EN 558-1 series 1, flange dimensions and drilling to EN 1092-2 PN16 (DIN 28605 / DIN 2501).

The valves shall be adequately sized to control the flow and pressure differential required for the application with an accuracy of $\pm 2.5\%$ of the set value. They shall be capable of operating at a sustained pressure 20% in excess of the nominal declared working pressure.

Globe-type control valves shall have a vertical spring and pressure loaded obturator, a pilot circuit with pilot valve, strainer, stop cocks, throttle needle valve as may be required for the particular purpose. Identical valves except for the elements making up for the pilot circuit shall be used for pressure reducing, pressure sustaining and flow limiting valves.

The main pressure control valve operation shall be actuated by a hydraulic differential pressure system in balance with a spring loaded bellows type diaphragm, the reference pressure being bled from the inlet and outlet of the main valve. The diaphragm spring shall be adjustable by a screw to cover the range of pressure adjustment specified for the valve application.

Pressure gauges of appropriate range shall be provided upstream and downstream and shall be of class 1,6 100 mm diameter.

10.23 Bulk water meter – woltman type

Bulk water meters of Woltman type shall be of best water works quality and suitable for use with potable water, in compliance with relevant provisions of EN standards and allow for fluid temperatures of at least 30°C, PN16, IP class 68, Metrological Class B. Bulk water meters shall incur minimal head loss.

Meters shall be equipped with dry dials, covered by metal protective covers. The dial shall allow readings in the range from 1 to 99,999,999m³ (eight digits!) and one low flow indicator.

The body shall be produced of grey cast iron, coated inside and outside with epoxy coating approved for application in potable water.

Both, turbine and dial shall be fully and easily interchangeable without dismantling of the body.

Flange dimensions and drilling shall conform to EN 1092-2 PN 16 (DIN 28605 / DIN 2501).

The meters shall be prepared for retroactive installation of pulsers or other equipment for data transfer.

Bulk water meters shall be tested and calibrated at the factory in accordance with relevant regulations. Test certificates shall be issued and submitted to the Engineer for approval. The meters shall bear the seal of the calibration bank. The certificate shall include precise information on the test and calibration processes applied.

10.24 Bulk water meter – IDM type

Bulk water meters of IDM type (measurement through electro-magnetic flow sensors) shall be of best water works quality and suitable for use with potable water, in compliance with relevant provisions of EN standards and allow for fluid temperatures of at least 30°C, PN10, IP class 68. The accuracy shall be at least 0.5% of the measured value

IDM type water meters shall be of modular construction, consisting of a flow sensor and a signal converter installed in one unit (compact).

Whereas the measuring tube shall be of stainless steel, the inside lined with hard rubber, flanges of carbon steel (Flange dimensions and drilling shall conform to EN 1092-2 PN 16 (DIN 28605 / DIN 2501), all polyurethane coated.

The signal converter shall be equipped with a graphic LC display, be suitable for ambient temperatures from -10°C up to +40°C, IP class 66, and have equal accuracy as stated above.

10.25 Electric actuators

Unless otherwise specified actuators for modulating valves and dampers shall be electrically operated. Self-contained sealed hydraulic units may be considered where high thrusts or high speeds of operation are required but each application shall be approved by the Engineer.

In order to prevent the risk of fire or explosion pneumatic actuators shall be used in hazardous areas and associated equipment (e.g. positioners) must be intrinsically safe in accordance with EN 50020.

With either action the failure mode shall be suitably monitored and the plant operator informed by some form of alarm. The failure response of all actuators in the event of the loss of the prime mover (air pressure, oil pressure, electrical power) shall be indicated on the Piping and Instrumentation (P&I) diagrams, valve schedules, etc.

For all actuators of control valves and dampers of main systems local indicating pointer and position transmitters for remote indication and closed loop feedback shall be provided.

All actuators shall have a handwheel for direct manual operation. A lockable mechanical clutch mechanism shall be provided to inhibit power control of the actuators when the handwheel is operated.

10.26 Pressure and vacuum gauges

Pressure and compound gauges shall be of metrological class 2,5 (=accuracy of $\pm 2,5\%$) shall be provided and fixed directly to and at the same levels on both delivery and suction sides of each dry well pump. The gauges shall be fitted with diaphragm type isolating valves and with siphon pipes and an additional branch allowing to connect precision gauges when required.

Gauges shall have concentric dials of 160 mm in diameter, pressure gauges being graduated in metres head, and compound gauges in cm of mercury and metres head. Capacity shall be selected approx. 1,5 times the OP. The face of the dial shall bear the following label: "IMPORTANT: CLOSE WHEN NOT IN USE".

The gauge shall be of the Bourdon tube type, of stainless steel and copper spring and shall comply with EN 837-°1. It shall be sealed from the fluid being measured by means of a diaphragm or capsule and be filled with silicone oil. All gauges shall be fitted with a pressure snubber to dampen pressure pulsations.

Before delivery to Site, each gauge shall be calibrated in accordance EN 837-1 and a calibration certificate for each gauge shall be provided. Further copies of the test certificates shall be incorporated in the operating and maintenance manuals.

10.27 Valves

i. General

All valves shall be suitable for the service conditions under which they are required to operate. The design, construction and choice of materials shall take into account all operational deviations including pressure surge and thermal shock.

Where the valves include the use of satellite or other hard facing material to the valve seats, there shall be a differential hardness of not less than 50 and not more than 100 Brinell between fixed and moving seats, with the harder material on the fixed seats.

All valves shall be positioned so as to be readily accessible for operation and maintenance from permanent floors, galleries or access platforms. No valve shall be installed with its operating spindle gland below the horizontal centre line so as to avoid dirt entering the gland and to ensure complete drainage.

When valves are required to be locked in position for operation they shall be provided with a chain, padlock with three keys or other secure locking device. The internal diameter of all valves at the ends adjacent to the pipes shall be the same as the internal diameter of the pipe to which they are joined.

Unless otherwise specified, all valves shall be anti - clockwise opening and operated by hand wheel for up to 300 mm, above 300 mm geared actuators shall be used if not otherwise specified. The maximum effort required to be applied at the circumference of the hand wheel to operate the valves against the maximum unbalanced head shall not exceed 200 Nm.

All hand wheels shall have the words “open” and “close” in English with arrows indicating the direction of rotation cast on. All hand wheels shall be of a solid cast type.

Hand wheels and hand stops shall be fitted with a padlock and chain to prevent unauthorized operation.

For valves not easily accessible, the Contractor shall furnish and install operation platforms, chain operated valves, extension handles, extension oil cups or such similar fittings or appliances as may be required to permit easy access for proper operation, lubrication etc.

Valves of all types shall be capable of withstanding corrosion in the ambient conditions and any parts manufactured from a material which is not itself corrosion-resistant must be protected.

ii. Drains and vents

The minimum size of the drain piping will be 50mm. Drain funnels may be manifolded into a common drain. Drains will be routed to the nearest drainage channel or floor sump.

The contractor shall provide all traps, drains and vents which are called for in the particular specification, drawings and where necessary for equipment operation, line or equipment filling, hydrostatic, and testing.

Air-lines shall be provided at all high points in pipe work to vent air during pipeline filling and for release of gases, which may collect during normal operation. Single small orifice, large orifice, or double air valves shall be provided as appropriate. Pressure ratings shall be appropriate to the maximum test pressure on the main.

iii. Hydrant valves

Wash water hydrant valves shall be of the screw down, bottom entry top to accord with DIN standards. Bottom flanges shall be 80 mm diameter, faced and drilled PN16. Each valve shall be provided with a spindle cap and outlet cap.

iv. Standpipe

Each hydrant valve shall be provided with one “screw-on” type standpipe with two outlets, one

65 mm and one 19 mm diameter. At the outlets shall be valves with instantaneous bayonet type connections.

v. Hose box

Adjacent to each valve point shall be a hose box containing one of each above specified standpipe and hoses (carried on hose reels) in addition to one valve key and tome bar. The hose box shall be of a stainless steel lockable type and shall be mounted above ground level on an angle bar frame or fixed on the wall on a base plate.

vi. Check valves, flap type

The delivery pipes (pressure side) of the pumps shall be equipped with smoothly operating check valves. The check valves shall be of disc type with counterweights in sizes DN 100 and above. The counterweight shall be guarded. The dimensions of the valve according to ISO5752, or equivalent. The valves shall be designed for PN 10/16 working pressure.

The bodies of the valves shall be of double flanged construction and made of ductile cast iron ISO 1083, or equivalent. The sealing surfaces shall be of stainless steel. Corrosion protection shall be with epoxy paint on the clean, sandblasted iron surface, DFT not less than 250 µm. The flanges shall be according to PN10. The shafts shall be of push-through design and made of stainless steel.

vii. Pressure gauge

Gauges shall be provided having mounting arrangements, scale ranges, designation and alarm contacts as required. Gauges shall be of the Borden tube type with isolating diaphragm, brass case with flanged neck and stainless steel bezels. They shall have removable backplate to facilitate inspection and adjustment. Diameter of dial shall not be less than 100 mm. The dial shall be calibrated in kPa. Pressure range shall not exceed system-working pressure more than 1.5 times.

Each gauge shall be fitted with a stainless steel isolating cock.

Pump delivery pressure gauges shall be mounted direct on to the pressure tapping in the delivery mains and be corrected to show actual pressure at the delivery flange of the pump.

viii. Flexible connectors

Flexible connectors shall be installed in all piping connections to engines, blowers, compressors, and other vibrating equipment, and where shown. Flexible connectors shall be flanged, braided stainless steel spools with inner, annular, corrugated stainless steel hose, rated for minimum 10 bar working pressure, unless otherwise shown. The connectors shall be minimum of 200 mm long, face-to-face flanges, unless otherwise shown. The Contractor shall submit manufacturer's shop drawings and calculations.

ix. Expansion joints

All piping subject to expansion and contraction shall be provided with expansion joints to compensate for movement, without exertion of undue forces to equipment or structures. Expansion joints shall be of stainless steel, monel, rubber, or other materials, suitable for each individual service. The Contractor shall submit detailed calculations and manufacturer's shop drawings and information on materials, temperature and pressure ratings.

x. Start-up strainers

Temporary start-up strainers shall be installed on the inlet connections to all equipment to prevent construction debris entering equipment during start-up. The temporary strainers will be

‘sandwiched’ between flanges for easy removal and shall be fitted with a tag so that they can be checked prior to start-up.

xi. Reducers

Eccentric reducers (bottom flat) only shall be used on suction lines to allow piping to be fully drained. Concentric reducers will be used only in vertical lines.

10.28 Insulation and cladding

All drinking water pipework which is located outside buildings and exposed to direct solar radiation e.g. at pipe bridges along the main pipeline DN UPTO 800 or which give a

condensation problem shall be lagged and clad. The scope of this specification is designed to provide an Insulation and Cladding Standard which is completely water/vapour proof, uses only chloride free materials, eliminates potential problems with stress corrosion cracking of stainless steel pipe- work and provides an acceptable standard of insulation and maintenance free cladding finish.

Procedure for insulation and cladding:

- All works are to be carried out under cover in a clean dry atmosphere and must be fully protected from the weather. All materials used must be new, clean and dry and from approved manufacturer.
- Form a complete water/vapour barrier on the pipework by fixing one layer of aluminium foil directly to pipe. All foil joints are to overlap by minimum 5 cm, all joints are to be sealed with an adhesive tape on outside face of foil. Foil is to be fitted without tears/damage and must form a full water/vapour barrier over the entire surface of the pipe. The foil is to be of 50 - 100 micron thickness commercial purity annealed aluminium without backing material or insertion of any sort and suitable for the duty.
- The pipe is to be insulated with Glasswool (Hot Insulation) or Coolphen (Cold insulation) to the prescribed insulation thickness. All corners and edges must be whole, true and free from defects. All joints and seams must be close faced and must not have more than 2 mm clearance, or gaps between them, and they must be laid so as to prevent ingress of water or vapours.
- Insulation material is to be secured, fixed and banded with stainless lacing wire. The wire is to be 20swg stainless steel material. The joints and edges, adjoining faces and outer surfaces of the Insulation material are to be totally sealed and plastered with a suitable chloride free mastic material to form a complete water/vapour proof barrier.
- Insulation to be clad with Stainless Steel Cladding. The cladding is to be designed and erected so as to provide full protection against ingress of vapour/water, and must incorporate flashings and gutters, etc, to shed water. All joints on cladding to be constructed with double overlap on profile sections with all joints internally sealed with silicone mastic material and secured with Stainless Steel self-tapping screws or pop rivets at 200 mm centres. All excess mastic material to be removed from joints. All precautions must be taken to ensure that method of jointing used does not damage or penetrate the Aluminium Foil barriers applied to the insulation.

The method of supporting and fixing of cladding material must be approved by the Engineer and must be designed so as to:

Provide a mechanically strong and fixed finished cladding. Ensure that the skin on the insulation and vapour barrier is whole and complete and does not allow water or vapour attack.

Pop Rivets are located on underside of all Horizontal pipework.

On vertical or near vertical piping all insulation shall be supported in position by means of rings, studs or cleats at intervals of no more than 3.6 metres.

Inspections will be carried out during the insulation/cladding stages by the nominated inspectors and written approval and clearance must be obtained on each stage, of the works, before proceeding with the next stage of insulation and cladding.

Fittings, such as elbows, tees and reducers, shall be all factory made acc. to the applicable standards for dimensions and quality.

i. Flanged Connections

Loose flanges shall be made in accordance with DIN EN 1024-2. If not stated otherwise all loose flanges of steel shall be hot-dip galvanised in accordance with ISO 1461 with a minimum thickness of 80 microns.

Submerged loose flanges shall be made of stainless steel.

Bolts, nuts and washers shall be made of hot-dip galvanised steel with at least 55 microns of zinc in accordance with ISO 461. Bolts and nuts shall comply with ISO 898 and be of at least property class 8.8. Washers shall be placed under both the nuts and the bolt heads.

Gaskets for flange joints shall be not less than 3 mm thick, full face, rubber gaskets, pierced to take the bolts and with steel wire reinforcement.

ii. Joints

Before making any joint the Contractor shall ensure that the interior of each pipe or valve is clean and that it remains clean. Immediately before starting a joint the Contractor shall clean the end of each pipe to be jointed and shall otherwise specially prepare the ends for jointing as may be necessary for the particular kind of joint. All mechanical joints shall be cleaned and have their paintwork or coating made good before assembly

.The Contractor shall use only the proper jointing parts as specified and obtained through the suppliers of pipes or valves. All joints shall be accurately made and shall be capable of passing tests for individual joints and for the completed pipeline.

After completing a joint any protective paint or other coating shall be made good, and any metal joint which is not already coated shall be cleaned and painted according to painting

specifications, the Clause "Corrosion Protection". Internal lining and additional external protection of the joints shall be carried out as specified.

iii. Drains and vents.

The Contractor shall be responsible for providing all the necessary facilities for the safe disposal of all matters arising from all drains and vents to the approval of the Engineer. All vents and drains shall be arranged to have a continuous rise or fall as appropriate, to the point of disposal of the matter being discharged. Where practicable, vents shall terminate 2000 mm above roof level or as otherwise approved by the Engineer.

Installing pipes in and through structures

The installed piping shall be sloped to prevent trapping of air bubbles, unless relieved by air valves. The lowest point of a pipe sling shall be provided with a drain or flushing valve.

Adequate clearance shall be given to parallel pipes to allow for easy maintenance without disturbing other lines. All overhead piping shall have a minimum clearance of 2 m from operating floors and platforms. Generally pressurised pipes shall not be embedded in concrete. When embedding such pipes, the approval of the Engineer is required.

Where pipes pass through a concrete wall or structure, they shall project from the external face(s) of the structure by 300 mm for pipes of DN 500 or less and by 500 mm for pipes in excess of DN 500, the surface of such pipes shall be prepared to the approval of the Supervisor to ensure a satisfactory bond between pipes and concrete.

The first pipe in open ground leaving a structure shall be a short length of either spigot and socket or double socket to suit the flow direction. The length of this pipe shall be one and a half times the nominal diameter or 600 mm whichever is greater.

Puddle flanged fittings for building into the walls may be of the single-flanged type or of the double-flanged type. Where the single-flanged type is used, it shall be positioned so that the puddle flange is in the centre of the wall. Where the double-flanged type is used, it shall be positioned so that the outside face of each flange is flush with the face of the wall. Pipe support blocks shall be provided by the Contractor where necessary in chambers to support the pipe adequately, both during and after construction.

Surfaces of cast iron or steel pipes, which are to have concrete cast against them, shall be clean and free of deleterious matter and loose rust at the time of concreting. The paint protection system, to be applied to the permanently exposed faces of these pipes before the pipes are built in, shall be continued for 50 mm as marginal stripes along the contact surface. No paint containing aluminium in metallic form shall be allowed to come into direct contact with the concrete

10.1 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

11 ELECTRICAL WORKS

11.1 Scope of works

All electrical planning shall be done in accordance with international laws, norms and standards.

The Contractor shall provide all tools, supplies, materials, equipment, and all labor necessary for the furnishing, construction, installation, testing, and operation of all electrical work and appurtenant work necessary to provide a complete and operable system, all in accordance with the requirements of the Contract Documents.

The provisions of this Section shall apply to all electrical items specified in the various sections of this Tender, except where otherwise specified or shown in the Contract Documents. The Contractor shall be responsible for:

- a. Complete systems in accordance with the intent of these Contract Documents.
- b. Contractor shall prepare the further required detail design of construction works and supplies including required documents for permit application
- c. If applicable: Coordinating the incoming electrical service with local authorities and prepare all required documents.
- d. Coordinating the details of facility equipment and construction for all specification
- e. divisions which affect the work
- f. Furnishing and installing all incidental items not actually shown or specified, but which are required by good practice to provide complete functional systems.

The following clauses shall specify general electrical requirements and standards of workmanship for the facilities, equipment, and installation materials. General specification clauses shall apply where appropriate except where particularly redefined in the individual specification clauses. The scope of this work includes the provision of all electrical equipment for the following:

- The electricity in-feed lines to the facilities (if required)
- If applicable (The work in the local supply points)
- The medium voltage installation
- The internal low voltage distribution network in the facilities
- The low voltage power and control cable installation
- GSM or equal data transmission interface/connection in the plant
- Control board
- Uninterrupted power supply (UPS) (as required for each facility)
- Area lighting
- The PLC systems for plant operation and control including all field devices, gauges, communication lines and devices.

- Low voltage switchgears with main breakers, automatic main and minor reserve switching (ARS) and breakers for each motors and outlet line.
- Fire alarm and security alarm systems for each facility.

The scope of supply covers all services for the complete automation of the electrical equipment. The Contractor shall include in his proposal the provisional sum for connection to the power supply network as included in the bills of quantities.

11.2 Contractor's submittals

Contractor shall submit the following information for all materials and equipment to be supplied, apart from technical information supplied with the proposal:

- a. Submittals shall be made in accordance with the General Requirements stated in section 10.3 of this specification.
- b. Shop Drawings: The Contractor shall submit complete shop drawings of all electrical and I&C equipment in accordance with the Section 10.3 of this specifications. Such shop drawings shall include all electrical and I&C requirements, weights, wheel loads, dimensions, and clearances required. Trademark, model, and. catalogue number, destination, description and testing data shall be indicated.
- c. Schedule of materials

The layout of systems of the electric equipment is schematic in the drawings, and dimensions, fixing and equipment are shown not final. When determining routes for inlets, cables, wires and locating outlets, mechanical, constructional and architectural conditions shall be followed. Plans, installation drawings and other documentation, necessary for preparation of final drawings, shall be submitted by Contractor in accordance with the time schedule agreed.

Any preparation of equipment, works or part of them shall not be started without written permission of the Engineer.

Drawings for revision and coordination shall be submitted in required number of copies. Documents submitted shall consist of the required number of copies of reference list.

11.3 Standards and general requirements

11.4 Manufacturer and Supplier Requirements

Equipment of similar design shall be from the same manufacturer. The tenderer shall verify local representative for chosen equipment with full name, contact person, address and telephone. Also the representative's experience, service and spare parts organisation, etc, shall be provided. All supplied equipment must be certified (CE). All components shall be marked visibly and understandably with indication of relevant standard numbers.

11.5 Electrical Power Supply

The Contractor has to ensure uninterrupted power supply for all operating facilities.

11.6 Relevant standards

All electrical work must be carried out by personnel in possession of a current licence acceptable to the Authority, which permit the Contractor to carry out work on low voltage equipment and cabling. The Contractor shall carry out works described in this Specification in accordance with the appropriate EN, IEC Standards. These are, but are not limited by, the following:

| | |
|------------|--|
| EN 418 | Safety of machinery. Emergency stop equipment, functional aspects |
| EN 837 | Pressure gauges |
| EN 1050 | Safety of machinery. Principles of risk assessment. |
| EN 60204-1 | Safety of machinery - Electrical equipment of machines |
| EN 60269 | Low-voltage fuses |
| EN 60439 | Low-voltage switchgear and control gear assemblies |
| EN 60947 | Low-voltage switchgear and control gear |
| IEC 60076 | Power transformers |
| IEC 60185 | Current transformers |
| IEC 60227 | Polyvinyl chloride insulated cables of rated voltages up to and including 600/1000 V |
| IEC 60364 | Electrical installations of buildings |
| IEC 60446 | Identification of insulated and bare conductors by colours |
| IEC 60529 | Degrees of protection provided by enclosures (IP code) |
| ISO 3046 | Reciprocating internal combustion engines - Performances |
| ISO 5167 | Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full |
| ISO 12100 | Safety of machinery - Basic concepts, general principles for design |

Further the Contractor shall comply with the following:

1. Sizing the cables in the control cabinet according to IEC 60204-1
2. Sizing the cables to the equipment unit according to IEC 60364-5-52
3. Sizing the cables to the machine according to IEC 60204-1
4. Sizing of copper rails according to IEC 60947-1
5. Control circuits: always grounded at one end, otherwise 2-pin disconnecter with ground fault monitoring according to IEC 60204-1.
6. Emergency stop circuit according to IEC 60204-1
7. Permitted areas for the arrangement of Actuators, this includes fuses and circuit-breakers according to IEC 60204-1
8. Traffic routes and dimensions of the passageways according to IEC 60364-1
9. IEC 60529: Degrees of protection provided by enclosures (IP Code)

Any other codes and standards and approved by the Consulting Engineer where the equipment or part of it complies with other internationally recognized standards, which are less

stringent than the above-mentioned standards, the differences shall be stated in writing and must accompany the Bid submission.

Any particular requirements of IEC standards shall take precedence to any other standards. All electrical equipment shall be approved by the Electrical Supplies Company.

11.7 Regulations

All the Electrical Works shall be carried out strictly in accordance with the following: -

- i) The 13th Edition of the “Regulations for the Electrical Equipment of Buildings” issued by the Institute of Electrical Engineers of Great Britain with Kenya amendments.
- ii) The Licensee’s By-Laws
- iii) The Government Electrical Specification (G.E.S. No 1 and No. 2).
- iv) The Power Act
- v) Relevant British Standard Specifications and Codes of Practice published by the British Institution (hereafter referred to as BS and GP, respectively).
- vi) The Contract Drawings and the working drawings, produced by the Contractor and approved by the Engineer.
- vii) The Engineer’s instructions

The Contractor shall undertake all modifications demanded by the authorities in order to comply with the regulations, and produce all certificates, if any, from the authorities without extra charge.

After completion of the work, the Contractor shall deliver a complete set of “as built” drawings showing the complete installation including all alternations and modifications. The set of drawings shall include but is not limited to all floor plans and diagrams.

11.8 Extent of Electrical Work Within Contract

The electrical works in the proposed development are required to be complete in all respects as specified herein and shall include all items of equipment, materials, accessories, switchgear, lighting fittings, cables, labour, etc., necessary whether such items are specifically referred in the Contract or not. The Contractor shall be deemed to have included in his Tender, price for all items necessary such that the installations are complete in all respects and left in a satisfactory working order.

The Contractor will be responsible for liaison with the Kenya Power & Lighting Company Limited and the Kenya Posts & Telecommunications Corporation to suit the incoming power and telephone requirements.

The Contractor shall include for all Civil Works, Structures, Foundations, Builder’s Works and associated requirements for the mounting, housing and support of all items of plant and

equipment supplied and installed under this Contract. The concrete foundation will be to approved manufacturer's details and instructions.

All work and materials are to be of the best quality approved by the Engineer and strictly in accordance with the Specification.

In the event of any portion of the work or materials failing to pass the tests specified herein, or set forth in the Maker's list for that particular item, the Engineer may at his discretion, reject that portion of the work or material entirely.

11.9 Materials

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

The use of dissimilar materials in contact shall be avoided, but where unavoidable these materials shall be selected so that the natural potential difference between them does not exceed 250 mV. Electro-plating or other treatment of contacting surfaces shall be employed as necessary to reduce the potential difference to the desired limit.

All materials and material finishes shall be selected for long life under the climatic conditions at Site. Materials used in ventilated or air-conditioned areas shall be selected to allow for the conditions expected in case of failure of the ventilation or air-conditioning equipment. Tropical grade materials and panel components shall be used except if not available.

If there are no other indications used materials shall be in compliance with testing programmes and certification requirements required by any Inspection Authority according to the regulations, issued by CEE (International Commission on rules for the approval of Electric Equipment) and if there is no contradiction with valid regulations. Contract Documents will govern where higher quality materials are indicated compared with these listed in "regulations" for materials, production, constructions and equipment.

All materials and equipment supplied according to the Contract shall fulfil all requirements preset in the specifications and be constructed and produced in manufacture's conditions. Equipment shall be the most modern model, new and not used. All electrical installations/equipment shall be checked and tested in the factory. During the installation special test shall be executed as per Engineer's request.

When it is required in the technical specifications that materials, construction etc. are of quality higher than in instructions and norms, then requirements of Technical Specifications are to be followed. All metal parts shall be rustproof or properly treated.

All materials, instrumentation and equipment shall be certificated (CE).

The work shall be carried out by competent workmen under skilled and experienced supervision. The Engineer shall have the right to have any part of the work taken down or changed at the Contractor's expense which is executed in an unsatisfactory manner.

Such materials supplied by others for installation and/or connection by the Contractor shall be carefully examined before installation and connection. Any defects noted shall immediately be reported to the Engineer.

Conduit fittings shall be the same metal as the conduit to which they are connected except that Zinc-alloy OR Aluminium-alloy fittings may be used with steel conduits.

Conduit fittings and accessories shall conform to the appropriate Standard. Conduits shall be mechanically and electrically continuous.

All bends and sets shall be made cold without altering the section of the conduit. The inner radius of the bend shall not be less than two and a half times the outside diameter of the conduit. Not more than two right angle bends will be permitted without the inter-position of the draw-in box. Where straight runs are installed draw-in boxes shall be provided at distance not exceeding 12m. Tees, elbows or sleeves of either inspection or solid type will not be permitted.

Conduits which terminate in fuse gear, distribution boards, adaptable boxes, non-spout switches, trunking, etc., shall be connected thereto by means of screwed sockets and smooth bore brass male bushes.

Where conduits are installed flush in floor slabs or in chases in walls, they shall be held firmly in position by means of substantial pipe hooks driven into wooden plugs. Where conduits are installed on surface they shall be fixed with spacer bar saddles at a distance not exceeding one metre. Conduits shall be installed entirely separate and at least 150mm clear of the hot water and steam pipes and at least 75mm clear of cold water and other services.

The Electrical Contractor shall be responsible to ascertain from site details of reinforced concrete and structural steel work and to check from the Main Contractor's drawings the positions of walls, structural concrete and steel work finishes, etc. No reinforced concrete or steelwork shall be drilled without obtaining permission from the Structural Engineer.

All the circular conduit boxes shall be of a malleable iron conforming to SRN 052 with 50mm fixing centres fitted with H.G. lids where required. They shall be long spouts internally threaded. Deep boxes or extension rings on standard circular boxes shall be used where necessary in order to bring the front face of each box flush with the ceiling or wall.

Conduit boxes installed externally shall be galvanised and where subjected to direct weather conditions they shall be compound filled.

Where the words or other approved or equal are used, they shall mean any make of equal quality but the written approval of the Engineer for the use of such alternative shall be obtained prior to their use in the installation. In the absence of any such request, the Engineer is entitled to suppose that materials used are specified.

11.10 Workmanship

Particular attention shall be paid to the neatness of appearance of the electrical installation; arrangements of which shall be agreed upon by the Engineer before the commencement of installation if the Contractor proposes positions of equipment deviating from specified arrangements in drawings. The Contractor shall ensure that the installation is completed to the highest standards of quality and neatness with respect to the visible appearance of cable runs and the arrangement and alignment of equipment, apparatus and fittings.

The Contractor shall determine the quantities and locations of fittings and equipment and shall prepare surveys and detailed design with installation arrangement drawings. The final locations of all building services, fittings and equipment shall be agreed at Site with the Engineer before installation.

The Contractor shall arrange for the switch-gear and panel manufacturers to provide skilled labour for the supervision of off-loading, placing in position on prepared foundations, erection and commissioning of all switch-gear and control panels.

11.11 General Requirements

Before starting manufacture and installation, the Contractor shall check dimensions and outlines of the buildings, sealing of piping, etc.

Also, the Contractor shall check location of the objects to be connected and adapt the installation depending on the situation, and check sizes and location of the holes and inserts sealed.

Electrical wiring shall be performed in accordance with international standards. In buildings open and hidden electrical wiring can be used. Electrical wiring, cables and installation boxes shall be laid and fixed according to international standards. Cables can be laid open on walls, horizontal and vertical cable racks, troughs, in pipes or under plaster.

Electric machines, apparatus and devices, the unit power of which is 2kW and more, shall be connected to switchboard by separate electric circuit (circuit breaker).

11.11.1 Safety Requirements for Installation Works

Electric equipment can be installed only by qualified and certified electricians, automation, communication and other specialists of power and automation systems. Installed equipment shall not endanger personnel working on site or persons who can get to the site.

Appropriate warning notes shall be fixed in the territories where there is a contact with dangerous parts of electric equipment in the period until their installation is not completed. These notes shall be easily noticed and read.

When not operating, all pipes and boxes shall be covered or closed. Factory-made PVC caps shall be used. Plates, control devices, commutation panels and other electric equipment shall

be well protected from dust and mechanical damages during installation. If the electric equipment is not duly protected and damages including damages of painted surfaces, incurred due to Contractor's fault, the Contractor shall promptly and regularly eliminate the damages while re-establishing the same condition or making them even better.

11.12 Marks and Marking

All equipment and cables shall be properly marked according to marking system and international standards. Marking shall correspond to technical documentation.

Housing of switchboards, panels, boxes shall be marked to identify part of the equipment which the unit is attributed to.

All equipment mounted on the housing shall be marked. Position numbers shall be indicated on all equipment mounted inside the housing.

Phase marking shall be done according to IEC 445 (L1, L2 and L3). Terminal position numbers shall be indicated on both ends of wires.

Multicore cables shall bear cable marking, and each core shall bear position marking of cable, core and terminal. If cores are connected in series, first and last core shall be marked. If cable is with plug, position number of the joint shall be indicated. No additional marking for multicore cables with already marked cores is required.

Connection wires between equipment and terminals shall bear terminal position marking in both ends.

Connection wires between both terminals shall bear terminal position marking in both ends. Marking of cables and wires shall be made with constant cable marks.

Marking of cores of wires and cables shall be made with constant marks or plastic hoses.

11.13 Power systems

11.13.1 De-rating due to particular properties of local grid, to geographic and / or climatic conditions

All ratings of equipment and components shall be understood as Site ratings only responding to the conditions on site. In the absence specific local conditions, the following shall apply:

- Altitude not exceeding 1800 m
- Ambient air temperature in shadow or closed rooms: not exceeding 60°C

- Ambient temperature in closed rooms: not less than 5°C
- Ambient temperature outside or in open sheds not less than 1°C
- Moisture 90%

11.13.2 Polarity

The polarity of all apparatus used for the Works specified shall be arranged as follows when viewed from the front:

- a) For two pole apparatus, the phase or live pole at the top (or left hand side) and the neutral or earthed pole at the bottom (or right hand side). On plug and socket outlets, the polarity shall conform to EN, IEC, or approved standards as appropriate for the country.
- b) For three or four pole apparatus the phases in the order L1, L2, L3 and neutral reading from top to bottom or left to right in the case of vertical and horizontal layouts respectively.
- c) Phase colours and sequence shall be according to national regulations of the country (i.e. RED, YELLOW and BLUE FOR 3 phase conductors, BLACK for neutral conductor, and GREEN or GREEN/YELLOW stripes for earth conductor)
- d) All cable cores shall be identified with phase references.

All non-flexible cables shall be connected between main switchboards, Motor Control Centre (MCC), distribution boards, plant and accessories so that the correct sequence of phase colour is preserved throughout the system.

On building services wiring installations, where more than one phase is incorporated on a common system in one room, then the live cores shall be phase identified as appropriate and fittings and switch accessories shall be permanently labelled and segregated in accordance with the relevant clauses of IEC standards.

11.13.3 Safety interlocks

A complete system of electrical and mechanical interlocks and safety devices shall be provided throughout the electrical installation for the safe and continuous operation of the plant in order to ensure:

- a) Safety of personnel engaged in operational and maintenance work on the plant.
- b) Correct sequence of operation of the plant during start up and shut down.
- c) Safety of the plant when operating under normal or emergency conditions.
- d) Interlocks shall be preventive and not corrective in operation.

The Contractor shall be responsible for the preparation of interlocking schemes for the approval of the Engineer.

11.13.4 Switchboards and motor control centres

LV switchboards and Motor Control Centers shall as far as possible from the wells and shall be manufactured by a single approved supplier and the construction of each individual panel shall be such that all components shall be selected for standardization.

Fully type tested designs to the fault levels specified with ASTA or KEMA certification is required. LV switch-gear (distribution boards) shall be designed and constructed in compliance with IEC 60439-3 and IEC 60947, and control boards (MCC) etc., shall be designed and constructed in compliance with IEC 60439-1. Form 3b barrier shall be adhered to all types of boards.

Switchboards shall be so positioned that access thereto shall not be obstructed by the structure or contents of the building. A distance of not less than 900 mm shall be provided and maintained in front of every switchboard/panel board for the purpose of safety and effective maintenance, operation and adjustment of all the equipment mounted thereon.

Where a switchboard incorporates rack-out switch-gear, doors or hinged panels there shall be a clearance of not less than 1200 mm between any wall or immovable structure and the switch-gear, doors, or hinged panels when it is in the racked-out or in open position. The racked out position of the switchgear must be effectively earthed in the racked out position for electrical safety.

Rear access switchboards and panels shall be provided with unhinged lift-off panels only. Hinged panels will not be permitted. All apparatus shall be positioned on a switchboard so that there is ample room for its safe and effective operation and handling. The maximum height of any operating controls shall not exceed 1,700 mm above finished floor level.

LV (Low Voltage) switch-gear shall be suitable for extending at either end and arranged so that additional cubicles may be installed in position and cables only made off while the existing busbars are not in operation. To gain access to the busbar, for the purpose of extending, it may only be necessary to remove external end covers.

Each switchboard panel or section shall be fitted with a de-mountable metal cable termination gland plate positioned at vertical or horizontal level but with adequate space for termination of cables, conduits, etc. The gland steel plates shall be efficiently earthed to the panel earthing system by a separate earthing conductor. The base of the panels shall be provided with removable plates of PVC or steel type to seal the cable/conduit entry.

All switch-gear shall be provided with lifting eyes, which shall be removable and replaced, at Site, with chrome plated screws.

11.13.5 Multi-cubicle-type assembly

Cubicles shall be constructed of not less than 1.5 mm thick sheet steel and be of a totally enclosed welded construction with covers and hinged front doors interlocked as specified. Panels shall be arranged for front access only.

Low voltage switch-gear and control boards and individual enclosures for installation in in-door locations shall have a minimum protection enclosure of IP54. Compartments shall be easily accessible for maintenance purposes. Barriers shall be included between each compartment to ensure safe maintenance on any out-going circuit when the remainder of the board is live. Cubicles shall not rely on any removable portion for their rigidity. All live terminals of equipment mounted on cubicle doors and/or enclosure covers shall be adequately screened unless protected by an interlocked isolator. All doors and hinged covers shall be efficiently earthen by a separate conductor.

All terminations for out-going cables, including lighting fittings, socket outlets, etc. shall be provided with terminals. Termination at fuse switches and miniature circuit breakers will not be acceptable.

Switchboards and panel boards shall be complete with the necessary interconnections, small wiring, labels and copper busbars, the interconnections being referenced to indicate phases, and they shall be properly earthed.

Where interconnections occur between various panels, the Contractor shall ensure that wire/terminal numbers have identical references.

11.13.6 Safety

Interlocks shall be provided so that it is not possible to gain access without tools to any compartment containing uncovered live connections unless all such equipment inside the compartment is isolated from the supply.

Where access to low voltage enclosures is necessary with equipment energised from an external source all equipment, terminals shall be fully shrouded to prevent accidental contact and warning labels shall be fitted. Safety barrier shall have a minimum degree of enclosure IP2x.

11.13.7 Switch-gear earthing works

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 provided with two terminal assemblies for connection to the installation main earth terminal.

The short-time rating of the earth busbar and connections shall be not less than that of the associated equipment, or the maximum through-fault current of the power source. The temperature rise of the busbars 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 8 mm diameter.

11.13.8 Main switches

The main switch or switches of every installation shall be marked as such and shall be identifiable from other switch-gear by grouping, colouring or other suitable means, such as to render it (or them) easily located in an emergency. When there is more than one main switch in any building, each shall be marked to indicate which installation or section of the installation it controls.

In a cubicle main switchboard, the main controlling switch (or switches) shall be located in their own section, completely segregated from all other parts of the switchboard with front access. All main switches on main switchboards (of either cubicle type or otherwise) shall be so located, that a minimum distance of 900 mm exists from the finished floor level to the bottom of the switch or connection straps, whichever is the less.

11.13.9 Distribution sections

Distribution sections shall contain miniature circuit breaker outgoing ways for the required circuits plus approximately 20% of spare ways. Access to the distribution board shall be possible without opening the associated fused isolator, but access to the fused isolator shall only be obtained with the isolator open. Miniature Circuit Breakers (MCB's) shall be insulated moulded case, non-adjustable, magnetic and thermal tripping type. MCB's shall comply with EN/IEC standards for isolating and switching. MCB's shall have a rated current and category of duty of not less than M4 or as otherwise specified to match the fault rating of the switch- gear. Backup fuses shall be provided as required, but the ratings of the MCB's must be correctly coordinated with the fuse to achieve the necessary degree of fault coordination. Loads on distribution sections shall be balanced between the three phases as far as possible.

11.13.10 Busbars and busbar connections

All busbars and busbar connections shall be of hard drawn high conductivity copper. Busbars and connections shall be identified by phase coding and adequately supported by suitable insulators. The whole installation shall be mechanically and electrically designed to withstand the full fault capacity. All busbars and connections shall be rated for continuous operation. The Contractor shall provide type test certification for the busbar and primary connection short circuit withstand and thermal performance.

Low voltage switch-gear busbars and connections shall be identified throughout their entire length.

11.13.11 Cable boxes, gland plates and terminations

The arrangement of cable boxes, gland plates and terminations shall permit easy installation. Cable gland plates shall be manufactured from sheet steel for multi-core

cables and non-ferrous material for single core cables. Gland plates shall be mounted not less than 300 mm above the base of the enclosure.

Space for cabling within terminal enclosures shall be not less than that stated in EN standards. Adequate space shall be provided for the termination of oversize cables.

When the cable gland is remote from the cable terminals, purpose made cable tray or trunking shall be provided within the enclosure for securing or accommodating the cable cores. Terminals for small low voltage power and auxiliary circuit application shall be fully insulated, and shall be of pillar type with indirect pressure plates unless otherwise approved by the Supervisor.

Terminals in a common compartment associated with different voltages or circuit types shall be segregated into clearly identified groups. Barriers shall be provided between each group. Terminals shall be provided for the connection of all cable cores and, where applicable, core screen drain wires.

Not more than one core of internal or external wiring shall be connected to a terminal. Where duplication of terminals is necessary, purpose made solid bridging links shall be fitted. Terminals, which remain energised when the main equipment is isolated, shall be shrouded and fitted with a warning label.

11.13.12 Auxiliary switches

Auxiliary switches for indication, protection, interlocking and supervision purposes shall be readily accessible and enclosed in a transparent dust proof cover or equal cover. Adequate secondary disconnection shall be included between the fixed portion of a circuit breaker and the moving portion. Spare auxiliary contacts, one normally open and one normally closed, shall be provided on each unit.

11.13.13 Isolating switches

The compartment isolating switch shall interrupt all supplies into the compartment to enable safe maintenance to be undertaken. Isolators shall have “ball and stick” type handles and a fixed post shall be provided to enable the isolator to be padlocked in the off position only. One padlock with 4 keys shall be supplied for each isolator on the board.

11.13.14 Auxiliary wiring and terminal blocks

Wiring used for internal connections shall be capable of withstanding, without deterioration, the conditions on Site, due allowance being made for such temperature conditions as may arise within any enclosure.

Butyl rubber/CSP insulated cables shall be employed or alternatively PVC-insulated cables to VDE 0250 suitably derated if necessary.

Single-strand wire shall not be used. Wires shall not be less than 1.5 mm² total cross-sectional area. Both ends of every wire shall be fitted with full ring interlocking ferrules of white insulating material. Letters and numbers shall read from terminal outwards and shall correspond to the appropriate wiring diagram. Crimped on terminal connectors shall be fitted to all wire ends.

Unless otherwise specified or approved, wiring shall be coloured as EN 60204-1 and IEC 446. Wiring shall be supported in insulated cleats or cable trunking. Wiring passing between compartments which may be separated for transport shall be taken to terminal blocks mounted near the top of each compartment, separately from those for external cable connections. The busbar chambers of the equipment shall not be used as trunking for small wiring.

All terminals which may be live when a compartment door is open shall be shrouded and provided with warning labels.

Connections to apparatus mounted on doors or between points subject to relative movement, shall be made in flexible wires, arranged so that they are subjected to torsion rather than bending. The Contractor shall submit for the Engineer's approval, samples of the types of wires, numbered ferrules, and terminal washers or lugs, if appropriate, which he proposes to use.

11.13.15 Indicating lamps

On AC operated circuits, indicating lights shall be of low voltage type with self-contained transformers. The lamps shall operate at not greater than 90% rated voltage to ensure long life.

On DC operated circuits suitably rated resistances shall be connected across each lamp operating contact.

Lights shall be well ventilated and be designed to permit the removal of the lamp glass and lamps from the front of the unit. Lamps units shall be of the “push to test” type to facilitate testing, or a separate “LAMP TEST” button for the whole control board/switchboard shall be installed.

11.13.16 Indicating instruments and meters

All indicating instruments and meters shall be flush mounted and generally of the same appearance throughout. They shall comply with relevant standards and shall be of industrial grade accuracy. They shall be sealed against the ingress of moisture and dirt.

Indicating instruments shall be of 270° scale type and shall have an external zero adjustment. They shall be positioned so that they can be easily read and the dial centres shall be not less than 400 mm and not more than 1700 mm above finished floor level. Instruments shall be fitted with an adjustable pointer or shall be inscribed on the scales to indicate the normal circuit rating for the associated circuit.

All indicating instruments shall have a square front appearance with width dimensions not less than 96 mm. Am- or kW meters fitted in a motor winding circuit shall be provided with adjustable red pointers. All instruments shall be mounted adjacent to the relevant circuit breaker, switch or starter, unless separate panel suites are specified herein.

At points of connection of instrument and meter potential circuits to LV busbars, fuses shall be provided to protect the auxiliary wiring. For cubicle gear, these fuses shall be housed within the cubicle and be readily accessible. Additional fuses to clear individual instrument faults shall be provided and accessible from the front of the cubicle where specified.

11.13.17 Low voltage fuses

Low voltage fuse links shall be to EN 60269-2 and one spare fuse for each fuse fitted in the panel shall be supplied, clipped adjacent to the position in which it would be in service with reusable clips. A complete schedule of all fuses in the panel shall be affixed in a convenient position in the panel.

Fuse link carriers and bases shall be fully insulated and shrouded type, the design of which shall prevent contact with “live” parts while the fuse carrier is being, or has been withdrawn. Fuse holders and bases shall be manufactured of moulded plastic. Ceramic material will not be accepted.

11.13.18 Current transformers

Current transformers shall comply with IEC 185 and shall be of the wound primary or bar primary type according to the ratio required. Current transformers shall be suitably rated and designed to carry out appropriate metering and protection functions as indicated.

The rated capacity of current transformers shall not be less than the total capacities of all relays, instruments and related loads. Unless otherwise specified current transformers shall be of Class 1 accuracy for use with measuring instruments and Class 5P for protection circuit duties.

Identification labels giving type, ratios, rating, output and serial numbers shall be fitted. Duplicate rating labels shall be fitted on the exterior of the mounting chambers suitably located to enable reading without removal of any cover. Labels shall be supplied for multi-ratio current transformers indicating the connection required for alternative ratios.

Bar type current transformers shall be supplied in preference to those with wound primaries. Current transformers short-time current ratings shall relate to the full fault level for one or three seconds as applicable and shall be not less than that of the switch-gear in which they are incorporated.

Removable links shall be located on each phase of the switchboard primary conductors to enable easy current transformer maintenance and replacement. One secondary terminal of each current transformer shall be earthed through a bolted link located in the switch-gear instrument/relay panel.

Current transformers shall have a rated burden as specified, sufficient for the connected Numerical Protection relays and Energy meters and instruments.

11.13.19 Extra low voltage supplies

Where extra low voltage supplies are required for illumination and power supplies (hand lamps, installation liable to flooding, portable hand tools, etc.) they shall be obtained via a portable step-down transformer with a 220 V primary winding and secondary winding at 24 V.

11.13.20 Fault level

Where a switchboard is directly connected to the low voltage side of the transformer or a transformer without any distribution cut-out, then the complete switchboard shall be manufactured to comply in total with a short circuit rating of 50 kA for duration of one second minimum.

With transformer distribution cut-out, the minimum short circuit rating for Main Distribution Boards and mmC shall be 25 kA and Distribution Boards 15 kA.

All small wiring for controls, voltmeter supplies, etc., that originate from the main and sub-main busbars shall be protected by means of busbar mounted cartridge fuses suitably rated for the purpose intended. The maximum size of fuse used shall not exceed 20 amps.

11.13.21 Protection relays

Protective relays shall be provided, for fault and overload protection, to operate circuit breakers.

The Contractor shall be responsible for ensuring that all details relating to the protection systems shall be submitted to the Engineer for approval and no work shall commence until such approval has been received in writing. All protective relays shall be manufactured by an approved manufacturer. They shall be suitable for climate and Site conditions and fully sealed against the ingress of moisture and dirt.

Relays shall be suitably rated to operate at the specified DC auxiliary circuit voltage and shall have output contacts suitable for operation of the switch-gear tripping mechanisms and associated alarm and indication systems.

Secondary injection shall be easily possible by means of purpose-made voltage and/or current plug-in type test terminal blocks which automatically open or short circuit the

integral voltage transformers or current transformer respectively and provide terminations for the test supply. Disconnection of any permanent wiring will not be acceptable.

Each individual element of the relays shall incorporate a visual operation indicator, which shall be reset by operating an external reset button mounted on the front of the relay case. Each relay shall be complete with panel mounting works and terminals for external circuit connection.

Protection relays and associated equipment shall be as detailed in the specific clauses and as determined by the Contractor.

11.13.22 Low Voltage Circuit Breakers

Air break circuit breakers shall be rated for controlling loads for maximum circuit operation and 380 V 3 phases 50 Hz. 4 wire operation under the specified Site climatic conditions. Test Certificates of the ASTA or KEMA type shall be provided for inspection with the by the Engineer.

All low voltage circuit breakers shall be housed in control boards, which comply with the requirements of the Specification and shall not reduce the degree of protection to less than IP54.

Low voltage circuit breakers shall comply with EN 60947, shall be of the air-break type, and shall be moulded case or open construction (metal clad casing) design. For the purpose of this specification the two designs are referred to as moulded-case and air circuit-breakers. Circuit- breakers shall be Utilisation Category B and shall have a service short-circuit breaking capacity not less than 50 % of the rated ultimate short-circuit capacity. Circuit-breakers shall be suitable for isolation and shall be to Overvoltage Category IV to EN 60947-1.

The rated current specified in the specific clauses shall be that with the circuit-breaker mounted within a switchboard. The service short circuit breaking capacity shall be not less than the maximum power system fault level. Unless otherwise specified, air circuit-breakers shall be used for rated currents of 630 A and above. Moulded case circuit breakers shall be provided where specified in the specific clauses.

Circuit breaker closing mechanisms shall be of the independent type. It shall be possible to manually charge power operated closing mechanisms. works shall be provided for padlocking in the OFF position.

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. The thermal element shall be adjustable. Adjustments shall be made

simultaneously on all poles from a common facility. Thermal elements shall be ambient temperature compensated. Where available, the thermal magnetic elements shall be interchangeable.

Unless otherwise specified, air 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.

Accessories such as shunt trips, undervoltage releases, auxiliary contacts and motor mechanisms shall be manufactured to allow easy installation. Closing mechanisms shall be suitable for operation at 80 percent of the nominal solenoid supply voltage. Closing and tripping batteries shall comply with the relevant clauses of the Technical Specification.

Auxiliary contacts for the indication of breaker state shall be provided.

Incoming feeder circuit breaker panels shall be provided with a purpose designed, separate earthing device. The device shall be arranged to earth either the cable box or the busbar side of the circuit breaker, and shall be stored in a suitable robust container which shall include a permanently fixed instruction label giving details of assembly and use. Auxiliary jumper connections, as necessary, shall be included.

11.13.23 Low voltage switches disconnectors and fuse switches combination units

Switches, disconnectors, switch-disconnectors and fuse-combination units shall comply with EN 60947-3 and shall be suitable for uninterrupted duty. Switching devices shall be suitable for isolation and shall be to Overvoltage Category IV to EN 60947-1

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. Fuse links for use in fuse-switch devices shall comply with relevant standards.

Combination units shall be contained within an enclosure of metal and shall be fitted with an earthing terminal or equivalent to enable the enclosures to be earthed irrespective of any means of connection such as is provided for attaching armouring or other metallic covering of the cable supplying the combination unit.

The enclosure shall be so constructed that the cover cannot be opened until the switch is fully opened and that when the cover is opened, a component examiner can override the interlock and operate the switch. After such operation, the cover shall be prevented from closing with the switch position indicator in a false position.

Switches and fuse switch units for switchboard installation shall be flush mounting. Switches shall be provided with mechanical ON/OFF indicators and operating handles. Means shall be provided for locking the switch in the OFF position only.

The fuse shall either include a suitable fuse carrier or it shall be capable of isolation. If the fuse carrier is included, it shall be such that when it is being withdrawn normally or when it is completely withdrawn, the operator is completely protected from accidental contact with any live metal of its fuse link, fuse contacts and fixed contacts.

If the fuse is capable of isolation, it shall be so interlocked with the switch that isolation is complete before the fuse enclosure can be opened; further the switch shall be prevented from closing while the fuse cover is open.

11.14 Starters

11.14.1 General requirements for motor starters

All starters to be used in the operation of pump motors shall be of the “soft start” type (autotransformer starters) and not D.O.L. starters or Star-Delta.

The starter cubicles are required to form part of a motor control centre and as such circuit connections, protection devices etc., shall comply with the relevant clauses of EN 60439-1 for form 3b switchboards. The cubicles shall be easily accessible for maintenance purposes and shall be damp and dust proof to IP54. Each motor starter shall be of a rating to carry the full load current of its rated duty at its most severe load conditions.

Motor starters shall be combination type as defined in and complying with EN 60947-4. Motor starters shall be of the electromagnetic non-latching 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 have Type 2 short-circuit coordination. The circuit breaker fuse, contactor and overload relay combination shall have undergone and passed all the tests specified for full Type 2 coordination. Motor starters to be PLC controlled shall be adapted for such control.

Each individual starter shall be housed in a separate and totally segregated compartment of fixed or withdrawable type as specified in Particular Technical Specification and shall i.e. contain the following:

- i. 1 No. Three Pole and neutral (T.P. & N.) externally operated fault making, load breaking isolating switch interlocked with the cubicle door with provision for using a padlock to hold it in the “OFF” position only. Isolator handles shall not be removable. The isolator shall be provided with suitable number of auxiliary contacts.
- ii. 1 No. T.P. & N. moulded case circuit breaker.
- iii. 1 No. set of frequency converter as follows:
 - The frequency converter shall be delivered with the newest technology including digitised control system, menu programming, display for reading of faults and operation conditions.

- The program system for the frequency converters shall be simple so that input of all data can take place without other equipment than the operation unit in the frequency converter. After programming of the unit, it must be locked with a code or similar.
- It must be possible to read all alarms in a display or with lamps. Regardless of the type of fault that may arise, it must be possible to transmit this alarm via a joint fault signal to the SCADA system. In the event of critical faults in frequency converter, motor or pump etc., the frequency converter must cut out.
- The frequency converter shall be protected against voltage surges, excess current, excess temperature as well as be secured against short circuits and earthing.
- The frequency converter shall be delivered with an EMC filter.

Where two or more contactors are installed within a starter they shall be electrically interlocked to ensure that the correct starting sequence is maintained. The following further devices shall be included.

- i. Power factor correction capacitor shall have protective fuses.
- ii. Include adjustable time delay relay on sequence starting (0 ÷ 10 minutes).
- iii. Provide normally open, potential-free contacts for local and remote indication
- iv. Provide one set of normally open volt-free contacts for remote overload alarm indication
- v. Provide one set of terminals for remote emergency lock-off-stop and remote indication lamps.

The following equipment shall be mounted on the front of the starter cubicle door:

- i. 1 No. Ammeter in motor circuit, fitted with suppressed scale showing motor running and starting current.
- ii. 1 No. kW meter in motor circuit, fitted with suppressed scale to read motor running and starting power.
- iii. 1 No. Pilot lamp “Motor in Operation”, shall be initiated by the final contactor stage.
- iv. 1 No. Pilot lamp “Overload Tripped”
- v. 1 No. Overload reset push-button.
- vi. 1 No. “Off-Local-Automatic” selector switch.
- vii. 1 Set. Stop/Start pushbuttons for operation under hand control.
- viii. 1 Set Component labels.

11.14.2 Actuator starters

When motorised valves are specified, the actuator starters shall be integrally housed within the actuator in a robustly constructed, totally enclosed weatherproof housing to enclosure protection standard IP65. The motor starter shall be capable of starting the actuator motor under the most severe load conditions.

The starter housing shall be fitted with contacts and cable terminations for power supply, remote PLC control and positional indication circuits.

Each actuator starter shall be equipped as follows:

- i. No. T.P. Magnetically operated line reversing contactors with arc chutes, no-volt releases and electrical and mechanical interlocks.
- ii. 1 No. T.P. Thermal overload device.
- iii. 1 No. Set of “Open”, “Close” and “Stop” pushbuttons.
- iv. 1 No. Set of “Torque”, “Open” and “Close” position limit switches.
- v. 1 No. “Local-Off-Auto” Switch with padlocking works. The “Auto” position will permit control to be initiated by a signal from automatic equipment as detailed in the relevant section of the Specification.

11.14.3 Automatic control

Where motors are required to operate in a predetermined sequence starters shall include suitable auxiliary relays and contacts. All starters which are not PLC controlled shall contain a timer, fully adjustable between 0-30 minutes, which shall only permit the drives to start in a staggered sequence on restoration of supply after an electricity supply failure.

11.14.4 Power factor correction capacitors

The power factor shall be corrected to 0.95 lagging for all motors rated above 10 kW. Unless otherwise specified in Particular Technical Specification, 3 phases unit power factor correction shall be provided for each motor circuit. On LV motor circuits the capacitors shall be housed in its respective starter compartment. Where due to space limitations the capacitors cannot be housed within the starters, they shall be installed in separate compartments adjacent to and fully interlocked with their respective starters.

The rating of capacitors shall be selected to correct the power factor of the motor when the associated drive is operating at its maximum duty point. Should the rating of the capacitor exceed 85% of the magnetising kVAR of the motor, it shall be switched by a separate contactor, interlocked and controlled automatically with the motor line contactor.

The capacitor(s) shall be connected after the line contactor but before the motor protection overloads, generally in accordance with the motor starter schematic diagrams. All capacitor circuits shall have three separate protection fuses housed within the respective starter compartments.

The capacitors shall be of the oil or synthetic mineral oil impregnated type with paper or paper and plastic, film dielectric in an oil tight steel tank complete with discharge resistances. A metal enclosed terminal box with a bolted or screwed cover shall be provided with cable entry sealing works.

A label shall be fitted on all capacitors warning that discharge resistances are fitted. All capacitors shall comply with relevant standards. Capacitors containing polychlorinated biphenyls will not be accepted.

11.15 Electric motors

All motors, shall be furnished, adjusted and connected ready for safe operation. They shall be of approved manufacture and shall comply with the requirements of the specifications. Motors of the same type and size must be fully interchangeable and shall comply, as far as applicable with IEC standard motor dimensions.

11.15.1 General requirements

Motors ambient shall be of the squirrel cage induction type suitable for direct-on-line starting, with starting current not exceeding 6 times full load current unless specifically detailed in the relevant Section as an alternative arrangement.

Care must be taken in selecting the type of motor in relation to the starting characteristics of the driven load. Although a direct-on-line squirrel cage motor may be suitable in respect of starting current limitations, the starting torque may be insufficient and a motor of wound rotor construction (slip ring) could be required. Conversely, where a mechanical overload device is employed, it may be necessary to limit the starting torque of the motor thus ensuring the overload device can be set to give maximum protection to the plant.

All motors shall be suitable for operation at 380 V, 3 phases 50 Hz. supply and shall comply with EN or IEC Regulations and Standards.

Motor frames for indoor use shall conform to a degree of enclosure protection not less than IP54.

Motor frames for outdoor use shall conform to a degree of enclosure protection not less than IP55.

Totally enclosed motors shall be provided with means of breathing and drainage. Motor frames for submersible pumps shall conform to a degree of protection not less than IP68. All motors, exclusive submersible pumps, shall be suitable for operation in the Site climatic conditions and in ambient temperature up to 40°C.

The rotors shall run in ball and/or roller bearings and the weight of the rotor shall be carried by ball thrust bearings incorporated in the motor body. Bearings shall have a minimum rated life of 6 years (50,000 hours) and have provisions for adequate lubrication.

The bearing caps on the non-drive end covers of the motors shall be arranged so as to allow a speed check to be taken. The efficiency and power factor of the motors shall be high over a wide range of load conditions and the motors shall be designed, manufactured and tested in accordance with relevant EN standards.

All windings shall have Class F insulation with Class B temperature rise limitations and this requirement is in addition to any adjustments necessary for the high ambient temperature at Site. A winding connection diagram shall be supplied permanently affixed to the inside of the terminal box or cover.

In addition to standard rating and performance data, motor nameplates shall include details of class of insulation, temperature rise and type of enclosure. Motors shall be S4 duty type and capable of a minimum number of 15 starts per hour unless specifically detailed elsewhere in the appropriate section of the Specification.

The continuous maximum rating (C.M.R) of each motor shall be in accordance with the following requirements:

Table 11-01: Continuous maximum rating for motors

| Application | Up to 125 kW drives | Above 125 kW drives |
|--|--|--|
| All pump motors (excluding positive displacement type) | 10% above the possible maximum power requirements under operating condition including allowable test | 5% above the possible maximum power requirements under |
| Positive displacement pumps and com- pressors | 25% above the calculated power requirements for normal duty or 5% above the power required for maximum duty whichever is the | 12.5% above the calculated requirements for normal duty or 5% above the power required |
| All other drives including screens, mixers, conveyors, tank scrapers, etc. and process plant | 50% above normal duty requirements | 25% above normal duty requirements |

The above percentages shall be added to the calculated power requirements for motors, prior to making the necessary adjustments (increased ratings) for high ambient temperature at Site. A higher percentage shall be added to the calculated power requirements for motors, if specified in the appropriate machinery section of the Specification.

All motors shall be capable of developing a minimum starting torque of 150 per cent of the full load torque. It may be necessary, however, to limit the starting torque on some drives and this shall be achieved by the form of starter and method of starting.

The motors shall be commercially silent in operation and run free from vibration. The rotors shall be balanced both statically and dynamically and shall be tested and adjusted for dynamic balance both in an approved manner. The Site rating and normal ratings of all motors together with all performance data shall be provided to complete all the various schedules of particulars.

All guaranteed and technical data shall be that for an ambient temperature of 40°C, although all proving tests at the manufacturer's works shall be carried out at ambient temperature. Manufacturer shall provide de-rating curves for each motor and these shall be included in the maintenance instructions. Where identical type and size motors are being supplied, one motor only shall be subjected to full tests and the remaining units to abbreviated tests.

Terminal boxes shall be provided with glands suitable for XLPE or insulated wire armoured, PVC sheathed cable. The motor stool base, where appropriate, shall be drilled at works, vertically below the terminal box gland for the passage of the cables and the edges of the hole slightly countersunk or the hole bushed.

Termination boxes and terminals shall be of suitable dimensions to accept appropriate over-sized cables in accordance with the schedules of particulars. All motors drives shall be labelled to correspond with their respective starters.

Arrangements shall be made with the manufacturer so that the Engineer may witness motor tests if so desired. Triplicate copies of motor test certificates shall be provided for approval. Additional copies shall be provided and included in the Operating and Maintenance Instructions.

11.15.2 Protection of motors

For motors rated less than 0.5 kW, three single pole thermal overloads with phasing protection shall be provided. For all motors rated above 0.5 kW three single pole thermal overloads and three single pole, wound magnetic adjustable overloads with phasing protection shall be provided or alternatively the motor shall be protected by a three phase motor protection relay.

11.15.3 Overcurrent and earth fault protection relays

Relays to be used for this duty shall incorporate selective Inverse Definite Minimum Time (I.D.M.T.) and Definite Time characteristics. Relays shall be arranged 2 pole overcurrent and 1 pole earth fault or 3 pole overcurrent and separate 1 pole earth fault to suit 3 phase 3 wire and 3 phase 4 wire system application respectively.

Inverse time characteristics shall be standard inverse or very/extreme inverse to meet the power system protection scheme requirements and shall fully comply with EN/IEC standards. Relays shall be of the static electronic pattern. Current and line settings shall be adjustable by integral switch or plug assemblies of approved pattern.

Relays shall be suitably rated to operate at the specified DC auxiliary circuit voltage and have output contacts suitable for operating the tripping mechanisms of the associated circuit breaker and initiating alarm and indication systems.

11.15.4 Direct motor thermal protection

Where specified, motors shall be provided with embedded thermal switches or thermistors with a protective relay operating in the contactor circuit. Thermistor protection on motors fitted with internal thermal devices shall be arranged such that in the event of device operation, a lock out function to prevent automatic re-start upon temperature reduction is operated. The tripped indication shall also operate.

Thermostat protection relays shall be ambient temperature compensated and have external manual reset works.

11.15.5 Emergency stop push buttons

Emergency stop push buttons of the mushroom headed, stay put type shall be provided adjacent to all motors as specified in EN 418 and EN 1050.

Once operated the motor shall remain locked out until both the push button twist to release mechanism, and the “emergency stop reset” push button on the control panel have been operated.

The emergency stop push button shall be direct acting on the motor circuit, i.e. no intermediate devices shall be utilised.

Emergency stop push buttons shall be mounted on a suitable framework arrangement at a height of 1m and in a position to be accessible for emergency operation by the works personnel.

11.15.6 Name plates on motors.

Manufacturer's name plates on electric motors shall contain at least the following information:

- a) Manufacturer,
- b) Type, serial number
- c) year of manufacture
- d) Rated power (kW)
- e) Power factor
- f) Efficiency (%)
- g) Voltage (V), type of starting.
- h) No. Of phases
- i) Degree of protection
- j) Frequency (HZ)
- k) Synchronous speed (rpm)
- l) rated current insulation class
- m) Rated Current
- n) Insulation Class

11.16 Cables

All cables used in the construction of the electrical installation unless otherwise specified, shall be manufactured to comply with IEE regulations and the relevant National Standards: All cables shall be of suitable voltage grade, with stranded copper conductors, selected for the climatic conditions specified and shall be rated by the approved factors laid down in the latest issue of relevant standards. The selection of all cables and rating factors shall be based on the followings:

- a) Ground Temperature.
- b) Thermal resistivity of soil.
- c) Cable depth L.V: 1.0 metres
- d) Cable depth, Control and Instrumentation: 1.0 metres
- e) Cable grouping in accordance with the relevant tables.
- f) Cable in air in accordance with the relevant tables.

Each cable shall be of sufficient rating for its duty under normal, fault and Site installation conditions. To assess the rating and cross-section required for each cable, the following factors must be considered as a minimum:

- a) Fault level.
- b) Conditions of ambient temperature relevant to method of laying.
- c) Voltage Drop.
- d) Voltage drops in motor circuits due to the starting method.
- e) Over current settings of circuit breakers.
- f) Disposition of cabling, whether in air, ducts or trays/ladders.

Where cables are run in conduit any requirements of the EN standards must be complied with. Where a neutral conductor is required, its cross-sectional area shall not be less than that of the phase conductors, unless otherwise specified. Each and every mains supply cable shall be provided with an individual earth continuity conductor (PE), which shall be not less than that of the phase conductors, unless otherwise specified. The PE conductor can either be one core of a multicore cable or a separately run, PVC insulated (yellow-green) stranded single core cable sized in accordance with the EN standards. The use of cable armouring, conduits, water or other service pipes as the only means of an earth continuity path is strictly prohibited.

Each cable shall be supplied in lengths suitable for a continuous run, as no through joints will be permitted in any cable run without the prior consent and written permission from the Supervisor.

Prior to dispatch to Site, the supplier shall pass to the Engineer, in triplicate, copies of the cable manufacturers test certificates for approval.

11.16.1 L.V. cables, General

All L.V. power cables shall be of the thermoplastic insulated type of either polyvinyl chloride (PVC) or cross linked polythene (XLPE). These shall be manufactured in accordance with VDE 0271 or DIN 46235. They shall be of 600/1000 V grade and comprise stranded copper conductor, PVC or XLPE insulated with suitable bedding, sheathed overall with extruded PVC. All L.V. cables shall be from an approved manufacturer.

11.16.2 L.V. cables small wiring

Small wiring cables for use on power, lighting, ventilation etc. shall be 600/1000V grade and a minimum conductor size of not less than 1.5 mm² cross sectional area. All conductors shall be stranded.

11.16.3 Control and instrumentation cables

Control and instrumentation Site cables shall be shielded and have polyethylene or PVC insulation. These shall be manufactured in accordance with VDE and IEC standards as IEC

227. Each cable shall have its individual cores identified along their entire length by permanently printed numerals or letters. At every point of termination, core identification shall be carried out using an approved system of ferrule markers. At points of interconnection of wiring at which a change of numbering is unavoidable double ferrules shall be provided on each wire.

Any change of numbering shall be recorded on the wiring diagrams of the equipment at which the change is made.

Where it is proposed to use junction boxes for the marshalling of control and instrumentation cables to a common item of equipment, etc., any such junction box shall be of the wall mounting type, purpose made, complete with double terminal blocks of the pressure plate pattern.

All incoming wires shall be identified with core ferrules in accordance with the system schematic and cable diagrams. Prior to the installation of any junction box, the Contractor shall submit to the Engineer full details of the box and proposals for its use and only commence installation on the receipt of written approval from the Engineer. Steelwire armouring is re-quired for underground cables.

11.16.4 Cabling method for electrical power

Every cable shall be installed in accordance with the relevant codes of practice and shall be neatly run in all situations.

When more than one cable is to be terminated at an item of equipment, particular care shall be taken to ensure that cables to that equipment are routed from a common direction and each is terminated in an orderly and symmetrical fashion. Each and every cable shall be permanently identified at each end by its cable number, as noted within the schedules. The identification label shall be of adequate size and style to a pattern approved by the Supervisor and shall be securely fixed to its relative cable.

Where cables enter or leave structures or panel plinths, the ducts shall be sealed at the points of entry or exit. Caulking shall be carried out with an approved compound and followed by not less than 40 mm of epoxy resin, two mix-cold waterproof compound or a weak sand/cement mixture as directed by the Engineer. This shall include any spare ducts. The Contractor shall be responsible for temporarily sealing all cable ducts into structures during the installation stage to prevent accidental flooding of the structures.

During caulking care shall be taken to ensure that the serving and/or armouring of any cable is not damaged. In the event of any armouring or serving fault being made it will be the responsibility of the Contractor to repair or make good any such fault to the satisfaction of the Engineer. Where any such fault occurs, these shall be made known to the Engineer and subsequently recorded on the final record drawings.

All power cables shall be connected to switchboards and the like, in such a manner that the correct phase sequence, phase number and colour coding are preserved throughout the systems.

The PVC and XLPE insulated L.V. cables shall have their cores identified, as follows:

- | | |
|---------------|-----------------------|
| a) No.1 Phase | L1 (RED) |
| b) No.2 Phase | L2 (YELLOW) |
| c) No.3 Phase | L3 (BLUE) |
| d) Neutral | Black or N |
| e) Earth | Green or Green/Yellow |

Single core power cables shall have their cores identified as follows:

- | | |
|------------|-----------------------|
| a) Phase | Red or Brown |
| b) Neutral | Blue or Black |
| c) Earth | Green or Green/Yellow |

All cable conductors shall be terminated in suitable copper lugs or brass thimbles using an approved compression tool.

Under no circumstances shall the use of hand crimpers be permitted. All cables shall be delivered on robust cable drums which shall bear the full details of manufacturer, size, length and insulation and shall be offered to the Engineer for inspection prior to installation.

Straight through joints will not be permitted except where a route length is in excess of a maximum drum length in which case the Engineer is to be notified. At the terminals of rotating machines, each cable core shall have core ferrules to match the notation of each connection terminal of each machine.

Wherever it is required to remove the PVC sheath of a cable e.g. at a point of termination, the minimum length necessary shall be removed and the exposed conductor, sheath or armouring shall be adequately covered by an adhesive PVC tape or a PVC sleeve.

All L.V. cables whilst on their drums shall be adequately sealed at each end against the ingress of moisture. When a cable is cut from a length on a drum the drum length shall be immediately sealed. All cables once cut and laid shall be terminated in their final position or effectively sealed. All cables shall be drawn from the top of its drum which shall be jacked and positioned for easy draw off in relation to its final position of installation, Where a long length of cable is drawn from its drum, cable rollers or skid boards shall be used.

The general routing of cables shall be as generally indicated on the Contract drawings but the final routes shall be those agreed with the Engineer prior to any cable installation work being carried out. All cables shall be installed in strict accordance with the requirements of this Specification.

11.16.5 Cable trench work

The Contractor shall prepare drawings giving the exact requirements for all cable trenches, detailing the width and depth of each trench and detailing road crossing cable ductwork to be provided. The drawings shall be prepared in conjunction with the Engineer and shall be approved in writing before issue to Site.

The excavation and back filling of cable trench work shall form part of the work by a civil works Contractor together with the supply and laying of road crossing and other ducts. The Contractor shall work closely with the excavating and back filling Contractor (the civil works Contractor).

The laying of all cables shall satisfy the following requirements:

- a) Cable depths shall be assessed from the finished ground level unless otherwise directed by the Engineer.
- b) Before laying cables the Contractor shall inspect the trench work to ensure that the trench bottom is of a smooth and firm contour and free from broken stones or rocks.
- c) Cable bedding within the trenches shall be of a 75 mm sand layer.
- d) Cables shall be laid with adequate separation and shall be “snaked” to avoid tension during backfilling operations and subsequent settlement.
- e) All cables when laid shall be inspected by the Engineer.
- f) Thereafter cables shall be covered by a further 75 mm of sand which shall be well tamped around the cables.
- g) After sanding, concrete cable covers and red warning tapes shall be placed as required.

11.16.6 Cable tray work

The Contractor shall supply and erect all required cable tray work. The following points shall be taken into account in selecting routes for cable trays:

- a) Number of drive, power and control cables to be located on each cable tray.
- b) Separate cable tray works for machinery (EN 60204-1) and building installations (IEC 364)
- c) The avoidance of existing pipework and pipework required for future extensions.
- d) The avoidance of maintenance areas of machinery, pipes, etc.
- e) The avoidance of unnecessarily long runs of cable.
- f) Tray runs to be at high level as far as possible with droppers to plant items.
- g) The tray to be arranged vertically as far as possible.

The cable tray shall be manufactured from heavy duty, hot dip galvanised mild steel complete with approved type fixings and installed in accordance with manufacturer's instructions to permit maximum expansion.

Support brackets shall be constructed from galvanised steel, heavy duty type, and installed at a maximum of 1,200 mm centres. Fixings of these brackets will depend on the tray loading. Bends, tees and junction pieces shall be of standard design and have an inside radius of not less than 300 mm.

The trays shall be of adequate width for cables to be laid flat and not bunched. All cables shall be saddled or cleated in position as they are installed along the route. Cables on vertical trays shall be securely fixed at 600 mm maximum spacing. Cables on horizontal trays shall be fixed at suitable intervals to ensure a neat and orderly installation.

Particular care shall be taken on vertically rising tray work, and adequate cable fixings shall be supplied to ensure security and distribution of load.

11.17 Building works

The Contractor shall mark out all necessary holes and chases in the course of carrying out the installation and be responsible for the correct positioning of all fixings. All cutting away and grouting in of fixings in brick and concrete work and the making good shall be carried out by the Contractor. The Contractor shall arrange for the general requirements necessary for the electrical installation such as floor ducts, chases, etc., to be carried out at various stages of building work to ensure continuity of construction. In all cases the Contractor shall drill and plug walls, ceilings, floors, etc., and provide any special fixings for securing conduits, cables, etc.

11.17.1 Conduit Systems

Approved conduit systems shall be rigid steel conduits with metric threads and for flexible steel conduit and adapters, as appropriate. All rigid steel conduit and fittings shall be screwed and hot dip galvanised, inside and outside.

In all plant buildings and structures, conduit shall be fixed to the surface of the wall or concealed in the floor screed when they cross the floor. Conduit shall be concealed in those locations where the wall or ceiling finishes as shown on the drawings or detailed in specific clauses make this possible.

All conduits shall be installed in an approved manner and arranged with adequate ventilation and drainage where necessary. Where practicable, all bends or sets, shall be formed in the conduit itself. Inaccessible junction boxes shall not be used.

The whole of the conduit system shall be completely swapped through to remove any loose matter or dirt before cables are drawn in. Where conduits connect to switch boxes, drawin boxes, etc., the conduits must have a machined faced socket, screwed on to the end which when tightened, is flush with the outside of the box. The conduit is then to be secured to the apparatus by means of a hexagon smooth bore brass bush screwed from the inside of the apparatus into the conduit socket, in order to make a sound and tight mechanical joint. Conduits secured by locknuts in plain drilled holes will not be permitted.

All exposed threads shall be cold galvanised after installation. Surface run conduits shall be supported at intervals in accordance with the following schedule:

Size Interval

- 20 mm 1.2 m
- 25 mm 2.0 m
- 30 mm 2.5 m

Where bends and sets occur in the conduit run, the conduit shall be securely fastened at a distance of 250 mm on either side of the diversion. Standard junction or adaptable boxes shall be provided at all junctions and at sharp changes of direction, in addition to any special positions where they are called for by the Engineer. Steel or malleable cast iron inspection couplers may be used in long runs to facilitate drawing in cables.

Only continuous lengths of buried conduit shall be installed between boxes, no joint boxes being allowed in the floor screeds. Conduits crossing expansion joints shall be fitted with couplings of approved manufacture, with an earthing clip at each side of the coupling, connected by the correct size of tinned copper stranded wire.

The ends of conduits laid or set in shuttering prior to concreting, shall be temporarily sealed off with a coupler and a solid brass plug. Installations of conduits shall be made on the exterior surface of buildings shall be done only after acceptance of the Engineer.

Fixing to surfaces of walls shall be by means of spacer bar saddles securely fixed by screws. Where conduits are concealed or laid in construction floors they shall be held in position with substantial fixings of make and pattern approved by the Engineer.

Conduit shall be of the screwed pattern galvanised by the hot dip process. All conduit fittings not carrying accessories shall be supplied with flat covers, fixed in position with round head brass screws. Each fitting shall be supplied with a neoprene gasket.

Adaptable boxes shall be constructed of minimum 3 mm sheet steel or best quality cast iron, finished as previously detailed for conduit fittings and sized to prevent the undue packing of cables.

Weather proof boxes and accessories shall be used outdoors, and where indicated in the Specification. Conduit shall be installed such as to permit complete rewiring, without the need to carry out builders works. No single conduit serving single phase socket outlets, lighting points and switches shall contain more than one phase.

11.17.2 Flexible Conduits

Where the conduit system terminates at any equipment requiring a non-rigid connection, a flexible conduit shall be installed of the PVC or PVC sheathed metallic type, fully watertight with purpose made connection adapters.

Each flexible connection shall include not less than 400 mm length of flexible conduit.

11.18 Lighting and sockets

11.18.1 Lighting switches

Indoor surface switches shall be of minimum enclosure standard IP44. Where appropriate, they shall be of the multiple phase type and where possible shall be arranged in multi-gang boxes.

Outdoor lighting switches shall be of minimum enclosure standard IP54. Rear entry shall be provided to allow concealed conduit installation.

Switches controlling fittings in toilets, washrooms, bathrooms, etc., shall be suitable for ceiling mounting, pull cord operated or shall be in accordance with this clause and installed outside the rooms.

Special care shall be taken to ensure that all switches are securely fixed, truly vertical and that flush mounted switches are flush with the wall finish so that the overlapping cover plates seat on to the rims of the boxes.

11.18.2 Lighting fittings

Lighting fittings shall be complete with all supports, suspensions, flexible cables, pendants and plugs. They shall be connected to the main circuit wiring with flexible cables of a minimum conductor size of 1.5 mm² insulated with silicon rubber or PVC. Break joint rings shall be used in conjunction with batten holders, ceiling roses or back plates mounted on to a flush installation.

Standard fluorescent lighting fittings shall have two suspension fixing points. All lamp-holders for flexible pendants shall be of the all-insulated skirted pattern with cord grips suitable for batten or wall mounting and shall be of similar pattern. All lamp-holders shall be of the Edison screw pattern.

All fluorescent tubes shall be of an approved manufacture and standard white. They shall be suitable for the lighting fittings in which they are installed and of correct voltage. All incandescent lamps shall be of an approved manufacture with metal coil filaments, gas filled, clear finish in all standard sizes with standard caps to suit the fittings in which they are installed.

The Contractor shall supply and install all lamps for the entire lighting fitting installation, and shall replace all burned out lamps up to the time that the Engineer takes final acceptance of the Works. The lighting layouts and fittings shall be approved by the Engineer.

11.18.3 Socket outlets

Socket outlets for installation in plant areas shall be manufactured by an approved manufacturer and in accordance with relevant Nationals Standards. Casings shall be produced from a thermoplastic material suitable for industrial application.

- a) 220 Vt sockets, shall be non-switched, 10 A 2 pole & PE and IP 54
- b) 380 Vt sockets shall be switched, mechanically interlocked, 16 A 3 pole and neutral and PE. Protection enclosure IP 54.

11.19 Control cabinets and distribution boards

11.19.1 Control cabinets

Where local starter panels are called for, each shall be provided with a fully metal construction cabinet. The cabinets shall be adequately sized to house the respective panels and be provided with front opening, hinged, lockable, access doors. Back panels shall be of durable material. The base of the cabinet shall be complete with a gland plate and the necessary ventilation devices. Construction shall be to a minimum of IP54. The requirement of control cabinets shall be approved by the Engineer.

11.19.2 Distribution boards

All distribution boards shall be of totally enclosed, metal clad pattern, manufactured in accordance with IEC 439-3. The enclosure shall be made from zinc coated mild steel sheet formed to a clean line and complete with a lockable hinged cover with gasket. Removable plates with conduit knockouts shall be provided at top and bottom.

The maximum height of any operating controls shall not exceed 1,700 mm above finished floor level. All distribution boards shall be complete with an isolator of the rating and phase as the fuse switch at the supply source.

Doors shall be fitted with suitable gaskets and shall be easily removable to preserve the finish and simplify installation. Each distribution board shall be arranged for top or bottom cable entry and shall be provided with ample cable termination plate and chamber, to enable cables to be neatly glanded with tails grouped and terminated on to the appropriate internal terminations.

Distribution boards shall be wall or floor mounted and shall, when specified, incorporate onload incoming supply switch disconnectors complying with EN 60947-1 which shall be of the front-of-panel operated type, with an "ON/OFF" indicator and capable of being padlocked in the "OFF" position. Distribution boards shall incorporate cartridge fuses, or combinations of single pole and neutral and triple pole miniature circuit breakers.

Miniature circuit breakers (M.C.B.'s) shall comply with relevant EN or IEC standards. They shall be fitted with thermal overload and instantaneous magnetic short circuit protection. Earth leakage protection, when specified, shall be current operated.

Back-up fuses shall be fitted to provide the specified rupturing capacity, but the ratings of the M.C.B.'s must be correctly coordinated with the fuse rating to achieve the necessary degree of discrimination.

Each bank of M.C.B.'s/fuses shall be clearly identified with its appropriate phase reference/code, and the mounting framework for the banks of M.C.B.'s/fuses shall be easily removable to simplify installation. Adequate phase barriers and shields shall be fitted to ensure that after installation and wiring, all bare terminals and wires are covered, to prevent

accidental contact with live conductors during the normal procedure of fuse changing and resetting of M.C.B.'s.

All neutral bars shall have a separate terminal for each fuse way within the distribution boards.

11.20 Earthing

11.20.1 General requirements

The metal framework of all electrical and associated equipment, exposed building steelwork, metal enclosures and associated screenings, supports, doors and any other metalwork that is not normally used to conduct electricity shall be effectively earthed at all times. Particular care shall be taken where moving parts are involved that they are earthed in any normal position, e.g., circuit breaker carriage, cubicle or substation door. A suitable flexible connection shall be provided for continuity between each and every moving part.

11.20.2 Earthing systems

A main earth terminal bar shall be provided for each earthing system of each section of the power system or building installation to which all main earth conductors, earthing leads, neutral earth connections, switchboard earth bars, frame earths, and electrode nests, etc. shall be connected. Connections shall be readily accessible for test purposes.

Earthing system network / earth mat shall be of interconnected mesh of GI flats buried in ground in the plant. The interconnections shall be done with GI flats of suitable sizes. The earth conductors shall be free from pitting, laminations, rust, scale and other electrical, mechanical defects.

Metallic frame of all electrical equipment shall be earthed by two/three separate and distinct connections to earthing system, each of 100% capacity, with the exception of solar panels, for which alternate means of code-compliant earthing shall be admissible if integrated with racking design

Each continuous laid lengths of cable tray shall be earthed at minimum two places by G.S. flats to earthing system, the distance between earthing points shall not exceed 30 meters. Wherever earth mat is not available, necessary connections shall be done by driving an earth electrode in the ground.

Neutral connections and metallic conduits/pipes shall not be used for the equipment earthing.

Each main earth terminal bar shall comprise a wall mounted mild steel channel supported on non ceramic insulators and of a length to accommodate all connections.

Earth pit shall be constructed as per IEC standard specified, Minimum spacing between electrodes shall be 2000 mm. Earth pits shall be treated with salt and charcoal/chemical Powder Earthing.

Earth resistance at earth terminations shall be measured and recorded. All equipment required for testing shall be furnished by successful bidder.

The armour wires on main cables shall be solidly bonded and earthed to provide additional earth paths. Particular care shall be taken on cable termination boxes, to ensure that the cable armour is adequately bonded to the associated item or plant.

Particular care shall be taken to ensure earth continuity across items of equipment situated within a cable run. Should the design of such equipment not give an adequate and lasting continuity through its structural body, then additional earthing clamps and conductors shall be provided to independently bond the cable sheaths together.

Joints and terminal boxes in underground cables (if approved by the Engineer) shall be bridged by tinned copper of adequate cross section, bonded to the cable sheath. Earthing systems shall be performed according to National standards.

Earthing Design and Layout

i) The successful bidder shall submit Design along with drawings showing the location of lightning arresters and protection zones to cover all arrays against lightning for approval from Employer.

ii) The earth mesh system design consisting of G.I Flats shall be submitted for approval of Employer.

iii) Total plant earthing system shall be designed to give an earth resistance of less than 1 ohm all along the earth mesh.

iv) Earthing conductors in outdoor areas shall be buried 1.5 to 2M below finished graded level and these buried conductors shall be brought 500 mm above ground level for making tap connections to the equipment.

11.20.3 Protection of Earthing Systems

The complete earthing system shall be protected against damage by corrosion where necessary.

11.21 Lighting protection

11.21.1 Structures and buildings

All structures and buildings shall be provided with lightning protection in accordance with relevant EN/IEC. Standards. Each structure shall be provided with one or more lightning arresters mounted at the highest point. Lightning conductors shall be routed as directly as possible avoiding acute bends. The installation shall generally comply with the requirements for earthing conductor installation.

11.21.2 Lightning protection devices for plant

Lightning mast/conductor, placed at strategic locations, shall be used to protect the arrays against lightning protection. The contractor shall give detailed design showing location of lightning conductor/masts and the protection coverage on array without causing any shadow on the modules to the Employer.

All design shall be submitted to the Employer before its implementation.

Necessary concrete foundation for holding the lightning conductor in position to be made after giving due consideration to maximum wind speed and maintenance requirement at site in future.

The lightning conductor shall be earthed through GI flats and connected to with earth pits per applicable International Standards. Three earth pits shall be provided for each lightning arrestor.

Each lightning conductor shall be fitted with individual earth pit as per required Standards including accessories, and providing masonry enclosure with cast iron cover plate having locking arrangement, watering pipe using charcoal or coke and salt as required as per provisions of IS

Lightning protection shall be selected to provide the highest degree of protection possible, for the circuit being protected, i.e. the clamp voltage shall be the lowest possible commensurate with normal operation of the circuit. The type and manufacture of the Lightning Protection Unit shall be approved by the Engineer.

Each lightning protection unit shall be earthed to an individual earth electrode, as directly as possible, without inductive loops and equipotential bonding to the nearest earth reference bar. A single unjointed earth cable shall be utilised.

Individual lightning protection units shall bolt directly onto a lightning earth bus bar. Cables and cores containing the circuits to be protected shall not be looped or grouped together until the circuits subject to induced lightning energy have passed through the protection units.

Where two or more lightning protection units are mounted on the same rail mounted earth bar, the earth cable shall be sized as follows:

- a) Cable length less than 6 metres 10 mm²
- b) Cable length greater than 6 metres 16 mm²

The whole assembly shall be mounted inside an insulated box, if not already mounted separately from other equipment, close to the chosen earth termination in order to achieve a short, straight connection.

Lightning protection units which are mounted in an enclosure supplied with an ac electrical power supply which utilise DIN rail mounted earth bars shall have the earth bars insulated by means of a proprietary standoff, or the DIN rail insulated in an approved manner from the electrical power earth or any earthed conducting surface.

The route for the earth conductor system shall be as far away as possible from the vicinity of signal- and LV cables. The earth conductor shall be copper, no smaller than 16 mm² in section, and its route shall be as short and direct as possible, in any case no longer than 10 metres. The cable run shall be straight, but any bends that are necessary shall have a long radius.

Where copper cables terminate to a GI bar, anti-corrosive coating shall be utilized.

The earth termination and the method of connection shall be approved by the Engineer.

11.21.3 Earth electrodes

The Contractor shall provide an earth electrode system in each cases where lightning protection unit, Motor Control Centre, control board, distribution board etc. provides for the facility of lightning surge diversion equipment. The system shall be equipotential bonding to the main protective conductor system at the common point of connection of the distribution system which it serves.

Earth electrode systems shall be provided where specified. Where lightning protection is specified to be provided, the Contractor shall provide an earth electrode system in full accordance with the relevant code of practice.

11.21.4 Earth electrode installations

Earth electrode installations shall connect earthing conductors to the general mass of the earth. The installation shall comprise earth rods, mesh or a combination in order to obtain the required earth electrode resistance.

Earth rods shall be of made of copper clad steel rods sized 16 mm outer diameter, made up of sections of 1.2 m long with internal screw and socket joints and fitted with a hardened steel tip and driving cap. They shall be driven into the ground to a minimum depth of 2.4 m.

A minimum of two earth rods or other electrode shall be provided by the Contractor for each main earthing system, and the conductor brought back to the main earth bus-bar for each.

Connections to the electrodes shall be made as to be easily accessible for periodic inspection and shall be protected against mechanical damage and corrosion. The actual connection to the earth rod shall be by means of a purpose made non-ferrous clamp and shall be made below ground level, in a concrete inspection pit, having a removable cover.

When the installation has been completed, soil resistivity or other tests shall be carried out and witnessed by the Engineer, in order to ensure that the required earth loop impedance figure of less than 5 ohms is attained.

11.22 Labels, marking

All external and internal labels shall be engraved multi-layered plastic affixed with chrome plated screws. Each switchboard, control panel, distribution board, compartment door, etc., shall have a title label and each door mounted component or control shall have a function label. Every internal component shall be identified

Each cubicle, panel, meter, switch and device shall be provided with a nameplate or escutcheon plate for identification with English and Swahili description on the front of the panel directly below each device as appropriate. On the inside of the control compartment of the switchgear panel, a yellow label, engraved in Black Letters and Numbers shall be fixed below each device. The Device Name/Number fixed on the inside of the control compartment shall correspond to the Name/Number used in the drawings. Each equipment shall be provided with a rating plate containing the necessary information specified in the relevant IEC standards, and each fuse shall be labelled with identification, fuse type, fuse current.

The plates shall be made of weatherproof and corrosion-proof materials and shall not be deformed under the service conditions at the site. The entries on the plates shall be indelibly marked by engraving with black letter on a white background.

Compartments with doors not interlocked to an isolator or removable covers having access to live parts shall have an external label affixed thereto: -"DANGER LIVE TERMINALS" - black letters on a yellow background.

A list of label inscriptions shall be submitted to the Engineer for approval before manufacture.

11.23 General instrumentation, monitoring and control requirements

11.23.1 General

The Clauses in this Section define the general requirements and standards of workmanship for the manufacture, supply, installation and commissioning of all instrumentation, monitoring and control equipment (excluding switchgear and motor control centres) and shall be applicable to these Works unless stated to the contrary in the application clauses.

11.23.2 Contractor's Responsibility

The Contractor shall be responsible for:

- a) all aspects of design, application and, where applicable, subsequent operation of the equipment, monitoring facilities and control circuits in accordance with the requirements of this Specification,
- b) liaison between sub-contractors to ensure complete compatibility of all equipment at both component and system interface levels,
- c) overall systems engineering to ensure that all equipment, components and systems together form a consistent, rational and fully integrated instrumentation, monitoring and control installation,
- d) ensuring that each system is handed over complete in all detail and in perfect working order,
- e) the supply and installation of all components including signal isolators, amplifiers, converters, filters, line/equipment protection devices, voltage stabilisers, inverters, power supplies and similar items which may be necessary to achieve the correct functions as specified in the application clauses and to provide a safe and reliable installation; whether or not such items are specifically called for in the Specification,
- f) providing protection on all relevant circuits and equipment against the effects of lightning and other induced voltages.
- g) the supply and installation of all interlocks, alarms and other facilities as the Engineer, may consider necessary to ensure safe and efficient operation ensure safe and efficient operation whether or not such items are specifically called for in the Specification.

The approval by the Engineer of any drawing shall not absolve the Contractor from his complete design responsibility. All the Contractor's proposals and working drawings for and in connection with the Works shall be submitted early in the Contract period to facilitate co-ordination with Contractors of other trades.

11.23.3 General design requirements

The equipment shall be guaranteed suitable for operation under the prevailing environmental conditions and shall be designed:

- a) such that routine and occasional maintenance throughout its life shall be a practical minimum, compatible with the preservation of maximum reliability,
- b) to withstand the electrical, mechanical, thermal and atmospheric stresses to which it may be subjected under operational conditions, without deterioration or failure,
- c) and constructed to the highest available standards of manufacture, reliability, accuracy and repeatability.

Where more than one component or item of equipment is supplied to perform a particular function, all such items shall be identical and interchangeable. The degree of protection for equipment enclosures shall be in accordance with IEC 60529 as follows:

- a) IP54 for indoor applications,
- b) IP65 for outdoor applications,
- c) IP68 for transducers and other equipment mounted within valve or meter chambers or similar locations.

All equipment cabinets shall have lockable doors and any ventilation openings or louvres shall have effective dust filters. Any cooling fans shall have fan failure alarm contacts connected into the relevant alarm system.

External equipment shall be protected from direct sunlight by a well ventilated cabinet, canopy or other approved type of sunshade. Equipment in air conditioned locations shall be rated for continuous operation in ambient temperature up to 40°C. External equipment and internal equipment not in air conditioned locations, shall be rated for continuous operation over the ambient temperature range 0°C to 40°C..

All equipment shall be protected against aggressive and/or corrosive environment. All instruments shall be installed in the locations shown on the Contractor's drawings and where connections shall be made into pipelines, each installation shall be complete with the necessary manifolds, isolating valves, drain valves, test points, sample cocks, etc., as appropriate. In all cases it shall be possible to isolate and remove the instrument, and fit check gauges, or take samples as appropriate.

All analogue transmitters, receivers and direct wire transmission systems shall have a signal level of 0/4–20 mA or 0–10 V. All panel indicator lamps shall have a lamp test facility.

11.23.4 Installation approval

Where there is no detail in the Specification or associated drawings regarding the exact location or method of installation of measuring equipment, sensors, or other Site mounted equipment, the Contractor shall submit details of his proposed installation to the Engineer for approval and obtain this approval before starting any installation work.

11.23.5 Testing and commissioning

All equipment, including panels, consoles, pillars and all separate items shall be subject to inspection and full function test at the manufacturer's works. All equipment, sequences, programs and the like shall be proved and demonstrated to the Engineer as being in accordance with the application requirements.

Test Certificates, including characteristics covering the full operating range of measured variable against output signal, shall be provided for all instruments or sets of equipment measuring primary quantities.

Site testing shall include demonstration of the satisfactory operation of each system individually and the complete system as whole, before the start of main plant commissioning.

As an integral part of the setting to work and commissioning procedures, the Contractor shall ensure and demonstrate, to the Engineer's approval, that all items of equipment incorporating any form of variable setting (level electrodes, float switches, transmitters, trip amplifiers, meter relays, controllers, timer etc) have been adjusted to achieve optimum control of the process or plant operation.

11.23.6 Cables and cabling

All cables necessary for the complete installation shall be provided and installed in accordance with the requirements specified above.

All signal and control cables shall be shielded. All signal and control cables for PLC shall be shielded.

All multi-pair cables, except those connected to remotely controlled actuators, shall include a minimum of 25% spare cores. This spare capacity shall be over and above any cores which may be required for proposed future installations or extensions. Spare cores in addition to the above may be required in some cables to cater for the spare alarm channels.

There shall be a separate multi-core cable between each motorised valve actuator and the local distribution enclosure or control panel. All such cables shall include a minimum of 2 No. spare cores except those associated with actuators having remote control which shall have a minimum of 12 No. cores. All cores, even spare cores, in the cables shall be connected to terminals in both ends.

11.23.7 Instrumentation and control

All instrumentation, monitoring and control circuits and equipment shall be supplied at a voltage not exceeding 55 volts to earth. These supplies shall be from one of the following three alternatives:

- a) A battery/charger unit, typically of 24 V nominal output, but under no circumstances exceeding 48 V nominal output,
- b) A double wound transformer having a fused primary, a 55–0–55 V secondary with the centre point earthed and each secondary line fused,
- c) A transformer/rectifier system, comprising a double wound transformer with a fused primary and a secondary having one end earthed, together with a full wave rectifier unit incorporating voltage stabilisation if necessary. The mean voltage of the rectified output shall not exceed the nominal output from the instrumentation battery/charger units.

Equipment such as battery/chargers, no break and control power supplies, inverters etc. shall be supplied as necessary to maintain the required electrical supplies to essential instrumentation, monitoring and control systems which shall be kept in operation during a mains power failure. The essential equipment to be maintained during a power failure shall include mimic diagrams, alarm systems, data acquisition equipment and flow measuring, indicating, recording, integrating equipment or as otherwise detailed in the application clauses.

11.23.8 Remote control supplies

On remote control/indication circuits (such as occur with valves, penstocks, etc.) DC voltages and relays shall be used in all cases where the cable capacitance could be of sufficient magnitude to maintain AC relays in an energised state. The Contractor shall be responsible

for establishing where such DC operation of control/indication circuits is required and for providing a suitable supply at locations where instrumentation battery/charger supply is not available.

11.24 Construction of panels

All panels, cubicles, cabinets, consoles, and desks together with any other types of enclosure (excluding motor control centres and switch-gear) which form part of the instrumentation, monitoring and control installation shall comply with the specified in the clauses above covering panel wiring, equipment and terminals.

Removable earthed, metal gland plates shall be provided to accommodate all incoming/outgoing cables, and shall be fitted not less than 250 mm. above the floor level. All equipment, other than front of panel items, shall be mounted on racks or fixing bars and not directly onto the panels.

Each enclosure shall be vermin proof and dust proof with the necessary provisions made for natural or forced ventilation. All panel construction and arrangement details shall be approved before manufacture, and panels shall be subject to inspection.

11.24.1 Panels for indoor use

All instrumentation, monitoring and control panels, designed for use within buildings shall be constructed of prime quality, cold rolled and annealed mild steel or zinc coated sheet steel, of adequate thickness welded and braced to form a rigid structure. The minimum sheet steel thickness shall be 1.6 mm, panel fronts and desk tops having not less than 2,0 mm to provide the necessary strength to prevent bowing. Panel fronts shall be flat and free of bow and ripple. External corners and edges shall be rounded to give a smooth overall appearance. No design involving the use of externally visible assembly bolts or screws will be accepted. All floor standing enclosures shall be constructed with a 60 mm. deep plinth arranged to provide a recessed kicking strip at the front.

Equipment mounting panels shall be not less than 2 mm. thick and shall be strengthened and/or braced to avoid any distortion or vibration. Equipment mounting plates and brackets shall if necessary be hinged to provide quick and easy access to equipment securing screws, terminals and wiring.

Doors and access panels shall be adequately braced or strengthened to avoid any buckling or twisting. Doors shall be of folded and welded construction mounted on lift-off hinges, with one hinge engaging before the other. Where necessary, removable access covers secured by quick release fasteners shall be provided. All doors and access panels shall close onto neoprene or soft rubber sealing strips which shall be held in place mechanically and not by

adhesive. All doors shall be lockable. Where "walk-in" panels or structures are provided, these shall be fitted with lockable car type handles operable from inside even when locked.

Surface preparation and finish shall be in accordance with relevant EN standards, with all internal surfaces finished in white. The external colour shall be as advised by the Engineer. The design and construction shall be such as to provide an enclosure of superior quality which shall match all other panels in the same location in style, appearance and finish, and have environmental protection to IP54. In cubicles for PLC (Programmable Logic Controllers) the temperature shall be between + 10°C and + 30°C. The relative humidity shall not exceed 85%.

11.24.2 Panels for outdoor use

All instrumentation and control cubicles, kiosks etc. designed for use outside shall be manufactured having walls of double skinned, resin bonded fibreglass, with a totally encapsulated infill of non-corroding alloy.

Box section steel shall be encapsulated into door edges and door frames. Hinges shall be of high tensile, 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. The door sill shall be protected by a non-corroding alloy material. The laminate material shall have flame retardant and shall retain "stability, integrity and insulation" for 30 min. when tested. An indicative fire test report shall be provided for approval of the Engineer.

Colour impregnated gel coats backed by coloured resin shall be used to ensure maintenance free and "colour fast" finishes. The finish colour, both internal and external shall be gloss white. Door mounted meters and transparent windows shall be of glass, which shall be protected from harmful direct sunshine by orientation or other approved means.

All internal equipment shall be mounted on supports built into the fibreglass structure. Fixing bolts through the skin will not be accepted. Each cubicle shall be constructed to provide environmental protection to IP55.

11.24.3 Panel wiring and equipment

The requirements of this Clause shall apply to all cubicles, desks, cabinets, mimic diagrams etc. being provided as part of the instrumentation, monitoring and control installation, but not motor control centres or switch-gear.

Panel wiring shall be carried out using cable to the appropriate British Standard, installed in a neat, systematic manner, securely fixed and supported on insulated cleats or trunking, and arranged so as not to impede access to any internally mounted equipment. Analogue signal cables and DC control cables at voltages not exceeding 48 volts (nominal), may be run

together in the same cable bunch or trunking; but these cables shall be run separately from all other cables. In any cubicle, panel, or structure which is not fully enclosed (such as some mimic diagram structures), all cabling which is or may be at a voltage in excess of 55 volts (nominal) to earth, shall be run in conduit.

For all cables, the sizing shall be fully adequate for the possible maximum loading, and derating shall be applied as appropriate for cable bunching and ambient temperature. Identification ferrules shall be fitted to both ends of all wires, and shall be of the full circle type, threaded onto the cable such that all numerals are in line, and read outwards from the terminal.

Where stranded conductors are used, each end shall be fitted with a sleeved termination lug. Terminations shall be restricted to one wire per terminal. Cabling to door mounted equipment shall be protected in flexible cable conduit(s) and cleated to form a loom with a loop of adequate length to allow easy door opening without causing strain to the components or cable.

Sharp edges of cubicles, trunking, components etc., which may be in contact with cables, shall be protected to avoid damage to cable insulation.

11.24.4 Panel protection

All terminals and all live parts (on equipment) which are or may be at a voltage in excess of 55 V (nominal) to earth, shall be enclosed by a protective cover, and carry a warning label stating the actual voltage.

For panels and enclosures covered under this section, the maximum potential between any two points within the panel or enclosure shall not exceed 250 V. Terminals and equipment which are supplied from other sources and which may remain live when the panel isolators are opened, shall be adequately protected and clearly labelled to this effect.

Adequate fuse protection for circuits and sub-circuits shall be provided and arranged such that any fuse failure causes the minimum disruption to controls and indications, and that any such fuse failure cannot create an unsafe operating condition. Fuses shall be of the HRC cartridge type and be mounted within fuse carriers. Ceramic fuse carriers and bases will not be accepted. All neutral links shall be bolted connections.

11.24.5 Panel earthing

A copper earthing bar shall be provided and bonded electrically to the main frame. It shall be provided with suitable brass screw terminals for the connection of the metal cladding, instrument frames, gland plates, cable tray, the armouring of all incoming cables and the Site earthing system.

11.24.6 Panel heating

Each enclosure shall be fitted with one or more heaters to prevent condensation and assist ventilation. The heaters shall be so arranged and located that no deterioration can be caused

to any equipment or wiring. The surface temperature of any part which may be accidentally contacted shall not exceed 65°C. The heating circuit shall be supplied via a fuse, an isolator and an Off/Auto switch. In the "Off" position the heater shall be isolated and in the "Auto" position the heater shall be controlled by a thermostat or humidistat. All switches and controls shall be mounted within the enclosure.

11.24.7 Panel equipment

A fuse and isolating switch shall be provided for each incoming AC and DC supply. Where instrumentation, monitoring or control equipment is to be operated on AC supplies derived from within the cubicle, a 110 V (55–0–55) control transformer (or transformers) shall be provided for this duty. Each micro-processor and/or programmable logic controller shall have its own control supply transformer.

Each cubicle other than terminal enclosures shall be complete with a distribution unit providing an adequate number of fused outlets at 110 V (55–0–55) for possible future requirements.

Cubicles for PLC shall be equipped with a two-way outlet 220 V, and a fluorescent lamp 18 W, automatical switch-on when the door is open. Both the outlet and the lamp shall be fused in the LV distribution board.

All items of equipment mounted within the enclosure such as relays, electrical transducers, indicators, recorders, switch fuses, terminals etc. shall be arranged so as to provide easy access, be securely fixed and clearly labelled as to their function, designation, and where applicable, the voltage. Where meters and recorders are mounted on vertical front panels, the height of the instrument centrelines shall be within the following limits above finished floor level:

- a) Indicating meters: not less than 1.35 m but not exceeding 1.90 m.
- b) Recorders: 1.45 m but not exceeding min. and 1.8 m.

11.24.8 Terminals and termination

Terminals for the connection of all incoming/outgoing cables shall be provided and comprise anti-tracking mouldings of melamine, phenolic or comparable material fitted on a purpose-built mounting rail. The conductors shall be secured by screw clamps or bars, but not pinch screws.

All terminals used on circuits not exceeding 55 V (nominal) to earth, excluding power supplies and auxiliary drives, shall be of the disconnecting link type. Every terminal shall carry a clear identity number. Terminals at different voltages shall be grouped separately, and each group shall be clearly labelled with its respective voltage and function. Each group shall be segregated with a propriety barrier to give a physical separation of 2 mm minimum.

Transparent protective covers complete with a voltage warning label shall be provided on all terminals which are, or may be, at a voltage in excess of 55 V (nominal) to earth.

Sufficient terminals shall be provided for terminating all cores of all cables (including spares) associated with the particular enclosure. The number of terminals shall be sufficient to cater for all anticipated requirements plus 20 per cent spare terminals and 30 per cent spare terminal rail. A minimum of 5 terminals and 50 mm of spare terminal rail shall be provided.

Terminals for connecting to incoming/outgoing cables shall be mounted vertically wherever possible, arranged to provide easy access and to enable ferrule numbers to be read without difficulty. Direct termination onto such equipment as distribution boards, fuses or miniature circuit breakers is not acceptable. Terminal rails shall be backplate mounted only, the mounting of terminal rails on the sides, bottom or top of cubicles shall not be allowed under any circumstances.

11.25 Batteries and chargers

11.25.1 Control battery / charger equipment

This Clause covers the requirements for batteries and chargers, specified in the application clauses for the operation of control, instrumentation, alarm and monitoring equipment, but not for switch-gear tripping/closing batteries or other special function batteries.

Where alternative AC supplies are available, provision shall be made for taking the supply to the battery charger from either source (e.g. from either side of the bus-section switch) with facilities for automatic change over from one source to the other in the event of failure of the supply source.

The battery and charger unit shall where possible form a composite unit and be housed in a single sheet steel, floor standing cubicle having adequate ventilation and separate compartments for the batteries (lower compartment) and chargers (upper compartment). Access to the batteries shall be via lockable, hinged doors, and to the chargers via removable covers.

11.25.2 Batteries

The batteries shall be of the nickel cadmium type having alkaline electrolyte with a nominal output of 24 V, and shall be of adequate capacity to maintain full operation of the relevant load equipment plus an additional 10 per cent, for a period of 2 hours during mains failure, assuming a normal charge condition at the start of the mains failure.

The battery cases shall be made of polypropylene or similar translucent material such that the electrolyte level can be seen through the battery casing. All batteries shall be suitable for the intended service under the prevailing site conditions without excessive gassing or loss of electrolyte.

11.25.3 Battery chargers

Duplicate chargers one “duty” and one “Standby”, shall be provided and mounted on their own respective chassis in the upper cubicle compartment.

The controls for each charger shall be mounted on their own respective mounting plate and these, together with all controls and indicators projecting through the front of the upper compartment shall be positioned at a height not exceeding 1800 mm from floor level. The front panel of each charger unit shall include:

- a) 1 No. "ON/OFF" Mains Isolator
- b) 1 No. Lamp to indicate "AC Supply On" (White)
- c) 1 No. Charger Ammeter.
- d) 1 No. Lamp to indicate "Boost Charge" (Red)
- e) 1 No. Lamp to indicate "Float Charge" (White)
- f) 1 No. Lamp to indicate "Charger Failed" (Amber)
- g) 1 No. Lamp test pushbutton.

Each charger unit shall also be provided with:

- a) 1 No. "Float/Boost" selector switch mounted internally.
- b) 1 No. Set of AC supply fuses.
- c) 1 No. Volt-free contact for duty charger failed alarm.
- d) 1 No. Volt-free contact for low DC output voltage alarm.
- e) 1 No. Volt-free contact for loss of DC output voltage alarm.

The above volt-free contacts shall open under fault conditions and be wired to a terminal block. The following items of common equipment shall also be provided and mounted on the front panel:

- a) 1 No. DC output voltmeter, scaled to indicate regions of "Low", "Normal" and "High" output voltages, by the use of different coloured sectors.
- b) 1 No. DC output isolator Switch.
- c) 1 No. DC output Ammeter
- d) 1 No. Duty/Standby selector switch (labelled "No.1 Duty, No.2 Standby/No.2 Duty No. 1 Standby").

The battery charger unit shall also be provided with one set of full capacity rated output DC terminals and fuses. In the event of failure of the duty selected charger, the standby charger shall be connected automatically and contacts for the remote alarm indication shall be provided. The alarm indicating failure of the duty charger unit shall remain on until the failed charger has been repaired and returned to operation.

Reversion from "Standby" to "Duty" charger shall be a manual operation. The chargers shall be of the solid state constant potential type, and shall be designed to regulate the charger output voltage to within ± 1 per cent for a mains input voltage variation of ± 6 per cent.

The DC terminal voltage shall be further regulated such that under "Float" or "Boost" charge condition the DC voltage does not rise to more than 10% above the nominal.

The charger unit shall also be provided with both short circuit and reverse polarity protection. The charger when selected to "Float" shall be capable of restoring the battery to 75% capacity within 7–8 hours.

Under "Boost" condition the charger shall be capable of restoring a fully discharged battery to 75% capacity within 4–5 hours. All internal and external components shall be labelled as specified above.

The cabinet shall be manufactured with additional treatment to the interior surfaces to prevent any corrosion by battery chemicals and with environmental protection to IP32.

For each battery/charger unit the Contractor shall supply a set of maintenance tools, equipment and spares, and for non-sealed batteries this shall include a re-sealable, 2 litre container of electrolyte, a pouring device and hydrometer; all of which shall be contained and secured within the charger cabinet.

The Contractor shall fix inside the cubicle a wiring diagram indicating and identifying all out- going terminals, components and fuses. Special precautions shall be taken in the sizing of the battery and charger for tropical use, and all equipment shall be adequately rated for the prevailing Site conditions.

11.26 Plant control and indicator circuits

The requirements detailed in this Clause refer specifically to control/indication circuits associated with power actuated valves and penstocks, but shall apply equally to all other plant controls/indications where similar conditions occur.

Although two or more auxiliary or limit switches may initially be set up to give simultaneous operation, it is impossible to ensure that such simultaneous operation will be maintained over an extended period. To avoid the possibility of a system malfunction due to the above, the use of duplicate auxiliary or limit switches to provide the same effective status signal will not be accepted.

Where a valve or penstock status signal is to be used in more than one circuit (e.g. control and indication), one set of auxiliary or limit switch contacts only, together with a slave relay if necessary, shall be used to initiate the operation of all such circuits.

11.26.1 Electromagnetic flow meters

Electromagnetic flow meters shall be in accordance with the following:

- a) meters shall be of the short form, having a modulated, direct current excitation and inherent total zero stability,
- b) the power consumption shall not exceed 16 W per 100 mm of diameter,
- c) the output shall be 0/4-20 mA or 0 - 10 V and the system accuracy shall be within $\pm 1\%$ of actual flow across the full range of the instrument,
- d) a test certificate shall be provided for each instrument,

- e) the field coils shall be fully encapsulated,
- f) the equipment shall be guaranteed suitable for the ambient and process liquid temperatures,
- g) each flow meter primary shall be supplied with a neoprene liner and electrodes of the material best suited to the particular process fluid,
- h) primary units shall be suitable for accidental submergence to a depth of 3 m,
- i) the Contractor shall provide primary units having flanges in accordance with the relevant specification relating to pipes, flanges, fittings, etc.,
- j) the Contractor shall ensure that all primary units are rated to withstand the maximum possible fluid pressure, including possible surge pressures,
- k) each primary unit shall be supplied and installed complete with a dismantling joint to permit removal for repair and inspection,
- l) the flow meter equipment shall be supplied complete with amplifier (converter), drive unit (if applicable) and all cable for connecting between the components. The termination box shall be sealed to IP68 minimum,
- m) the amplifier/converter shall be fully screened to prevent interference from adjacent equipment and shall be remote from the electrodes,
- n) the amplifier/converter shall incorporate voltage stabilization to ensure maintenance of system accuracy with a supply variation of $\pm 10\%$,
- o) the Contractor shall provide a length of pipe having the same length and being flanged as the flow meter primary, to replace the meter should this have to be removed for repair,
- p) the flow meter primary shall incorporate an electrode (or electrodes) to detect when the pipe is not full. The detector output shall control circuits within the converter to open circuit the analogue signal and initiate an indication of the "pipe not full" condition.

11.26.2 Ultrasonic in-line flow meter

Ultrasonic flow measuring equipment for "in-pipe" applications shall operate on the phase difference technique employing 2 No. ultra-sonic probes displaced longitudinally and mounted on opposite sides of the pipe to detect the difference between the upstream and downstream flight times. The equipment shall include acoustic transducers and a transmitter, and shall be installed complete with all necessary fittings, cables and connectors.

The acoustic transducers shall be non-intrusive and arranged so that they may be removed without shutting down the process line. All materials in contact with the process liquid shall be approved for use in the specified application. All items of equipment attached to the pipe and/or pipe insert shall be of non-corrosive material, designed to withstand continuous submergence to a pressure of 3 m head and guaranteed suitable for the temperature and process pressures, including maximum possible surge pressures. The transmitter shall process the signals from the acoustic transducers and shall:

- a) provide an output of 0/4-20 mA or 0 - 10 V proportional to flow,
- b) be suitable for direct or wall mounting with up to 30 m of cable,
- c) incorporate contacts to initiate an alarm in the event of malfunction,
- d) incorporate temperature compensation,

- e) include facilities for field checking and zero adjustment.

The complete system shall operate with a minimum accuracy of $\pm 1.5\%$ of full scale deflection over the full ambient temperature range. A test certificate shall be provided for each set of equipment.

11.26.3 Orifice plate installations

Orifice plates shall be designed in accordance with ISO 5167 and supplied in carrier rings incorporating the pressure tapings. The sensing lines shall be installed with a continuous slope such that condensation will not collect in the pipe. Stop cocks shall be provided close to the tapping points.

11.26.4 Ultrasonic level measuring equipment

Where ultrasonic level measuring equipment is specified in the relevant application clause, level measurement shall be accomplished by the use of non-contact, echo-time measuring equipment operating at ultrasonic frequency. The equipment shall transmit pulses which are reflected back to the sensor from the surface of the liquid whose level is being measured. The equipment shall consist of a sensor incorporating both transmitter and receiver, together with a separate control unit.

The equipment shall be provided with automatic temperature compensation, shall be suitable for operation in the designated application under the specified climatic conditions. The sensor shall be suitable for mounting in the open, or within an enclosed tank, and shall be totally enclosed to IP68.

The control units shall incorporate facilities for adjusting independently both zero and span, and shall have an output of 0/4–20 mA or 0–10 V proportional to level.

The overall accuracy of the level measurements shall be within $\pm 1.0\%$ of the instrument span. The connection between the sensor and control unit shall be via commercially available screened cable, and the equipment shall operate with up to 150 metres of such cable. The Contractor shall ensure that each equipment is suitable for the application, particularly with regard to the blocking distance and transmitted beam angle or cone.

11.26.5 Installation of ultrasonic level equipment

Each ultra-sonic level sensor shall be installed on a robust and rigid structure provided for the purpose under this Contract. The structure shall include a means of levelling the sensor so that the transmitted beam is perpendicular to the liquid surface and shall provide a safe and easy access to the sensor for servicing and maintenance.

The Contractor shall provide, where applicable, a canopy above the sensor and/or the control unit to provide a protection from direct sunlight.

11.26.6 Differential pressure transmitter

Each differential pressure transmitter shall be of rugged construction, suitable for the application and:

- a) have an electrical output of 0/4-20 mA or 0 - 10 V proportional to the differential pressure,
- b) be capable of withstanding a 100% overload (i.e. twice the differential pressure required for full output) without sustaining damage,
- c) have fully adequate static pressure rating to withstand all possible surge pressures,
- d) have stainless steel sensing elements,
- e) have independent span, zero and damping adjustments,
- f) have an accuracy within $\pm 0.5\%$ of span, repeatability within $\pm 0.2\%$ of span and a dead band not exceeding 0.2% of the span,
- g) be operable on a 2 wire system,
- h) incorporate an output indicator.

Each installation shall be supplied and installed complete with:

- a) sensing lines of stainless steel,
- b) a 3 or 5 valve manifold as required,
- c) test point(s) with separate isolating valve(s).

11.26.7 Pressure transducer level measuring equipment

Pressure transducer level measuring equipment shall comprise a strain gauge or differential transformer type pressure transducer, a controller/transmitter and be complete with all necessary cable, conduits, etc., as detailed below. Differential transformer transducers shall be preferred for very low ranges. Each pressure transducer shall be enclosed within an all welded, stainless steel case not less than 19.0 mm in diameter and shall:

- a) have a single moulded cable which is securely bonded to the stainless steel case and comprising electrical connections, venting tube, strain cord or wire within the cable to obtain the necessary strength, and an outer covering suitable for the application,
- b) be suitable for continuous immersion in all process fluids likely to be met in water applications including potable water, distillate, wastewater, raw sewage, primary sludge, secondary sludge, thickened sludge and final effluent,
- c) be constructed so that the sensor diaphragm is protected against damage by shock, debris, etc., without restricting the transference of pressure changes from the surrounding medium,
- d) incorporate automatic temperature compensation,
- e) withstand a continuous overpressure of up to 400% without sustaining permanent deformation or calibration change. The controller/transmitter shall:
- f) be suitable for mounting within a control panel,
- g) accept the signal from the transducer and provide a 0/4-20 mA or 0 - 10 V output proportional to level (gauge pressure), for indication and control,
- h) include independent zero and span adjustments,
- i) have a system checking module which will simulate the transducer output.

The complete system shall provide an accuracy within $\pm 0.75\%$ of span with a linearity superior than $\pm 0.1\%$.

11.26.8 Pressure transducer installation.

For installations in sumps and for similar applications where the depth is in excess of 3 m or where the available headroom over the sump is limited, the pressure transducer shall be installed within a 100 mm dia. G.R.P. tube to provide protection against mechanical damage to both the transducer and the cable. The G.R.P. tubing shall have an adequate number of holes and/or slots to allow it to fill and drain as the level varies. The tubing shall be fixed to the sump wall at intervals not exceeding 2.5 m.

For installations where the sump depth does not exceed 3 m, the sensor shall be supplied and installed as a rigid assembly comprising a stainless steel tube, a tube holder (both as used for control electrodes) and the transducer, with the cable passing through the tube. The transducer shall be a close fit, located completely within the tube at the lower end. The assembly shall be fixed at not less than two places to the sump wall and installed with the bottom of the tube just clear of the sump invert.

For all installations the cable between the transducer and the controller/transmitter shall be a continuous length, and kept as short as is reasonably possible. This cable shall be run in conduit and installed well clear of all AC mains and power cables. All fixings, brackets, etc., as required for the complete installation shall be provided.

11.26.9 Electrode level control equipment

Electrode level control equipment shall consist of a control unit or units and a number of electrodes, together with all brackets and fixings as required for the complete installation. For all applications, sufficient electrodes and associated controls shall be provided to prevent "hunting" between the two states. The control unit shall:

- a) have all live parts at a voltage in excess of 55 V to earth completely shrouded and fitted with warning labels,
- b) have an output relay with double pole changeover contacts of suitable material for the application,
- c) have a light emitting diode mounted on the front panel to indicate when the relay is energised,
- d) have a lockable sensitivity control potentiometer,
- e) be capable of operating at a distance of up to 100 m. from the electrodes. f) have a voltage on the electrodes not exceeding 25 V.

The electrode and holder shall comply with the following:

- a) the electrode holder shall be of the heavy duty type, fully weatherproof, constructed from die cast aluminium and provided with a mounting flange having a minimum of 4 No. fixing holes,

- b) the electrode holder shall be designed to allow a minimum of 75 mm adjustment of the electrode length,
- c) the electrodes shall be of stainless steel, having a minimum O.D. of 25 mm a wall thickness not less than 2.6 mm. The lower end of the electrode shall be sealed, and the upper end shall be locked to the insulator by a brass clamp,
- d) cable entry shall be via a standard screwed gland entry,
- e) each electrode shall be firmly secured to avoid any movement due to turbulences or flow velocity. The securing brackets shall be of the same material as the electrode and shall be installed above top water level,
- f) where the electrodes pass through securing brackets; they shall be protected by heat shrunk sleeving extending from 300 mm above the bracket to 300 mm below the bracket.

11.26.10 Float switches

Float switches shall be the pendant type with the float suspended on a flexible cable, such that with the float free of the liquid the float and cable hang vertically, but with a rising liquid level the float shall rise and tend to invert.

The float shall be of robust design and comprise a mercury switch having changeover contacts encapsulated in a hard plastic foam and connected to a 3 core cable. The whole assembly shall be covered and hermetically sealed in Hypalon or similar material. With the tilting action which occurs on rising level, the contacts shall change over, but there shall be a deadband between opening one contact and closing the other, during which period both contacts shall be open. This deadband shall operate over an arc approximately 20° either side of the horizontal.

The contacts shall be rated for a minimum of 5 A at 110 V. The voltage on the contacts shall not exceed 55 V (nominal) to earth. In all applications the installation shall be complete with approved means of preventing the float (and lead) from movement due to wind or liquid turbulence.

Where float switches shall be used in applications under which they may be submerged during normal operation (e.g. pump control and/or low level alarm); they shall be attached to a weighted chain to minimise movement due to turbulence and also to provide a means of raising the units for maintenance and repair. All brackets, fixings etc. as necessary for the complete installation shall be provided. The chain/float assembly shall be installed such that the point of suspension is not less than 400 mm from any side wall.

11.26.11 Flow switches

Flow switches for installation in pipelines shall:

- a) be suitable for the maximum possible flow rate,
- b) withstand reverse flow without sustaining damage,

- c) have the operating set point adjustable over the range 20% to 100% of the normal flow, d) have change-over contacts rated at 5 A 110 VAC (50 Hz) or 1 A 24 V DC,
- d) be complete with all fittings necessary to carry out installation in the pipeline, including waterproof cable gland,
- e) have a metal housing compatible with the pipe material and rated for the system temperature and pressure,
- f) be suitable for the application and process fluid in respect of the principle of operation and the material of the wetted parts.

11.26.12 Pressure switches

Pressure switches shall be of either the bellows or bourdon type, and shall be rated to withstand the maximum possible surge pressures. The switches shall:

- a) have a signal pole change-over contact, with the contact material and rating suitable for the application,
- b) have a calibrated setpoint adjustment which shall be lockable to prevent any movement due to vibration,
- c) have a switching differential adjustable between 5% and 25% of the setpoint adjustment range,
- d) have all wetted parts compatible with the process fluid,
- e) be housed within an enclosure to IP55 or IP67 according to location.

11.26.13 Indicating meters and meter relays

All indicating meters and meter relays for use in control and instrumentation panels, control desks, mimics etc. shall comply with this Clause and the appropriate subclauses. All meters and meter relays:

- a) shall comply with IEC 51 to accuracy Class 1 for instruments having a DC input and accuracy Class 1.5 for instruments having an AC input,
- b) except those having digital, indication, shall have a linear scale, with clear graduations and markings,
- c) shall have the units of the measured variable and any multiplying factor clearly marked on the scale plate or its equivalent,
- d) shall be flush mounting with matt or semi-matt black bezel,
- e) shall match all other instruments on the same panel or on similar panels in the same room as regards style, finish and appearance,
- f) intended for installation within a control room shall be fitted with antiglare or low reflectivity glass,
- g) intended for installation on an inclined surface shall be suitable for that application, and when so mounted, the accuracy shall be maintained over the full range,
- h) accept input signals of 0/4 – 20 mA or 0 - 10 V.

11.26.14 Digital indicators

The digital indicators shall have a 4 digit display with floating decimal point and shall:

- a) display positive and negative readings,
- b) display digits approximately 14 mm high,
- c) have standard DIN format 96 x 48 mm,
- d) accept a 0/4 20 mA or 0 - 10 V input and display in the relevant engineering units,
- e) have a sampling rate not less than 10 per second,
- f) include a remotely initiated display hold facility,
- g) be powered from the 24 V battery supply,

11.26.15 Meter relays

Meter relays shall comply with the requirements as detailed in the Particular Technical Requirements but shall additionally incorporate one or two adjustable set point contacts for alarm or control. The set point shall be visible and adjustable from the front and the signal output shall be via volt-free change-over contacts of suitable material and rating for the application.

11.26.16 Trip amplifiers

Trip amplifiers or analogue alarm relays may be single or dual set point instruments as required and shall:

- a) accept input signals of 0/4–20 mA or 0–10 V,
- b) have switched outputs with changeover contacts of suitable material and rating for the application,
- c) have a set point (or points) which is infinitely variable over the whole input range by means of a lockable knob calibrated 0–100%.
- d) have a deadband or hysteresis of not less than 3% of input span.

The units shall be located within the cubicle and mounted so that they are easily accessible for adjustment of set points. Trip amplifiers required to continue in operation during a period of power failure shall be supplied from the instrumentation system battery, either directly or via an inverter.

11.26.17 Integrators and counters

The integration equipment shall comprise an integrator and a 6 digit numerical display unit or counter. The integrator and counter may be combined into a single unit, or the integrator may be mounted remotely from the numerical display unit.

The counter shall be flush mounting with a matt or semi-matt bezel, and shall match all other instruments on the same panel as regards style, finish and appearance.

If a counter reset facility is provided, this shall be arranged such that accidental operation is impossible, and should preferably not be located on the front panel.

The integrator shall accept a 0/4-20 mA or 0 - 10 V signal proportional to flow. Integrators required to continue operating during a period of power failure shall be supplied from the instrumentation system battery, either directly or via an inverter. A low signal cut-off facility shall be provided on all integrators, and this shall be adjustable over the range 0.5% to 5% of the flow.

Integrated flows shall be in cubic metres and this, together with the measurement designation and any multiplying factor shall be clearly marked on the face of the counter, or on a matching label immediately below the counter. Unless otherwise stated in the application clause, the multiplying factors shall be as follows:

Table B6-02: Multiplying factors for integrators and counters

| From | to | unit | multiplier |
|----------------|---------|---------------------|------------|
| 0 | 5,000 | m ³ /day | x 1 |
| 5,001 | 50,000 | m ³ /day | x 10 |
| 50,001 | 500,000 | m ³ /day | x 100 |
| Alternatively: | | | |
| 0 | 60 | l/s | x 1 |
| 61 | 600 | l/s | x 10 |
| 601 | 6,000 | l/s | x 100 |

The Contractor shall submit for approval by the Engineer details of integration rates and multiplying factors for all integrators to be supplied under the Contract.

11.26.18 Predetermining counters

Where a liquor sampler is to be function of flow and/or where indicated in the application clause, the relevant integrator shall incorporate a predetermining counter having a minimum of 3 digits. The predetermining counter shall be on the front of the instrument with thumb-wheel setting facilities and shall operate such that a relay with changeover contacts is energised when the preset quantity is reached. The relay shall remain energised for approximately 1 second, following which the counter shall automatically reset and start counting again.

11.26.19 Control and interposing relays

All control and interposing relays, except those used for lamp switching, shall operate on a supply not exceeding 55 V (nominal) to earth and shall:

- operate reliably over the range +10% to 20% of the nominal supply voltage,
- be of the plug in type complete with plastic cover and retaining clip,
- have vacuum impregnated coils and be suitably treated for operation under the specified environmental conditions,
- have contact material suitable for each application,

- e) have relay bases of the front connected, screw clamp type,
- f) incorporate indication of energisation

All relays operating on a DC supply shall have a surge suppression diode connected directly across the coil. Mixed voltages shall not be connected to the contacts of any relay. All relays and the associated wiring shall be protected by suitably rated fuses. Relays having different contact arrangements or coil voltages shall not be interchangeable. A permanent means of identification shall be fixed to each relay base and this identification shall be in accordance with the circuit diagram reference.

Where voltages from a remote source (i.e. voltages which cannot be readily isolated from within the cubicle), are connected to a relay or associated terminals, fuses etc., the Contractor shall ensure that all such live parts are fully shrouded and that appropriate warning notices are fitted.

The Contractor shall be responsible for ensuring that AC relays cannot be held in due to capacitance effects on long switching lines. Where such a possibility exists, a DC supply shall be provided.

11.26.20 Discrepancy switches

Where illuminated control switches are used to provide discrepancy indication, the circuits shall be arranged such that the lamp is energised via a flasher unit. This flashing discrepancy indication shall operate if the switch is not fully activated or if the controlled item is not in the position shown by the switch blade.

The switches shall be of the type having a rotary action to select the operation and a push button action to initiate the operation. All discrepancy switches shall be included within a lamp test facility.

11.26.21 Illuminated push buttons and status indicators.

All lamp indicators (except discrepancy switches) located on instrumentation and control panels, mimics, desk or consoles shall:

- a) be of similar size and appearance,
- b) have bezel dimensions of not less than 24 x 36 mm,
- c) incorporate two lamps,
- d) be included within a lamp test facility,
- e) be supplied complete with the required engraving on the screen,
- f) be supplied from the local instrumentation power system or the local instrumentation system battery, unless stated to the contrary in the application Clauses.

11.26.22 DC operated lamps

All DC indicator lamps shall have diodes in series to prevent reverse current when making lamp tests.

11.26.23 AC operated lamps

In applications where a battery supply is not available, status indicator lamps shall be operated on available AC supplies. For these applications the indicator shall be a low voltage lamp supplied via a transformer incorporated within the light unit. The lamps shall have a voltage rating higher than the transformer secondary.

11.27 Commissioning and handing over.

The Electrical works shall be commissioned and operated to the satisfaction of the Engineer and officially approved and accepted by the Employer. The procedure to be followed will be as follows: -

- a) On completion of the Contract works to the satisfaction of the Engineer, the Contractor shall request the Engineer to arrange for handing over.
- b) The Engineer shall then arrange a handing-over meeting or a series thereof at the site.
- c) The Contractor shall arrange with the Engineer and the employer a complete demonstration to be carried out of each and every service and for instructions to be given to the relevant operating staff and other representatives of the Employer.
- d) The Contractor shall arrange approved Handing Over Certificate and check Lists of all controls and items of equipment, tools, spares and the like.

11.28 Maintenance and Defects Notification Period

The contractor shall maintain the complete electrical installation and associated equipment for a period of a minimum of 24 months from the date that the installation is handed over to the client. The Contractor shall be held responsible for and shall make good all defects in materials and workmanship that occur during the twenty-four (24) months maintenance period. The period of liability shall not end until all defects which appear during the maintenance period have been rectified. Any item of material found to be defective shall be replaced by the contractor within seven days of his being notified and any results of defective workmanship shall be repaired including supply of new parts necessary immediately upon being notified.

The Contractor shall allow in his tender price for this maintenance and service and shall provide for all tools, instruments, plant and scaffolding, and the transportation thereof, as required for the full correction and full execution of these obligations, and the provision, use or installation of all materials whether they are normal maintenance materials such as oils, greases, sand paper etc. and parts which are periodically renewed such as relay contacts or parts which are faulty for any reason whatsoever excepting always Acts of God such as storm, tempest or flood, lighting and earthquakes; and civil revolt, acts of war and vandalism.

11.29 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

12 SOLAR POWER SYSTEM

12.1 Applicable Standards

12.1.1 International Standards

In the event of a discrepancy between international and national standards or any other standard outlined herein, then these international standards shall prevail and be deemed to be the applicable standard for purposes of the Project.

- ISO International Standardization Organization
- IEC International Electro Technical Commission

12.1.2 National Standards:

- ANSI American National Standards Institute
- BSI British Standards Institution
- EN European Standards
- ASTM American Society for Testing Materials
- IEEE Institute of Electrical and Electronics Engineers
- BS 7671 Requirements for Electrical Installations

12.1.3 PV Installation:

- IEC 60364-7-712:2002, Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems
- EN 50521:2008, Connectors for PV systems
- IEC 60228, 60364-1, 60332-1-2, 60754-1 and -2, 61034, TÜV approval 2Pfg1169: cable design and wiring for the electrical infrastructure and connection infrastructure (DC cables should be solar cables)

12.1.4 Commissioning and Documentation:

- IEC 60364-6, Low-voltage electrical installations – Part 6: Verification
- IEC 62446, Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection

12.1.5 Power Transformers:

- IEC 60076, Power Transformers-Part 1: General

12.1.6 HV and MV Switchgears:

- IEC 62271, High voltage switchgear and control gear

- IEC 60376, Specification of technical grade sculpture hexafluoride (SF6) for use in electrical equipment

12.1.7 LV System:

- IEC 61439, Low-voltage switchgear and control gear assemblies - Part 1: General rules
- IEC 60439, Low-voltage switchgear and control-gear assemblies
- IEC 60947, Low-voltage switchgear and control-gear - Part 1: General rules

12.1.8 Earthing & Lightning Protection:

- IEEE Std. 80
- IEEE 60665
- IEC 62305 (all parts), Protection against lightning
- IEC 60099 Surge arresters
- NFPA 780: Standards for the installation of lightning protection system
- ISO 14123; *Lightning protection for electrical and electronic systems*

12.1.9 EM:

- IEC 61000, Electromagnetic compatibility (EMC)

12.1.10 Buildings and housings, inverter protection:

- IEC 60721-3-3 Section 3: Classification of environmental conditions (stationary use at weather protected locations)
- IEC 60721-3-4 Section 4: Classification of environmental conditions (stationary use in non-weather protected locations)
- In addition to the standards stated above, the design of the Plant shall strictly meet all requirements of the Grid Code & Solar Code

12.1.11 Interconnection and Quality of Supply standards:

- IEC 61727, Photovoltaic (PV) systems – Characteristics of the utility interface. The embedded generator's AC voltage, current and frequency will be compatible with the utility system in accordance with IEC 61727.
- IEC 60364-7-712, Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems.
- IEC 62116:2008 (ed. 1), Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.

12.1.12 Inverters:

- IEC 62109-1, Safety of power converters for use in photovoltaic power systems - Part1: General requirements.

- IEC 62109-2, Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters.
- IEC 61683, Photovoltaic systems - Power conditioners - Procedure for measuring efficiency.
- UL 1741: Standard for Inverters, Converters, and Controllers for Use in Independent Power Systems.

12.1.13 Balance of System:

- IEC 60870, Tele-control equipment and systems
- IEC 62093, Balance-of-system components for photovoltaic systems - Design qualification natural environments.

12.1.14 Wiring:

- IEC 60502 Power cables with extruded insulation from 1 to 30 kV,
- IEC 60228 Conductors for insulated cables,
- IEC 60391 Identification of insulated conductors,
- IEC 60446 Color marking of insulated cables,

12.1.15 Other Relevant Industry Standards

- IEC 60364 (all parts), Low-voltage electrical installations
- IEC 61936-1, Power installations exceeding 1 kV - Part 1: Common rules
- IEC 60071, Insulation co-ordination - Part 1: Definitions, principles and rules
- IEC 60068, Environmental testing. Part 1: General and guidance
- IEC 61000, Electromagnetic compatibility (EMC)

12.2 General Requirements

The Contractor shall be expected to do the work in conformity with the relevant technical standards, specifications, protocols and regulations including but not limited to the Energy Act, 2019 and the Energy (Solar Photovoltaic Systems) Regulations, 2012 as amended and/or replaced from time to time and shall be required to demonstrate professional, technical and financial competency to undertake the works under the terms and conditions as shall be set forth herein and in the ensuing contract.

The photovoltaic installation proposed shall include components designed to withstand the local climatic conditions. All materials will be professionally chosen to ensure optimum mechanical strength over time for a minimum period of 25 years. The main constraints identified are, but not limited to: Temperature and its variations, corrosion, UV rays, humidity, precipitation.

All the dimensions and capacities of the equipment to be supplied shall not be less than those required in these specifications. Deviations from the basic requirements, if any, shall be

explained in detail in writing with the offer, with supporting data such as calculation sheets, etc.

The client reserves the right to reject any products, if such deviations shall be found critical to the use and operation of the proposed plant.

12.3 Temperature

All materials sensitive to high temperatures as well as elements sensitive to temperature variations will be chosen with operating ranges compatible with the operating thermal stresses of the site of the proposed solar power plant.

In case where a component is to be procured by the Contractor, the contractor must prove the capacity of the equipment to operate for a long duration under the prevailing site operating temperatures specified.

12.4 Corrosion

All materials that are sensitive to corrosion will be protected by a suitable coating following a surface treatment in accordance with the applicable standards. A factory surface treatment will be preferred to any work performed on site.

Any steel structure will be hot dip galvanized or composed of an alloy compatible with exposure under the site conditions.

12.5 UV

Any external component exposed to solar radiation must be chosen so as to resist UV radiation, in particular LV and MV electrical boxes, surface cables, prefabricated substations, etc. It may be chosen to shelter sensitive components from UV radiation by suitable protections. All the equipment chosen for the project shall be able to function properly under extended UV exposure.

12.6 Topicalization

The electrical boxes will have ventilation devices compatible with such tropical environments. The Contractor must justify the suitability of the cooling devices installed, in particular for the LV and MV electrical boxes.

Outdoor equipment shall have a minimum protection rating of IP 65. The installed equipment will have minimum impact strength of IK07.

- IEC 60540/811 Test methods for insulation and shielding of electric cables,
- IEC 60287 Permanent admissible current calculations in cables.

12.7 Design Requirements

12.7.1 General Design Requirements

The System design will be in full compliance with the requirements of the relevant international norms and standards, in addition to the local grid connection codes, building codes, health and safety regulations, etc. The solar PV power plant will be designed, constructed, operated, and maintained using the state-of-the-art systems and technologies targeting the optimum use of site solar resources for the generation of electrical energy at the minimum cost, maintaining the highest possible system availability.

The System will be designed to withstand all the conditions which are expected to occur at the Site during the System's lifetime. Wind, humidity, condensation, temperature, dust, sand, sandstorms, etc. may have severe impact on the equipment and hence the enclosures of all the equipment and all the exposed parts and components will have adequate protection against the penetration of moisture, dust and sand; and also will have their surfaces painted/treated with approved materials protecting them against corrosion, abrasion, water condensation, etc. allowing them to maintain the required functionality throughout the life time of the project.

All parts of the Plant must be suitable in every respect for a maximum efficient use of the site and area allocated under the anticipated operation conditions as well as the climatic conditions and environmental restrictions which are characteristic for the Site.

The design will consider the less possible self-consumption of main components and power plant auxiliary supply for services (where applicable).

The equipment will be commercially available, of first-class quality and designed for safe, reliable, and minimum maintenance continuous satisfactory operation as continuity of supply is of prime consideration. All equipment will operate satisfactorily under variation of load, voltage, and short circuit or other conditions which may occur on the system provided that these variations are within assigned ratings of the apparatus. All the equipment will be designed to withstand accidental short circuits. The equipment used will be suitable for the climatic conditions prevailing at site.

Personnel safety during installations, testing, commissioning, operation and maintenance of the system after the start of operation has been an integral part of the system design and must be maintained throughout the project.

The Contractor is fully responsible to make the necessary de-rating calculations – if needed - according to acceptable international standards to ensure that the offered equipment and all its entire component shall perform as required in this specification under the site conditions and especially the altitude, the humidity, and the temperature.

12.7.2 Design Life for Electrical Equipment

The design life is 25 (twenty-five) years for all new facilities. Materials shall be designed for maximum reliability and availability. Suppliers shall state the anticipated service life of the materials, assuming maintenance in accordance with the Supplier recommendations (if and where applicable).

12.7.3 Design Temperature for Electrical Equipment

The design temperature for electrical equipment for indoor and outdoor installation will be suitable for the all-different area. In any case all electrical equipment will be sized for 40°C for indoor use (especially inside the compact substation) and for 50°C for outdoor installations.

12.7.4 Voltage Levels and Neutral Condition

Voltage levels at normal operation of the plant will be according to the specifications outlined in Table A below:

Table A: System Voltage Levels

| | |
|------------------------------------|---|
| LV Main distribution: | 415 V \pm 5%, 50 Hz – 3 Ph + N |
| LV DC distribution: | 340 to 440 Vdc (or different voltage suggested) |
| Lighting & small power: | 415 / 240 V, 50 Hz – 3 Ph + N / 1 Ph + N |
| AC UPS System (where applicable): | 240 V \pm 5% |
| Battery System (where applicable): | 24Vdc (or different voltage suggested by the Vendor). Voltage tolerances are intended to be |

Under normal steady state conditions, the system voltage and frequency variations shall be within $\pm 5\%$ and $\pm 2\%$ respectively. However, all electrical equipment shall be rated for a steady state voltage variation of $\pm 10\%$ and system frequency variation of $\pm 5\%$.

12.7.5 Voltage Drops

The maximum allowed voltage drop during normal operations will not be higher than the following values:

Table B: System Voltage Drops

| DC Section | |
|--|---|
| From String to Inverter | 0.5 % at full load rated current of incoming. |
| LV Section | |
| From Inverter (AC side) to Main LV Switchboard | 0.5 % at full load rated current of incoming of |
| Lighting, small power and other circuits | 1 % at distribution board |
| Lighting sub-circuits | 1.5% average with a maximum 3% for any lighting fixture |

In any case, the total voltage drops on cables of the entire plant shall not exceed 3%.

12.7.6 Conductor Sizing

The sizing of wires satisfies the following major aspects.

- Thermal short circuit capacity,
- Voltage drop (steady-state and starting conditions),
- Current rating and rating factors,
- Operating of protections.

Temperatures shall be contained within permissible limits depending on the type of cable both at normal operation current and, by means of co-ordination with electrical protections, at overload and short circuit currents in the actual conditions of installation. Voltage drops shall be within fixed values.

Correct intervention of protections shall be assured depending on the minimum impedance of the fault circuit. Ampacity cable sizing is based on International Standard prescription, in particular the following are considered:

- IEC 60364-5-52, used for low voltage cables,
- IEC 60502 series, used for medium voltage cables.

The connection wires of each part of equipment (e.g., PV field, transformers) shall be sized according to the equipment rated power. The supply wires of a joint multi-section bus-bars system shall be sized for according to the maximum power required in normal operating conditions with one of the supplies being out of order. The supply wires of several loads shall be sized according to the maximum power required in normal operating conditions, taking into account a contemporaneity coefficient of the loads.

All other wires shall be sized according to the maximum power required in normal operating conditions, that is the maximum value absorbed with a duration not shorter than 8 hours when the system runs according to the design conditions.

12.7.7 DC Wiring

The PV cables should be of Direct Current DC type cables especially designed, manufactured, and tested for Solar PV applications. The DC wiring shall comply with the dimensioning and implementation provisions of the applicable IEC standards. In particular, a distinction will be made between the cables of the photovoltaic strings. The maximum admissible joule loss shall be equal to 1% under the standard test conditions.

To prevent damage from UV sunrays and high temperature, the power outdoor cabling shall be made of copper conductors with double sheath type HO7RNF inside HDPE or PVC pipes and inside cable trays or cable ducts, all complete with mounting and fixing accessories, junction and connection boxes as well as any needed additional accessories. All cables and wires shall be colour coded, labelled and numbered according to specified local and international standards.

The DC solar cables shall be TÜV approved and intended for the interconnection of the various elements of the Photovoltaic system.

The cables shall be suitable for fixed installations internal and external, within unprotected pipes, or in similar closed systems. The cables shall be ozone-resistant according to EN50396, UV-resistant according to UNE-HD 605:2008 (HD605/A1), and is tested for durability according to EN 60216. Suitable for use at an ambient temperature up to 90°C (120° overload). The cable shall be designed to last 25 years.

Table C: DC Cables Technical Specifications

| Technical Specifications for the DC solar Cables | |
|---|---|
| Standard: | TÜV 2 PfG 1169/08.2007, UV: HD 605/A1; IEC 61034, EN 52067-2, IEC 60754; EN 50396, IEC 60332-1-2, IEC 60216-1 |
| Conductor: | Class 5 flexible tinned copper according to IEC/EN 60228 |
| Insulation: | Halogen free cross-linked compound |
| Sheath: | Halogen free cross-linked compound |
| Sheath Colour: | Red or Black |
| Rated Voltages: | AC: 600/1000V DC: 900/1800V |
| Operating Temperature: | - 40°C to +90°C |
| Rated Frequency: | 50 Hz |
| Minimum Bending Radius: | Fixed: 4 x Overall Diameter Flexing: 5 x Overall Diameter |
| Max temperature at conductor: | +120 °C (for 20000 h) |
| Test voltage: | 6.5 kV AC according To EN 50395 |
| Insulation Resistance: | 1000 MΩ-km |
| Ampacity:8:15B101:157:156:15B101:15 | According to current rating requirements for cables for PV systems. |

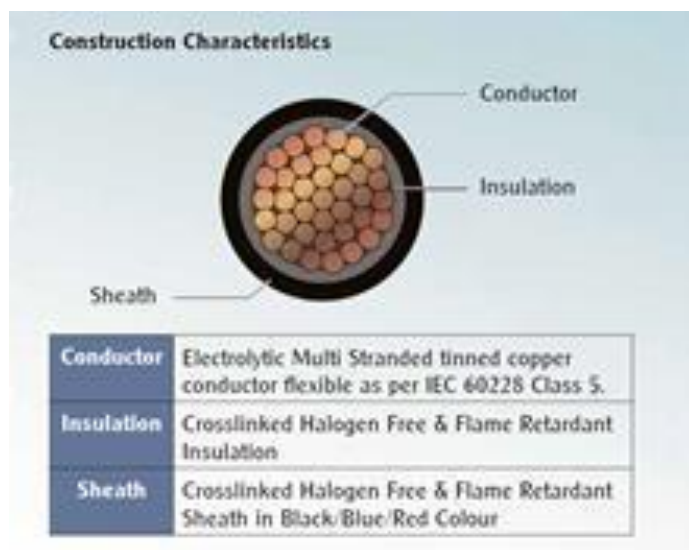


Figure A: Cable Construction Characteristics

12.7.8 AC Wiring

The LV, AC wiring shall comply with the dimensioning and implementation provisions of the mandatory standard IEC. The MV, AC wiring shall comply with the dimensioning and implementation provisions of IEC. The maximum admissible joule loss shall be equal to 1% under standard test conditions (STC).

12.7.9 Protection Systems

During the implementation phase, the successful Contractor shall endorse the definition of system protection.

The following design criteria have been followed in the protective system selection and shall be maintained throughout the Project.

- Reliability: the capability of the relay system to operate correctly when called to operate (dependability) and to avoid unnecessary spurious operation (security);
- Speed: minimum fault time clearance to prevent equipment damage.
- Selectivity: maximum service continuity with minimum system disconnection; and
- Economics: maximum protection at minimum cost.

The choice of type of protection devices will be based on the equipment and circuit (board, transformer, etc.) and on the type of service (normal, emergency or safety).

12.7.10 Earthing and Lightning System

The earthing systems design for aims for the following:

- operating earthing of electric systems (when required).

- protection against direct contacts.
- protection against the accumulation of electrostatic charges.
- protection against lightning.

The Solar plant shall be provided with lightning and over voltage protection connected to proper earthing pits. Earthing pits shall be measured to have an earthing resistance of 1Ω or less at the time of installation. If this level cannot be obtained with the soil at the facility, then soil conditioning shall be implemented to improve the earthing resistance within acceptable levels.

Each array structure of the SPGP yard/shed shall be grounded properly as per standard.

The Array Structure is to be connected to earth pits as per standards. Junction boxes shall be connected to the main earthing conductor/electrode.

The arrays shall be in protected zone of lightning arrester/spheres by installation of suitable lightning surge diverters/arrestors. The earth electrodes for the same shall have to be completely separate from the plant/array earthing.

The main aim of over voltage protection is to reduce the over voltage to a tolerable level before it reaches the PV or other sub-system components per NFC 17-102. The source of over voltage can be lightning or other atmospheric disturbance.

It shall be ensured that the resistance to earth of metal piping for fluids or any exposed conductive metallic parts which may lead to the formation of electrostatic charges, and installed in hazardous areas, is not higher than 5Ω . Various metal parts, not being exposed conductive parts, such as framework of doors, windows, etc. should not be connected to the equipotential system.

12.8 Solar PV equipment and Machine Requirements

12.8.1 PV Modules

The scope of work of the successful Contractor includes supply, installation, testing, commissioning and maintenance post commissioning.

The photo-voltaic module shall be full squared Monocrystalline and designed to ensure high standards in term of power, continuity, and reliability in electrical performance, even under non - optimal operating conditions of poor solar radiance.

The module shall have bus bars to reduce the series resistance of the module and to limit the operating temperature of the module thus reducing the overheating due to the electrical current being generated by the photovoltaic cells.

The module shall be assembled with a smooth prismatic tempered solar glass with a minimum thickness of at least 3 mm to protect the cells from rigid climatic and atmospheric conditions.

The minimum of insulation shall be 1000 V attained from the coupling of a Back -Sheet with layers of ethylene-vinyl-acetate (EVA) materials.

Aluminium frames shall be used for a greater mechanical resistance and to facilitate installation. The resistance of the module to heavy wind loads shall be maximum pressure 5000 Pa – (about 500 kg/m²).

G Glass: Tempered, surface with waveform knurling, thick-ness of at least 3 mm, guided refraction, high efficiency at least (+2% for angles of incidence of 20°, +4% for angles of incidence of 60°).

P Glass: Tempered, surface with pyramidal-shape knurling, thickness of at least 3 mm, guided refraction, high efficiency (+2% for angles of incidence of 20°, +6% for angles of incidence of 60°). Smooth glass: shall be tempered, prismatic, perfectly smooth surface, thickness of at least 3 mm. Photovoltaic cells: photovoltaic cells shall be monocrystalline silicon with bus bars. The cells shall be encapsulated in layers of EVA (ethylene vinyl acetate).

Back-Sheet shall be double layer of high-performance polyester with guaranteed resistance against atmospheric agents, oxygen, and humidity.

The mounting frame shall be made of Anodized Aluminum Alloy with a minimum thickness of 4.5 mm

The warranty periods for the PV modules shall be;

- Manufacturer's Warranty against defects: not less than 20 years.
- Manufacturer's Performance Guarantee: minimum of 25 years.

The preferred Electrical Characteristics of the PV modules should be as shown in Table 7 below.

Table D: Electrical Characteristics of Solar PV Modules

| ELECTRICAL CHARACTERISTICS | |
|-----------------------------------|-------------------------|
| Solar Data Sheet | |
| Maximum Power (Pmax) | 600Wp |
| Maximum Power Voltage (Vmp) | 41.7V |
| Maximum Power Current (Imp) | 9.60A |
| Open Circuit Voltage (Voc) | 49.8V |
| Short Circuit Current (Isc) | 10.36A |
| Module Efficiency at STC | 19.88% |
| Cell Type | P type Mono-Crystalline |

| ELECTRICAL CHARACTERISTICS | |
|------------------------------------|---------------|
| Solar Data Sheet | |
| Dimensions (mm) | 2008*1002*39 |
| Power Tolerance | 0 ~ +3% |
| Maximum series Fuse Rating | 20A |
| Maximum System Voltage | 1000VDC |
| Operating Temperature | -40°C ~ +85°C |
| Nominal Operating cell Temperature | 45±2°C |
| Weight | 22.5kg |

Note: Supplier is at liberty to propose PV modules with alternative specifications provided they meet the minimum system requirements.

The modules will be electrically connected in series in order to form strings. Strings of the same number of modules, with the same characteristics, shall be connected in parallel in order to form arrays. Strings must have the same electrical characteristics. The photovoltaic modules terminal cables will be secured directly to the metallic structure using UV resistant nylon cable ties suitable for external use, whilst string or subfield cables will be laid directly inside one of the appropriately sized heat galvanized channels or, where previously arranged, within one of the supporting sections of the actual module holder itself.

The installation of the connectors must be carried out using suitable manual or electric tools approved by the connectors' respective manufacturers. The photovoltaic modules will be connected through the use of solar connectors (MC3 or MC4), depending on type of modules. Minimum Protection degree of connectors shall be IP 65. Maximum system voltage shall be 1500 Vdc similar to all other equipment (inverter, and DC cables) shall be sized for 1500 Vdc. In any case, maximum system voltage shall be not less than 1000 Vdc, class II.

During the electrical connection of the modules their serial numbers must be captured through an automatic reading by a barcode scanner (not supplied by the client) and must automatically be saved on an excel or equivalent type of spreadsheet.

An ID plate identifying the part of the overall system will be applied to every photovoltaic string, with reference to the "module layout plan" drawing, the single wire layout and or block schematic.

The junction box behind the module with their positive and negative terminals has to be equipped with bypass diodes and with at least IP 68 protection and UV resistant.

The cableways must be arranged in such a way as to minimize any visual impact, laying them down into spaces created around the building structure or into cable trays/trunking neatly installed in place.

The DC cable used with the PV generator must be able to withstand thermal and mechanical loads. The insulation and jacket material has to be extremely resistant to weathering, UV-radiation, and abrasion. Further, the cables must resist temperature up to 60°C. In general,

the wiring on the DC side is required to be double insulated and with UV stable cables. It is recommended to use cable that is flexible suitable for fixed installation as well as for thermal movement of modules

12.8.2 Mounting Structures

The solar power plant including the solar modules shall be installed in the parcel land/space provided. The modules shall be fixed about 1.2 m above the ground for the low height side and maximum of 1.5m above the ground for the high height side in case of a 2m length solar panel or any other height on the high height side as long the tilt angle is not more than 15° from the horizontal. They should rest on aluminum frames or standard hot dipped galvanized steel of not less than 60mm x 40mm using stainless steel bolts. The frames shall rest on aluminum fixtures or racks that are firmly anchored to the ground with a layer of ballast aggregate of 16mm size laid on the ground 50mm thick below the solar PV arrays.

The number of rows in each solar PV array shall be no more than three (3). Setting of the angle of inclination and orientation of the modules shall be computed and done on site by the tenderer so as to give maximum power radiation at midday. The modules must be of proven design and the tenderer must indicate countries where they are manufactured, countries where they have been used and for how long.

The module-mounting frame has to be earth grounded. The modules shall have a tilt angle of not more than 15° from the horizontal.

12.8.3 Cleaning of Modules

According to IEC 61724 - 1 standard, losses due to clogging should not exceed 5%. The cleaning system that will be adopted by the contractor during the O&M period before final take-over by the client will endeavour to control water contamination. The Contractor will detail the actions to be executed to meet this requirement.

12.8.4 Inverters

The scope of work of the successful Contractor includes supply, installation, testing, commissioning and maintenance post commissioning.

The inverter converts direct current (DC) from the solar PV panels into alternating current (AC) and supplied to AC Loads and the surplus is used to charge the batteries. The installation can be indoors or outdoors depending on the location and design. The device has to be protected from harsh conditions with high ambient temperatures and dust. The inverter has to comply with the international norm IEC 61727 and has to be all electrical protections on DC and AC side.

Technical Specifications of Grid-Tie String Inverter

| Inverter Data sheet | |
|--|--|
| Maximum Efficiency | 98.70% (380 V/400 V) |
| Maximum input power | AS DESIGNED |
| Maximum input voltage a | 1100 V |
| Operating voltage range b | 200–1000 V |
| Maximum input current (per MPPT) | AS DESIGNED |
| Maximum short-circuit current (per MPPT) | AS DESIGNED |
| Maximum SUN2000 backfeed current to the PV array | 0A |
| Minimum startup voltage | 200 V |
| Full power MPPT voltage range | 520–800 V (380 V/400 V), 600–850 V (480 V) |
| Rated input voltage | 600 V (380 V/400 V), 720 V (480 V) |
| Number of inputs | 12 |
| Number of MPP trackers | 6 |
| Display | LED, Bluetooth module+app, USB data cable+app, WLAN module+app |
| Communication networking mode | MBUS/RS485 |
| Dimensions (W x H x D) | 1075 mm x 555 mm x 300 mm |
| Net weight | 74 kg±1 kg |
| Operating temperature | –25°C to +60°C |
| Cooling mode | Natural convection |
| Highest operating altitude | 4000 m |
| Humidity | 0%–100% RH |
| Input terminal | Amphenol Helios H4 |
| Output terminal | Cable gland+OT terminal |
| Ingress Protection Rating | IP66 |
| Input DC switch | Included |
| Anti-islanding protection | Included |
| Output overcurrent protection | Included |
| Input reverse polarity protection | Included |
| PV string fault detection | Included |
| DC surge protection | Type II |
| AC surge protection | Type II |
| Insulation resistance detection | Included |
| Residual current monitoring unit (RCMU) | Included |
| Overvoltage category | PV II/AC III |

Note: Supplier is at liberty to propose inverters of equivalent specifications provided they meet the minimum system requirements.

12.8.5 Diesel Generator

The Diesel Generator shall have a 3-phase 40KVA power output with 415 V at 50 Hz. It should include a highly corrosion resistant enclosure, control panel and monitoring, fuel tank and circuit breaker protection. The diesel generator shall be suitable for outdoor installation

and perform accordingly with the battery inverter and the system design. The diesel generator shall work in a fully automated manner with the above stated component. A concrete plinth to be constructed for the generator placement plus a shed of steel hollow sections and IT 4 sheets to engineer's approval to house the generator.

12.8.6 Data monitoring

In order to achieve a high performance of the solar PV hybrid power plant, the incorporation of automatic data acquisition and monitoring technology is essential. This allows that the yield of the PV plant can be monitored easily and compared with calculations made from solar irradiation data to raise warnings on a daily basis in case of a shortfall. Important information on for example energy and power value from the system including time stamps of diesel generator operation can be detected and rectified before they have an appreciable effect on system performance. A data monitoring system shall be installed to meet the requirements above and has to give the opportunity to receive the system data via GSM and to allow remote access to the solar PV hybrid power plant. The electrical power supply of the data monitoring system shall be from DC power of the battery. Corresponding electrical adaption of the monitoring to the DC power supply level shall be installed. Remote monitoring and data acquisition through Remote Monitoring System Software with latest software/hardware configuration and service connectivity for online / real time data monitoring complete to be supplied by the supplier. Reliable sensors for solar radiation, temperature & other electrical parameters are to be supplied with the data logger unit. Communication interface the entire system can be operated and monitored via various interface viz (RS232, RS485, MPI, Profit-bus, Telephone modem), in addition to the information indicated on the operator panel. Remote Monitoring may be achieved directly via inverter interface or via third party data acquisition system. Remote monitoring system should allow for rudimentary parameter adjustment.

12.8.7 MV/LV Transformer

The transformers shall be suitable for installation in photovoltaic plants and, preferably, Oil Immersed transformer will be selected. The power transformer shall be installed as per NFPA 850.

In particular, the transformer shall be designed and sized taking into consideration the presence of current harmonics produced by the inverters. To this end, the transformer shall not have no-load and load losses exceeding 110% of nominal losses.

The transformer must be low-loss, three-phase, encased type in class F resin, designed with natural air cooling, AN type for indoor installation.

The transformers must in any case comply with EN 60076-11 and IEC 50541-1 standards. The transformer must be designed for use in locations with altitudes up to 2000m a.s.l. MV and LV windings must be provided for uniform insulation.

For the LV winding, the insulation level must not be lower than the one specified for an Um voltage of 3.0 kV. A lightning impulse test is not required for this winding.

All power transformers will be equipped with 5-step off-load tap changer $V_n \pm 2 \times 2.5\%$ (the 5 positions required are: $V_n - 5\%$, $V_n - 2.5\%$, V_n , $V_n + 2.5\%$, $V_n + 5\%$).

The transformers must respect the following primary specifications:

Transformer Technical Specifications

| TECHNICAL SPECIFICATIONS TRANSFORMER | |
|---|---|
| Standard: | IEC 60076 |
| Rated Power: | Varied |
| Continuous Rated Power: | 100 % Duty Cycle |
| Number of Phases: | Three (3) |
| Number of Windings | Two (2) |
| Rated Voltages (Currents) at No - Load: (where specified) | Primary: 800 V (1443.38A) Secondary: 11000 V (104.97 A) |
| Voltage Regulation (Off-load Tap-switch): | ± 2 steps @ 2.5% |
| Rated Frequency: | 50 Hz |
| Connections of Phases: | Secondary (HV) Winding: Delta - Cu Windings Primary (LV) Winding: Star - Cu Windings |
| Connection (Vector Group) | Dyn11 |
| Type of Core: | Three Limb Core Type |
| Core material: | Cold-Rolled Grain Oriented Silicone Steel |
| Type of Tank: | Corrugated, Free Breathing with Upper Bolted Cover |
| Coolant: | Mineral Oil According to IEC 60296 |
| Cooling Method: | ONAN |
| Installation Type: | Suitable for both In Door & Out Door (Max Ambient temp. 40°C) |
| Max Temperature - Rise Limits: | Windings: 55°C Top Oil: 50°C |
| Power Frequency Withstand Voltage: | Primary Winding: 3 kV Secondary Winding: 28 kV |
| Lightning Impulse Withstand Voltage: | Primary Winding: - kV Secondary Winding: 75 kV |
| No - Load Loss: | (Tolerance as per IEC 60076) |
| Load Loss: | (Tolerance as per IEC 60076) |
| Impedance Voltage: | $\leq 6\%$ (Tolerance as per IEC 60076) |
| Altitude | ≥ 2000 |

| |
|---|
| TECHNICAL SPECIFICATIONS TRANSFORMER |
|---|

| |
|--|
| The transformer should at minimum have the following accessories: Oil Level Indicator, Off - Load Tap Changer, Silica gel breather, Buchholz relay, Double Contact Thermometer, 2No. Earthing Terminals, Conservator tank, HV & LV bushing enclosures/cable boxes. |
|--|

The transformer must be class AO for no-load losses and noise level AK for losses under load. As such, maximum losses and noise levels must be in accordance with the tolerances given in IEC60076.

The short circuit impedance values and losses under load refer to a temperature of 120°C. In addition, in all cases, the noise level for the units cannot exceed 80 dB.

The transformers must be built so as to resist electrodynamic and thermal effects due to short circuits without being damaged, as required by current regulatory standards. The transformers must meet class E2 environmental requirements, class C2 for climate and class F1 for fire behavior, as defined under paragraph 13 of IEC 60076-11. The transformers must have an electrostatic shield between the low voltage and high voltage winding, made by wrapping a shield grounded with the transformer box, if applicable.

12.8.8 Compact Substation

The compact substation shall be designed to accommodate primarily:

- MV switchgear,
- Low Voltage Switchboards,
- Auxiliary Service Panel / Lighting Panel (ASP/LP)

12.8.9 MV Switchgear

Where needed, the Main MV switchgear shall be used to tie-in the solar PV plant to the grid. The switchgear shall be equipped with intelligent electronic devices (IED) to perform, monitoring and protection functions. The IEDs shall have capabilities for remote monitoring from higher level supervisory systems (SCADA).

MV switchgear shall be formed by a solid steel structure suitable for fixing (on the floor) and with external plate plugging, adequately reinforced or ribbed. The switchboards with the metal casing will be constructed with a degree of protection in accordance with the requirements laid down in the IEC 62271-200.

The electrolytic copper bars system, main and shunted, shall be anchored so as to withstand electrical and mechanical stresses due to short circuit currents for a duration defined in the normative references. The MV switchgear shall be IAC (Internal Arc Classification), the execution of internal arc sealing may be provided as part of the project documents.

Fixed installation switches and contactors shall be provided with disconnections and shall be mechanically interlocked to prevent disconnections to work when the circuits are closed.

Furthermore, interlocks shall enable the access to normally live parts only when the circuits are disconnected and earthed.

A legend with a simplified scheme with a clear and distinct description of bringing-into-service and taking out- of-service events sequence should be positioned on every panel.

The metal enclosed switchgear and control gear assemblies shall be designed and manufactured according to LSC2 loss of service continuity category.

Power switches shall have the electrical and mechanical characteristics defined in the project documentation. Circuit breakers shall be Vacuum type provided with:

- systems against reclose,
- auxiliary contacts 4 NO + 4 NC,
- operation counter,
- position mechanical indicator,
- closing and opening mechanical indicator,
- manual mechanical opening and closing with pre-loaded springs,
- Remote controlled opening and closing.

The technical specifications for the MV switchgear shall be as shown in Table below:

Technical Specifications of Medium Voltage Switchgear (RMU)

| Technical Specifications for Ring Main Unit (RMU) | |
|--|--|
| Application Standards: | IEC 62271-100, IEC 62271-102, IEC 62271-200, IEC 60044-1, IEC 60255, IEC 60529 |
| Main System: | 3 phase, 3 wire AC 50Hz |
| Service Conditions: | Altitude: 2200m a.s.l, Ambient temp.: 40°C, Humidity: 90% |
| Insulation media for Busbar and ring switches: | Vacuum |
| Type of Circuit breaker and Switches: | Vacuum and Load break switches |
| Number of incomer and Feeders | 1 incomer (DS); 2 feeder (CB) |
| Electrical and Mechanical Interlocks: | To be provided |
| Busbar rating and Material | Electrolytic Copper, 630A |
| Rated Frequency: | 50 Hz |
| Equipment Service Life: | 25 years and above |
| Internal Arc Fault/Protection | 21kA/3s |
| Rated Peak withstand Current, Ip | 52.5kA |
| Rated short circuit making current of the breakers | 52.5kA |
| Nominal System Voltage: | 11kV |
| Rated voltage: | 12kV |
| Impulse Withstand Voltage (1.2/50µs dry); Up: | 95kV |
| Power frequency Withstand Voltage (50Hz 60s wet) - Ud: | 38kV |
| Ring Main Switches rated current: | 630A |

| Technical Specifications for Ring Main Unit (RMU) | |
|---|--|
| Ring Main Switches & Earth switch rated short time current (3sec) | 21kA/3s |
| Circuit Breaker rated short time current (3sec) | 21kA/3s |
| Tee-off Circuit operating positions: | ON- OFF - EARTH |
| Current transformer ratios: | 200/1A; 2core: (1) 5P10, 5VA (2) 0.5 5VA |
| Ring circuits Earth Fault indicators: | To be provided |
| Earthing Position indicator: | To be provided |
| Phase Voltage Indicators (VPIS): | To be provided |
| Remote operation capability and Auxiliary switches for remote supervisory and status indication | To be provided |
| Relay SCADA communication protocol: | IEC 61850 |
| Extensible: | Left + Right Hand extensible |
| Phase Colour markings | Red, Yellow & Blue |
| Panel Colour: | RAL 7035 |
| Cable Termination | Complete with cable boxes and terminals suitable for 3core XLPE copper or aluminium cables of up-to 300mm ² |
| Equipment Class | =>15kV |
| Mounting: | Base frame mounting with cable trench beneath |
| Cable entry and exit mode: | Bottom into and bottom out |
| Application Type: | Indoor and Outdoor |
| Degree of Protection for Enclosure: | IP54 and above |
| Minimum Sheet thickness for outer enclosure | 2mm |
| Motorized control for load break switches: | Yes |
| Manual operation option for load break switches and circuit breaker: | Yes |
| Auxiliary Voltage for the motors and spring charging: | 24V DC |
| Panel Locking Mechanism | To be provided |
| Approximate Panel Dimensions | State |
| Panel Label | “Property of the Employer” |

12.8.10 Auxiliary Service Panel / Lighting Panel (ASP/LP)

This section describes the essential requirements for the design, construction, supply and commissioning of an auxiliary low voltage electrical panel powering lights and sockets within the compact substation.

To power this auxiliary service panel, a LV/LV step-down transformer with 600-800/240V voltage has been proposed. This transformer will be equipped with an input and output circuit breaker for protection. The transformer must be designed, built and tested in full compliance with all IEC applicable standards and shall, at the minimum, have the following characteristics as per Table below:

Technical Specifications of Auxiliary Transformer

| | |
|--|-----------------------------------|
| Cooling: | (ONAN) |
| Power: | 15 kVA (maximum) |
| Primary voltage: | 800V |
| Secondary voltage: | 240V Ph+N |
| Over-temperature class: | F |
| Nominal frequency: | 50 Hz |
| Leaking: | < 2m5 % |
| Short circuit voltage: | 4 % |
| Minimum degree of protection: | IP 54 external IP 23 internal (*) |
| Low voltage (cat. I) in relation to the transformer's output voltage | |

12.8.11 Ventilation

Ventilation inside a Compact Substation must be achieved by means of ventilation windows made of resin or stainless steel positioned in the box's external walls. The Compact Substation must be equipped with an adequate ventilation system that is able to prevent condensation as well as guarantee the correct cooling of the transformers and all other equipment.

If installed, the fan must guarantee adequate protection against the entry of foreign bodies, water penetration and sand inside electrical and electronic components.

In the LV/Service room two permanent openings minimum 25cmx10cm shall be placed on the opposite walls. One at the floor level and the other at ceiling level. They have to be covered with a grating and a grid against insects.

12.8.12 Low Voltage Switchboard

LV board shall be defined as any switchgear and control gear panel that has its main bus-bar rated above 1000A and a voltage rating up to 1000V. All switchgears shall be designed for rated performances at natural cooling and project ambient temperature conditions. The switchgears panels shall be completely assembled, wired, adjusted and tested at the manufacturer's works to reduce installation and commissioning at site to a minimum.

12.8.13 Spare parts, Consumables and Special Tools

The Contractor shall provide all spares (except Transformers) necessary for discharging his responsibilities in carrying out the work, including commissioning and during the Defects Liability Period. The Contractor shall ensure that he has prompt access to the spares to avoid delay to completion, commissioning or loss of generation.

The contractor to provide 2 spare PV modules for every group of 100 modules to be supplied.

All the special tools that are necessary for the overhaul, maintenance and adjustment of the whole

Plant shall be provided. Toolboxes and tool cabinets shall be provided to the extent required.

12.9 Quality Assurance and Quality Control Plans

12.9.1 Specification, Engineering and Design of the Plant

The Contractor shall undertake design review, procurement, installation, testing and commissioning of the plant in accordance with the technical specifications stipulated by the client.

- a) Produce fabrication Drawings, as required.
- b) Prepare AS BUILT documentation at the end of the work, within thirty (30) days of the agreed completion date.
- c) Provide all equipment, materials, temporary facilities, labor and supervision required to construct the plant.
- d) Supply, install, hook-up and maintain all facilities and services required to enable it to carry out the works.
- e) Provide and be responsible for maintenance of all Construction Site Equipment, consumables and materials.
- f) Be responsible for all aspects of the construction, installation and testing of the works/plant.
- g) Supply all consumable, expendable permanent and temporary materials, tools, inspection and testing services.
- h) Provide an on-site supervision team to ensure that the works are carried out in accordance with the provisions of the contract.
- i) Be responsible for all planning, recording, provision and supervision of all pre-commissioning activities.
- j) Procure all Materials and Equipment necessary for implementation for a complete working Solar PV plants in accordance with Approved Technical Specifications and Data Sheets.
- k) Attend Supplier Factory Acceptance Testing of equipment where applicable.
- l) Prepare detailed Operating Manuals and Maintenance Manuals.
- m) Ensure that technical integrity is maintained throughout the Project.
- n) Training Plan

12.9.2 Project Construction

The Contractor will perform all the civil works, erection, electrical and instrumentation installation and interconnection activities, construction management, resource management, planning, quality control and supervision activities connected with the proper execution of the project scope.

The Contractor shall provide personnel, tools, machineries and consumables; all what is deemed necessary for the proper execution of the EPC contract. It will be fully independent for utilities and services necessary during construction phase, including but not limited to electricity, air, diesel, potable water, etc.

12.9.3 Electromechanical Works

The scope includes the electromechanical works in accordance with the International and local regulations, standards and procedures applicable to:

- Solar PV Modules and structures installation
- Inverter installation
- Diesel Generator installation
- DC Cables
- AC Cables
- Switchgears
- Control Circuits
- Data monitoring system
- Earthing and lightning System

12.9.4 Testing Commissioning and Start Up

The successful Contractor will undertake the testing, commissioning, and start-up works of the Plant in accordance with the International and local regulations, standards and procedures and in compliance with suppliers' testing, commissioning, and start-up manuals for equipment supplied. The contractor shall sign a final acceptance certificate.

The successful contractor shall submit with the bid document a schedule of commissioning test to be contacted during testing and commissioning and the expected output values where applicable

12.9.5 Spare Parts

The Contractor shall provide with the proposal a detailed list of spare parts and consumables recommended for different system components, based on his previous experience with similar systems.

12.9.6 Training

The Contractor shall include (as a separate, detailed, and itemized item); the recommended in-depth Theoretical and practical training program which shall be developed and conducted by the Contractor for this project. This training program shall be mixed between; theoretical and practical lectures and on-the-job-training (OJT) at the project site.

The topics shall cover engineering and design basics, health and safety, installation, testing, commissioning, and operation & maintenance of the PV power plant and all its appurtenances, the generator on both manual and automatic mode.

Information for Installer Companies

The contractor is obliged to adhere to the Energy (Solar Photovoltaic Systems) Regulations from 2012, which state “A person shall not import, distribute, promote, sell or install any solar PV system unless he is licensed by the Commission as a vendor

12.10 Operation and Maintenance

The Contractor shall include a detailed proposal for the operation and maintenance of the system during the Defects Liability Period of up-to 12 months.

The Contractor shall supply detailed instructions manuals concerning the correct manner of assembling/Installing/Erection, configuring, setting, Testing and Commissioning, operating and maintaining the equipment and devices constituting the Switchgear Board, including the board itself. The maintenance details of each component shall also be described, including the frequency of inspections and lubrication.

The instruction manual shall include a separate and complete section describing the normal and emergency operating procedures for the Switchgear, and shall include explanatory diagrammatic drawings to facilitate understanding the instructions.

The Manufacturer shall, in preparing the instruction manuals, take into account the lack of experience and familiarity of the Operators with this type of equipment.

The manual shall give specific information as to oil, grease, or any other materials needed for maintenance operations. This information shall include brand names and manufacturer’s numbers or designations for at least two brands available in Kenya, preferably manufactured in Kenya.

A complete set of the Operating and Maintenance manuals for All the Plant, Equipment and Accessories to be installed/mounted in the switchgear panels shall be sent to the Employer together with the Drawings for Approval. The operating and maintenance manuals shall be original copies printed by the manufacturer. Any illegible copies of the operating and maintenance manuals submitted shall be rejected.

**TECHNICAL SPECIFICATIONS FOR THE
CONSTRUCTION, REHABILITATION AND
EXPANSION OF GROUNDWATER – BASED
RURAL WATER SUPPLY SCHEMES - BATCH 1
SCHEMES IN WAJIR COUNTY**

**SECTION 4: DAYWORKS, TESTING,
TRAINING, COMPLETION AND
COMMISSIONING**

13 DAYWORKS

13.1 Measurement And Payment

Where items of major equipment listed in the schedule of Dayworks are specified by type (e.g. concrete mixer etc.) the power rating of such items of equipment to be provided by the Contractor shall not be lower than the power ratings of such equipment, manufactured within the last two years prior to the date of Tender. Any item of major plant employed upon Dayworks which has a power rating lower than specified shall be paid for at rates lower than those in the schedule of Dayworks. The reduction in the rate payable shall be in proportion to the reduction in power rating below that specified above.

14 TRAINING OF EMPLOYER'S PERSONNEL

14.1 Training

On commissioning all the Works, the Contractor will be responsible for the operation and maintenance of the Works for the DLP, during which period training of the local WSP Staff will be done. During the above training period, the Contractor will deploy specialized persons capable of giving theoretical and practical training to the WSP's Staff in the following fields:

- operation and maintenance
- treatment process and laboratory tests
- mechanical / electrical units

After the training period, the Plant Manager(s) or other Designated Staff by WSP will take over the operation of the Works.

In the Tender, the Contractor shall outline his proposal for training. An item for such training is allowed for in the Bills of Quantities. Prior to Commissioning of the Works, a detailed training programme shall be submitted to the Engineer for approval. The training shall be divided into four different levels:

- i. Training of Management Staff and Department Heads:
 - Theoretical and Practical Seminar(s)
- ii. Training of Skilled Personnel:
 - Short theoretical introduction and practical seminar(s)
 - The operators shall be trained in analyzing various parameters and handling of equipment. Include for training of Plant Operators especially in operation and maintenance of electro/mechanical equipment
- iii. Training of Unskilled Personnel:
 - Familiarization with various appurtenances of the Works and daily and routine works associated with maintenance work
- iv. General Operation and Maintenance of all the Works i.e. daily, weekly, monthly and yearly procedures to be followed, recording of observations, and reporting action plan for any remedial works, etc.

14.2 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

15 PRE-COMMISSIONING TEST

15.1 Technical documentation (on completion)

Upon the Contractor's Notification on Test on Completion and provision and approval of as built documents and, if applicable, operation and maintenance manuals in accordance with the Specification and in sufficient detail for the Employer to operate, maintain, dismantle, reassemble, adjust and repair this part of the Works, Pre-commissioning Tests shall be carried out on all civil, mechanical, electrical and control components in order to obtain the acceptance of the Engineer. Pre-commissioning Tests shall include but not be limited to the following:

- Tests at the completion of the Civil, mechanical and electrical installations.
- Tests of completed parts of the Works (e.g. tightness tests and functional tests at pumping stations, part of the piping, etc.).

Upon successful Pre-commissioning the Engineer shall issue the Taking Over Certificate subject to relevant Clauses of the Conditions of Contract. Remedy of defects shall be done according to the decision of the Engineer before or during the Commissioning.

Upon completion of work, the Contractor shall submit technical documentation with the following contents subject to approval by the Engineer. Documentation is mandatory for proceeding with Pre-commissioning and issuance of the Construction Completion Certificate:

- General Information
- As-built drawings
- Test Certificates

A register for clarity shall separate the various sections. The numeration given above shall be strictly adhered to. This applies even if individual sections are not used.

The following information shall be included:

15.1.1 General Information

- Numbering and arrangement of the documentation according to the Contractor's bid as well as the Contractor's project number,
- Characteristics of equipment,
- Medium, capacity, delivery head, energy consumption, etc.,
- Details of calculation documents (structural, etc.),
- Details of topographic surveys (benchmarks, protocols, etc.)

15.1.2 As-Built drawings (as approved by the Engineer)

- As-built drawings shall comply with the provisions set forth in this Technical Specifications.

15.1.3 Test Certificates

Certificates of all tests during construction / installation until date shall be submitted, (i.e. compaction tests, pressure tests for pipelines, concrete delivery notes or tests, tightness, tests and loop impedance, lightning protection, potential equalizing and earthing system etc.) together with the appropriate official test-, acceptance- and approval documentation and approval permits (i.e. tests at factories premises, cranes, lifts, electrical equipment etc.). Certificates from the respective manufacturers shall be submitted for each equipment.

15.2 Testing of earthworks

15.2.1 General

The Contractor shall furnish all equipment and materials necessary for collecting samples and carry out field laboratory tests on materials for earthworks.

15.2.2 Main Tests and Standards

The Contractor shall carry out all tests in accordance with ASHTO or BS standards. For the various tests the following (where needed):

- Moisture Test
- Consistency Test
- Proctor Test
- Grading Tests
- Loading Test
- Density Test (solid volume without voids)

15.2.3 Compaction of Soils

The Contractor shall carry out the compaction to safely achieve the specified dry density and control soil compaction during backfilling and filling operation.

Where the sub grade or layers of soil material require moisture conditioned before compaction, the Contractor shall uniformly apply water to the sub grade or layer of soil to attain the optimum moisture content required. The application of water shall be carried out in a manner to prevent free water appearing on surface during compaction operations.

The Contractor shall replace soil material that is too wet for compaction to the specified densities.

15.2.4 Testing of Compaction

The Contractor shall inspect, perform and report all testing and retesting as to ensure that the works conform to the specified requirements. In order to test the degree of compaction, the Contractor shall carry out field density tests in accordance to BS. 1377

For each compacted backfill of trench the required number of field density tests to ensure compliance with specification shall not be less than three passing tests between each 2 manholes or 100 linear meters (whichever is smaller) of filled and compacted trench.

If, in the opinion of the Engineer, the sub grade, backfill and fill layers have been placed and compacted to densities below the specified limits, the Contractor shall provide additional compaction and testing until satisfactory results are attained or remove certain sections of the work and reconstruct them according to the Specifications at his own expense.

All holes made for the purpose of tests shall be restored by the Contractor to conform to the characteristics of the adjacent layers. This work shall be conducted at the Contractor's expense.

The compaction required for various fills shall be as follows:

Compaction requirements

| Item of Works | Materials Prescribed | % of Max. Density |
|---|-----------------------------|--------------------------|
| Backfill for over-excavation | Granular material | 100 % |
| Formation and bedding layers | Fine granular material | 95 % |
| Crushed stone supporting layers | Crusher runs | 95 % |
| Final backfills of trenches under roads | Fine granular material | 100 % |
| Backfill of trenches in general | Fine granular material | 98 % |
| | Sandy material | 95 % |
| | Clayey material | 93 % |
| Backfill below structures | Fine granular material | 100 % |

15.3 Inspection and testing of structural works

15.3.1 Inspection Prior to Commencement of Works

Buildings and other structures in close proximity to the Construction Site that might be damaged by excavation or other work shall be inspected before work is commenced. All parties concerned shall be invited by the Contractor to participate in the inspection. The Engineer and the Contractor shall make the inspection jointly and the Contractor shall, at his own expense, set out an inspection report, including "preconstruction photos. The report shall describe the conditions of the buildings, roads, footpaths etc. in question.

Any failure or damage caused by excavation or other works, shall be repaired and maintained by the Contractor at his own expense without any delay.

15.4 Testing Concrete Works

15.4.1 Concrete Works, Test Certificates

Unless otherwise directed by the Engineer, the Contractor shall supply and submit to the Engineer:

- Manufacturers test sheets with each consignment of cement and admixture certifying compliance with the relevant standards.
- Certification of the calibration of weighing and dispensing equipment on the batch mixing plant.
- The certified test results for all tests carried out on aggregates, water fresh and hardened concrete.

In case of doubts, new tests shall be executed upon the Engineer's direction at the Contractor's expense.

15.4.2 Concrete Works, Inspections

No concrete shall be placed until the Engineer has inspected and approved the surfaces upon which the concrete is placed the formwork and the reinforcing steel. If requested by the Engineer to do so, the Contractor shall institute a "pour card" system in which a card is made out for each lift of concrete and is initialed by the Contractor and the Engineer confirming that the inspections have been carried out.

The "pour card" shall include spaces to identify the concrete being placed and to signify the completion of the inspections by the Contractor and the Engineer in regard to:

- Preparation of surfaces on which concrete is to be placed.
- Formwork;
- Reinforcement;
- Readiness for concrete placing;
- Striking time of formwork
- Inspection after removal of framework (remedial work directed);
- Curing procedures
- Completion of remedial work (if any)

15.4.3 Sampling and Testing of Aggregates

The Contractor shall sample and carry out mechanical analysis of the fine aggregates and each normal size of coarse aggregate in use, employing the method described in BS8110 at least once a week when concreting is in progress and at such more frequent intervals as the Engineer may require.

The grading of all aggregates shall be within specified limits. Should the fraction of aggregate retained on any sieve differ from the corresponding fraction of aggregate in the approved mix by more than 5% of the total quantity of fine and coarse aggregate, the Engineer may instruct the Contractor to alter the relative portions of the aggregates in the mix to allow for such differences.

15.4.4 Sampling and Testing of Concrete

The Contractor shall provide the equipment necessary to determine the compacting factor of freshly mixed concrete at each place where concrete is being prepared and shall determine the compacting factor of the freshly mixed concrete by the method described in BS standards on each location where a set of test cubes is made and not less than once a day or as the Engineer may direct.

Unless particularly specified, for each grade of concrete works test cubes shall be made whenever required by the Engineer but not less frequently than one set of cubes per 25 m³ or part thereof concreted at least one set per day.

Each set of cubes (six cubes per set) shall be made from a single sample of a concrete batch taken by random. Each three cubes shall be tested 7 and 28 days after manufacture.

When requested by the Engineer, additional set of cubes shall be made for testing 3 days after manufacture. Test reports shall be submitted to the Engineer in duplicate.

15.4.5 Compliance with Specified Requirements

(i) Sampling

For each class of concrete in production at each plant for use in the works, samples of concrete shall be taken at the point of mixing and/or of deposition as instructed by the Engineer, all in accordance with the sampling procedures described in BS 1881 and with the further requirements set out below.

Six 150 mm or 200 mm cubes as appropriate shall be made from each sample and shall be cured and tested all in accordance with BS 1881, two at seven days and the other four at 28 days.

Each sample shall be taken from one batch selected at random and at intervals such that each sample represents not more than 20 m³ of concrete unless the Engineer agrees to sampling at less frequent intervals.

Until compliance with the Specification has been established the frequency of sampling shall be three times that stated above or such lower frequency as may be instructed by the Engineer.

(ii) Testing

The slump or compacting factor of the concrete shall be determined for each batch from which samples are taken and in addition for other batches at the frequency instructed by the Engineer.

The slump of the concrete in any batch shall not differ from the value established by the trial mixes by more than 25 mm or one third of the value, whichever is the greater.

The variation in value of the compacting factor, if used in place of a slump value, shall be within the following limits:

| | |
|----------------------------------|------------|
| For value of 0.9 or more | ± 0.03 |
| For value of between 0.8 and 0.9 | ± 0.04 |
| For values of 0.8 or less | ± 0.05 |

The water/cement ratio as estimated from the results of (a) above, determined by samples from any batch shall not vary by more than five per cent from the value established during the trial mixes.

The air content of air entrained concrete in any batch shall be within 1.5 units of the required value and the average value of four consecutive measurements shall be within 1.0 unit of the required value, expressed as a percentage of the volume of freshly mixed concrete.

Until such time as sufficient test results are available to apply the method of control described in (e) below, the compressive strength of the concrete at 28 days shall be such that no single result is less than the value shown in Table 5-1 under the heading 'early works test cubes' and also that the average value of any four consecutive results is not less than the value shown in Table 5-1 under the same heading.

The 7-day cube result may be used as an early strength indicator, at the discretion of the Engineer.

When test cube results are available for at least 20 consecutive batches of any class of concrete mixed in any one plant, the average of any four consecutive results at 28 days shall exceed the nominal strength by not less than half the current margin (see table below) and each individual result shall not be less than 85 per cent of the nominal strength.

The current margin shall be defined as 1.64 times the standard deviation of cube tests on at least 20 separate consecutive batches produced from one plant over a period exceeding five days but not exceeding six months or on at least 50 separate consecutive batches produced from one plant over a period not exceeding 12 months. If both figures are available, the smaller shall be taken.

The current margin shall in any case at be less than the figure given below: -

| | Minimum current margin for | | |
|------------------|----------------------------|---------------------|--------------------------------|
| | 10N/mm ² | 15N/mm ² | 20N/ mm ² and above |
| After 20 batches | 3.3 | 5 | 7.5 |
| After 50 batches | 1.7 | 2.5 | 3.8 |

(iii) Failure to comply with requirements

If any one test cube result in a group of four consecutive results is less than 85 per cent of the nominal strength but the average of the group of which it is part satisfies the strength

requirement, then only the batch from which the failed cube was taken shall be deemed not to comply with the Specification.

If more than one cube result in a group of four consecutive results is less than 85 per cent of the nominal strength or if the average strength of the group of which it is part fails to satisfy the strength requirement then all the batches between those represented by the first and last cubes in the group shall be deemed not to comply with the Specification, and the Contractor shall immediately adjust the mix design subject to the agreement of the Engineer to restore compliance with the Specification.

After adjustment of the mix design the Contractor will again be required to comply with sub-clauses 5.4 (b) and 5.4 (c) of this Section of this Specification.

The Contractor shall take necessary action to remedy concrete which does not comply with this Specification. Such action may include but is not necessarily confined to the following:

-

- (i) Increasing the frequency of sampling until control is again established.
- (ii) Cutting test cores from the concrete and testing in accordance with BS 1881.
- (iii) carrying out strengthening or other remedial work to the concrete where possible or appropriate.
- (iv) carrying out non-destructive testing such as load tests on beams
- (v) removing the concrete

15.5 Inspection and testing of pipes for mains

15.5.1 Testing at Place of Manufacture

Prior to shipment, all material shall be inspected in accordance with the requirements set out this Specification.

All field welds at main diameters exceeding DN 300 or PN10 shall be subject to tests as described in this Technical Specification.

15.5.2 Pressure Testing of Mains

The Contractor shall submit a systematic procedure for testing and method of filling and draining all mains and pipework for approval to the Engineer. The pressure drop method shall be applicable as set forth by EN 805 Chapter 11 or ISO Standards.

Table: Pressure test requirements for water mains

| System test pressure STP | | |
|--------------------------|---------------------|--------------------------|
| Kind of main | Pressure Class = PN | System Test pressure STP |
| Local main | PN10, PVC-U | 11bar = 6 bar + 5 bar |
| | PN10, HDPE, SDR 17 | 12 bar |
| | PN10, DI or steel | 15bar = 10bar + 5bar |

| | | |
|----------------|--------------------|-----------------------|
| Principal main | PN10, HDPE, SDR 17 | 12 bar |
| Trunk main | PN10, DI or steel | 15bar = 10bar + 5bar |
| | PN10, HDPE, SDR 17 | 12 bar |
| | PN16, DI or steel | 21bar = 16bar + 5 bar |
| | PN16, HDPE, SDR 11 | 21 bar |
| | PN25, DI or steel | 35 bar |
| | PN 40, DI or steel | 40 bar |

The Contractor shall perform the hydrostatic test, on all complete piping, prior to field coating of welds and fittings and prior to backfilling of the joints.

The Contractor shall provide and fit any test heads required, and the Engineer shall be informed in time to make a final check of each section to be tested before test heads are connected. The Contractor shall ensure that any necessary bosses on the test heads or pipework are included as required for filling and venting during Site testing. Fill and vent points in the pipe shall be closed afterwards. Thrust blocks shall be provided and removed after testing. Tests shall not be performed against valves but against blank flanges and test heads exclusively.

Calibrated manometers of class 0,6 160mm shall be used for testing and be placed at the lower end of the test section.

The Contractor shall supply all of the water required for the tests. Water may originate from the existing distribution system through direct connections or through hydrants, where permitted by the Employer in writing and approved by the Engineer or from Contractor's tanker trucks. Before start of test, air must be completely removed from the test section as its presence falsifies the test results.

In the event visible leaks are detected in the test section, the test is declared unsuccessful irrespective of the recorded pressure drop. Pressure drop shall not exceed 20kPa = 0,2bar during 2 hours of main test, otherwise the test has failed.

15.5.3 Disinfection

The disinfections shall be carried out in accordance with the following procedure. This procedure shall be done together with the "main pressure test".

The disinfection agent can be NaOCl or Ca(ClO₂). The concentration of the disinfection agent per litre in the water must be between 35 and 50 mg/l. The duration of disinfection shall not remain under 12 h. After that period the pipeline shall be flushed with potable water.

The entire disinfection procedure requires documentation in written form and confirmation by the Engineer.

The Contractor shall be responsible to maintain the quality of the works from disinfection to commissioning at his costs.

15.6 Testing of Water Meters for House Connections

Water meters for house connections shall be tested and calibrated at the factory in accordance with test certificates shall be issued and submitted to the Engineer for approval. The meters shall bear the seal of the calibration bank. The certificate shall include precise information on the test and calibration processes applied.

Tests shall be conducted with 10 meters out of 1000 but not less than 5 per size. Test pressure shall be 16 bar during 15 minutes. Meters shall show no of leakages of body and seals. The hydraulic parameters shall be determined and compared to the requirements of the standard. If two or more meters do not pass the tests, the batch shall be rejected.

15.7 Test of water tanks / reservoirs

Tightness test shall be carried out before any backfill around the tank / reservoir subject to test takes place. All outside surfaces of the tank / reservoir walls must be cleaned, smoothened and be completely visible and accessible. Each tank of a multi-tank reservoir shall be subject to a separate test.

Filling of a tank / reservoir shall take place during daylight to allow for continuous inspection during filling. Tanks / reservoirs shall be filled up to high water level as indicated on the drawings or as otherwise instructed by the Engineer.

For tanks / reservoirs completely or partially made of concrete shall be maintained full over a period of 7 consecutive days prior to the test to achieve saturation of the concrete exposed to water.

For tanks / reservoirs completely made of steel such saturation period is not required, and the

Contractor shall maintain the tank / reservoir full one day prior to start of test.

A visual check of all concrete wall surfaces shall then take place. If such inspection does not identify visible leakages or wet spots, the test can continue. If such inspection however identifies leakages and wet spots, the test will be terminated and the Contractor shall proceed with repairs of the respective parts as instructed by the Engineer. Thereafter the procedure shall be repeated.

After having successfully passed the visual inspection of the external surfaces, the main test shall be undertaken. The main test shall last 48 hours. During that period of 48 consecutive hours all ventilation hoods and accesses shall be tightly closed and sealed. Water level shall be measured at the beginning and end of the main test period. If water level drop does not exceed one (1.0) cm or 3/1000 of storage height, whichever is less, the test is successful.

In accordance with 2.2.5 the Contractor shall supply all of the water required for tests.

From start of filing until completion of the test, the Contractor shall monitor the settlements of the tanks through precision levelling on the benchmarks grouted into the concrete as

directed by the Engineer, particularly at the four corners of rectangular tanks and every 90° at the circumference of round tanks.

Frequency of levelling and recording formats shall be as instructed by the Engineer.

15.8 Test during commissioning

In the event tests carried out earlier on the respective parts of the Works have not been successful or if necessary to proof the tightness between two sections of the Works that have been tested before separately additional Tests during Commissioning shall be carried for any hydraulic system upon request of the Engineer of such parts of the Works.

15.9 Inspection, testing and pre-commissioning of facilities, mechanical and electrical works

15.9.1 General

The Contractor shall request inspection and testing of all items of the facilities, mechanical and electrical works and shall give the Engineer four weeks' notice that the equipment is ready for testing and of his intention to carry out tests.

If any of the tests are beyond the resources of the Contractor or the Manufacturer, The Contractor shall make arrangements for these to be carried out elsewhere on suitable test benches.

The Contractor shall carry out tests as stated in the applicable International Standards (EN, ISO or IEC), for performance tests and such other tests that are expressly stated and as may deemed necessary in the opinion of the Engineer, to proof that the Works comply with the Specifications set forth by the Contract Document as a whole. Each test certificate shall contain concise information of the test, such as: Contract number and details, pay item number, pertinent specifications, manufacturer, type, model, serial number etc. shall be given for unambiguous identification of the material or equipment tested and the extent of the certificate's validity. However, no inspection, release or approval of any part of the Works by the Engineer, shall release the Contractor from any of his obligations under the Contract. Whenever tests and inspections have been completed to the Engineer's satisfaction and when the test certificates (including reports, notes, tables, graphical representations of results etc. as technical annexes) have been checked and deemed complete, the Engineer shall confirm acceptance in writing.

Where witnessed tests are not required by the Contract or waived by the Engineer, the complete test certificates including technical annexes shall be forwarded to the Engineer:

- either within two weeks after shipment of the respective goods together with any other commercial document issued at the time of shipment; and
- or within 2 weeks after receipt of such waiver.

The Contractor shall bear any extra costs that may arise from a failed test or inspection, or failure to forward unwitnessed test and inspection certificates within the period of time set forth. The Engineer may require the Contractor to remedy a failed test, or inspection may require through supply of new parts from the manufacturer or return to manufacturer's plant of damaged parts for repairs if such repairs are still technically deemed feasible by the Engineer. Any equipment used in testing shall in all respects comply with the appropriate safety regulations and/or requirements regarding electrical apparatus for the safety of the Plant and the men working thereon.

The Contractor shall make sure that all sub-contractors are given copies of the relevant parts of the Specifications. Full details of the testing method proposed for each item shall be submitted to the Engineer.

15.9.2 Cost for testing deemed to be included

The Contract price is deemed to include for all costs of all tests, including temporary works, labour, materials, instrumentation, stores, fuel and power used, as may be required during all inspections and tests and for the provision of certified records and curves whether on site or any other place deemed appropriate by the Engineer.

The Contractor shall also bear all costs of Third Party as may be required from time to time and of the Engineer if required to carry out inspections at places other than on the site or in the Contractor's storage facilities close to the site. Such costs of the Engineer shall comprise the per-day-fee, travel and accommodation cost and all other incidental costs occurring during the performance of test and inspection.

15.9.3 Test Instruments and Equipment

The Contractor or the manufacturer as may be the case shall satisfy the Engineer as to the accuracy of all instruments required for the tests and if requested by the Engineer shall produce recent calibration tests, or otherwise have them calibrated at his own expense by an independent authority.

kW-meters and kVAR-meters shall be checked for correct rotation and creep tests shall be carried out to ensure that the meter is inoperative with voltage alone if the secondary of the current transformers is left connected with the primary current interrupted.

15.10 Factory test

Whilst the Engineer shall be provided with facilities to witness testing and/or inspection of all items of equipment at the manufacturer's works, he may at his discretion advise that part of the tests shall proceed in his absence, the tests shall be made as if in his presence.

The Contractor shall submit to the Engineer a duly countersigned copy of the readings of any witnessed test and, within two weeks after completion of any witnessed or unwitnessed tests, a complete test certificate.

The Contractor shall submit to the Engineer unwitnessed factory test certificates where applicable giving a detailed record of all electrical and mechanical tests and its results carried out on the equipment and material.

If after inspecting, examining, or testing any material or equipment, the Engineer shall decide that such items or any part thereof is defective, or not in accordance with the Specification or performance requirements, he may reject the said items or part thereof, giving to the manufacturer within a reasonable time, notice in writing of such rejection, stating therein the ground upon which the said decision is based. Any repetition of an unsuccessful test shall be at the Contractor's expense.

As and when the Engineer is satisfied that the equipment shall have passed the required tests he shall notify the Contractor in writing to that effect. Copies of test certificates shall be included in the Operating and Maintenance Instructions as detailed elsewhere.

15.10.1 Pumps

i. Inspection

The inspection carried out prior to the test runs serves to verify the compliance of pump and motor type and size with the Contract, the correctness of pump materials, motor protection, anti-condensation heating, the scope of supply, pressure, etc. as laid down in the specification and the design standards for the pump types. The supplier shall make sure that all parts and materials can be inspected. If necessary, the pumps have to be dismantled to ensure inspection of the correct materials.

The inspection shall also include packing and correct marking of the parts, crates, boxes, etc. as described in the Contract respectively the instructions of the Engineer.

Product inspection witnessed 3.1B to EN 10204 (with the necessary certificates), including:

- Hydrostatic pressure test of complete pump with 20°C water, test duration 15 minutes, test pressure 16 bar
- Dimensions check and visual inspection
- Coating inspection
- Balancing check of the impeller
- Vibration test
- Measurement of bearing temperature
- Strip test, optional
- Guarantee of submersible motor according to IEC 60034
- Final inspection

ii. Vibration Test

Vibration values of the pump shall be according to ISO DIN 1949, in the operating range from 0.5 up to $1.2 \times Q_{opt}^{veff} < 4.5 \text{ mm/s}$.

iii. Hydraulic Performance Test Standard

Material and product inspection and certificate 2.2 according to EN 10204. The products shall be manufactured and tested under a certified quality assurance system according to ISO 9001/ EN 29001.

The centrifugal pumps installed with their proper drives on the common base plate shall be inspected and tested in the presence of the Engineer at the pump manufacturer's test stand. The pump power input may be calculated either from the power input in the motor and its previously tested efficiency or by measuring torque and speed. The performance test shall generally follow the procedure, and the accuracy laid down in ISO 9906 Class 1, with the particulars as set forth hereinafter.

- each individual pump shall be tested with cold and clean water
- each individual pump shall be tested according to ISO 9906 Class 1
- each individual pump shall be tested together with the pertaining electric motor
- at the main duty point(s) flow, head, power demand, pump efficiency and NPSHr shall be measured respectively established
- at the other data points no NPSHr shall be measured
- the pumps shall be tested at the manufacturers test stand at his own expenses (details as to costs for testing are described below)
- details of place, date, testing personal, test procedure, measuring methods, NPSH-test, etc. have to be agreed upon by all parties prior to the testing in writing
- the pumping units shall be tested at their actual speed and frequency
- the tolerances for the main duty point(s) and the other measuring points shall comply to the below specification
- submersible motor pumps shall be tested as one unit together with the non-return valve

iv. Pump Performance Curves, Tolerances

The pump test shall provide at least six or more data points, of which one is the main duty point, another ones shall be at or near the shut-off head at Q_0 and a further point shall be at or near the maximum flow Q_{max} of the published Q-H curve. The remaining data points shall be suitable to allow the establishment of pump performance curves for Q-H (head against flow), Q- (pump efficiency against flow) and Q-P (power consumption at pump shaft against flow). Unless otherwise specified, the required NPSH value of the pump shall be verified at the main duty point.

Accuracy of measurement of the various parameters shall be in accordance with tables 8 and 9 of ISO 9906 Class 1. Tolerance factors applicable to the main duty point shall be the values of table 10 of ISO 9906. Class 1, i.e. t_Q (flow) = 4.5 %, t_H (head) = 3 % and t_{η} (pump efficiency) max. - 3 %, with respect to the performance curves submitted with the Bid.

Tolerance factors applicable to the measuring points other than the main duty point shall be 150% of the tolerance factors in table 10 of ISO 9906 Class 1, i.e. t_Q (flow) = 6.75 %, t_H (head) = 4.5 % t_{η} (pump efficiency) = - 4.5 % with respect to the performance curves submitted with the Bid.

v. Special Tolerances

Tolerances other than set forth hereinabove may be specified together with the duty points elsewhere.

15.10.2 Factory Inspection and Testing of Special Valves

All valves shall be factory inspected acc. to ISO 5208 and pressure tested acc to DIN 3230 Part 4. Where special hydraulic performance is specified elsewhere (e.g. head loss), such parameter shall be tested and certified acc. to EN 10204, Table 1 3.1B.

15.10.3 Blowers or compressors

Each blower or compressor shall be witness tested as an integral unit for a complete sequence of operation for capacities of 80 %, 100 % and just below the action of the relief valve. The witness test shall obtain the guarantees of performance for each item of equipment. Impellers of centrifugal air blowers shall be overspeed tested to 15 percent above the maximum continuous service speed. The assembled blower units shall be proved mechanically by testing at contract service speed. Full tests shall conform to the appropriate requirements of BS 2009.

Tests shall be completed and witnessed at the manufacturer's works using a pipework system as required by the agreed code for aerodynamic testing. Blower testing shall be undertaken using the driver motor which will be coupled to the blower on Site.

The manufacturer's test drive motor may be used subject to the Engineers written approval. Adequate reason for this option shall be supplied to the Engineer with the request to use other than the final drive motors to be used on Site. Where variable volumetric output is required, the blower and motor shall be tested in combination with the control system which will ultimately be used for this purpose on Site.

15.10.4 Vessels, pipes, valves

All hydraulic equipment subject to hydraulic tests such as but not limited to: pressure vessels, pipes, fittings and valves, shall be hydraulically tested 1,5 times the maximum working pressure but not less than the test pressure applicable to the PN rating. Such tests shall not be witnesses except if specified elsewhere in the Contract Documents.

15.10.5 Electrical Equipment

Low Voltage Devices

Low voltage circuit breakers shall be delivered with CE-marking in accordance with low voltage directives. Miniature circuit breakers shall be delivered with CE-marking in accordance with low voltage directives.

Low- and moulded voltage air-break switches and fuse combination units shall be delivered with CE-marking in accordance with low voltage directives. Low voltage contactors shall be delivered with CE-marking in accordance with low voltage directives.

All other electrical equipment shall be delivered with CE-marking in accordance with relevant directives.

All low voltage switching devices of current rating 100 A or greater shall be subjected to measurement and recording of circuit resistance. The test shall comprise measurement, at the main terminals of each pole with the contacts fully closed, of DC voltage and current (at 100 A or greater). The values of resistance for any two similar examples from a particular manufacturer's range shall not differ by more than 20%.

15.10.6 Transformers

If it is decided to supply transformers, they shall be routine tested at the manufacturer's works in accordance with IEC 76. The Engineer will require witnessing the following tests:

- Measurement of winding resistance.
- Ratio, polarity and phase relationship.
- Impedance voltage.
- Load losses.
- No-load losses and no-load current.
- Insulation resistance.
- Induced overvoltage withstand.
- Separate source voltage withstand.
- Further witness tests shall also be carried out in accordance with the following:
- Impulse voltages withstand. If the manufacturer can provide evidence covering impulse voltage withstand tests for transformers of similar type and design, Type Test certificates will be acceptable.
- Temperature rise. Where transformers of identical design and rating are being supplied, only one unit need be subjected to the full Temperature rise test and Type Test certificates supplied for the duplicate units.

15.10.7 H.V. power factor correction capacitors

Where utilized, tests shall include H.V. dielectric resistance, phase to earth - measurement of dielectric loss and loss angle capacitance and verification of kVAr.

15.10.8 Process control and indicating instruments

All flow, level and process measurement controllers, transmitters, recorders, indicators, vacuum and pressure gauges shall be subject to routine tests in accordance with EN 60269-4 and EN 837-1. Test Certificates shall be provided against each item of equipment.

15.10.9 Electrical measuring instruments

Tests to ensure accurate operation of all meters, voltmeters and kilowatt- and kiloVar hour meters shall be undertaken in accordance with relevant EN/IEC standards.

15.10.10 Programmable logical controller (PLC)

The Contractor shall be responsible for testing all items of equipment comprised in the PLC system for correct operation.

15.11 Site test

15.11.1 General

Site testing includes both tests during installation and tests at completion. The Contractor shall prepare and submit to the Engineer a comprehensive and detailed site testing program of all parts of the Works subject to Site testing. This program shall be submitted to the Engineer one month before start of erection / installation and be reviewed and updated as may be required from time to time.

15.11.2 Composite hydraulic systems subject to test during installation

Site testing includes tests during construction and installation, Pre-commissioning and Commissioning.

All joints, pipe foundations and the like shall be inspected during testing and pressure shall be maintained until such inspections are completed or as specified by EN 805 for the duration of testing, which ever lasts longer.

In the event that pressure loss encountered during test is higher than acceptable and / or any visible leak occurs, or any foundation or puddle flange is found to have moved or cracked or appears damaged in any way, or if any pipe barrel or flange shows deformation, the test shall be declared as being unsuccessful.

15.11.3 Cable tests during installation

As cable installation proceeds, the Engineer will carry out an inspection of the works to ensure the standards of workmanship meet the Specification and are to his satisfaction. In the event of any part of the cabling installation failing to meet these requirements, the Contractor will be informed immediately and shall remedy the deficiency to the satisfaction of the Engineer. The Contractor shall:

- a) Inform the Engineer prior to the testing of the cables and shall be responsible for liaising with any other Contractor to whose equipment the cables may be terminated to ensure that all parties concerned are aware of the impending tests, to guarantee the safety of personnel and that the isolation of any equipment has been completed. Any special isolation or preparation required to be carried out before cable testing can be completed, will be carried out by the Contractor responsible for that equipment. All tests shall be carried out by the Contractor but shall be supervised by the Engineer.

- b) Provide DC test equipment and apply (after isolation) in the presence of the Engineer, the following DC test voltages on all cables between cores, cores and sheath and cores and armour.
- c) Measure HV cables as follows:
 - XLPESWA PVC20,000/35,000 V grade cable between cores and between any core and screen/armour 76,000 V
 - XLPESWAPVC 5,800/10,000 V grade cable between cores and between any core and screen/armour 25,000 V/15,000 V
- d) Measure LV cables 600/1000 V as follows: PVC or XLPE 600/1,000 V grade cable between cores and between any core and armour 3,500 V
- e) Demonstrate correct phasing out of cores in all cables throughout the works and test the insulation of all the cables, both between the cores and between the cores and earth, during installation with a "Megger" 500 V hand generator.
- f) Conduct soil resistivity tests in the presence of the Engineer to obtain the most suitable location for the earth electrode system.
- g) Demonstrate to the Engineer that the resistance of the earth electrodes to earth conductor continuity and earth installation is in accordance with the specified requirements.

Tests shall be performed from each major item of plant, by using an "Earth Megger" and auxiliary return conductor. If any portion of the works fails to pass the tests, another test of the failed portion shall be repeated within a reasonable time upon the same terms and conditions.

Certificates of all tests carried out shall be provided giving full details and description of each test.

15.12 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Materials. The rate provided by the contractor in the bill of materials shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

16 WORKS COMPLETION

16.1 Testing and Commissioning

16.1.1 General

The testing and commissioning plan is to cover the Facilities for the purposes of confirming the performance of the designs, plant and construction proposed and provided by the Contractor as part of its Proposal.

The Contractor is responsible for submitting a detailed test program as part of his program to implement the Works for the approval of the Engineer, carrying out all tests as per the approved program and of additional tests if requested by the Engineer, submission of test reports and test certificates, retest if needed, and for providing all apparatus, assistance, documents, electricity, equipment, fuel, consumables, instruments, labor, materials, and staff needed to carry out the tests. The tests themselves shall be carried out in accordance with the Technical Specification.

The Contractor shall provide for the tests:

- a) All skilled and qualified operating and test staff for the testing of all equipment.
- b) Provisions and disposal of all services, lubricants, and fuels and electricity.
- c) All measuring and testing instruments to demonstrate that the equipment fulfills the requirements, in particular instruments to monitor transient processes such as surges, etc.

The overall testing program for the Project shall consist of the following:

- a) Shop inspections and testing: these are inspections and tests, at the place of manufacturing. This applies for building materials, mechanical (e.g. pumps) and electrical items of plant (e.g. instruments). The manufacturer shall issue the relevant certificates. Please refer for further details also to paragraph [define]Error! Reference source not found.
- b) Construction inspections and testing at site: These are routine inspections and tests during construction. Please refer for further details also to paragraph [define]
- c) Tests on mechanical completion: These tests are performed at the completion of the mechanical and electrical installations.
- d) Tests on part completion: These tests are conducted on completed structures (e.g. leak tests at pumping stations) or parts of the Works (e.g. for a part of the drainage network);
- e) Pre-commissioning tests: These tests are performed before putting the Works or part of them into operation.
- f) Performance tests (Test on Completion): Under these tests the Works or part of them shall be operated for a period of 3 days to prove that the specifications

and provided performance guarantees (as specified in clause 4.2 of the GCC) are met; and

- g) Reliability test run (Test on Completion): Under this test the Works, or part of them, shall be operated for a period of time as stipulated in the Contract to prove its reliability.

As a general rule, passing successfully tests on mechanical completion and on partly completion shall be the pre-requisite for starting with pre-commissioning tests. Passing successful tests on pre-commissioning shall be the pre-requisite for the commissioning. At the end of commissioning the performance tests and the reliability test run will be carried out.

After successfully passing the above tests, and after submission of the as-build documentation and of the operation and maintenance manuals, and after submission of all test results (For electrical installations in compliance with Appendix 6 of 16th Edition of the IEE Wiring Regulations – BS7671: 2008. The installation / system shall not be considered complete without this certificate. If the Contractor fails to produce these documents within one month from the date of tests on Commissioning, the Engineer may employ the services of third party to produce these documents and all costs shall be borne by the Contractor) the Works or parts of them, can be deemed to be completed and the Engineer will issue the Construction Completion Certificate.

16.1.2 Test and Commissioning reports

Reports about Tests and Commissioning shall be prepared and supported by recorded data and calculations. Reports shall be submitted to the Engineer not later than 7 days after the test.

Three (3) months after the Commencement Date, the Contractor shall submit to the Engineer all relevant test documents, which shall include:

- a test program.
- test standards.
- type of inspection and tests.
- tests which are to be witnessed by third parties; and
- quality control procedures.

Three (3) months prior to the proposed start of commissioning the Contractor shall submit to the Engineer:

- a commissioning test program.
- commissioning procedures; and
- tests on partly completion.

Three (3) months prior to the Performance Tests Contractor shall submit to the Engineer

- a test program.
- test standards.
- manpower and deployment schedule of Contractor for performing the tests, forms of test records and report.
- description of instrumentation to be used, including accuracy, and calibration test results.

- method of data recording; and
- method and equations/correction curves used for the adjustment of recorded data to the design conditions.

Upon successful Commissioning the Engineer shall issue the Final Acceptance Certificate.

16.1.3 Tests on Completion for Works

The following gives the general approach concerning Tests on Completion for Works. All tests shall be carried out in accordance with the applicable standards and as per the Contractor's program.

The reliability test run is scheduled for five days, while performance tests will last two days. During the Reliability Test Run, the Works shall be operated continuously or as required by the Engineer. The Reliability Test Run will not be deemed to be completed unless the relevant Performance Tests have been made. In the event of interruptions during the Reliability Test Run, for which the Contractor is responsible, the duration of the Reliability Test Run shall be extended by a period equal to the accumulated time of interruptions. If an interruption of operation of a Pumping Station lasts more than four (4) hours, the Reliability Test Run shall be restarted, after making good the defect. The Reliability Test Run may be interrupted on a maximum of three occasions, provided that no interruption exceeds four (4) hours and that the Engineer is notified of the interruption in good time.

The hydraulic capacity of the transmission pipelines shall be proved during designing, when submitting the hydraulic report. Consequently, the Works shall be certified to be partly completed after passing all tests, including pressure tests, which prove that civil and pipe construction was done in accordance with the design. Pressure mains shall undergo a complete functional test which shall include a test of the surge protection system, partial and full load operation. In addition, the pumps etc. shall pass the manufacturing, reliability and performance tests. The compliance of drinking water parameters will be tested during performance tests.

The power consumption and consumption of consumables which are subject to liquidated damages shall be tested during the performance tests based on the same provisions as described above. After successful passing all above tests, the Works shall be deemed to be completed, and the Engineer shall issue the Certificate on Completion.

16.1.4 Tests after Completion

The Engineer may, at his own discretion, instruct the Contractor to carry out the Reliability Test Run and the Performance test after Completion of Works (Test after Completion).

16.2 Facilities, mechanical and electrical works subject to commissioning

16.2.1 Pumps

Each set tested for flow, head, power consumption, current and mechanical reliability. Thereafter parallel operation shall be tested likewise.

Satisfactory operation of surge control equipment shall be tested with instantaneous shut-downs of an increasing number of parallel running main pumps. Pressure and flow in the surge vessels shall be recorded.

16.2.2 Dosing Equipment

Each set shall be tested for dosing the specified volumes. Efficiency of mixing shall be determined by taking samples and analysing for dissolved agent after 15 minutes, 30 minutes and one hour after start of mixing.

16.2.3 Lifting Equipment

Each installation inclusive of rails and beams shall be tested with test loads, provided by the Contractor, to prove that the equipment is capable of satisfactorily lifting 125 per cent above its rated load (lift in centre of gantry and between cantilevers of track support) and total deflection shall be measured and compared to the tolerable maximum.

16.2.4 Electrical plant and power systems

For electrical plant and power systems the Tests on Completion shall comprise pre-commissioning tests as detailed below, prior to energization from the power supply system, followed by energization and demonstration of the operation of the plant and associated protection and control systems to the specified performance requirements and maximum operating and load duties.

On energization a certificate of temporary acceptance will be issued for all Plant operating at 1000 V and above. Certificates of temporary acceptance will be issued for equipment on lower voltages on satisfactory demonstration of on-load operation.

All tests shall be carried out by the Contractor under the supervision of and to the approval of the Engineer.

16.2.5 SCADA and I&C systems

The Test on Completion shall encompass the checking of all of the functions of the I&C and SCADA systems, including the checking of the measuring ranges and dimensions and process parameters.

All measures needed for these tests shall be carried out by the Contractor at his own responsibility and at his own expense, including travel costs, but only after the Engineer has approved the related test program.

At least 4 weeks ahead of any tests the Contractor shall provide the Engineer with a list of the stand-by devices or boards and a list of the necessary testing and maintenance devices.

16.2.6 Switch-gear and Motor Control Centers:

- a) Insulation testing.
- b) Power frequency pressure tests shall be carried out on all equipment for operation on systems above 1000 V.
- c) For systems up to 1000 V equipment insulation tests shall be carried out at 500 volt using an approved test instrument.
- d) These tests shall be carried out with all circuit breakers/contactors panels closed in the circuit position, between phases and phase to earth. All secondary small wiring circuits shall be similarly tested.
- e) Mechanical tests
- f) All mechanical tests specified for conducting on manufacturer's premises shall be re-checked to ensure satisfactory operation of the plant in the final erected state.
- g) Protection and control circuits
- h) The satisfactory operation of all current operated protection circuits over their whole operating range shall be tested by secondary current injection, where primary injection tests have been previously carried out on manufacturer's premises.
- i) Primary injection tests shall be carried out on restricted earth fault circuits, after pilot circuits have been completed, for stability and fault conditions. On transformer differential protection circuits where primary injection was not possible at the place of manufacture, the completed relay circuits shall be fully tested by secondary injection, and simulated fault conditions. Stability tests shall be carried out using normal load conditions after the system has been completed and energized.
- j) Instrument and metering equipment
- k) Tests shall be carried out to ensure the correct operation of current and voltage operated indication instruments when energised by the actual supply system.
- l) Continuity of earth conductors
- m) Continuity tests shall be carried out on the earth conductor within the switchboard, such tests being by current injection.

16.2.7 Power Transformers (if applicable):

- a) Samples of insulating oil shall be taken from each transformer at top and bottom levels and from every container and subjected to dielectric strength tests.
- b) Buchholz surge relays shall be tested after completion of pilot cables by stimulated oil level changes at the relay. Buchholz gas relays shall be tested with pilot cables connected by mechanical operation of contacts.

- c) On-load tap changer equipment shall be tested to ensure correct operation from associated control relays mounted on the switch-gear relay panels by voltage injection on the control relays.

16.2.8 Rotating machines (motors and generators):

- a) Before the application of electric power the machine windings, the insulation resistance shall be tested (with a suitable insulation resistance tester) and shall be greater than the manufacturer's minimum recommended figure when corrected for Site winding temperature. Any necessary drying out the windings on Site shall be in accordance with the manufacturer's recommendations.
- b) Before rotating any machine under power, the mechanical alignment of the shaft with the driven load (or driver) shall be checked (and adjusted if necessary) and shall be in accordance with the manufacturer's recommended figure.
- c) Before mechanically coupling any machine to the driven load, the direction of rotation shall be checked.
- d) Before running any machine on-load, all heavy current connections shall be checked for correctness of make-up and tightness.

16.2.9 Control and communication systems

All control systems shall be tested for satisfactory operation under any possible permanent and transient status of operation. Trigger points for alarm at maximum and minimum of variables shall be tested thoroughly.

16.2.10 Diesel generator sets

Tests shall be carried out in accordance with ISO 3046 by of the Contractor's staff and supervision of the Engineer. The purpose of the tests on completion shall be to confirm the factory tests and each engine and generator shall be tested to verify the performance for a period of up to 4 hours or as the Engineer may determine.

16.2.11 Bulk fuel storage tanks(if used)

Prior to being put into service, each tank and associated equipment shall be subjected to a sustained pressure of 0.7 N/mm² to ensure that the installation is sound and shows no leaks or distortions.

16.2.12 Earthing systems

Test resistance of the earthing networks and electrodes for compliance with international standards.

16.2.13 Building services

The Contractor shall demonstrate that the building services installations conform to the Specification and applicable international Standards. The tests shall include but not be limited to:

- a. Lighting installations
- b. Plumbing
- c. Ventilation and air conditioning

Demonstrate that the illumination levels conform to the specified values.

16.3 Measurement And Payment

All items for measurement and payment are provided under the relevant sections of the Bills of Quantities. The rate provided by the contractor in the bill of quantities shall be deemed to cover the cost of complying with all the requirements in this section of the specification.

**TECHNICAL SPECIFICATIONS FOR THE
CONSTRUCTION, REHABILITATION AND
EXPANSION OF GROUNDWATER – BASED
RURAL WATER SUPPLY SCHEMES - BATCH 1
SCHEMES IN WAJIR COUNTY**

**SECTION 5: OPERATION AND MAINTENANCE
SERVICES FOR REVERSE OSMOSIS (RO)
SYSTEMS**

17 Maintenance Services for RO Systems

17.1 General

The maintenance of Reverse Osmosis (RO) systems installed in the schemes during the after-sales period is critical to ensure optimal performance and longevity of the systems. Maintenance shall be carried out by the Contractor/Supplier according to the following GUARANTEED maintenance regimes:

- Routine preventative maintenance
- Breakdown repair maintenance service

17.2 Routine Maintenance

Each RO system should be visited according to the following schedule for routine maintenance:

Table 17-1: Routine Maintenance Schedule

| Routine Visit No. | Within Maintenance Period | Outside of Maintenance Period |
|--------------------------|----------------------------------|--|
| Maintenance Interval | Every 3 months | Ideally every 3 months, but outside of this scope of works |

At each routine maintenance visit, the following actions should be undertaken:

17.2.1 Coordination Tasks

- Confirm maintenance visit with the responsible facility manager or the water service provider (WAJWASCO).
- Meet the responsible WAJWASCO officer or facility manager on site.
- Obtain feedback on system performance since the last maintenance visit.

17.2.2 Technical Tasks

- Perform visual inspection of the RO system, including pre-treatment filters, membranes, pumps, and piping.
- Check for leaks, corrosion, or physical damage.
- Measure system parameters (e.g., pressure, flow rates, and water quality) using non-invasive methods to avoid introducing new issues.
- Diagnose any identified issues, check all wiring, connections, and piping, and repair loose connections, corroded parts, or damaged components.
- Ensure pre-treatment filters (e.g., sediment, carbon) are clean and replace as needed per manufacturer recommendations.
- Check membrane condition and performance, clean if required, and re- place if performance is below acceptable levels.
- Verify functionality of high-pressure pumps and motors, checking for unusual noises or vibrations.
- Confirm calibration and reliability of any remote monitoring system.
- Check water quality output (e.g., Total Dissolved Solids (TDS), pH) and take samples for further testing if required.
- Inspect and test all valves, pressure gauges, and control systems, ensuring proper settings.
 - Check inventory of on-site spares (e.g., filters, membranes, seals) and replace as necessary.

- Replace any faulty or damaged equipment.

17.2.3 Administration Tasks

- Record system status and measurements on maintenance log sheets.
- Obtain the signature of the responsible staff member on log sheets.
- Complete hard copy documentation.
- Place one copy of the completed log sheet in the Operations & Maintenance (O&M) manual stored at the site.
- Retain one copy of the log sheet for storage at the RO supplier's office.
- Retain one copy for submission with the bi-annual report to the Purchaser.
- Capture maintenance activities in a spreadsheet, including at least the following:
 - a. Date of maintenance
 - b. System identifier verification
 - c. Name of purchaser
 - d. System unique number
 - e. County, Sub-County, Ward
 - f. GPS coordinates for location verification
 - g. Items checked
 - h. Components replaced and new component information:
 - i. Filter type, rating, quantity, serial numbers
 - ii. Membrane type, rating, quantity, serial numbers
 - iii. Pump type, capacity, serial number

17.2.4 Training Tasks

- Assess the understanding and responsibility of facility staff or WAJWASCO members for the RO system based on communications.
- Check for staff changes and ensure new staff are trained.
- Provide follow-up training targeting:
 - i. End-users and staff who received initial training.
 - ii. New end-users and staff.

17.3 Breakdown Repair Maintenance Service

17.3.1 Response Times

Over the course of the 36 Months' Maintenance Period, a breakdown repair service, as defined below, will be available to address system breakdowns. Users of RO systems installed under this scope of work will have access to this service.

During the Warranty Period, all callouts shall be unconditionally on the Contractor's/Supplier's account.

Table 17-2: Breakdown Repair Maintenance Services

| Warranty Period (Defects and Maintenance) | Maintenance Period After Warranty Period |
|---|---|
| As many as necessary, unconditionally for Supplier's/Contractor's account | Contractor/Supplier to budget for breakdown repairs |

Breakdowns may be identified through complaints reported to the WSP (WAJWASCO) or via remote monitoring and reporting of system performance.

Table 17-3: Breakdown Repair Response Times

| Breakdown Type | Results and Impact | Response Time for Making Good |
|--|--|--|
| Tier 1: No water delivered for one (1) working day, likely due to critical failures (e.g., pump failure, membrane rupture/clogging, or electrical faults). | No water access for the facility. | 24 hours for diagnosis, including remote monitoring. 48 hours after Supplier receives Fault report. |
| Tier 2: Limited water supply due to partial system failure (e.g., clogged filters or reduced membrane performance). | Reduced water quality or quantity, increasing operational strain. | 5 working days after supplier receives fault report. |
| Tier 3: Limited water supply due to failure of non-critical components (e.g., secondary pumps or monitoring systems). | Minor impact on water supply with no significant operational cost. | 10 working days after supplier receives fault report. |

A response to a recorded enquiry or complaint should be provided within forty- eight (48) hours, and the system should be restored to full functional capability within the period specified in Table 17-3 above.

Each logged complaint or system failure notification shall be recorded by the WAJWASCO's Fault Report Office, forwarded to the Supplier (and copied to the County Department of Water), and actions taken, including action times, should be recorded using the log sheet provided in Section 17.3.2

17.3.2 Maintenance/Breakdown Log Sheets

Templates for maintenance log sheets are provided below for routine maintenance and breakdown maintenance. Three copies of these log sheets must be completed for each system at the time of each routine maintenance or breakdown visit. One copy should be inserted in the O&M folder on site, one retained for submission bi-annually to the Purchaser, and one kept by the Supplier.

Table 17-4: Routine Maintenance Log Sheet

| Site Details | | |
|---|--|-----------------|
| Customer ID: | | |
| System ID: | | |
| Site name: | | Starting time: |
| Date: | | Finishing time: |
| Weather conditions: | | |
| Type of system: | | |
| System Status on Arrival | | |
| <i>Pre-treatment Filters</i> Status? Condition? | <i>Membranes</i> Status? Pressure and TDS? | |
| <i>Pump</i> Status? Water output? | | |
| Maintenance Tasks (tick each circle as complete) | | |

| | | |
|---|---------------------------------|--|
| <ul style="list-style-type: none"> • Clean pre-treatment filters and check for damage • Replace filters if necessary • Check membrane condition and clean if required • Check for leaks, corrosion, and physical damage to installation • Check all piping and connections • Check electrical connections and continuity • Check pressure gauges and set correctly • Check valve functionality and set correctly • Check pump status and operation • Check water quality output (TDS, pH) and take sample for testing • Check remote monitoring system and compare outputs to on-site readings • Download remote monitoring system data to laptop, check connectivity • Replace membranes or components as needed • Confirm system operational • Conduct system performance tests as per specification | | |
| Register of Equipment Replaced | | |
| Existing equipment removed: | Replacement equipment provided: | |
| Responsible staff member: | Maintenance technician: | |
| Signature: | Signature: | |
| Name: | Name: | |
| Date: | Date: | |

Table 17-5: Breakdown Maintenance Log Sheet

| Site Details | | |
|---|---------------------------------|-----------------|
| Customer ID: | | |
| System ID: | | |
| Site name: | | Starting time: |
| Date: | | Finishing time: |
| Weather conditions: | | |
| Type of system: | | |
| Description of Problem(s) | | |
| What problems are reported by the customers/users? | | |
| Description of repair(s) Describe all repairs made. Complete routine maintenance checklist also. | | |
| Register of Equipment Replaced | | |
| Existing equipment removed: | Replacement equipment provided: | |
| Responsible staff member: | Maintenance technician: | |
| Signature: | Signature: | |
| Name: | Name: | |
| Date: | Date: | |

17.4 Maintenance Reporting and Tracking

The Supplier/Contractor will maintain organizational, staffing, logistical, inventory, recording, and reporting capabilities sufficient to meet the managerial and technical requirements of providing maintenance and other post-installation services to RO systems installed in the schemes.

The Supplier will establish and maintain clear, accessible communication channels for users and managers of RO facilities to report faults and other problems.

The Supplier will maintain recording and reporting systems within a database that enables:

Accurate tracking of component and system performance and maintenance services, including records of complaints, repairs, component or system failures, downtimes, and component replacements.

Capture of maintenance activities in a spreadsheet, including at least:

- a) Date of maintenance
- b) Verification of system identifier
- c) Name of purchaser
- d) System unique number
- e) County, Sub-County, Ward
- f) GPS coordinates for location verification
- g) Items checked
- h) Components replaced and new component information:
 - i) Filter type, rating, quantity, serial numbers
 - j) Membrane type, rating, quantity, serial numbers
 - k) Pump type, capacity, serial number

Access by the Purchaser to current electronic records and systems for tracking repair requests, responsiveness, and system status.

Accurate reporting by the Supplier on a bi-annual basis to the Purchaser.

The Supplier will submit bi-annual reports to the Purchaser detailing the status of the systems and maintenance activities conducted. The reports will include log sheets and information on complaints, repairs, component or system failures, downtimes, and component replacements.

**TECHNICAL SPECIFICATIONS FOR THE
CONSTRUCTION, REHABILITATION AND
EXPANSION OF GROUNDWATER – BASED
RURAL WATER SUPPLY SCHEMES - BATCH 1
SCHEMES IN WAJIR COUNTY**

SECTION 6: DRAWINGS

18 DRAWINGS

The drawings referred to in the Conditions of Contract and the Technical Specifications are bound separately in an accompanying folio titled Book of Drawings of the Bid Documents, together with such further drawings and amendments as shall be made and issued by the Engineer during the execution of the contract.