Section 1: General

1.1 Introduction

The China - Zambia Renewable Energy Technology Transfer Project carried out jointly through cooperation by UNDP, with Ministry of Energy of Zambia and Ministry of Science and Technology of the People's Republic of China, is focusing on the rural electrification in Zambia. By way of capacity building and demonstration projects, this project will absorb and utilize the Chinese experience to promote social and economic development in Africa. The China-Zambia Renewable Energy Technology Transfer Project is being funded by the Danish Government through UNDP and is being implemented by the Department of Energy, Zambia.

The Chipota Falls mini hydropower station (hereinafter referred to as Chipota hydropower station) is located on the Mulembo River, Chela Tambule village, Serenje District of the Central Province of Zambia, 400 km away from Lusaka, the capital.

The Department of Energy through support from UNDP completed the completed the Feasibility Study and basic design of Chipota Falls Hydropower Station in August 2016. The feasibility study carried out proposes the under-listed main project features for construction.

- 2 x 100kW Turgo generator-turbine sets with rated head of 46 m and design head of 45.38 m
- Design flow rate of 0.68m^3/s
- Low overflow weir (3.5m) with crest length of 30m, crest width of 1.5m and maximum dam bottom width of 4.0m
- Unregulated overflow spillway
- Penstock (1No. 530m long, 0.65m diameter, pipe wall thickness of 6-8mm)
- Surface power house
- Substation with transformer rating of 250kVA
- Access road (Gravel Finish), 15km
- Management House and staff house

The work to be performed under this contract comprises of planning, design, engineering, procurement, construction, manufacture, assembly, shop-testing, packing and forwarding for shipment, inland transportation to site, insurance, delivery at site, receipt, unloading, handling, storage, in-plant transportation at site, installation, field testing, commissioning, trial and testing and handing over to the Employer of the proposed 200kW Chipota Mini Hydropower Station.

The Powerhouse shall accommodate two units. As part of the works, an 11kV Substation shall be constructed close to the Powerhouse. The 11kV Substation shall accommodate two generator transformers, switch gear, and one feeder.

1.2 Scope of Facilities

The scope of the works to be provided under this contract comprises the Design and Build of a fully equipped facility, ready for commercial operation including, but not limited to, the engineering, design, procurement, manufacture, workshop testing, construction, erection, testing, commissioning and hand over to the Employer of the 200kW Chipota Mini Hydropower Station.

The Chipota Mini Hydro Power Station includes, but is not limited to, the following:

Civil Works and Hydro-mechanical Plant including:

a) Preparatory Works:

- site topographical survey;
- site investigations (e.g.hydrographic, geophysical survey, geotechnical, meteorological studies if necessary);
- data collection (including verification of design data provided in the Specifications);
- site facilities including camp sites, storage facilities and a materials testing laboratory;
- temporary access works and site installation required for the construction of the works such as water supply, sewerage, electricity supply etc;
- construction of the 15Km main access road to gravel finish complete with bridges at stream crossings wherever applicable
- The Design and Build contractor shall also construct one Management House and staff house to be used as an office by the employer during construction.

b) Temporary Works:

- Construction of coffer dams, diversion canal, etc
- Site facilities such as electricity, water, air, sanitation etc,
- Facilities for construction works such as batching plants, magazine, quarry, crusher etc.
- Working platforms, temporary camps etc for purposes of smooth construction of works.

c) Permanent Works:

- The Permanent Works shall include but not be limited to construction of:

- Low concrete overflow gravity WES curve weir.
- Intake including provision of trash rack, intake sluice gate, gantry with chain block, stop logs, sediment sluice gate, water level measuring instruments.
- 530m long steel pipe penstock, 0.65m in diameter
- Power house including turbine generator machine hall, unloading and maintenance bay, relay/switchgear room, control /battery room
- Two Turgo Turbine generating units, two inlet valves, draft tube and handling equipment, ventilation system , cable ways, auxiliary equipment.
- Tailrace Channel
- 11kV Substation station next to the Power Station
- Management House and staff house to house the administrative office, store room and maintenance workshop complete with equipment and tools
- Permanent access road complete with bridges at stream crossings
- Construction of water reticulation and sewerage system for Management House and staff house and power house
- Construction site roads, parking, landscaping and environmental mitigation measures
- Auxiliary equipment
- Security guard house and perimeter fencing;
- An emergency diesel generator and portable/movable fire extinguishers
- Any other structures as may be required for the proper functioning of the power station.
- Domestic water supply to the power station and permanent camp.

1.3 Mechanical Plant including:

a) Intake sluice gate and handling mechanisms and trash rack

b) Power house overhead hoist of adequate capacity to lift the heaviest plant component and for use in erection, dismantling and maintenance operations

c) Power station auxiliary equipment including:

- Air conditioners for the PLC, relay rooms and control room
- power house ventilation extraction fans
- fire protection and detection systems;
- workshop equipment and tools;
- All mechanical structures related to dams and other appurtenant structures

1.4 Electrical Installation including:

(a) Two synchronous generator complete with all auxiliaries, generator main connection systems and generator neutral earthing equipment

(b) two generator transformers

(c) Diesel Gen-set for black-start.

(d) Substation equipment - list not exhaustive:

- Transformer
- 11kV circuit breaker
- 11kV disconnector
- Voltage transformer
- 11kV arrester
- essential supplies systems including all battery systems, emergency lighting and uninterruptible power supplies;

(e) Electrical control, inter-locking, protection, operational and tariff metering systems complete with all associated current and voltage transformers;

(f) lighting and power outlet systems;

(g) internal and external lighting systems;

(h) earthing and lightning protection systems; and

(i) cabling systems

(j) Electrification of permanent camps/structures comprising but not limited to Management House and staff house.

1.5 Control and instrumentation including:

(a) Complete control, instrumentation and alarm equipment packages for the plant being provided, including water turbine, generator, common services and all auxiliary equipment;

(b) SCADA (PLC) will provide central monitoring and control. Visual Display Units (VDUs), keyboards, printers, data storage devices, redundant data highway laid in different trays following different routes, uninterruptible power supply, interconnecting cables, software and all associated hardware;

(c) Local instrumentation (suitable for fiscal metering where required), including pressure, temperature, level and flow gauges/switches and all associated tapping points, pipe-work, valves, local cubicles and racks;

(d) Control room equipment including operator desk;

(e) Condition monitoring equipment for plant and auxiliaries;

(f) All hardwiring for safe plant running, shut-down and protection systems and all necessary interlock control, instrumentation and power cables; and

(g) Metering systems.

1.6 General Works shall include:

Works testing and inspection;

a) Site erection, installation and commissioning;

b) operating and maintenance manuals;

c) communications systems including telephone system

d) Spare parts and miscellaneous items including:

- spare parts and consumables requirements;
- tools for maintenance; and
- Workshop equipment and storage facilities.

e) Environmental mitigation and monitoring measures as required by the Environmental Management Plan

f) Staff training, before scheduled commissioning of the Unit.

The works shall be such that all maintenance of the Power Station may be undertaken by the Employer without the requirement for temporary lifting equipment not provided under the contract.

All accessories required for the erection, dismantling, inspection and maintenance of the plant and equipment, such as tools, computer software and hardware, slings, lifting equipment, trolleys for transporting components around the Power Station, ladders, access platforms, and other similar items any accessories and instrumentation required for tests together with initial fillings of oil and grease shall be provided for the Power Station.

For Chipota Mini Hydro Power Station Substation, all accessories required for the erection, dismantling, inspection and maintenance of the plant and equipment, such as special tools, computer software and any accessories and instrumentation required for any tests together with initial running of gas, oil and grease shall be provided.

A conceptual design and layout of the works is presented in the Tender Drawings.

The scope of work outlined above does not necessarily include all the works to be supplied under the contract.

1.7 Contract Terminal Points

The principal terminal points are as follows:

a) The Contract terminal point:

b) Civil works: From Intake to Tailrace end.

c) Access roads: to terminate at the junction with road T2 – Bidder to be guided during pre-bid site visit

d) Electrical power: At the transmission line terminal bays in Substation.

1.8 Basic Site Data

Basic indicative site data is given below for information only.

The Contractor shall be solely responsible for his own interpretation, verification and use of the data and information below.

1.8.1 Altitude

All references to elevation (El.) in the Contract are in metres to the Government of Zambia survey datum and are indicative only.

The altitude of the 200kW Chipota Hydro Power Station site generally lies at an altitude of 1421.50 masl at the dam crest.

1.8.2 Ambient Air Conditions

Below are typical ambient air conditions likely to be experienced in the project area:

Maximum temperature 36°C

Minimum temperature 15°C

1.8.3 Rainfall

The project area is one of the wettest places in Zambia with annual rainfall of about 1133.6mm falling in the rainy season from October to May.

1.8.4 River Sediment

The catchment above the Chipota mini hydro power station has thick ground vegetation with less human activity effect and very low water and soil erosion. Thus, the sediment quantity in the river is small. However, the contractor will be required to undertake further studies.

1.8.5 Chipota River Flow Duration Curve

There are no meteorological stations or hydrological stations near the site and rivers surrounding the site. Thus, it lacks hydrological data. However, in order to identify the data of the section runoff, a value of 1.3 m^3/s was derived through field measurement and identified this value as the monthly average in April. The distribution regularities of the average monthly flow at Shiwang'andu gauging station located in the Northern Province were used to work out the average monthly flow of the whole year. Based on the average monthly flow series, the average monthly flow duration curve of the Chipota Falls hydropower station site was determined.

Figure 1 below shows the Average Monthly Flow Duration curve for Chipota Falls:

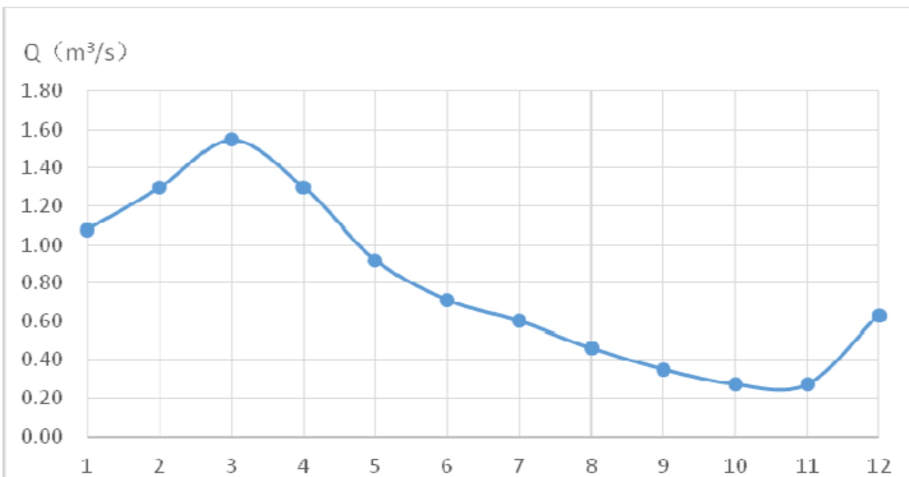


Figure 1: Average monthly flow duration curve of the Chipota Falls Site

1.9 Reference Documents & Information

1.9.1 Study Report

The report on a study titled 'Chipota Mini Hydro Power Station Feasibility Study, November 2016 has been prepared for the Employer.

Extracts of the Report shall be made available to the Contractor by the Employer.

The Contractor shall be responsible for his own interpretation, verification and use of any data and information contained within the Report.

Where conflict exists between the employer's requirements in the tender document and the feasibility study report, the requirements in the tender document shall prevail.

1.9.2 Site Investigation and Topography

The Employer has undertaken a site investigation including:

- Preliminary topographic survey.
- Preliminary geotechnical survey together with a Report. The results of the site investigation will be made available to the Contractor by the Employer.

The Contractor shall be responsible for his own interpretation, verification and use of the results of the site investigation topographic survey. The Contractor shall undertake, at his own cost, any other site investigation work and topographic mapping that he deems necessary to ensure compliance with the Contract.

1.10 Reference Points

The Contractor shall be responsible for establishing Reference Points, lines and levels for setting out purposes, at appropriate locations on the site. The location and level of the Reference Points, lines and levels shall be reviewed by the Employer. The Contractor shall be responsible for carefully maintaining these Reference Points, lines and levels at all times.

1.11 Statutory Requirements

Contractor shall comply with all the applicable statutory rules and laws pertaining to works in Zambia.

i. All design and construction work, including the materials used and methods applied, shall be in accordance with internationally recognized standards of practice. By definition, such standards comprise organizations such as the ASTM (American Society for Testing and Materials), ISO (International Organization for Standardization), DIN (German Code), BS (British Standard), SS (Swedish Standard), EN (European Standard), or equivalent.

ii. All equipment supplied shall be in compliance with the appropriate International Standards current at the time of contract signature unless otherwise approved by the Employer. Such approval shall be given only if the Contractor can demonstrate to the satisfaction of the Employer that the equipment is of equivalent quality to the appropriate National or International Standards. Installation shall be in accordance with the appropriate standards and the manufacturers' recommendations.

iii. The design of all elements of the civil works shall fully comply with the current recommendations of ICOLD, CIRIA, USBR (United States Bureau of Reclamation), USACE (United States Army Corps of Engineers) and organizations of similar standing. In addition the design of the Works shall satisfy the requirements of relevant Zambian regulations.

iv. To the extent required in the Design and Build Contract, the Contractor shall take into account and comply with all statutory regulations applicable to the performance of this Agreement and any other standards and codes of practice relevant to the type of plant, some of which are referred to within this document.

v. The design shall meet the Zambian Grid Code requirements.

vi. Fire detection and protection systems shall be provided throughout the Works. These shall include fixed water protection systems, fire alarms and portable appliances. The design of these systems shall comply with the current requirements of the National Fire Prevention Authority (NFPA) or the Loss Prevention Council (LPC), and the Laws of Zambia.

vii. Electrical installation work shall be executed in accordance with BS 7671 for Electrical Installations in Buildings where appropriate and in accordance with statutory regulations.

viii. The Contractor is responsible for complying with all Zambian electrical supply and safety regulations with respect to the plant output and auxiliary supply system, and for carrying out those studies (harmonic, fault level, stability, load flow etc.) necessary to demonstrate compliance with these regulations.

ix. Provision shall be made in the design of the works for the health and safety of the operating personnel, the visiting public, and all other persons potentially affected by the operation of the Works. As far as is reasonably practicable the Works shall be designed to avoid, reduce or control risks to health and safety. Where risks remain, these shall be effectively drawn to the attention of those potentially at risk, and provisions for risk reduction and control shall be made.

x. Should the Contractor request alternatives to the standards specified, other relevant standards may be used subject to Employer's approval. Differences between the standards specified and the proposed alternative standards must be fully described in writing by the Contractor and submitted to the Employer for review and approval.

xi. The latest editions, 28 days prior to the receipt of the Contract, of the standards and codes, including amendments, shall be used by the Contractor, unless expressly stated otherwise.

xii. An English translation shall be submitted if the standards and codes proposed by the Contractor are in a language other than English.

xiii. All specific references to standards and codes throughout these Employer's Requirements and the Specifications are governed by this part.

xiv. The contractor shall take into account and comply with all statutory regulations applicable to the performance of this Agreement and any other standards and codes of practice relevant to the type of plant, some of which are referred to within this document.

xv. The design of the Hydroelectric Power Station shall be in full accordance with the provisions of the United Kingdom Construction (Design and Management) Regulations 1994 or equivalent international standards, noting that such regulations shall cover the construction, maintenance and operation of the Hydroelectric Power Station.

1.12 Work Schedule

The Contractor shall submit to the Employer for review, a detailed program of works as required by the Conditions of Contract.

The Contract program of works shall be in the form of a Gantt chart indicating the critical path, utilising Microsoft Project or other software agreed by the Employer.

The Contractor shall make due allowance in the program of performance for any traditional and National holidays which could impact upon completion dates for the Facilities.

1.13 Documentation

The necessary detailed drawings and documentation shall be prepared by the Contractor and submitted for the Employer's review.

The Contractor shall submit a detailed list of drawings and documents to be submitted during the course of the contract, which will be subject to the Employer's review and which shall include, but not be limited to the following:

i. Layout of Contractor's site facilities and temporary works
ii. General arrangement and sectional drawings
iii. Foundation drawings including static and dynamic loading details
iv. Equipment layout drawings
v. Detailed equipment drawings
vi. Outline drawings of all cubicles and terminal arrangements

vii. Piping and instrumentation drawings

viii. Single line diagrams

ix. Schematics

x. Control logic diagrams

xi. Calculations

xii. Turbine model test report

xiii. Generator characteristic and capability curves

xiv. Protection setting calculations and relay co-ordination

xv. Alarm schedules

xvi. Manufacturers' data sheets and equipment details

xvii. Finishes

Before submitting drawings for review, the Contractor shall fully examine and check the drawings for compliance with the requirements of the Contract.

Samples submitted for review shall be accompanied by all the associated relevant drawings and documents.

1.14 Drawings

In the preparation of drawings the following requirements shall apply:

i. The SI (Système International) unit shall be used for all drawings.

ii. Paper size ISO AO to A4 shall be used for all drawings.

iii. Symbols shall be to the approved International Standards.

iv. Title blocks and numbering shall be subject to approval by the Employer.

The Contractor shall develop a common drawing and document identification numbering system which shall be subject to the Employer's approval.

A computerised document control system shall also be maintained and regularly updated by the Contractor to indicate:

a) Drawing or document number

b) Title

c) Revision number

d) Date of original issue and subsequent revisions

e) Target drawing or document submission date

The updated document control schedule shall be submitted monthly in an electronic format for the Employer's review.

For any drawing revised, the revision number, date of revision and a short description of the revision shall be marked on the drawing.

1.15 Contractor's Documents

The Contractor shall prepare and submit documents in the English language for the Employer's review including, but not limited to, the following:

Document	Submission Period within	
Work Schedule		In accordance with the General Conditions of Contract. Thereafter monthly.
Project Quality Plan	14 days	after the Time for Commencement
Site Quality Plan	45 days	before start of site activities
Health and Safety Plan	14 days	before start of site activities
Contractor's Environmental Management Plan (CEMP)	14 days	before start of site activities
Construction Method Statements	14 days	before the activity
Progress Reports	weekly	1st day of the week
	monthly	before the 6th day of the month
	quarterly	before the 6th day of the month
Document Control Register and Drawing List	14 days	after the Time for Commencement ; thereafter monthly updates
Design Drawings and Information		in accordance with Contractor's Document Control Register

Document	Submission Period within	
Employer's Personnel Training Syllabi and Programs	60 days	before commencement of training
Draft Commissioning Procedures	30 days	before commencement of commissioning
Final Commissioning Procedures	30 days	before commencement of commissioning
Draft Operation and Maintenance Manuals	90 days	before commencement of commissioning
Final Operation and Maintenance Manuals	14 days	after Operational Acceptance Certificate date
As-Built Drawings	30 days	after Operational Acceptance Certificate date
Draft Commissioning Report	14 days	after completion of commissioning
Final Commissioning Report	30 days	after Operational Acceptance Certificate date

1.16 Quality Assurance

1.16.1.1 Policy

The Contractor shall apply the formal requirements of Quality Assurance to the supply, Construction, erection and testing of the works. This shall be achieved through the Implementation of a Quality Assurance System compliant with the requirements of International Standards.

Positive commitment to Quality Assurance shall be expressed in a formal policy statement given in the Contractor's Quality Assurance and Control Plan which form part of the Technical Schedules of the bid document.

1.16.1.2 Objectives

It shall be the stated aim of the Contractor to achieve and demonstrate the achievement of quality as expressed by 'due care and diligence' of the procurement, manufacture, construction, testing and repair of the Works.

The criteria to define 'due care and diligence' shall be explained in the Contractor's Quality Assurance Plan and shall embody all of the procurement, manufacture, construction, testing and repair requirements of the Works.

1.16.1.3 Quality System

The Quality System shall be fully integrated for all of the Works. The system will be defined by the organizational structure, responsibilities, activities, resources, and events that together demonstrate the capability of the Contractor to meet the stated quality requirements.

The Contractor shall ensure that all sub-contractors and sub-consultants establish quality systems and shall supply to the Employer such evidence as is necessary to demonstrate the effective implementation of a quality system in each sub-contractor or sub-consultant organization.

The Employer's representative shall be entitled to audit any aspect of the Quality System of the Contractor and of his sub-contractors. The Employer's representative will give two weeks' notice of such audits.

On a day-to-day basis the Contractor shall afford reasonable availability of staff and documentation for the Employer's representative to assess the implementation of the Quality System. The Contractor shall ensure that all relevant personnel and documentation are available for such audits.

1.16.1.4 Quality Assurance Plan

The implementation of the Quality System shall be through the establishment of a comprehensive Quality Assurance Plan approved by the Employer's representative. No work shall be taken up at site without the approval of the Employer's representative prior to the approval of the Quality Assurance Plan which will include methodology adopted for Quality Assurance and procedures for keeping records and reports.

The documented procedures shall include but not limited to:

I. Management Procedures;

II. Supply/Procurement;

III. Manufacture (where applicable);

IV. Construction;

V. Putting to work/Commissioning/Reliability Trial/Performance Test;

VI. Operator Training;

VII. Internal Control.

1.16.1.5 Quality Performance, Monitoring and Review.

There shall be procedures to control transmission of information across all interfaces both internally (that is, within the Contractor's Quality System) and externally. Those of the latter shall include all Statutory Bodies, Authorities and the Employer's representative.

Formal assessment of any non-compliance with the Quality Plan shall be achieved through periodic reviews undertaken by a team appointed by the Contractor. All deficiencies shall be recorded and appropriate corrective measures shall be assessed, within an appropriate timescale, through subsequent formal reviews undertaken by the Contractor.

1.16.1.6 Quality Feedback

The Quality System shall include for the reporting back, recording and incorporation into the system of deficiencies and remedial measures to correct them noted during the control of the project.

1.16.1.7 Material

All goods and materials to be used into the Works shall be new and most recent or current models and shall incorporate all recent improvement in design and materials.

The Contractor shall place orders for the material and equipment only after approval of the Employer's representative, the Contractor shall submit the detailed drawings from the approved manufacturer for all equipment along with the Quality Assurance Plan and inspection, stages/procedures for the approval of the Employer's representative.

1.17 Progress Reports

During execution of the Contract, the Contractor shall furnish monthly progress reports to the Employer in a format as specified here by the 6 th day of following month, indicating the progress achieved during the month and total progress up to the month as against scheduled and anticipated completion dates in respect of key phases of work such as release of drawings for fabrication, procurement of raw material, fabrication, erection, inspection, testing & commissioning and shipment.

1.17.1.1 Format for Monthly Progress Report

The Progress Report shall also include status report on the following in approved individual formats:

I. Drawings,

II. Supplies of Plant Items,

III. Equipment and manpower deployment,

IV. Construction Programme,

V. Construction Progress,

VI. Overall Progress Curve and

VII. Payment details

VIII. Safety and Health Issues.

In Progress Report the Contractor shall submit the targeted and achieved progress in such a form that actual progress to the end of the preceding month may be compared with the Contractor's programme.

The Contractor shall regularly review his programme in the light of the progress actually achieved and shall submit for approval and update PERT/CPM network and bar charts at intervals to be agreed with the Project Manager. If progress falls behind that needed to ensure timely completion of the various parts of the works, the Contractor shall submit proposals for improving his methods and pace of working to the satisfaction of the Employer and shall carry out such measures as are needed to ensure that the works are completed on time.

The Contractor shall provide the Employer, with weekly reports giving the number of labourers, skilled workers, supervisory staff and major construction equipment - his own as well as that of the Sub-Contractor employed by him deployed at site.

1.18 Document Control Register

The Contractor shall prepare and maintain a Document Control Register detailing the current status of all documents including drawings that are to be submitted to the Employer for review.

The Document Control Register shall be initially submitted to the Employer for review and thereafter updated each month and submitted to the Employer with the monthly Progress Report.

1.19 Methods of Working

1.19.1 General

The Contractor's Equipment and methods of work shall at all times be such that the Employer can be reasonably satisfied that the results will be acceptable and achieved without undue risk to personnel involved.

The Contractor shall take appropriate measures to protect the Facilities from adverse effects of weather during construction. Temporary drains shall be provided to prevent ponding, erosion or other damage to incomplete works. All reasonable precautions to prevent an outbreak of fire shall be taken.

1.19.2 Construction Method Statements and Risk Assessments

The Contractor shall submit to the Employer for review method statements for each major activity detailing his planned method of work, including relevant risk assessment and details of manpower requirements. The Contractor's working methods shall not depart from his written method statement without this departure having previously been notified to the Employer. Method statements shall be accompanied by sketches, drawings and diagrams wherever necessary for clarification of details. Method statements should include, as a minimum, details of:

i. Temporary works and utilities;

ii. Workshop arrangements;

iii. Material quality control;

iv. Quantity of materials;

v. Training and briefing of workforce;

vi. Labour and plant to be used;

vii. Concrete production and supply, including quarry areas;

viii. Earthworks sources, transport and placement;

ix. River and waterway diversions;

x. Details of working methods including stability of temporary works and construction plant, placement/construction rates as well as techniques and equipment to be used;

xi. Transport arrangements for Plant;

xii. Erection sequences for Plant, including information regarding the state of completion of the relevant civil structures;

xiii. Inspection and testing for quality control;

xiv. Quality assurance;

xv. Erosion control and protection of exposed surfaces;

xvi. Environmental management, including waste disposal and site restoration;

xvii. Contingency plans in case of plant breakdown or material supply interruption, pumping capacities;

xviii. Risk assessment and safety measures to protect workforce and others;

xix. Fire precautions;

xx. Programme (time schedule);

1.20 Commissioning Documentation

The Contractor shall prepare and submit documentation setting out how he will commission the Facilities. This documentation shall include, but not necessarily be limited to:

i. Commissioning Plan setting out the organisation of the commissioning including requirements of the Employer;

ii. Commissioning programme setting out the sequence of commissioning activities in the form of a GANTT chart;

iii. Commissioning procedures setting out details of the tests to be performed on all equipment to be commissioned;

iv. Complete set of drawings of the plant installation at the commencement of commissioning;

v. Complete set of draft O&M Manuals.

1.21 Operation and Maintenance Manuals

The Contractor shall prepare and supply Operation and Maintenance (O&M) manuals (English) for the Facilities as required under the Contract.

The O&M manuals shall be specific to the Plant supplied and shall include detailed descriptions of the following:–

i. Description of the Facilities
ii. Operation of the Facilities
iii. Maintenance of the Facilities.
iv. Relevant Manufacturer's Literature
v. Relevant As-Built drawings and other drawings.

All modifications made to the Facilities during construction, installation and commissioning shall be detailed and included in the O&M Manual.

The Contractor shall submit Operation and Maintenance Manuals in draft and final form as follows:

a) Draft Manual

- 4 Hard copies and 2 Electronic Copies

b) Final Manual

- 5 Hard copies and 2 Electronic Copies

1.22 As-Built Drawings and Documents

The Contractor shall prepare and supply to the Employer 'As Built' drawings and documents as required under the Contract.

The Contractor shall supply 4 paper copies and 4 electronic copies of all drawings (in AutoCAD version to be supplied by the Contractor) and documents including, but not limited to, the following:

i. General arrangement and sectional drawings.
ii. Detailed drawings of all civil and structural works.
iii. Equipment layout drawings.
iv. Detailed equipment drawings.
v. Outline drawings of all cubicles and terminal arrangements.
vi. Cabling schedules.

vii. Piping and instrumentation drawings.
viii. Single line diagrams.
ix. Schematics.
x. Control logic diagrams.
xi. Calculations.
xii. Generator characteristic and capability curves.
xiii. Protective relaying co-ordination.
xiv. Alarm schedules.

1.23 Commissioning Reports

The Contractor shall submit to the Employer copies of comprehensive Commissioning Reports in line the commissioning schedule (Per milestone).

The reports shall include, but not be limited to, the following:

i. A written summary of commissioning noting particularly the problems that were encountered and the actions undertaken to resolve these.
ii. Defects which have occurred and the remedial action taken to resolve these defects.
iii. Signed Checklists and Test Sheets.
iv. Copies of all factory and site test reports and certificates.

Number of copies shall be as specified in the relevant clauses herein.

1.24 Inspection and Testing

1.24.1 General

The hydroelectric plant and equipment and the hydro-mechanical equipment are subject to inspection and testing by the Employer during the course of and on completion of manufacture and erection and construction to ensure compliance with the Specification and to provide necessary operating data.

The Contractor shall be responsible for the conduct of all inspections and the provision of all equipment, instrumentation, personnel and labour required for carrying out the inspections and tests.

The Contractor shall give the Employer notice of the date, time and place of all inspections and tests to be attended by the Employer together with other necessary information not later than twenty one (21) days prior to the date of any such inspection and test. In the case of tests with long duration as much notice as possible shall be given, in any event not less than one month.

The Contractor and his sub–contractors shall provide the Employer with all facilities for the proper and timely execution of the inspections and tests including free and unrestricted access to the test and inspection facilities.

The inspections and tests shall comprise:

(a) Factory Manufacturing Inspection and Tests;

(b) Tests at Completion.

The subsequent clauses list some of the specific inspections and tests which the Employer requires. Except as otherwise provided in the Contract, this shall not preclude the Employer's right to call for modified or further inspections and tests in order to ensure compliance with the Minimum Requirements, whether under test conditions or in ordinary working, or to cover materials and methods of construction different from those indicated in the scheduled inspections.

Except as otherwise provided in the Contract, all materials and components shall be subject to type, sample and routine tests and inspection while in the process of and upon completion of manufacture.

The Contractor shall make available to the Employer upon request four bound copies of results of all tests required under the Contract. The results of each test shall be recorded in the form of test certificates or test reports.

The results of factory and site tests shall be submitted to the Employer upon request within one month of the tests being carried out. The results of tests at site shall be submitted to the Employer upon request within one week of the tests being carried out.

The passing of factory inspection and tests shall not prejudice the right of the Employer's or the Contractor's rights and/or obligations to the extent set forth in the Contract.

All instruments and their calibration shall be to approval, and if required by the Employer, shall be calibrated by a National Testing Laboratory or other such body as may be approved by the Employer. Calibration data shall be made available to the Employer. All inspection, measuring and testing equipment that is required to carry out the inspections and tests shall be provided by the Contractor.

The Contractor shall provide all equipment and personnel required to carry out the tests, including the provision, installation and removal of all test instruments, the connection and disconnection of plant items and obtaining all records.

The tests shall be arranged to represent the working conditions as closely as possible.

Type tests, when called for, shall be made on equipment which has previously passed its routine tests.

Where type tests have been carried out under previous contracts on equipment similar in all essential respects to the equipment included in this Contract, the Employer may waive the type tests on production of complete test records relating to the equipment concerned.

All inspection methods, procedures and acceptance criteria relating to the manufacture of cast steel components for the water turbines shall be in general accordance with Specification CCH 70-3 Steel Castings for Hydraulic Machines.

The Contractor shall submit, for approval by the Employer, all quality sheets appertaining to the manufacture of steel cast components, including turbine runner buckets. These sheets shall be in the same general format as given in with Specification CCH 70-3 Specification for Inspection of Steel Castings for Hydraulic Machines.

During the testing period, starting from compliance checks through the reliability test run, the Contractor shall establish a start-up organisation including all personnel, their responsibilities and the hierarchy of the organisation.

The Contractor shall appoint a Commissioning Manager, who shall be responsible for the Contractor's obligations during compliance checks, initial tests, system demonstrations and performance tests. The Contractor shall be solely responsible for testing all systems and subsequent performance tests to the extent set forth in the Contract and Standards.

1.24.2 Tests on mechanical equipment in manufacturers' Works

1.24.2.1 Material tests on component parts

Test specimens shall be taken from the main forgings and castings; drawings giving the positions of all test pieces are to be submitted to the Employer for approval. Forgings and castings shall be in the finally heat treated condition before detaching the specimens.

All material test certificates shall be in accordance with EN10204 3.1B as a minimum and shall include full details of chemical analysis, heat treatment mechanical tests and the specified limiting values of acceptability to enable verification by the Employer.

The material used shall in all cases conform to the requirements of the applicable clauses herein and shall include chemical analysis and mechanical properties tests as appropriate.

For the Turgo turbine runner, each casting shall be provided with a sufficient number of cast-on test bars to verify the chemical and mechanical properties of the casting. For governing equipment, certification shall be provided to the Employer for check tests on the materials of construction.

The subsequent clauses of this Section list specific inspections and tests as the Employer requires. This shall not preclude the Employer's right to call for modified or further inspections and tests to the extent set forth in the Contract in order to ensure compliance with the Minimum Requirement, whether under test conditions or ordinary work, or to cover materials and test methods of construction different from those indicated in scheduled inspections. If a test is required in resolution of a dispute, the non-prevailing party shall bear the cost of the test.

1.24.2.2 Non-Destructive Testing (NDT)

The Contractor shall submit for approval, at least eight weeks prior to the commencement of forging, casting, rolling or fabrication, details of the following:

(a) The techniques and procedures of examination to be employed on the principal items scheduled below under clause (1.24.2.3) and other items as necessary.

(b) Inspection programs indicating the stages at which the Contractor proposes inspections are to be carried out.

(c) The standards of acceptance proposed by the Contractor, if these differ from the specified standards where included in clause 1.24.2.3, and if a standard is not specified in Clause 1.24.2.3.

NDT operators shall be qualified in accordance with an agreed nationally accredited scheme. Alternative NDT equivalent qualifications may be submitted to the Employer for approval.

The Contractor shall institute and maintain a record of all approved NDTs and these records shall be readily available for verification by the Employer.

1.24.2.3 Principal items to be examined

Provision shall be made for, but need not be limited to, the following witnessed NDTs. Acceptance of welds by the Employer will depend on tests carried out after final heat treatment. Use of simulated heat treatment will not be permitted.

I. Units

(a) Shafts – Ultrasonic examination of the final heat treated and finished bored condition for the purpose of final acceptance. The forging manufacturer shall undertake a preliminary examination of the shaft at an earlier stage to confirm the likelihood or otherwise of compliance with the agreed acceptance standards and also to determine diameter of the bore (within given limits) such that defects in the bore zone will be removed during subsequent machining.

Ultrasonic examination shall comprise 100 percent scanning in radial and axial directions.

Boroscope examination of the finish bore, including magnetic particle inspection. Magnetic particle inspection of dye penetrant examination of all transitional fillets.

(b) Bearings - Ultrasonic examination of sleeve or pad segments (prior to white metalling), white metal to confirm soundness of bond to the bearing sleeves or pads and on bearing surfaces (after machining).

II. Water turbines

a. Runner – magnetic particle inspection of radii of any castings.

b. Runner – 100 percent ultrasonic examination of castings.

Magnetic particle examinations shall be carried out on all surfaces as follows:

1. After preliminary preparations by grinding, supplemented by radiographic and ultrasonic examination to determine the extent and nature of any major defects.

2. After grinding and machining to the surface finish stipulated in the drawings.

3. Subsequent to both repair welding undertaken to eliminate defects detected by examination (1) and stress relief.

Ultrasonic examination shall be carried out after preliminary preparation by grinding as a supplement to magnetic particle examination and after quality heat-treatment but prior to post weld heat-treatment.

Dye penetrant examination shall be applied to the parts of the blade surfaces subject to cavitation damage as a supplement to magnetic particle examination.

The quality sheets and relevant acceptance criteria proposed by the Contractor should be included for Employer approval.

III. Governor equipment

Distributing valve and other governor control valves – magnetic particle inspection of radii and changes of section castings.

IV. Auxiliary plant

Pressure vessels and air receivers – Non-destructive examination shall be in accordance with the relevant codes and statutory requirements.

High pressure piping – All butt welds in piping subjected to reservoir head shall be radiographed or ultrasonically examined, supplemented where necessary by magnetic particle examination.

V. Hydro-mechanical equipment

General

Material tests shall be carried out on all important stressed steel components.

Radiographic examination of ultrasonic examination shall be carried out on major steel castings and forgings. The areas proposed for such examination shall be nominated by the Contractor when submitting drawings of the component concerned. The decision as to whether further examination is required shall be determined on the incidence of defective materials disclosed by the initial examination. The acceptability of the material shall be judged in accordance with American Society for Testing Materials Standard E446 and E186, severity level 1 for cracks and hot tears being "unacceptable", severity level 2 for all other forms of defect being "border line", as defined in those Standards. Any areas found by these examinations to contain unacceptable defects shall be subject to re-examination after repair.

Radiographic, ultrasonic examination and crack detection shall be carried out on welded components.

Crack detection of all steel castings and forgings shall be in accordance with the relevant British Standards.

Non-destructive testing of welds in steel components shall be carried out as follows:

1. All full-penetration welds on important stressed components shall be examined for their full length radiographically or ultrasonically. The examination methods and the standard of acceptability shall be in accordance with PD 5500 for Class 1 Vessels.

2. In addition, a percentage of all other welds on important stressed components shall be examined ultrasonically, radiographically or by magnetic particle testing. The examination methods, extent of examination and standard of acceptability shall be in accordance with PD 5500 for Class 2 Vessels.

3. The toes of all fillet welds on important stressed components shall be subject to crack detection.

4. Radiography of welds shall be carried out in accordance with BS EN 1435.

5. The Contractor shall submit radiographs and reports to the Employer upon request within seven days of the taking of site radiographs. The report shall contain complete identification of the component concerned, definition of the location of the radiographed areas, full description of the radiographic techniques and report on all indications of the film.

6. Ultrasonic techniques and acceptability of defects found by ultrasonic examination shall be in accordance with BS 3923.

7. Welds in which unacceptable defects are found shall be repaired using the same method as the original weld and subjected to re-examination.

Non-destructive testing of welds in aluminium components shall be tested in accordance with applicable standards. The actual scope of tests shall be to the approval of the Employer dependent on the design and function of the components concerned.

Gates and associated equipment

Each gate and set of seal seats, tracks and guides shall be completely assembled in the factory, where appropriate, for inspection to ensure that all parts to be connected fit properly, and that all the dimensions, clearances and tolerances are as shown on drawings or as required in the specifications. The gate frames, seats and guides shall not be more than lightly clamped at their anchor bolt attachments, when dimension and tolerance checks are made. The seals shall be shop assembled with the gate and match-marked.

Each fully assembled gate shall be supported by its lifting point(s) and shall hang vertically with machined surfaces of the seal seats plumb with ± 6 mm and the machined bottom lip of the gate horizontal within ± 3 mm.

Each fully assemble gate shall be tested for operation with its lifting hoist and trash rake to ensure that the lifting hooks engage and disengage correctly with the lifting lugs on the gate.

Shop assembly of all balance and bypass valves and pipework shall be undertaken for inspection to ensure that all parts to be connected, and that all of the dimensions, clearances and tolerances are as shown on drawings or as required in the specification.

1.24.2.4 Hydraulic pressure tests and leakage tests

General

Test pressure shall be applied and maintained for a period of not less than 30 minutes. If considered necessary by the Employer, strain gauge measurements shall be carried out during pressure tests. The number and position of each measurement shall be to the approval of the Employer.

The period of test for static pressure leak tests shall be 24 hours.

Valves, pipes and other parts subject to hydraulic pressure

All parts subject to pressure water from the reservoir, all pressure valves and all connections thereto shall be subjected to a test pressure, applied for a minimum period of 30 minutes.

The test pressure is to be 1.5 times the maximum momentary pressure arising under any conditions if accident or emergency.

All parts subject to pressure water from the tailrace shall be tested to a pressure equivalent to 1.5 times the head due to the maximum possible tailwater level. The test pressure shall be applied for a minimum period of 30 minutes.

Bearing oil coolers and bearing housings

Wherever applicable, all bearing oil coolers shall be tested on the water side with a test pressure equal to the maximum momentary pressure arising under any conditions of accident or emergency.

On the oil side, bearing coolers shall be tested to a pressure of at least 1.5 times the maximum working pressure. Bearing housings shall be subjected to leak testing using oil or paraffin.

Governor oil system and bearing oil systems

All parts of the governor oil system including pumps, relief and relating valves, oil/air vessel, pipes and fittings and regulating ring operating cylinders shall be pressure tested to 1.5 times working pressure.

Air receivers and nitrogen accumulators

All air receivers and nitrogen accumulators shall be pressure tested at 1.5 times working pressure.

Lubricating oil or leakage oil tanks

On completion of fabrication these tanks shall be subjected to leak testing using oil or paraffin.

Hydro-mechanical equipment

Hydrostatic tests shall be carried out on all equipment (excluding the main gate assemblies) subjected to water, oil or air pressure during normal or abnormal working conditions, in accordance with the relevant British Standards, subject to the test pressures not less than twice the maximum working pressure.

Leakage tests shall be carried out with paraffin for all sump tanks.

1.24.2.5 Other equipment

Pipe work

The supply, fabrication and erection of all pipe work shall comply with the requirements of ASME B31 or agreed equivalent.

All butt welds shall be full penetration welds with complete fusion between weld runs and base metal.

Structural steelwork

Welding and inspection in both shop and site shall be in accordance with Section 5 of BCSA publication No 203 - National Structural Steelwork Specification for Building Construction.

Where only partial inspection is required the location of the joints selected for testing shall be agreed by the Employer.

Should any of these welds prove to be defective on inspection, the number of welds to be tested in that system shall be twice that originally required. Should any of the second increment welds prove to be defective, then all the welds in that system shall be tested.

Weld defect acceptance levels shall be in accordance with Table 2 of BCSA document No 203.

Castings, forgings and wrought products

All castings, forgings and wrought products shall be subjected by the manufacturer to chemical analysis, material tests and inspections in accordance with the agreed standards/Specifications, except where otherwise agreed by the Employer. Inspection must be scheduled pursuant to the terms and conditions of the Design and Build Contract. In case of a rejection influencing the delivery time, written notice must be given in due time to the Employer.

The Employer reserves the right to examine and witness acceptance tests, prior to and following weld repairs and subsequent post weld heat treatment, mechanical tests etc. at the material supplier's works.

Weld repair procedures are subject to approval of the Employer.

Pressure vessels

All pressure vessels shall be designed, fabricated and tested in accordance with ASME Section VIII. The Employer reserves the right to verify or witness any activity required by the Specification.

Valves

All castings and forgings shall comply with the requirements of this Specification as applicable to the service of the valves. In addition valves supplied with butt weld ends shall be subject to radiographic or ultrasonic examination for a length of 75 mm from the prepared weld tip and magnetic particle examination of the weld tip profile.

Pumps

All castings and forgings shall comply with the requirements of this Specification. In addition the radii, changes in section and butt weld ends of the castings shall be subject to magnetic particle and radiographic or ultrasonic examination unless otherwise agreed by the Employer. Castings shall be subject to hydraulic test at 1.5 times the design pressure.

Pump rotors shall be subject to ultrasonic examination in the rough machined condition and magnetic particle or dye penetrating examination in the final machined condition unless otherwise agreed by the Employer.

Dynamic balance shall be carried out on the completed rotor and performance tests carried out on the completed pumps to the requirements of BS EN ISO 9906.

Pumps shall be factory tested with their motors.

Motor driven auxiliaries

All motor driven auxiliaries shall be run at 20 per cent overspeed for two minutes.

Hoists and lifting equipment

Principal items of all hoists to be examined for compliance with the requirements of this Specification are:

- **i.** main girders
- **ii.** hoist drums
- **iii.** hooks
- **iv.** Ropes, slings and shackles.

Testing of lifting appliances including ropes, slings, hooks, eye-bolts, shackles, swivel or pulley blocks shall be in compliance with latest International Standards prevailing at the time of tendering.

The Contractor shall certify tests and examinations on a form based upon the Standard International Form of Certificate and examination of lifting machinery and gear used in the loading and unloading of ships.

Material tests and proof load tests shall be in accordance with the appropriate British Standard or the equivalent.

Inspection shall include:

a. ultrasonic examination and magnetic particle inspection of all welds on fabricated lifting devices before proof testing

b. magnetic particle inspection of all welds in fabricated lifting devices after proof testing

c. Magnetic particle inspection of all hooks after proof testing.

Before despatch to Site, the various parts of the hoisting, travelling and traversing motions shall be erected in sufficient detail to ensure their correct assembly at Site. The hoisting and traverse motions shall be given no-load running tests and the travel motion shall be given a running test with the wheels free of the ground.

In addition, the deflection of the hoist girders shall be measured when the design safe working is suspended at the centre of the span, to prove compliance with BS 466.

1.24.2.6 Water turbine model tests

A water turbine model test will not be performed for the Project if results of existing model tests for similar turbines can be utilized in determination of turbine characteristics. A detailed report shall be submitted in either case to the Employer.

1.24.2.7 Tests on electrical equipment in manufacturers' works

The equipment provided is subject to inspection and tests by the Employer during the course of manufacture and on completion in order to ensure compliance with this Specification. For tests of long duration at least one month notice shall be given.

The Contractor shall provide to the Employer as soon as practicable after tests have been witnessed three copies of the relevant test certificates. These shall contain details of each test performed. Records, results and calculations of all electrical tests shall be provided.

The Employer shall be given opportunity to witness all significant tests. All instruments used shall have valid calibration certificates, and calibration data shall be made available to the Employer upon reasonable request. All the inspection, measuring and test equipment required for inspections and tests shall be provided by the Contractor.

Where type tests are called for these may be omitted, at the discretion of the Employer, only if the Contractor can provide certified test results for identical or essentially similar equipment which satisfies the Employer. Such certified results shall be presented to the Employer for consideration no later than one month before the factory acceptance of such equipment.

Four copies of test certificates detailing all the works tests performed shall be issued by the Contractor to the Employer within one month of completion of works tests on each item of plant or equipment.

1.24.2.8 Generator

Routine tests.

The following tests shall be carried out:

a. **Stator winding conductor bars and coils.** Routine and random tests shall be carried out in accordance with BS 4999: Part 144. In addition routine and random impulse tests on the main and inter-turn insulations of coils (not applicable to single-turn roebel bars) shall be carried out in accordance with IEC 60034-15. On completion of manufacture all conductor bars and coils shall be subjected to a high voltage tests at an approved voltage.

b. **Rotor winding coils**. The impedance of each rotor pole coil shall be measured as a check for shorted turns. In addition the impedance shall be measured at 400 V 50 Hz for subsequent comparison at Site**.**

c. **Stator core laminations.** Sample laminations as selected by the Employer shall be subject to:

i. Inspection of deburring of punched laminations.

ii. Insulation thickness measurements.

iii. Solvent test.

iv. Franklin test.

v. Bend test

vi. In addition stator core spacer plates shall be checked to ensure the integrity of welded components.

vii. Air gap and other related tests performed in accordance with Canadian Electric Association (CEA) standard/guide 000 G 1977 "Hydroelectric Turbine Generating Units - Guide for Erection Tolerances and Shaft Alignment."

1.24.2.9 Thyristor rectifier

Type tests.

The excitation rectifier shall be type tested in accordance with IEC 60146.

Current and temperature rise tests shall be performed at the excitation system rated current as defined in the Specification. Cooling conditions during the temperature rise test shall represent Site conditions. During these tests the current equivalent to field forcing conditions shall be applied for 10 seconds at agreed intervals.

The ability of the rectifier to withstand the field current induced by a sudden short circuit at the generator terminals at full load shall be demonstrated.

The insulation test voltage applied to the equipment shall not be less than the test voltage applied to the generator field winding insulation.

Routine tests

Tests in accordance with IEC 60146 shall be performed on each rectifier equipment.

The insulation test voltage shall not be less than the test voltage applied to the generator field winding insulation.

The light load test shall be performed at a voltage equivalent to that existing at the excitation transformer secondary terminals when the generator terminal voltage is at its maximum steady state value.

1.24.2.10 Field circuit breaker

Type tests

For these tests the field circuit breaker shall be mounted as in service. Where necessary the tests shall be carried out in a direct current short circuit testing laboratory.

The tests performed shall include the following:

a. demonstration that the circuit breaker can interrupt a direct current equal to the maximum direct component of field current resulting from a short circuit at the generator output terminals at rated load; the re-striking voltage shall be equal to the direct voltage equivalent of the rms ac insulation test voltage for the field winding plus the excitation system coiling voltage;

b. verification that the time between energizing the trip coil circuit and final arc extinction does not exceed the specified value;

c. demonstration that the discharge circuit contacts can close a circuit carrying a direct current equivalent to the worst case possible in service, and that these contacts do not bounce;

d. verification that the interval between main and discharge contact operation is sufficient to ensure satisfactory operation of both circuits;

e. demonstration of circuit breaker closing;

f. demonstration of correct operation of all auxiliary switches;

g. demonstration that the circuit breaker can complete at least 1500 mechanical close-open cycles without the need for adjustment or maintenance;

h. Dielectric tests.

If in addition to field suppression duty the circuit breaker also has to interrupt the current due to the short circuit across the connections between the rectifier and the generator field winding terminals, then the following test shall be included:

a. Demonstration that the circuit breaker can interrupt the current due to a short circuit across the rectifier terminals, and that short circuit current is limited to a value which will not damage the rectifier.

The tests and the manner of their execution shall be agreed with, and approved by, the Employer.

Routine tests

Tests shall be performed on each circuit breaker to demonstrate correct mechanical operation, electrical control circuits, auxiliary circuits and high voltage withstand. The tests shall be agreed with the Employer.

1.24.2.11 Excitation system

Type tests

One excitation system shall be tested together with its associated thyristor rectifier to prove compliance with the Specification. The tests and the manner of their execution shall be agreed with, and approved by the Employer, and shall include at least the following:

a. range and rate of travel of reference voltage setting device;

b. static and dynamic characteristics of the system including time required to reach maximum and minimum field forcing conditions in response to a step change of 2 and 10 per cent rated generator terminal voltage;

c. operation of limiters, using synthetic or simulated signals where necessary;

d. sensitivity of excitation system to frequency variation within specified operating range;

e. range and sensitivity of manual control device including frequency variation;

f. demonstration of all alarm and protection circuits including changeover from automatic to manual control;

g. sensitivity of automatic and manual control circuits to changes in power supply voltage as specified;

h. performance of excitation control equipment during thermal cycles;

i. demonstration that control circuits are immune to emissions from external sources as follows:

Test	Standard	Class/Severity Level
Impulse withstand	IEC 61000 4-5	2
Electrostatic discharge	IEC 61000 4-2	2
Radiated electromagnetic energy	IEC 61000 4-3	3

1. demonstration of start-up excitation equipment;
2. Dielectric tests.

1.24.2.12 Excitation control equipment

Routine tests

Tests shall be carried out on the automatic voltage regulator, standby manual controller and thyristor rectifier control equipment to prove the correct assembly and functioning of the equipment, and its compliance with the Specification.

A routine test programme shall be agreed with the Employer before testing commences.

1.24.2.13 Unit local control panel

Type tests

The following tests shall be carried out:

a. Demonstration of automatic run-up sequence.

b. Demonstration of automatic stop sequence.

c. Changeover from run-up to stop sequence at randomly selected points.

d. Observe sequence stages on indicator panel.

e. Response of auto sequencer to external faults in run-up/stop equipment.

f. Demonstration of diagnostic equipment.

g. Demonstration of correct functioning of interface equipment.

h. Demonstration of immunity to omissions from external sources as follows:

Test	Standard	Class/Severity Level
Impulse withstand	IEC 61000 4-5	2
Electrostatic discharge	IEC 61000 4-2	2
Radiated electromagnetic energy	IEC 61000 4-3	3

1. Thermal cycle test.
2. Dielectric tests.

Routine tests

Tests shall be carried out to prove the correct assembly and functioning of the equipment and compliance with the Specification.

A routine test programme shall be agreed with the Employer before testing commences.

1.24.2.14 Motors

Type tests

Performance tests shall be carried out on the first motor of each type and design to determine its characteristics and to show that it complies with the specified performance requirements.

The tests shall include the following:

a. Temperature rise test in accordance with IEC 60034-1.
b. Variable speed motors without separately driven fans shall be subjected to a temperature rise test at minimum speed or such other speed as may be agreed.
c. Measurement of power factor.
d. Tests to establish efficiency.
e. Momentary overload test.
f. Vibration tests in accordance with IEC 60034-14.

Routine tests

Each machine shall be subjected to the following routine tests where applicable:

a. Measurements of winding resistance (cold).

b. No load test at rated voltage for determination of fixed losses.

c. An overvoltage test at 1.5 times rated voltage (1.3 times rated voltage for commutator machines) applied with the machine running at no load for a period of 3 minutes to test inter-turn insulation.

d. Locked rotor test to determine starting current and torque. The tolerances quoted in IEC 60034-1 will be allowed when starting current and starting torque is measured at full voltage (all machines except commutator machines). When starting torque and starting current are measured at reduced voltage corresponding to full load current, the corresponding values at rated voltage shall be determined by increasing the test values in the ratio of rated to test voltage for current and in the ratio of the square of rated to test voltage for torque. The tolerance as quoted in IEC 60034-1 for starting current will not be allowed but the tolerance as quoted in IEC 60034-1 for starting torque will be allowed.

e. High voltage test in accordance with IEC 60034-1.

f. Measurement of insulation resistance.

g. Slip ring induction motors shall be excited at 110 per cent rated voltage for 3 minutes with the rotor open circuited.

h. Commutation to be checked from no-load to momentary overload in accordance with IEC 60034-1.

i. Over speed test.

1.24.2.15 Main connections

Type tests

A complete section of each type of main connection equipment incorporating an approved selection of fittings, connections, etc., with at least one right angle bend and a vertical section shall be erected as in-service for the purpose of these tests. Tests shall be carried out as follows:

a. **Test of fault current carrying capability.** The rated fault currently carrying capacity, as determined by the Contractor shall be proven by means of short circuit tests.

b. Temperature rise. The temperature rise shall be measured at points to be selected by the Employer and shall, unless otherwise approved, be by means of maximum reading thermometers fixed to the conductor in an approved manner**.**

c. **Conductivity.** The resistance of the lengths of conductors containing joints, flexible connections and connectors when measured, and expressed as a percentage of equivalent lengths without joints, flexible connections or connectors, shall not exceed the figures stated in standards.

d. For the resistance tests a current of not less than 100 A DC. shall be used.

e. **Power frequency test.** The connection section shall be subjected to an A.C. high voltage test at the value stated in the standards for one minute. The test shall be carried out at 50 cycles per second and the rms voltage shall be measured in an approved manner. Each phase shall be tested separately with the other two phases earthed. The insulation resistance shall be measured before and after the HV test in an approved manner.

Routine tests

The extent of a programme for routine tests shall be agreed with the Employer.

Neutral earthing equipment

Type tests and routine tests shall be agreed with the Employer.

Unit auxiliary transformers

Type tests and routine tests shall be carried out in accordance with IEC 60076.

Unit auxiliary switchboards

Provided type tests have already been undertaken on similar equipment and provided that they can be verified from test certificates, the following tests shall be carried out:

a. Routine tests as described in the IEC Standard.

b. Primary current injection tests shall be undertaken on the incoming circuit breaker protection circuits.

1.24.2.16 Control and instrumentation equipment

General

In addition to the manufacturer's production tests, the Contractor shall carry out witnessed tests on completed equipment. Tests on each equipment shall include at least the following:

a. Visual inspection.

b. Voltage withstand test and insulation test.

c. Software configurations and all hardware serial numbers of the final system to be supplied shall be recorded prior to the Factory Acceptance Test (FAT). The FAT shall be performed against an approved system test specification which shall be designed to verify the correct operation of the complete control and monitoring system.

d. Final visual inspection before despatch.

Equipment containing electronic components or assemblies shall be subjected to a 100 hour soak period prior to the performance test. Where a number of items of equipment are intended to operate together, the complete assembly shall be tested to demonstrate that the interconnected items are compatible.

Type tests

a. Switches shall be subjected to the conditions appropriate to the specified enclosure after which a high voltage test shall be applied, all as detailed in IEC 60947.

b. A mechanical duty test for the minimum number of operations required for Class I intermittent duty to IEC 60947 followed by a performance test which consists of making, carrying and breaking rated current at rated voltage 100 times at approximately 5 second intervals.

c. If required, the Contractor shall test to destruction (mal-operation) a switch of each type. The number of operations shall, under no circumstances, be less than the life expectancy quoted by the manufacturer.

Tests shall be carried out at a maximum rated load and the conditions under which a test is carried out shall be to approval and be such that they approximately reproduce the most arduous Site conditions likely to be experienced.

Routine tests

The following tests shall be carried out.

a. Insulation resistance measurement.

b. High voltage tests of 2 kV 50 Hz for 1 minute.

1.24.2.17 Plant Control System

The SCADA (PLC) with its operator consoles shall be arranged to communicate with the actual external systems to which it is to be connected so far as reasonably practicable. Equipment which can simulate the functionality and performance of these external systems may be used with the approval of the Employer. The databases shall be configured and populated with all system specific data. All system graphic displays, tabular displays, log reports etc. shall be constructed for the test.

As a minimum the following data acquisition and power management functions associated with the turbine controllers, transformer and switchgear shall be tested:

i. Data acquisition and processing
ii. Alarm and event processing
iii. Measured value processing
iv. Calculated values
v. Human-machine communication
vi. Graphics displays
vii. Trending
viii. Reporting and archiving
ix. Performance - data handling capacity and response times
x. Data and graphic display management
xi. Analogue and digital inputs and outputs
xii. Command outputs
xiii. Scanning, time tagging
xiv. Communications processing
xv. Manual turbine generator start/stop
xvi. kW and kVAr
xvii. Voltage control
xviii. System management including power fail/auto start-up, system degradation, etc.
xix. Redundancy and fail-safe features
xx. Hardware and software diagnostics
xxi. Energy metering system

1.24.2.18 Generator transformer circuit breaker

To be in accordance with IEEE C37.013.

Motor control equipment

Type and routine tests shall be carried out in accordance with IEC 60439, IEC 60947 and IEC 61095 as appropriate.

Secondary wiring

All secondary wiring, including panel wiring and control circuits and all apparatus connected thereto shall be subjected to the following tests:

Routine tests

a. Voltage - 2 kV applied for one minute except where this requirement is modified by a British Standard, in which case item the appropriate test shall be applied.

b. Insulation resistance - By Megger tester of not less than 500 V.

1.24.2.19 0.4kV – 11 kV XLPE cables and accessories

Routine tests at Manufacturer's works

The cable and accessories shall be subjected to the routine tests described in IEC 60502.

Special tests. The cable and accessories shall be tested in accordance with the requirements of IEC 60502 and the IEC publications referred to in IEC 60502.

Type tests. The cable and accessories shall be tested in accordance with the requirements of IEC 60502, and the publications referred to in IEC 60502.

Low voltage power cables. Low voltage power cables shall be tested in accordance with IEC 60502 and 60811. Wiring cables shall be tested in accordance with IEC 60227.

Multicore cables. Multicore cables for ac and dc protection, control and alarm circuitry, single core cables for cubicle wiring shall be subjected to the specified electrical, mechanical and climatic tests to comply with BS 3573, BS 6346 and BS 6234.

1.24.2.20 Batteries and associated equipment

Battery charger

Constant voltage chargers. Tests shall be carried out to show that the output voltage remains constant with any combination of the input voltage, frequency and load variations required under this Contract. The output voltage on each voltage tap shall be measured at rated load and frequency.

The efficiency shall be measured at normal output voltage and current and normal input voltage and frequency.

Tests shall be made to prove that the insulation resistance of the transformer complies with the Specification.

The output terminals of the charger shall be short circuited and the output current measured. This shall not be greater than the value required for this Contract.

In the case of 48 V battery chargers only, tests shall be made to show that the psophometric noise level specified is not exceeded and for this purpose the following notes shall be observed.

Boost charger. Test shall be carried out to prove compliance with the particulars given for this Contract.

Tests shall be made to prove that the insulation resistance of the transformer complies with the Specification.

1.24.2.21 Low voltage switchboards

Type and routine tests shall be performed in accordance with IEC 60439. All individual components contained in the switchboard shall be tested in accordance with the relevant part of this Specification.

1.24.2.22 Protection equipment

Routine tests

All relays shall be subjected to routine tests at the manufacturers' works to confirm that they comply with the claimed performance and design limits.

For measuring relays (i.e. relays which have a defined setting of the input and/or characteristic quantity subjected to accuracy requirements, e.g. current, time, etc.) these routine tests shall include as a minimum the following:

(a) Measurement of the assigned error(s) under reference conditions, i.e. measuring accuracy and operating time characteristics.

(b) Measurement of the resetting ratios.

(c) Dielectric tests as specified in Clause 6 of IEC Publication 60255-5, the test voltage being 2 kV rms. All normally open output contacts of all relays shall withstand a test voltage of I kV rms.

For 'all-or-nothing' relays, the routine tests shall include a check of relay operation and resetting, together with the dielectric tests described above.

Unless otherwise agreed with the Employer, all unit protection schemes using either, biased differential, current balance or voltage balance principles shall be subjected to heavy current conjunctive tests using the actual current transformer windings which will be used in service. Tests shall be made to prove operating sensitivity, time of operation and to demonstrate stability of the protection under the worst transient external fault conditions. Tests will only be waived if the manufacturer is able to produce type test results for an identical scheme. In this case it will be sufficient to prove that individual component characteristics are identical, e.g. current transformers are of the same design, have the same magnetization characteristics, knee-point voltage and secondary resistance.

For protection schemes including phase comparison protection routine tests shall be performed on each complete scheme to ensure that all possible operational sequences and features are fully functional. Where necessary, this shall be done using simulation of any ancillary equipment normally used in conjunction with the scheme, e.g. circuit breakers. These routine tests will be performed in addition to the tests normally applied to individual elements of the scheme and details of the proposed test programme shall be submitted to the Employer for approval not less than one month before they are to be performed.

Each circulating current protection scheme must fulfil the following routine testing requirements:

a. Each current transformer, which must be of the low reactance type, shall be individually tested for turns ratio, secondary winding resistance and excitation characteristic up to a secondary voltage equal to 120 per cent of the "knee-point" voltage.
b. The VA consumption at operation of current operated relays shall be measured and shall not exceed the maximum value declared by the manufacturer.
c. The operating current of voltage relays shall be measured and shall not exceed the maximum value declared by the manufacturer.

Type tests

Approved type tests shall be carried out in the manufacturer's works on each type of protection system. During the tests, ancillary equipment shall be erected and connected so as to reproduce service conditions as closely as possible. The main purpose of these tests shall be to determine the performance of the protection for the range of system conditions which will be encountered by the protection in practice, and to determine all the appropriate application parameters. The test condition shall be as agreed by the Employer.

Where type tests have been carried out under previous contracts on protective equipment similar in all essential respects to the equipment included in the Contract, the Employer may waive the type tests on production of complete test records which he approves, relating to the equipment concerned. Each set of test records shall include a full statement of the performance claims, e.g. performance under reference conditions, effect of influencing the quantities, steady state and dynamic stability for unit protection schemes, current and voltage transformer requirements, etc. and full details of tests performed on representative samples of production equipment to demonstrate that the performance claims have been met.

1.24.2.23 Transformers

Routine, type and special tests shall be carried out in accordance with IEC 60076. The following additional tests shall be made.

Routine tests

1. The impedance voltage test should also be carried out on the maximum and minimum tapping positions.

2. Magnetic circuit insulation test (where appropriate).

   A power frequency voltage of 2 kV for 1 minute applied as follows:

   a. Core to yoke clamps and to core leg side plates.

   b. Core bolts to core, to yoke clamps and to core leg side plates.

   c. Immediately prior to despatch, 2 kV for 1 minute applied between core and earth. A Megger may be used for this test.

3. No load current at:

   a. 90 per cent rated voltage.

   b. 100 per cent rated voltage.

   c. 110 per cent rated voltage.

   d. The maximum voltage equivalent to the value quoted for this Contract.

4. Noise level: The level of noise shall be measured to IEC 60076-10.

5. Vibration measurements shall be taken and the level recorded shall be subject to approval. This test shall be carried out unless it can be shown to the satisfaction of the Employer that the level of vibration in the transformer and its auxiliaries is harmless.

6. Dissolved gas analysis: A dissolved gas analysis test shall be carried out before and after a temperature rise test and before and after the series of dielectric tests, for all windings of 22 kV and above. The tests shall be in accordance with IEC 60567 and IEC 60599.

Type tests

Capacitance: the capacitance between windings and between each winding and earth shall be measured.

Transferred surge: Where transferred surge tests are required, the transformer shall be tested so that with the test voltage, applied to the other windings, the maximum surge that can be transferred to the unloaded winding(s) does not exceed its specified insulation level. Conformance with this requirement may be achieved by the use of external equipment connected to the unloaded winding and shall be proved by recurrent surge oscillograph measurements, by comparison with the transferred voltage on open circuit.

The test shall be repeated with the unloaded winding(s) connected to earth via a circuit simulating a connected machine and the transferred surge shall not be greater than 50 percent of the winding BIL.

During the temperature rise test the accuracy of oil and/or winding temperature indicating devices shall be determined.

Where temperature rise test have previously been carried out on equipment similar in all essential respects to that included in this Contract, the Employer may waive one or all these tests on production of complete test records which they consider satisfactory, and any savings shall be allocated pursuant to the terms and conditions of the Contract.

1.24.2.24 Voltage control equipment

Routine and type tests shall be carried out in accordance with IEC 60214.

1.24.2.25 Cable boxes and disconnecting chambers

Routine test

Oil tightness - All cable boxes and disconnecting chambers shall be tested with oil, having a viscosity not greater than that of IEC 60296 insulating oil when at a temperature of 15°C, at a pressure of 70 kN/m^2 for 12 hours; during this time no leakage shall occur nor shall there be any permanent set when the pressure is released.

1.24.2.26 Tanks and ONAN coolers

Routine tests

Oil leakage - All tanks and oil filled compartments including all forms of radiator but excluding separate coolers using forced oil circulation, shall be tested for oil tightness by being completely filled with oil of a viscosity not greater than that of IEC 60296 insulating oil at a temperature of 15°C and subjected to a pressure equal to the normal pressure plus 35 kN/m^2. This pressure shall be maintained for a period of not less than 24 hours, during which time no leakage shall occur.

Detachable radiators may be tested as separate units.

Type tests

1.24.2.27 Actuated relays

Routine tests

Routine tests shall be made on relays when completely assembled where applicable.

1.24.2.28 Insulating oil

Sample test

Samples of oil from each consignment shall be tested and shall comply with the tests specified in IEC 60296 for insulating oils, before any oil is despatched. Test for Sulphur content and for the presence of Corrosive Sulphur and potentially Corrosive Sulphur shall be carried out in accordance with IEC 60296 (clauses 6.6.9 and 6.6.10 respectively).

1.24.2.29 Factory Inspection and Tests

All Facility materials and components shall be subject to inspection together with type, sample and routine tests during the factory manufacturing period including but not limited to:

(a) Inspections and tests for each piece of material, plant or component, as specified in the relevant section of the Technical Specification;

(b) The manufacturer's inspection and test requirements;

(c) The tests and inspection required by the relevant standards;

(d) Such other tests and inspections as may be necessary in the opinion of the Employer to demonstrate compliance with the Contract.

The Contractor may offer type test results for similar equipment, within the type tested range, in lieu of the type tests specified; in which case the specified type tests may be waived by the Employer. If type tests for similar equipment are offered in lieu of the specified type tests, the Contractor shall be responsible for proving, to the satisfaction of the Employer, that the equipment tested is similar to the Contract equipment.

The results of factory inspections and tests including inspection and test certificates and reports shall be submitted to the Employer within one week of the inspections and tests being carried out.

Unless otherwise approved, no equipment shall be despatched from the Contractor's premises to Site or from a subcontractor to the Contractor or to Site, until it has been inspected and the appropriate release certificate has been issued.

In the event of any test piece failing to comply with the requirements of the appropriate Standards, the Employer may reject the whole of the material represented by the test piece.

The Contractor shall facilitate the visit by Employer's Personnel who will witness the inspections and tests. The actual inspections and tests to be witnessed shall be decided during the course of the works; however for the purpose of planning these activities, the Contractor shall assume

1. Three (3) inspection visits to the manufacturers' works for five (5) persons, and

2. Three (3) factory acceptance visits for five (5) persons.

For Tender purposes duration for inspections shall be taken as seven (7) days while factory acceptance tests shall be taken as seven (7) days for each participant. UNDP shall be responsible for all costs associated with the visits including:

(a) All travel, including return economy class airfares, from Zambia to the various manufacturers' works.

(b) Per diem at current prevailing rate

Systematic factory and on-site test methods for all equipment shall be developed and described by the Contractor to the satisfaction of the Employer prior to commencement of testing and inspection.

Upon successful completion of all factory acceptance tests (FATs), the Contractor shall despatch all equipment and materials to site.

1.24.2.30 Responsibilities

The Contractor's responsibilities shall include but not be limited to requirements to:

- Produce written test plans, schedules, procedures, method statements, test record sheets and procedures for fault reporting, for all tests.
- Submit all test documentation associated with any subsystem or system test for approval by the Employer within the required time scales.
- Ensure that all test documentation associated with any testing has been approved by the Employer prior to the commencement of the corresponding testing.
- Provide the equipment, test equipment, test software, personnel and facilities to conduct the testing.
- Successfully carry out internal acceptance testing using the approved test procedures and correct any errors found in either the test procedures or the subsystem/system being tested prior to the commencement of the witnessed acceptance tests.
- Provide facilities for the Employer and/or its representatives to witness any factory tests.
- Produce permanent records of all test progress and results in a formal systematic manner.
- Carry out all remedial work and re-testing necessary for the equipment to pass the tests.

Each of the above responsibilities shall be discharged to the satisfaction of the Employer, but approval by the Employer shall not imply any diminution of the Contractor's responsibilities. It is expressly the responsibility of the Contractor to satisfy himself that items 'supplied by others' are in a satisfactory condition for the Contractor's tests to be conducted.

The formal stages of testing to be performed fall into the following categories:

a. Type tests.

b. Routine tests.

c. Factory acceptance tests (FATs).

d. Site acceptance tests (SATs).

1.24.2.31 Mechanical tests at site

1.24.2.32 Non-destructive tests

High pressure pipe work

All Site butt welds in piping subjected to penstock pressure shall be radiographic or ultrasonically examined, supplemented where necessary by magnetic particle examination.

Hydro-mechanical equipment

Hoists

The preliminary tests shall, for each hoist, include the following:

- Radiographic or ultrasonic examination of the full length of all site welds on all important stressed components.
- Radiographic or ultrasonic examination of a percentage of the length of all other site welds. (The examination methods, extent of examination and standard of acceptability shall be respectively the same as for the examination at the manufacturer's factory).

1.24.2.33 Hydraulic pressure tests and leakage tests

Pipe work

Pipe work subjected to reservoir head shall be subjected to a test pressure of not less than 1.5 times the maximum momentary pressure arising on full load rejection under maximum head, for a minimum period of 30 minutes.

Oil pipe work shall be tested after assembly at a pressure of 1.5 times working pressure.

Components

If, in the opinion of the Employer, there is any reason to doubt the soundness of individual components such as pressure vessels or coolers, the pressure test specified to be carried out in the Manufacturer's works shall be repeated at site.

Bearing oil reservoirs

Leak tests shall be carried out on assembled bearing reservoirs to ensure oil tightness before the fitting of internal bearings and components.

Compressed air systems

All compressed air piping in the governor and station service systems, together with all valves and fittings shall be tested after assembly at a pressure of twice the maximum working pressure.

1.24.2.34 Checks on main assemblies

Unit

Generating set shaft alignment and couplings. The turbine/generator shaft systems shall be aligned by centralizing and rotational run-out checks on the turbine runner, the Unit bearings and the generator. Shaft run-out tolerances shall conform dimensionally with the metric equivalent of ANSI/IEEE Standard 810. Coupling bolt tightness and locking arrangements shall also be checked.

Bearing assemblies. During and on completion of Site assembly of the bearings, the installation, including coolers, baffles, piping and fittings shall be examined and all clearances and settings noted.

Water turbine

Turbine homology. During and on completion of Site assembly, the clearances of the runner in the runner chamber shall be taken and compared with the design and Work's - measured figures.

Regulating gear. During and on completion of Site assembly the installation of the turbine regulating gear including levers, links and protection devices, servomotors and connecting rods shall be examined and on finalization, all clearances and settings noted.

Auxiliary plant

Pumps and auxiliary plant. The installation of pumps and auxiliary plant shall be checked during and on completion of installation. In particular the alignment of coupled rotating parts and pump gland assemblies shall be included.

1.24.2.35 Operation and performance checks and testing

General

Prior to running the set all auxiliary equipment shall be tested to prove satisfactory operation and performance.

Power station hoists

After erection at Site, installation checks on the rails and hoists shall be undertaken in accordance with BS 466 and other relevant Zambian government regulations. Each power station hoist shall be tested in all motions when carrying the design safe working load, followed by tests on the hoist motion using the change speed equipment but with each hoist subjected to only 20 per cent of the safe working load.

Subsequently each hoist shall be tested in all motions when subjected to the following overloads:

a. 1.25 x the design safe working load.

b. 1.25 x 20 percent of the safe working load (with the change speed equipment engaged in the fast hoisting system).

All the above tests on hoists at Site shall, unless otherwise specified, be carried out in accordance with BS 466, to prove compliance with the Specification and other relevant Zambian government regulations.

The loads for all the above tests and the necessary slings and cradles shall be provided by the Contractor.

Control and instrumentation

The performance of control and instrumentation equipment, including sequence control provisions, shall be checked on Site to prove correct and satisfactory operation in accordance with design requirements.

Check calibrations shall be carried out on all instruments, relays, pressure switches, flow and level switches, thermometers and similar devices. These tests shall be regarded as supplementary to the full calibrations carried out as a part of the Works tests and for the purposes of determining that the equipment is still in adjustment and satisfactory for the purposes intended.

Valves

The operation of all motor, solenoid and hydraulically operated valves shall be demonstrated.

It shall be established that all valves are correctly labelled for identification and opening position where applicable and, in addition, the manual operating mechanism shall be fully serviceable.

Compressed air systems

Each compressed air system shall be demonstrated to perform satisfactorily. Safety valves and cooling system operation shall be proved.

Hydro-mechanical equipment

Hoists

The hoists shall be tested to prove compliance with the requirements of the Contract and other relevant Zambian government regulations regardless of any tests which may have been carried out at the manufacturer's factory.

Tests shall be performed to demonstrate the satisfactory service performance of the hydro-mechanical equipment. The tests shall include, but shall not necessarily be confined to, the following:

a. Gates

i. Each gate and its hoist and controls shall be given full operational tests under the condition of no-flow in the relevant waterway passage. Such tests shall include the testing of gate control and indication facilities at the power station as well as all local and automatic controls and indications. Similarly, where applicable, tests on manual operation of each gate shall be carried out.

ii. Each gate shall be closed into progressively increasing flow up to maximum design flow.

iii. The rate of leakage past each closed gate shall be measured before and after each test.

iv. The operating speed of each gate shall be measured.

v. The water discharge by each gate under maximum operating water level shall be checked for satisfactory operation.

vi. Balance and by-pass valves and pipe work shall be checked for satisfactory operation.

Tests on completion shall be conducted in the presence of the Employer's representative. Any test weights required for the tests shall be furnished by the Contractor.

During the tests, starting and running current readings shall be recorded.

The tests listed below shall be generally required for all gantry hoists where applicable.

i. Tests of the responses to all controls, without load, to ensure efficient operation of all controls.

ii. Tests of the operation of the hoist, travel and traverse limits, without load.

iii. Tests of operation of the automatic and manual brakes of the hoists when loaded to 25 percent in excess of the rated load.

iv. Measurement of the maximum deflections of the crab frames and main beams of the hoists under rated load and the over-load condition of 25 percent in excess of the rated load.

v. Recording of the travel and traverse speeds under the over-load condition of 25 percent in excess of the rated load.

vi. Measurement of the lateral hook approaches, without load, and the overrun remaining when the limits have tripped and the automatic brake has applied.

vii. Measurement of the hook approach to the ends of the runways, without load, and the overrun remaining when the limits have tripped and the automatic brake has applied.

viii. Recording of the hoisting and lowering speeds without load and with rated load.

ix. Recording of the distance travelled after automatic brakes are applied, in the raise and lower directions, without load and with rated load.

x. Recording of travelling and traversing speeds without load and with rated load.

xi. Any other tests that may be considered necessary to prove compliance with the Contract and other relevant Zambian government regulations.

Gate and associated equipment

Preliminary tests shall include but shall not necessarily be confined to the following:

a. Gates

i. Each gate shall be raised and lowered several times through its full travel and shall operate satisfactorily in all gate slots.

ii. Seal adjustment shall be inspected to ensure proper sealing against the embedded seal seats.

iii. Wheel adjustment shall be inspected to ensure proper bearing of the wheels on the crowns of the tracks.

iv. The lifting frame shall be tested to ensure that the frame engages and disengages properly with the stop log and it can be stored properly in its parked position.

v. Balance and by-pass valves shall be operated several times to ensure proper operation.

b. Hoists

Wherever applicable:

i. Relief valve and pressure switch settings shall be checked.

ii. Each hoist and its controls shall be tested for proper functioning of electrical and mechanical components, firstly by operating individual devices and then as a system.

iii. High pressure piping shall be tested at 1.25 times the design pressure. Pressure testing will not be required on the low pressure piping which is subject only to static oil pressure. All piping and hoist parts shall be absolutely oil tight under the required pressure tests.

iv. Each hoist shall, when completely assembled, be tested by operating the hoists, with the gates suspended by their stems, through a sufficient number of complete cycles to enable the Employer to determine that all parts are properly installed. Required adjustments shall be carried out including adjustment to the gate stems, limit switches, and gate position indicators, until the operation of the hoists and controls is satisfactory.

v. Each hoist test shall include but shall not necessarily be limited to the following:

   a) The correct functioning of the electrical circuits and devices shall be proved by operational tests. During the tests the equipment shall be connected to the nominal electrical supply and tested for correct operation at supplies of 87.5 percent, 100 percent, and 120 percent of the nominal supply voltages.

   b) The electrical equipment shall be tested in accordance with the IEE Wiring Regulations (BS 7671) except that the a.c. test voltage between phases and between each phase and earth shall be 2 kV rms for one minute.

1.24.2.36 Electrical tests at site

Generator

Routine tests.

The following tests shall be carried out on the generator:

a. **Core test.** A core test at approximately full load flux shall be carried out on the stator core before being wound to give an indication of the core losses and to prove the efficiency of the inter-laminar insulation and the correct assembly of the core.

b. **Stator slot wedging.** Check on tightness of slot wedging following completion of winding.

c. **Pole impedance test.** The impedance of each rotor pole winding shall be measured at 400 V 50 Hz after assembly but before any interpole connections are made.

d. **Dry-out.** The generator shall be dried out before any electrical tests are carried out. The dry-out shall preferably be achieved by means of a short circuit run but alternatives, if desired, will be considered by the Employer. The only evidence of dry conditions which the Employer will accept is the insulation resistance curve obtained during the dry-out.

e. **Rotor impedance tests.** The rotor winding impedance shall be measured before and after the running tests. The winding impedance shall be measured at 400 V 50 Hz.

f. **Winding resistances.** The cold stator and rotor winding resistances and temperatures shall be measured by an approved method. The rotor winding resistances shall be measured both before and after the running tests.

g. **Phase sequence test.** After the generator terminals have been painted in accordance with the specified requirements a test shall be carried out to prove that the phase sequence is correct.

h. **Short circuit characteristics.** The short circuit characteristics shall be measured in accordance with IEC 60034.4.

i. **Open circuit characteristics.** The open circuit characteristics shall be measured in accordance with IEC 60034.4.

j. **Direct axis synchronous reactance and short circuit ratio.** The direct axis synchronous reactance and short circuit ratio shall be determined in accordance with IEC 60034.4.

k. **High voltage tests.** In addition to the high voltage tests carried out on the windings during the various stages of assembly, high voltage tests on the stator and rotor windings shall be carried out after the completion of all running tests. The tests shall be made in accordance with IEC 60034.1. The winding under test shall be at its normal working temperature. The generator shall be completely assembled as in service. The rotor shall be tested when stationary.

l. The insulation resistances shall be measured immediately before and after the high voltage tests.

m. **Characteristics of stator windings insulation system.** After completion of the winding, measurements shall be made to determine the characteristics of the stator insulation in its original new condition. These measurements shall include tan delta, capacitance and partial discharge intensity, integrated loss energy characteristics and partial discharge activity.

Type tests. The following type tests shall be carried out on the generator assembled complete with its own cooling equipment, excitation equipment, voltage regulator and controls:

a. Wave-form and harmonic analysis. The wave-forms of the generator phase and line voltages at rated speed and voltage on open circuit shall be recorded by means of an oscillograph and analysed by a harmonic analyser.

b. The telephone harmonic factor shall be determined in accordance with lEC600341.

c. Temperature rise tests. The generator shall be tested for temperature rise at the guaranteed maximum continuous rating.

d. Additional temperature detectors shall be installed in the generator, and metering equipment shall be provided to enable the quantities of cooling media to be determined. Temperatures of all permanently installed and test temperature detectors shall be measured at agreed intervals.

e. Time constant. The direct axis transient open circuit time constant shall be determined in accordance with IEC 60034.4.

f. Reactance measurements. The zero and negative phase sequence reactances shall be determined in accordance with IEC 60034.4.

g. Sudden short circuit tests. Short circuit tests shall be made by applying a sudden short circuit at a point immediately adjacent to the generator terminals simultaneously across the three phases. The shorting device and any other equipment necessary shall be provided by the Contractor. Records of voltage and current waveforms shall be made during these tests from which the reactances and time constants of the generator shall be calculated, in accordance with IEC 60034.4.

h. The generator shall be tested at normal speed with the voltage set at around 70 percent rated voltage at the generator terminals. A further test shall be carried out at normal speed at approximately 50 per cent of rated voltage at the generator terminals with the automatic excitation control equipment in service.

i. After any of the short circuit tests described above, the generator shall not have suffered damage or distress.

j. The test shall be carried out before the short circuit and open circuit heat runs.

k. Losses and efficiency. Tests shall be carried out to determine the separate losses and overall efficiency. The test method shall be in accordance with IEC 60034.2.

In addition the following measurements shall be made and the losses included in the calculations of generator efficiency:

a. Measurement of generator field current under rated conditions to determine the field FR loss at 759 C.

b. Measurement of losses in the excitation system by the input/output method.

Excitation system

Routine tests

Tests shall be carried out on each machine to demonstrate that the equipment performs correctly and as specified, and that stability margins are adequate.

A commissioning test programme for the completely assembled excitation equipment shall be agreed with and approved by the Employer, and shall at least include the following:

a. Verify trigger pulse sequences, triggering current magnitude and rate of rise applied to thyristors;

b. Demonstrate that phase currents to thyristor rectifier are balanced over operating range and that parallel connected thyristors share current adequately;

c. Determine settings for automatic regulator adjustable controls for best performance with generator on open circuit, and demonstrate, for example by step response or harmonic response tests, the stability margin over the full operating range of generator terminal voltage and frequency;

d. Demonstrate start-up and shut-down sequences;

e. Demonstrate operation of limiters and set at required operating point;

f. Demonstrate generator steady state performance and, verify margin between under-excitation limiter setting and theoretical steady state limit or a leading power factor thermal limit;

g. Demonstrate operation of power dependent stabilizer if specified;

h. Demonstrate dead-line energizing if specified;

i. Demonstrate performance on full load rejection and specified load pick-up;

j. Demonstrate transfer between automatic to manual control by simulated fault and by deliberate selection, and transfer between manual and automatic control;

k. Demonstration of operation in manual control;

l. Demonstration of all control functions, alarms and protection circuits;

m. Temperature rise test at rated generator load overexcited to verify that ventilation and cooling conditions are adequate.

Machine local control panel

Tests shall be agreed between the Employer and the Contractor.

High voltage tests

The routine tests specified previously shall be repeated after the main connections and other apparatus have been erected and connected up on Site.

Main connections

The temperature rise of the main connections shall be measured at Site at not less than six locations per machine; the locations shall be selected by the Employer. Measurements being made at one location shall consist of temperature measurements of the busbars and the enclosure. This test shall be demonstrated with rated busbar current to obtain steady-state conditions. The method of temperature measurement shall be approved by the Employer.

Unit auxiliary switchboards

The tests shall include:

a. Insulation resistance

b. Conductivity tests on Site-made busbar joints.

c. Manual and electrical operation, as appropriate, of each device

d. Operation of entire equipment according to control scheme.

High Voltage Cables and Accessories

The cables and accessories shall be tested in accordance with the requirements of relevant standard i.e. IEC 60502, IEC 60840 and IEC 62067.

In addition, the conductor d.c., resistance of each complete circuit shall be measured and recorded.

Low voltage power cables

1000 V insulation tests shall be made on 400 V power cables.

500 V insulation tests shall be applied between all cores and earth on all multicore cables.

On terminations with insulated glands (single core cables) a 1000 V insulation test shall be carried out between armour and/or sheath and earth.

Electrical braking equipment (if provided)

Tests shall be agreed between the Employer and the Contractor.

1.24.2.37 Tests at Completion

The Contractor shall conduct the Tests at Completion of the Facilities in accordance with the Contract.

The Contractor shall provide all equipment and the experienced personnel required to carry out the tests, including the provision, installation and removal of all test instruments, the connection and disconnection of plant items together with recording test data and preparing test results and reports.

The Contractor shall submit one copy of the results of each of the tests to the Employer within one week of the tests being carried out.

The Tests at Completion shall comprise;

- Pre-commissioning tests;
- Commissioning tests including operational and performance guarantee tests; and
- Trial operation tests including reliability tests for the turbine generator unit.

1.24.2.38 Commissioning, start-up and testing

1.24.2.39 General

All electrical and mechanical equipment and systems shall be tested as required to demonstrate conformance to the Specifications.

The Contractor shall be responsible for functional testing, commissioning, performance testing and reliability testing of the system to confirm conformance with the design, operating and performance requirements and criteria set out in these Specifications. The Contractor shall also be responsible for the internal inspection of the turbine during a planned inspection outage at the end of the cavitation guarantee period. The Reliability Test for the system shall be carried out after the Performance Tests. The Employer shall be given the opportunity to witness all testing and inspections.

The Performance Tests demonstrating the fulfilment of the electrical output guarantees shall make use of the permanently installed calibrated metering instrumentation of the Main Measuring System specified within these Specifications. For other tests the permanently installed instrumentation shall also be used to the maximum extent possible. The Contractor shall be responsible for providing all the necessary permanent and temporary equipment, materials, consumables and services to meet his commitments with regard to this phase of the work.

The Contractor may make use of a temporary PC-based test data acquisition system (TDAS) for the duration of the Performance Tests, for the purposes of collecting and co-ordinating all data acquisition for the tests. The TDAS shall be of the dedicated-type, connected directly to output signals of water levels, gate positions, power output and nozzle position, and any other parameters as necessary. All data is to be collected and stored on a time-correlated basis.

The results from all checks, inspections and testing activities shall be logged by the Contractor on suitable pro-forma and shall be available for inspection by the Employer at all reasonable times during the course of the works.

The Contractor shall supply the Employer with two copies of the complete test documentation for pre-commissioning, commissioning, performance and reliability tests for the system. After the conclusion of the tests, the Contractor shall compile comprehensive test reports for the system, which shall include calibrations, copies of all log and calculation sheets and all necessary tables and curves to record the results of the tests. The Contractor shall supply to the Employer as many copies of the test reports as may reasonably be required.

1.24.2.40 Performance testing procedure

A Final Performance Test Procedure document detailing the methods of discharge simulation and plant testing, together with sample calculations and including consideration of accuracies of measurement, shall be prepared by the Contractor. The Final Performance Test Procedure shall be submitted to the Employer for approval, in draft final form, on finalisation of the civil works layout/design, the hydraulic model study (if required) and the turbine model test report and no later than six months after Contract Award.

The Final Performance test Procedure shall be submitted for the Employer's approval not less than six months prior to the first programmed Performance Test date and shall encompass the following:

- Scope of Tests
- Guiding Principles
- Test dates and timetable
- Preparation for tests and requirements of the power system
- Method of tests
- Plant mode of operation
- Testing Conditions
- Operating conditions
- Constancy of test conditions
- Maximum permissible variations in plant operating conditions
- Duration of tests
- Instruments and Method of Measurement
- Plant test parameters

- List of test instruments
- Calibration of test instruments
- Instrument measuring tolerances
- Computation of Test Results
- Data acquisition system log sheets
- Frequency of readings
- Observers and labour
- Specified requirements and Guarantees
- Correction curves and data
- Instrument list and diagram of test measuring points
- Diagram of electrical test measuring equipment
- Instrumentation for electrical output

The Performance Tests shall be witnessed by the Employer and the evaluated test results submitted to the Employer for approval within the period specified. The Performance Test Procedure shall also define a methodology to accurately measure, at the end of the cavitation guarantee period, the material loss from the turbine due to cavitation.

1.24.2.41 Performance testing

The Performance Testing Procedure shall observe the following requirements:

Check calibration

Check-calibration of the water level measuring devices and gate position indicators shall be undertaken immediately prior to and following the Performance Tests. Any deviation or offset in calibration characteristics will be accounted for in the test results at the approval of the Employer. The Employer may require a retest should any deviation in calibration be reasonably deemed to be excessive.

Data acquisition

Signals of gate positions, Head Pond level and Tail Water level shall be collected by the TDAS and all data measured shall be logged and collated on a chronological basis.

During all performance testing, acquisition of all data including water levels, gate positions and power output shall be undertaken simultaneously at equal increments of 1 s intervals.

On-line data acquisition during performance tests will be witnessed by the Employer. All data shall be stored and archived in both electronic and paper format, with signed copies being provided to the Employer as the tests proceed.

Pre-testing

During pre-tests, calibration and system connectivity tests shall be undertaken, in addition to any other trial runs necessary to establish satisfactory conditions required for the performance tests. Data acquisition methods shall be coordinated in order that recordings of water levels, gate positions, system electrical output and other related parameters are triggered automatically when pre-set values of acceptable margins of head water level for the tests are realized.

Duration of Performance Test Points

Once pre-test results have been agreed, the Contractor shall notify the Employer that a complete series of individual tests dedicated to the demonstration of the system output guarantee is to be performed (the results of pre-tests shall have no contractual significance).

Repeat tests

A maximum time limit of 24 hours will be given for the purpose of satisfactorily performing the individual tests within the margins of required head levels. Should adequate simulation of head not prove to be possible within this 24 hour time period, due for example to uncontrollable fluctuations in water levels or other practical or unforeseen difficulties, then at the discretion of the Employer the tests shall be repeated with relaxed tolerances of margin on the head.

Power output measurement

All wattmeter instruments and other power measuring devices shall be check-calibrated both before and after the tests. The method of power measurement, connection into the system, and data acquisition will be agreed and witnessed by the Employer before the start of tests.

The accuracy of the power measuring instrumentation will be in accordance with standards. As with the measurements of water levels, electrical output measurements shall be made at simultaneous increments of 1 s intervals, simultaneously and exactly in phase with the corresponding recordings of water level and other parameters as specified. Power output measurements shall be correlated and archived with the respective head measurements, corresponding flow values and gross head measurements on a chronological basis.

Report

Within 6 weeks of the date of finalization of the performance tests, the Contractor shall submit a final draft test report for the approval of the Employer.

Inconsistencies of test data

If during pre-test or performance testing, spurious test results are obtained (i.e. results which are generally inconsistent with the particular set from which they belong), the Employer may reject the particular test and require a re-test. Only test results with values of head, conforming to acceptable the tolerances will be allowed.

By way of containing any extreme scatter in values of electrical output obtained on test, individual readings measured at 1 s intervals which are outside a tolerance of ±10 percent of the average for the particular test shall be omitted, and the definition of the average value adjusted accordingly.

1.24.2.42 Pre-commissioning

The Contractor shall perform additional mechanical testing and functional testing of the System. During this period the Contractor shall undertake all installation checks, preliminary mechanical and electrical checks, pressure testing, flushing and cleaning of equipment and pipe work, proving the integrity of all connections, voltage phasing and check safety, interlocking, inter-tripping and protection systems and also verify that all plant is functionally complete.

In the course of pre-commissioning the Units, the intake gate shall be closed and locked. All pre-commissioning tests shall be carried out, generally in accordance with IEC 60545, prior to filling the water passages of the turbine.

The pre-commissioning checks on each Unit shall include:

a. Run-out and alignment checks of the Unit shaft system.

b. Check operating times of turbine guide vanes prior to, and following, watering of the hydraulic system.

The pre-commissioning tests on the System and the substation shall include:

a. Verification of Head Pond and Tail Water level measuring devices and gate position indicators.

b. Checks and resistance measurements of the primary current carrying conductors and joints to confirm correctness of installation.

c. Checks and resistance measurements of earthing grids and earthing systems.

d. Check the operation of protection and control systems.

e. Check the operation of the DCS and communication installations.

f. Check the operation of the primary isolation equipment.

g. Check the insulation integrity of all electrical equipment.

h. Perform dielectric tests on all electrical equipment in accordance with relevant Standards.

Where plant components form part of a system, then each component shall be inspected and tested prior to placing the system into service. Static tests to demonstrate interactive operation of components within the system shall also be completed prior to charging, energizing or pressurizing or otherwise putting into an operational state, the system for the first time. Auxiliary systems shall be commissioned independently of the Units.

During the pre-commissioning, the Contractor shall provide the Employer with a list of any items which Contractor knows to be incomplete or not fit for purpose and for which remedial action is necessary.

1.24.2.43 Commissioning

The Contractor shall be responsible for carrying out all the commissioning work associated with bringing the System to conditions ready for reliability and performance tests.

Prior to the start of commissioning, the Contractor shall provide the Employer with the latest edition of all relevant documents codes, Standards and drawings.

Once the component or system is charged, energized, pressurized or otherwise put into an operational state, the Contractor shall conduct commissioning tests. These tests shall demonstrate that the system and its constituent components function collectively as designed, that individual components operate at varying loads under steady state conditions within their stated operating parameters and that the components and system respond correctly to transient conditions.

The Contractor shall undertake whatever adjustments are necessary to achieve the best level of System reliability, capacity and performance.

In addition, the Contractor shall demonstrate correct operation of components and systems by execution of the following tests:

<u>No-load running tests</u>

i. Auto run-up and shut-down sequencing

For the Unit, automatic start-up and shut-down sequencing using the automatic control equipment.

ii. Starting

The Unit shall be started from standstill and run up to normal speed under both manual and automatic control.

iii. Braking

a. The Unit operation of the mechanical brakes and determination of the time to decelerate the rotating parts from normal speed to standstill.

b. The speed/time characteristic shall be recorded for rundown from normal speed with the mechanical brakes being applied at the appropriate speed.

iv. Balance and bearing heat runs

a. Dynamic balance of the Unit at all speeds up to that attained on full load rejection. When a satisfactory degree of balance at normal speed has been achieved, bearing runs shall be carried out. The bearing runs shall be of sufficient duration to attain steady bearing temperatures.

v. Over speed and check on safety devices

a. The Unit shall be run for five minutes at the speed attainable on full load rejection. It shall be thoroughly inspected before and after the test and shall show no sign of permanent deformation or distress.

vi. Open circuit: AVR

a. Determine the settings of the AVR adjustable controls for best performance with the generator on open circuit.

vii. Generator open and short-circuit characteristics

a. Measure the open circuit and short circuit characteristics of the generator in accordance with IEC 60034-4.

viii. Governor full speed no load stability

a. Step response tests to demonstrate the governor no-load stability.

Load running tests

i. Line charging tests

a. Demonstrate that the generator and excitation equipment is capable of operation under-excited at leading power factor and of line charging.

ii. Governor and control equipment tests

a. Measurement of the dynamic performance of the Unit under various load conditions and with different values of stabilizing control settings, with various step signals and also low frequency harmonic signals injected into the speed reference device.

b. A series of sudden load rejection tests from 25 percent, 50 percent, 75 percent and 100 percent of rated load and maximum load to determine the momentary Unit over speeds and pressure rises when the Unit is under governor control.

c. Demonstration of load ramping and step response rates and conformance with system requirements.

d. Setting of the permanent speed droop.

e. Proving tests of all control equipment, safety and protective devices.

f. An index test of the turbine to determine the optimum running and setting of the Unit over the operating head range, to be used for setting the electronic cam relationship in the governor and as a datum for future turbine performance assessment.

g. During load rejection tests the Contractor shall make recordings of such quantities as the Employer shall require. These shall include the following:

- Pressure variations in the water passages of the turbine
- Speed variation
- Governor servomotor stroke
- Pressure change in oil pressure systems in the process of governing
- Vertical shaft movement
- Temperatures of bearings and shaft seal.

iii. Excitation system

a. Performance check of all main, auxiliary, stabilizing, limiting and protective circuits after adjusting to the correct setting.

b. Sudden load rejection tests at:

1) Zero kW at rated kVAr over-excited

2) 50 percent maximum continuous rated output, at rated power factor lagging,

3) 100 percent maximum continuous rated output at rated power factor lagging.

4) Steady state stability of the generator when operating at leading power factor, to demonstrate an acceptable margin of operation with its thermal rating.

iv. Generator on-load characteristics

a. Measurement of the waveform and harmonic analysis of the generator open circuit voltage in accordance with IEC 60034-1.

v. Characteristics of stator windings insulation system

a. Measurements shall be made to determine the characteristics of the stator windings insulation system in its original new condition. These measurements shall include tan delta, capacitance, integrated loss energy and also partial discharge intensity and phase characteristics.

vi. Metering equipment

a. Verification of the operation and accuracy of the station Main and Check metering systems.

vii. Any other tests deemed necessary by the Employer

1.24.2.44 When the Contractor has completed all commissioning of the local and remote/supervisory control functions, every function shall be demonstrated to have been commissioned, calibrated and loop tested. Tests to verify the correct and safe operation of the plant, the operation of all safety and protective devices and the overall control scheme will also be conducted to a protocol agreed between Contractor and Employer.

1.24.2.45 Performance Guarantee tests

General

Following commissioning of the Unit, the Contractor shall carry out Performance Guarantee Tests to demonstrate the fitness for purpose of the plant prior to commercial operation and taking over by the Employer. The scope of tests shall include but not be limited to the following:-

- Performance tests on the generating set.
- Tests on the System.
- Reliability test.

Performance tests on the Unit

The following tests shall be performed by the Contractor on the Units, at a time mutually agreed by the Employer and Contractor, but prior to, or at the completion of the Reliability Run. The tests shall include verification of guarantees for:

a. Generator efficiency.

b. Generator temperature rises.

c. Unit output (and determination of Unit capability over the full range of gross head).

d. Maximum Unit output.

e. Minimum Unit output.

f. Generator lower bracket deflection on full load rejection, and varying hydraulic thrust.

g. Conformance with noise and vibration criteria.

h. Generator reactances.

i. Excitation ceiling voltage.

j. Generator overvoltage and recovery time.

The Employer may, at its own expense, call for efficiency tests on the turbine to be carried out by the Contractor in accordance with IEC 60041 (in such an instance, the layout and number of current meters to be used will be to the approval of the Employer). Measurements of test sections will be made by the Contractor and witnessed and agreed by the Employer before the hydraulic system is filled so that, unless required for installation of equipment, emptying of the system will not be necessary when the tests are carried out.

Unit output guarantees and System performance guarantees

The Unit Output Guarantees and the System Performance Guarantees shall be demonstrated by the Contractor during tests performed subsequent to Provisional Acceptance of the Unit.

In addition to demonstrating the Output Guarantees and the System Performance Guarantees the Contractor shall demonstrate the overall performance and output capability of the System. The scope of tests shall include, but not be limited to, the following:

i. Voltage control

ii. Frequency control

iii. Output of the System under varying head

iv. Auxiliary power consumption:

- The auxiliary power consumption of the Complex shall be demonstrated at each of the Performance Guarantee Points.

  - Turbine cavitation behaviour:

- The cavitation behaviour of the turbine and its progression throughout the operating envelope shall be assessed by audible observation, and mapped as a practical guide for optimal operation of the Units.

  - Measurement of turbine cavitation:

- During a planned inspection outage provided at the end of the cavitation guarantee period (16,000 running hours from the date on which each Unit is taken into commercial service), the Contractor shall compare the weight loss of metal from the turbines with the cavitation guarantee.

  - Plant and equipment control and response times
  - Noise control aspects
  - Fire venting measures
  - Electrical power consumption
  - Testing shall be carried out over a sufficient period of time to enable the performance of the installed plant and equipment to be unequivocally proven against the design data and listed parameters.
  - Tests shall be carried out using agreed and recognized procedures such as those published by the Chartered Institution of Building Services Engineers in the form of the Commissioning Codes 'A', 'C', 'W' and 'R' and related publications.

1.24.2.46 Commissioning Tests

Commissioning tests of the Facilities shall include operational tests together with performance guarantee tests as follows:

(a) Commissioning tests, as specified in the relevant section of the technical specification for the Facilities.

(b) The manufacturer's commissioning and test requirements.

(c) Commissioning tests required by the relevant standards.

(d) Such other tests and inspections as may be necessary in the opinion of the Employer to demonstrate compliance with the Contract.

Performance Guarantee Tests shall be carried out on the turbine generator Unit as detailed in the Technical Specification including:

- Turbine Output Guarantee Tests
- Turbine Efficiency Guarantee Tests
- Generator Output Guarantee Tests
- Generator Efficiency Guarantee Tests

Additionally Performance Guarantee Tests shall be carried out, at the factory, of each generator transformer unit as detailed in the Technical Specification including:

- Generator Transformer Output Guarantee
- Generator Transformer Losses Guarantee

These generator transformer performance guarantee factory tests shall be deemed to be part of the Tests at Completion.

1.24.2.47 Trial Operation Tests (Reliability Test)

The Tests at Completion shall include a Reliability Test of the turbine generator unit and associated plant to demonstrate that the Unit can operate reliably in commercial operation.

The Reliability Test period of the turbine generator unit and associated plant shall commence when the Contractor has notified the Employer that the Unit is ready for commercial operation.

During the Reliability Test period the unit shall be operated in the normal commercial operating conditions, within the unit operating limits, either continuously or intermittently as required by Employer, without failure or interruption for a period of 30 days.

During the Reliability Test period of the unit it shall be operated by the Employer's staff under the direct supervision of the Contractor. The Contractor shall provide at his own expense suitable supervisory staff on a 24-hour per day, 7 days per week basis to supervise and direct the Employer's staff in the operation of the unit.

The Contractor may make minor adjustments to the Unit, provided that such adjustments do not in any way interfere with or prevent its commercial operation or result in reducing the output or efficiency.

In the event that any failure or interruption occurs in the operation of the Facilities due to faulty design, manufacture, installation, materials or workmanship under the Contract sufficient to interrupt the commercial operation of the Facilities, the Reliability Test Period of 30 days shall be recommenced after the Contractor has remedied the cause of the defect.

Minor failures on interruption of less than 2 hours duration, subject to an aggregate maximum of 10 hours during the 30 day Reliability Test Period, shall not be a cause for recommencing the Reliability Test Period.

The Contractor shall be responsible for proving that any interruption that may arise is due to causes other than faulty design, manufacture, installation, materials or workmanship of the Facilities.

1.24.2.48 Delayed Commissioning Tests

In the event that there is insufficient river water flow, electrical power demand or for any other reason not attributable to the Contractor to undertake all the commissioning tests immediately after substantial completion it will be necessary to perform such tests in accordance with General Conditions of Contract as agreed with the Employer.

1.24.2.49 Post Commissioning Tests

Following Commissioning Tests, and for the duration of the Defects Liability Period, the Contractor shall undertake regular testing and inspection of the turbine runners for cavitation and or cracking as detailed in Technical Specifications – Turbines and Governors.

1.25 Training of Employer's Personnel

1.26 General

The Contractor shall be responsible for the instruction of the Employer's personnel in all aspects of plant design, manufacture and operation and maintenance of the Facilities as detailed below. Such instruction shall be provided in the English language at all times.

All training programmes shall be subject to audit by the Employer.

1.26.1 Training at the Manufacturer's Works

The Contractor shall be responsible for the provision of training to the Employer's personnel at the manufacturer's works in all aspects of hydro plant design and manufacture.

General training shall include:

a) General design principles

b) Visits to major suppliers and manufacturers

c) Visits to hydro power plants

Specific training shall include:

a) Turbines including actuation mechanisms.

b) Generators

c) Excitation and Protection

d) Generator Transformers

e) Energy meters

f) Telecommunication equipment

The training shall be provided to the Employer's personnel as follows:

- Four (4) mechanical engineers
- Three (3) electrical engineers

- Three (3) civil engineers

For Tender purposes each engineer shall be provided with twenty (20) business days of training. The Contractor shall be responsible for all costs associated with the training of each engineer including:

(a) All travel, including return economy class airfares, from Zambia to the various manufacturers' works.

(b) Per diem at current prevailing rate

(c) Course fees, relevant training materials and training notes and training facilities including the use of any test instruments and equipment during the training period.

The training shall provide sufficient hand-on experience to enable the Employer's staff to operate and maintain the various systems fully by themselves.

All training courses, notes and documentation shall be in the English language.

The Employer's staff shall be present during the installation/commissioning period and it is essential that they are fully involved in any on-site corrections/modifications to software and hardware.

1.26.2 Content

The training courses for each of the equipment components shall cover, as a minimum, the following:

a. System overview.

b. System operation and configuration.

c. System design/budget calculations.

d. System hardware and software.

e. System expansion and upgrade capability.

f. Cabling requirements.

g. Installation, testing and commissioning techniques.

h. Fault finding and trouble shooting.

i. Repair and routine maintenance.

The Contractor shall prepare and submit the detailed training syllabi and programmes to the Employer for approval.

1.26.3 Proposals for Training

For each course the following information shall be provided:

a. Course name and identification.

b. Short description of the content.

c. Level of competency required for each course.

d. Date and duration.

e. Location of training.

f. Maximum number of staff that can attend.

g. Other important information.

The times at which the various training courses will take place shall be stated, and fully documented notes shall be available to the Employer no later than 2 months before the commencement of the course.

The prices of the training courses shall be detailed in full such that additions/deletions to personnel/courses can be calculated by the Employers without recourse to the Contractor.

1.26.4 Employer's Staff Assigned to the Contractor during Site Erection

During the erection periods, the Contractor shall give "on-the-job" instruction and training to the Employer's personnel using the supervisory staff employed on the Contract works.

Two Engineers, Two technicians and four craftsmen from the Employer's personnel will be permanently assigned to the Contractor during the erection period to assist with "hands on" erection of the turbine, generator and associated equipment. These staff will work the same hours as the Contractor's other erection staff. The Contractor shall accept legal responsibility for all work carried out by these personnel when assigned to the Contractor.

During the course of this "on-the-job" instruction/training the Contractor's supervisory staff shall familiarise the Employer's personnel with the plant and equipment associated with the Facilities including:

1. Erection and dismantling procedures and techniques.

2. Maintenance procedures and techniques on all plant items.

3. Operational techniques relative to all plant and equipment.

The Contractor shall be responsible for accommodation and out-of-pocket allowance at a rate of US$ 70 per day during this "on-the-job" instruction/training period.

During the Commissioning period the Employer's personnel will be assisting in the witnessing of tests and they will not be available for use by the Contractor during this period.

1.27 Progress Reporting

1.27.1 Contract Progress Meetings

Throughout the duration of the Contract regular Contract Progress Meetings will be held and attended by the Employer and the Contractor.

The Progress Meetings will include review of the current Monthly Contract Progress Report and the Quarterly Progress Report where relevant.

Following commencement of activities at site the Contract Progress Meetings will generally be held at monthly intervals at site.

1.27.2 Monthly and Quarterly Progress Reports

Throughout the duration of the Contract, the Contractor shall before the tenth (10^{th}) day of each calendar month and quarter submit five (5) copies of the monthly progress report and the quarterly progress report in a format acceptable to the Employer detailing the progress of the work during the preceding month and quarter. The reports shall include, but not be limited to, the following:

(a) A general description of the Facilities performed during the reporting period on each main activity to include any notable problems which were encountered.

(b) The total overall percentages of project Facilities completed as well as scheduled by the Contract Program of Performance at the end of the reporting period, together with appropriate comments in writing to explain any differences.

(c) A list of all activities of scheduled progress or actual progress during the reporting period including the Contractor's actual or forecast start date versus scheduled start date together with the actual or forecast completion dates versus scheduled completion dates for each activity, with appropriate remarks in writing to explain any differences.

(d) For the monthly report, a list of activities scheduled to be started within the next two (2) months, with expected starting and completion dates. If the expected starting and / or completion dates are different from those shown on the Contract Program of Performance an explanation is to be given together with details of actions that are being taken to mitigate the effect of any delays.

(e)A list of local manpower (by trade classification) employed during the reporting period.

(f) A list of expatriate personnel (by position) employed during the reporting period.

(g) A list of the Contractor's Equipment and materials in use at site for the execution of the Facilities together with a list and status of equipment and materials which have arrived in Zambia but have not been delivered to site.

(h) Site progress photographs.

(i) Main items of temporary facilities constructed during the reporting period.

(j) A Gantt chart showing the progress of Facilities.

(k) A statement detailing the status of progress on the overall programme and how the impact of any delays will be mitigated.

(l) A statement on current labour relations and details of any potential difficulties.

(m) A report on Health and Safety issues including details of any incidents that may have occurred in the period together with actions being taken to prevent any reoccurrence of the incident.

(n) A report on Environmental Management issues including details of any incidents that may have occurred in the period together with actions being taken to prevent any reoccurrence of the incident.

(o) A report on security issues including details of any incidents that may have occurred in the period together with actions being taken to prevent any reoccurrence of the incident.

(p) A schedule of the contract payment status including invoiced amounts and payments.

(q) A record of any change orders agreed or change orders in preparation during the reporting period to include any changes in costs and any extension of time.

(r) A list of any claims submitted during the reporting period including value of amounts claimed and any extension of time claimed.

(s) A list of all correspondence submitted to the Employer and the status.

1.27.3 Weekly Site Reports

Following the commencement of site activities and in addition to the Monthly Reports the Contractor shall at each week end submit four (4) copies of a written weekly Site Report.

The Site Report shall include details of progress during the previous week together with details of the works to be undertaken in the following week. The Site Report shall also address other issues including Health and Safety, environmental management and site co-ordination.

The schedule shall be in a format and content approved by the Employer.

1.28 Sub-Contracts and Sub-Orders

The Contractor shall submit unpriced copies of all Sub Contracts and Sub Orders placed to the Employer for information together with one copy of any drawings and or documents referred to in Sub Contracts and Sub Orders.

All Sub Contracts and Sub Orders shall contain a full description of the equipment being ordered together with all relevant data including the guarantee performance requirements.

1.29 Quality of Materials

1.29.1 General

All material shall be new and of the best quality and of the class most suitable for the purpose specified and shall withstand the range of working conditions without distortion or deterioration or the setting up of undue strains in any part, such as to affect the efficiency and reliability of the Facilities, and also without affecting the strength and suitability of the various parts for the work they have to perform.

Electrical equipment shall be of the class most suitable for working in the local conditions.

1.29.2 Proscribed Materials

The Contractor warrants:

(i) that he, or any subcontractors, has not used or specified and will not use or specify for use;

(ii) that he has exercised and will continue to exercise, reasonable skill, care and diligence to see that such materials are not used;

(iii) that he is not aware and has no reason to suspect or believe that such materials have been or will be used; and

(iv) that he will promptly notify the Employer in writing if he becomes aware or has reason to suspect or believe that such materials have been, or will be used;

In connection with the Facilities, any of the materials or substances identified as follows:

(a) high alumina cement in structural elements;

(b) wood wool slabs in permanent formwork to concrete;

(c) calcium chloride in admixtures for use in reinforced concrete;

(d) asbestos products except (with Employer's consent in writing) in mechanical or electrical equipment where their use cannot reasonably be avoided;

(e) naturally occurring aggregates for use in reinforced concrete which do not comply with British Standard 882: 1983;

(f) cast iron for any oil service;

(g) carcinogenic materials and

(h) Any others generally known in the construction industry at the time of use to be deleterious if used or incorporated in the Facilities.

1.30 Packing and Marking

All items for transportation to Site for incorporation in the Facilities shall be robustly packed and protected.

Tube ends, flanged openings and other similar open ends are to be protected from both external damage and ingress of dirt and moisture during transit and while awaiting erection at Site. Preformed plate shall be provided with substantial supports of correct shape to prevent distortion during transportation.

Careful attention shall be paid to the provision of lifting and securing features to facilitate handling and transportation to site.

Bolts, nuts and similar small items are to be packed in strong wooden boxes.

Each crate or package is to contain a packing list in a waterproof envelope. Component parts are to be clearly marked with the symbols stamped in the metal as well as painted thereon. Pipe assemblies shall be clearly match marked.

All cases, packages, etc., are to be clearly marked on the outside to indicate the total weight and are to bear an identification mark relating them to the appropriate documentation, the Project, the number of the Contract and the name of the Contractor. All stencil marks on the outside of cases are to be such that they cannot be obliterated in transit.

1.31 Spares

The spares to be supplied under the Contract shall be of the same quality as the corresponding original parts and shall be fully interchangeable with them. Additionally they shall be of the same material and workmanship together with the provisions and features of the original parts.

Spares which include microprocessors shall be pre-programmed and ready for installation, without the need for technical input from the Contractor services or the services of other external specialists.

All spares shall be suitably protected and packed for long term storage under the conditions prevailing at the project site. Each spare part shall be clearly identified and all packages, boxes or containers shall also be labelled or marked with spare part identification details on the outside.

An inventory of spares shall be provided in both hard and soft copy formats for use on a PC, including unique identification number, name/description, item of plant to which it belongs, shelf life if applicable, any health and safety warnings that may be applicable together with the original suppliers reference number and contact details.

1.32 Maintenance Tools and Equipment

Maintenance equipment shall include, but not necessarily be limited to, the items specified below.

The Contractor shall supply one complete set of special tools, gauges, tackle, lifting devices etc., to the Employer's approval, as required for quick and convenient dismantling and assembly of all the equipment.

All slings, shackles, pins, ropes, jacks and lifting devices shall be supplied on Operational Acceptance with test certificates as applicable.

Spanners and all small hand tools shall be mounted on neat hardwood or steel boards in lockable cabinets arranged for wall mounting and provided with ready means of identification. Larger tools and tackle shall be mounted in lockable cabinets in such a way that each item can be easily identified by moulding, painted outline or similar, such that the absence of a tool can be detected readily. Cabinet arrangements will all be to the approval of the Employer.

1.33 Documents, Goods & Materials to be handed over to the Employer

In addition to the requirements of the Contract on Operational Acceptance, the Contractor shall obtain a signed receipt by the Employer, for all documents, goods, materials, maintenance equipment, spare parts, instruments, etc. required by the Contract to be handed over to the Employer other than the permanent Facilities erected on Site.

The receipt shall clearly state that all items have been received in a satisfactory condition as required under the Contract. The Contractor shall, as required, be responsible for demonstrating the satisfactory condition of all items delivered to the Employer including the repacking for storage at Site.

1.34 Use of the Site

The Contractor shall not use the Site for any purpose other than that of carrying out the Facilities.

Where the Drawings show limits of land available around the area of the main construction Site, the Contractor shall have no rights to use areas outside these limits except for short periods and/or by such arrangements as may be formally agreed with the Employer.

1.35 Assistance to the Employer

The Contractor shall allow free use of his equipment and personnel by the Employer for the purposes of verification and checking the Contractor's Facilities. The cost of such use of equipment and personnel shall be deemed to be included in the Contract Price.

1.36 Site Temporary Facilities

The Contractor shall be responsible for the provision of all temporary facilities for the execution of the Facilities including, but not limited to, access and internal site roads, offices, workshop, stores, lay down areas, accommodation and facilities for construction workers, water supplies, electrical power supplies, communications, sewage and refuse disposal, and the security of the facilities.

Sixty (60) days prior to commencement of the site activities the Contractor shall submit to the Employer for review details of planned site facilities including but not limited to, a site plan of temporary facilities together with details of each building and associated infrastructure.

1.36.1 Contractor's Office Accommodation and Facilities

The Contractor shall be responsible for the provision of his own site facilities and compound including site office, workshop, stores and lay down areas.

The arrangement and overall design of all buildings and facilities shall be agreed with the Employer.

The Contractor shall construct a temporary access road to service his site facilities. The road shall be constructed to local standards and be maintained for the duration of the Contract.

The Contractor shall be responsible for providing and maintaining all facilities including all temporary roadways within his site compound area. The Contractor shall also be responsible for keeping his own compound area secure and in a clean, sanitary and orderly condition.

The Employer shall have full access during working hours to the Contractor's compound and storage area.

At the completion of the Contract the Contractor shall demolish and dispose of all his temporary buildings and site facilities including floor slabs and roadways.

In the area allocated for the Camp, the Contractor shall build such houses and supply related services, furniture and equipment as he may need for his own purposes, including the housing of personnel resident on Site employed by Sub Contractors.

All buildings shall be constructed to normal local standards in cement block or similar approved material. Roofing material shall be other than thatch to minimise the risk of fire.

1.36.2 Contractor's Labour Accommodation

The Contractor shall be responsible for the provision of accommodation for his own labour.

Such Contractor's labour accommodation shall as a minimum comprise barrack type labour lines divided into separate rooms. The rooms and facilities shall as a minimum comply with the following:

- Each room shall accommodate no more than two persons and shall not be less than 10 m^2 in area.
- Each room will be provided with an electric light.
- For every five (5) twin rooms, two (2) washrooms each of minimum area 6 m^2 and each containing a water closet, wash basin, shower and urinals if appropriate, shall be provided
- Segregated similar washroom facilities shall be provided for female employees.
- For every five (5) twin rooms, two (2) kitchens of minimum area 6 m^2 and each equipped with work top, washing sink, piped drinking water, electric light and electrical power supply.
- For every ten (10) twin rooms, a covered communal lounge building of minimum area 50 m^2 together with separate covered veranda 1.5m in width.

1.36.3 Common Facilities

The Contractor shall provide, operate and maintain a welfare centre.

1.36.4 Water Supplies

The Contractor shall be responsible for the provision of water supplies including drinking water to site.

All drinking water shall comply with the current World Health Organisation 'Guidelines for Drinking-water Quality'.

The Contractor shall provide all supervision, labour and consumables necessary to operate and satisfactorily maintain the drinking water system throughout the Contract Term.

1.36.5 Electrical Power Supplies

The Contractor shall be responsible for the provision of all electrical power supplies to the site facilities.

1.36.6 Sewage Disposal

The Contractor shall be responsible for the provision of sewage treatment and disposal from all temporary Facilities.

All offices, housing, amenities and other buildings erected on the site shall be connected to sewage treatment facilities by a piped sewage system.

Sewage treatment facilities shall be provided, operated and maintained for the duration of the Facilities.

Under no circumstances shall untreated sewage be discharged into watercourses.

The Contractor shall carry out regular inspections of the sewerage system and be responsible for all necessary maintenance work.

1.36.7 Refuse Collection and Disposal

The Contractor shall be responsible for the provision of a refuse collection and disposal service from all temporary office facilities. This service shall be provided throughout the duration of the site works and shall be provided at a frequency of not less than twice per week. The service shall include the provision of dustbins and replacement as necessary.

The refuse shall be disposed of in a purpose made pit at a location to ensure that water courses and supplies are not affected. The location of the pit will be agreed with the relevant local authorities and the Employer. The refuse deposit shall be covered with earth as necessary to prevent any objectionable conditions arising.

1.36.8 Provision of Temporary Toilets

In addition to any sanitary arrangements provided in the temporary buildings, the Contractor shall at his own expense construct and maintain for the duration of the Contract approved temporary toilets in adequate numbers for the use of his employees at each individual work site. The Contractor shall allow the use of these temporary toilet facilities by the employees of the Employer and others working on the Site.

The Contractor shall ensure that these temporary toilets are always maintained in a clean and hygienic condition and are kept adequately disinfected. The sewage effluent from these temporary toilets shall be disposed of in the septic tanks or other means agreed with the Employer.

1.37 Site Co-ordination

1.37.1 Site Cleanliness

The Contractor shall be responsible for keeping the Site clean and tidy at all times to the satisfaction of the Employer. The Contractor shall be responsible for the removal from site, and safe disposal of, any debris associated with the Facilities.

1.37.2 Site Security

The Contractor shall be responsible for the security arrangements for the project site and all associated facilities.

The Contractor shall establish an identity card system for his staff and personnel to enable them to be positively identified. The identity card system shall be to the approval of the Employer.

1.37.3 Fire Precautions

The Contractor shall be responsible for taking all reasonable precautions against outbreaks of fire at site and to ensure that a nucleus of persons trained in the use of fire-fighting equipment are included in each work section team, on each shift.

Appropriate fire-fighting devices shall be provided by the Contractor at all site locations.

The arrangements to deal with the outbreak of fire on the project site shall be agreed with the Employer.

1.37.4 Advertisements

The Contractor will be permitted to display appropriate notice boards on or near the Site, or access road to the site, in a form and positions approved by the Employer. He shall not display advertisements, nor permit advertisements of others to be displayed without the written authority of the Employer.

1.38 Health & Safety

1.38.1 Health & Safety Plan

The Contractor shall be responsible all aspects of health and safety associated with the Facilities.

The Contractor shall prepare and submit to the Employer a Health and Safety Plan for the execution of the Facilities.

The Health and Safety Plan shall address all Facilities activities and shall include, but not be limited to the following:

- Responsibilities and arrangements for the management of health and safety for the Facilities.
- Identification of health and safety standards being adopted.
- Arrangements for monitoring to ensure that the Health and Safety Plan is being followed.
- Risk assessment and mitigation of any health and safety risks that may arise during the execution of the Facilities.
- Emergency procedures.
- Arrangements for provision of welfare facilities.
- Health and safety information and training of site staff (weekly tool-box meetings).

1.38.2 General Health Precautions

Various tropical diseases occur in the region. Special precautions shall be taken by the Contractor at his own expense to keep the incidence of malaria and other diseases as low as possible. The Contractor shall accordingly spray with approved insecticide the interiors of buildings which he occupies within one week of their occupation under the Contract and at two monthly intervals thereafter.

All pools of water and other likely mosquito breeding places within and adjacent to the Facilities area shall either be eliminated or sprayed in an approved manner.

The Contractor shall ensure that all Site staff (including all of the Contractors' employees and all subcontractors' employees; and all truck drivers and crew making deliveries to Site) is made aware of the dangers and impact of HIV/AIDS. Consequently, the Contractor shall organize Information, Education and Consultation (IEC) campaigns every month addressed both to all Site staff/labour and to the immediate local communities. Such campaigns shall be conducted through counselling, lectures, and distribution of literature, pamphlets, posters and other related information on HIV/AIDS.

In project areas where there are no health facilities, the Contractor shall ensure that Site clinic(s) is /are provided and equipped for diagnosis and free treatment of Sexually Transmitted Diseases (STDs). Where health facilities equipped for diagnosis and free treatment of Sexually Transmitted Diseases (STDs) exist, the Contractor shall make use of such facilities in consultation with respective health authorities. The medical staff working in these clinics shall provide adequate HIV/AIDS counselling services to all Site staff.

The Contractor shall provide and ensure that all project staff has access to condoms at all times irrespective of gender, ethnicity, etc.; and to all truck drivers and crew making deliveries to Site upon arrival.

The Contractor shall consult, liaise and work closely with existing health and local authorities, NGOs and other stakeholders in project areas in order to effectively control and prevent the spread of HIV/AIDS.

The Contractor shall also sensitize the local community regarding the control of livestock and vandalism/theft.

Unless provided for separately, all the above provisions shall be deemed to be provided at the Contractors cost and priced as part of the Contractor's overheads. Evidence of the sensitization campaign on HIV/AIDS shall be submitted to the Employer in form of a report by the Health Institution every three (03) months.

1.38.3 Safety Signage

The Contractor shall provide all necessary signage for the Site. Signage shall be in the local language and in English. The Employer will provide translations from English to the local language at the request of the Contractor. The Contractor may also provide a third language on signage.

In locations at which the Facilities present a hazard to personnel the Contractor shall provide barriers to prevent access to the location and display a notice bearing the word "DANGER''.

1.38.4 Health, Safety and Environment Officers

The Contractor shall formally appoint an experienced and qualified member of his staff to be responsible for health and safety aspects of the work and shall ensure compliance with all health, safety and environment requirements of local legislation. He shall be responsible for the health and safety aspects of the Contract and shall liaise directly with the Employer's Health, Safety and Environment Officer to ensure safe working conditions at all times.

1.38.5 First Aid Provisions

The Contractor shall be responsible for providing and operating on site a dedicated first aid room for the duration of the site works for the use of the Contractor's and Employer's personnel.

The dedicated first aid room shall be fully equipped with first aid facilities to treat any minor injuries and ailments on site and to render first aid to any personnel sustaining severe injuries prior to transfer off site to better equipped medical facilities.

The Contractor shall provide and make available on a 24 hour per day 7 day a week basis, qualified first aid personnel to render any first aid as may be required.

At suitable locations in relation to the working areas of the Site the Contractor shall provide adequate boxes of First Aid materials. These locations shall be prominently marked and available to all Contractor's and Employer's personnel The Contractor shall be responsible for providing and operating, for the duration of the site works, a suitable vehicle, for use in the event of an accident, for the transport any injured project personnel to an appropriate hospital or medical facility.

The vehicle and the arrangements for its use in the event of such an emergency shall be to the approval of the Employer.

The vehicle must be available on site for use with a driver, at all times whilst site Facilities activities are taking place.

1.39 Environmental and Social Requirements

1.39.1 Environmental Regulations

The Contractor shall comply with the Statutory Regulations of Zambia together with the requirements of the Project Environmental Impact Assessment and any conditions stated in the approval Decision Letter by the Zambia Environmental Management Agency (ZEMA).

1.39.2 Environmental Management Plan

The Contractor shall be responsible for all environmental aspects of the Facilities.

The Contractor shall prepare and submit to the Employer an Environmental Management Plan for the Facilities. The Environmental Management Plan shall include, but not be limited to the following:

- Details of the measures which shall be taken to protect the environment.
- Details of the measures which will be taken to mitigate any potential negative impact on the environment by the Facilities.
- Environmental monitoring and reporting programme including details of activities, measures and responsibilities.
- A contingency response plan in the event of the occurrence of an incident which threatens or damages the environment.

1.39.3 Specific Construction Environmental Requirements

The Contractor shall comply with specific construction environmental requirements including, but not limited to the following:

1. The Contractor shall exercise all due care and diligence to preserve the natural environment and execute the Facilities in such a manner as to prevent any unnecessary destruction, scarring or defacing of the natural environment in the vicinity.

2. Reclamation of borrow areas by grading slopes to less than 45°, re-vegetation where topsoil can be stockpiled before construction, and removal of all construction equipment, including foundations, rendering quarry areas safe.

3. Spoil areas for disposal of waste rock and overburden shall be selected to avoid sedimentation or pollution of runoff. Spoil areas shall be prepared by removal of topsoil before construction and placement on the spoil surface.

4. Measures shall be implemented to control erosion and sedimentation for all aspects of the Facilities.

5. Hazardous wastes and spoil not suitable for landfill shall be removed from the site for disposal at an approved facility.

6. Hazardous liquid wastes including oil, fuel, paints, chemical substances, and solutions shall not be discharged to drainage systems and shall be disposed of at appropriate approved facilities.

7. In case of an environmental emergency situation (e.g. oil spills or chemical spills), the Contractor shall immediately notify the Employer together with relevant authorities and immediately implement any measures necessary to redress the emergency.

8. In the event that there is any inherent risk that a given situation or event may develop into an emergency, then the Contractor shall, to the extent possible, give advance notification of such a possibility to the Employer and the relevant authorities.

9. Dumping of any kind of material, including excavated earth, construction materials, concrete, or wood, into rivers or water courses shall not be allowed except as may be specifically agreed with the Employer and the relevant authorities.

10. The Contractor shall preserve and protect from any damage all trees and shrubs which are not required to be cleared or removed for the execution of the Facilities.

11. The Contractor shall be responsible for any damage to trees and shrubs arising from the execution of the Facilities. Any damaged trees or shrubs shall be replaced or immediately compensated.

12. The Contractor shall strictly control emissions of dust arising from the execution of the Facilities and shall take such measures as may be necessary to prevent emissions of dust together with any subsequent clean up and disposal of dust that may be required.

13. The Contractor shall limit operations producing high intensity noise levels including blasting, pile driving, rock crushing and the use of jack hammers, to daylight hours only unless otherwise specifically agreed with the Employer and the relevant authorities.

Section 2: Functional Requirements

2.1 Minimum Functional Requirements

The Facilities shall be designed and constructed such that the requirements of this Section shall be complied with and implemented without variation.

The conceptual arrangement of the Facilities shall be as described by the Outline Design Drawings. The details presented in these drawings define the required project layout, the approximate location, orientation and general arrangements of its principal structures and components. Outline details of engineering solutions that may be appropriate are also shown. All engineering details and dimensions shown on the Outline Design Drawings are indicative only and are to be developed, determined, verified or amended by the Contractor to ensure compliance with these Employer's Requirements.

2.2 Basic Design Philosophy

The objective of the 200 kW Chipota Falls Mini Hydropower Power Project is to provide the Employer with a complete and fully functional 200 kW Hydro Power Station.

The function of the Chipota Falls Mini Hydropower Station is to harness the energy potential of the Mulembo River over this reach of river, on the basis of a design flow rate of 0.68 m^3/s. whilst maintaining a continuous Environmental Flow at all times in the Mulembo River downstream of the overflow weir.

The Chipota Falls Mini Hydro Power Plant shall have a nominal installed capacity of 200 kW comprising two (2) Turgo turbine generator units.

2.3 Operating Philosophy

2.3.1 Operation Mode

The Chipota Falls Mini Hydropower Station shall operate as an isolated grid to supply the available electrical load demand in the surrounding load centres.

2.4 Plant Design Operational Life

The general design operational life of the Facilities shall give a minimum operational life of 50 years for the Plant, buildings and penstock together with a minimum operational life of 100 years for the civil structures.

2.5 Power Quality

The Facilities shall be capable of meeting all the operational requirements of the Zambian Grid Code.

2.6 Applicable Standards

The Facilities shall be designed, manufactured, constructed, commissioned, tested and completed in compliance with the applicable standards as well as the Zambian Grid Code.

To ensure standardisation of the Facilities all civil works, plant, equipment and systems provided for each feature of the Facilities shall be designed and provided from the same suite of relevant applicable standards.

Applicable standards are those standards, codes of practice, guidelines and references published by the institutions listed below as are pertinent, consistent and appropriate to the design and construction of a particular element of the Facilities.

Where applicable standards are silent, or do not fully or satisfactorily address an issue, or have a national or regional application inappropriate in the context of the design and/or construction of a particular element of the Facilities, the Contractor may with the Employer's non-objection adopt other standards, such non-objection being at the Employer's absolute discretion. In considering the Contractor's proposals the Employer will have regard to the implications of such standards on the function and quality of the Facilities.

If the Contractor seeks to adopt standards published by other institutions that are not applicable standards, it shall submit a written proposal for the Employer's consideration, nominating the standards on which it seeks to rely and giving reasons for the preference for such other standards. The proposal shall include copies of such other standards. If written in a language other than English, official English translations of such documents shall be provided. Any non-objection provided by the Employer to the use of such other standards, shall not in any way diminish the Contractor's obligation to design, execute, complete and remedy any defects in the Facilities in accordance with this Contract or transfer any liability to the Employer in respect of the use of that standard.

Institutions Providing Applicable Standards

1. American Association of State Highway Transport Officials (AASHTO)
2. American Concrete Institute (ACI)
3. American Institute of Steel Construction (AISC)
4. American National Standards Institute (ANSI)
5. American Society for Testing and Materials (ASTM)
6. American Society of Civil Engineers (ASCE)
7. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
8. American Society of Mechanical Engineers (ASME)
9. American Welding Society (AWS)
10. Association of Engineering Geologists
11. British Standards Institute (BSI)

12. Construction Industry Research and Information Association (CIRIA)
13. Deutches Institut für Normung (DIN)
14. Earthquake Rules 1992 (PS 92 Standard NFP 06 6013) and appendices together with AFPS 90
15. Energy Power Research Institute (EPRI)
16. Européen Committees for Standardization (EN)
17. Eurovent Standards
18. Fédération Européenne de la Manutention (FEM)
19. Institute of Electrical and Electronic Engineers (IEEE)
20. Institution of Mining and Metallurgy, London (IMM)
21. International Commission on Large Dams (ICOLD)
22. International Electrotechnical Commission (IEC)
23. International Standards Organisation (ISO)
24. Japanese Industrial Standards (JIS)
25. Kraftwerk-Kennzeichensystem (KKS)
26. Le Comité Européen de la Chaudronnerie et de la Tolerie
27. National Electrical Manufacturer's Association (NEMA)
28. National Electrical Safety Code, National Bureau of Standards (NESC)
29. National Fire Protection Association (NFPA)
30. National Fire Protection Association, National Electric Code (NEC)
31. Norwegian Geotechnical Institute (NGI)
32. UK Chartered Institution of Building Services Engineers (CIBSE)
33. Uniform Building Code (UBC)
34. United States Army Corps of Engineers (USACE)
35. United States Bureau of Reclamation (USBR)
36. Verein Deutscher Elektrotechniker (VDE)
37. Verein Deutscher Ingenieure (VDI)
38. Bureau Veritas
39. Zambia Bureau of Standards (ZABS)

2.7 Weir and Spillway

The weir shall be designed as a low concrete overflow gravity structure with an ogee spillway and concrete abutments. The design flood shall be 1:100 years with a design discharge of 110m^3/s

The bridge is 1422.23 m ASL high and 12m wide, and the riverbed elevation at the bottom of the bridge is about 1419.50 m ASL.

2.8 Intake

The intake shall be designed as a submerged orifice with a discharge of 0.68 m^3/s under nominal operating conditions

The intake shall include but not limited to the following:

i. Intake Gate

ii. Intake gate handling equipment

iii. A sediment sluice gate to flush sediment from below the intake area and to draw down the reservoir level for weir inspections and weir maintenance.

iv. Instrumentation for reservoir level measurement.

2.9 Penstock

The penstock, the pipeline will be laid mostly along the stable ridge with the total length of the penstock's main pipe being 530m.

The main pipe axis is 530m long made of non-corrosive steel, with at least 6 anchorage blocks and 6 expansion joints along the line. The diameter of the main pipe is 650mm, the pipe wall thickness will be 6-8mm.

Measures should be provided to protect the surfaces of the pipe from corrosion.

2.10 Power House

2.10.1 General

The power house shall be a weatherproof structure suitably sized to house the turbine generator unit, all associated auxiliary plant and equipment together with sufficient space to carry out all operational and maintenance related activities.

Particular attention shall be given to the provision of access for the maintenance and repair of the hydro-electric plant, and all essential services and components which may require frequent attention. Such equipment shall be arranged such that operational, maintenance and refurbishment related activities may be undertaken swiftly and efficiently, and without affecting plant that is to remain in service. ***The powerhouse shall be designed such that a single hoist shall be able to handle all powerhouse equipment and plant under one roof.***

The outline drawings provided for the powerhouse are merely a guide. The requirements given below shall be the basis of the contractor's design.

2.10.2 Power House facility description

The powerhouse will be located at the end of the waterway, on the right bank of the Mulembo River. It is parallel to the riverbed, with the mounting site and the entrance gate on the right. The penstock will lead via a sluice gate into the powerhouse where the turbine-generator sets will be housed. A tail race will discharge water from the powerhouse back into the Mulembo River.

The main powerhouse will be equipped with two sets of 100kW inclined type turbine-generator units, with a spacing of 5m between them.

The design of the power house should be to B S 8007:1995 with an additional loading for earthquake.

The power house shall comprise the following:

	Minimum Area per unit (m^2)
Machine hall including loading & maintenance bay	
Battery Room	
Control room	
Charger /protection Room	
Ladies and gents toilets comprising 2 hand wash basins & 1 urinal bowl.	

The Control Room shall be positioned such that the generating units and main auxiliary equipment in the machine hall are in view.

2.10.3 Power House Hoist

A suitably sized hoist shall be installed in the powerhouse able to access all the equipment.

2.10.4 Power House Access

In general all areas within the power house shall have a minimum of two means of exit, one of which may be in the form of an external fire escape.

The power house machine hall shall have, as a minimum, one exit door at each end for personnel use. A stairway located within the machine hall shall provide access to first floor control and other facilities. The loading and maintenance bay shall be provided with at least one external door, suitably sized for fully loaded transport vehicles to load and off load all necessary items of power station equipment.

2.10.5 Power House Finishes

Externally the power house shall have a pleasing appearance of an appropriate architectural style in keeping with the surrounding area. Finish colours and textures shall have predominantly natural tones. Low maintenance insulated walling and roofing systems shall be adopted throughout. Windows shall be installed to provide natural light within the structure.

Internally, the power house shall be finished to a minimum functional standard.

Typically, within the machine hall, finishes shall comprise the following:

- walls above the level of the machine hall floor to be either rendered and painted masonry or steel cladding finished in accordance with the proprietary system selected;
- plain concrete walls below the machine hall floor (e.g. turbine pits);
- painted structural steel;
- colour coded pipework and services;
- Galvanised miscellaneous steelwork (e.g. ladders, flooring, hand railing etc.);
- and floors treated with non-slip heavy-duty industrial grade epoxy paint.

The battery room shall have acid resistant finishes, wash-down facilities, eye bath, extractor fans and electric light fittings, as well as suitably designed drainage containment for safe handling of floor run-off.

Toilets and showers shall be fitted with standard European style sanitary fittings and hand basins with running water, mirrors, warm air hand dryers and similar fittings.

2.10.6 Building Services

All required building services shall be provided throughout the Facilities, including lighting, power outlets, air-conditioning and ventilation, hot and cold water systems for wash basins, sinks and the kitchen, a treated water supply and suitable wastewater disposal and sewage disposal systems.

For both the cold water and the treated water systems, readily accessible storage tanks shall be provided having a capacity equivalent to 24 hours consumption, in case of interruption of supplies. The tanks shall be insulated and be arranged such that they may be cleaned internally with minimum effort.

2.11 Tailrace Channel

Immediately downstream of the powerhouse the tailrace shall comprise concrete lined channels with inverts set above the 25 year return period river flood elevations and with falls sufficient to ensure channels are self-draining. The length of concrete lined channel shall extend a distance sufficient to ensure the powerhouse structure is protected against erosive actions. Beyond the concrete lined channels water shall be returned to the Mulembo River.

2.12 Management building

Management building/office complex shall house the administrative office, store room and maintenance workshop complete with equipment and tools

The buildings shall be separate from the powerhouse and comprise the following:

	Minimum Area per unit (m^2)
Offices	
Workshop	
Warehouse	
Kitchen.	
Ladies and gents toilets comprising 2 toilets, 1 urinal bowl, 2 wash basins and mirrors.	

Internally, finishes shall be plastered and painted walls and ceilings, ceramic tiles to floors, hardwood skirtings, steel doors, proprietary window frames, and covered electrical reticulation, plumbing, air-conditioning and other building services.

Sufficient car parking space shall be provided for at least 5 vehicles.

2.13 Substation

The layout and location of Substation and Substation structures and environs shall be selected to minimise their visual impact and to provide the most suitable orientation for the outgoing transmission line.

Ducts conveying power, control and instrumentation cabling from the powerhouse to the Substation shall be suitably sized to facilitate access for inspection and maintenance along their entire length without disruption to the normal vehicular access to other parts of the power station complex or to operation of the Complex. The design of the ducts shall be such that they are maintained in a fully drained and ventilated condition. Openings providing access to ducts through building structures shall be sealed suitably with fire-retarding material that should also prevent ingress of water and vermin from the outside environs.

Generator transformer shall be located in a dedicated bay within the Substation, suitably confined to prevent the spread of fire. The unit shall be mounted on a concrete plinth within an enclosure capable of containing the entire unit oil content and filled with grating system and finished with a covering of stone chippings. All drains shall be valved and routed through suitably sized oil separation tanks.

A 11KV switchgear will be located in the Substation.

2.14 Power Station Environs

2.14.1 Security

Entrance to the Power Station Complex from the access road shall be controlled by security gates and a guardhouse. The guardhouse shall have a clear view of the access road and shall be provided with office furnishings and services for one security officer per shift. Services shall include lighting, small power, ventilation, telephone, water supply, toilet and wastewater to a suitable septic system.

The boundary to the Complex shall be enclosed with a perimeter wire fence with a total height of 2.3 m. There shall be a 10m wide strip outside the fence that shall be clear of bush and trees and landscaped with local short grass in order to provide visibility for security purposes. The substation shall be further enclosed by a fence with a total height of 3.2 m and provided with suitable access gates. All fencing and gates shall be to BS 1722-10 with heavy duty galvanised mesh.

External security lighting shall be provided to the power station, Substation and guardhouse areas and along the perimeter security fence.

All manholes duct and other covers shall be of the lockable type.

2.14.2 Parking

A paved parking area suitable for 5 vehicles within a minimum area of 120 m^2 shall be provided adjacent to the powerhouse building.

2.14.3 Storm Water Drainage

Storm water drains shall comprise trapezoidal perimeter, catch-water and road drains. The storm water drainage system within the powerhouse complex, including the powerhouse, management building and employer's house shall be interconnected with water being disposed of, via existing natural drainage channels, to the Mulembo River. Drains shall be designed with velocities that are self-cleansing.

2.14.4 Water Supply

Water will be supplied by a borehole to the power station complex, including the powerhouse, management building and staff house.

The water shall be treated to comply with the current World Health Organisation 'Guidelines for Drinking Water Quality'.

2.14.5 Sewage Disposal System

An appropriate sewage disposal system shall be provided to treat all sewage arising from the installations of the power station complex, including the powerhouse, management building and employer's house. The system shall be designed in accordance with the requirements of BS 6297 based on a continuous population of 20 people and a time interval for the removal of sludge from septic tanks of at least one year.

2.15 Staff House

The operator's house shall be located close to the power house. It is to occupy a land of size 30m x 20m.

Its architectural features will be similar to those of the power house and the house is to have two bedrooms, a kitchen and a living room. Water supply will be supplied using a borehole while the waste water will be disposed via a septic tank.

The house shall be a masonry-wall building and covered with corrugated iron sheets. The level of safety of all facilities shall be designed according to the Zambia building code.

2.16 Roads

2.16.1 General

Roads shall comprise a single, two lane carriageways having a width suitable to accommodate power station service vehicles.

2.16.2 Power Station Site Roads

Power Station site roads to be constructed shall include roads to the intake /weir, power house, management building, tailrace, staff house. The site roads are to be laid with gravel. Road gradient shall be limited to 10% to enable the transportation of equipment and materials easily within the site. The site road alignments will be as close to the project feature as possible and shall be provided with sufficient drains. Its length shall be about 600m.

During construction of the Facilities roads within the power station complex shall be surfaced with a natural gravel wearing course suitable for the requirements of the construction traffic. On completion of construction activities the road base shall be refurbished.

2.16.3 Power Station Access Road

There is an existing access road which accessible with small vehicles. It is about 15 km from the proposed power station to the main road T2 (Great North Road) 1 small streams.

It shall be reconstructed before the start of the project to allow access by construction vehicles to transport construction and operational plant and materials. These vehicles are invariably large and heavy and will influence the design of the road and the stream crossings.

The new road shall be prepared and surfaced with a natural gravel wearing course suitable for the requirements of construction traffic. On completion of construction activities the road base shall be refurbished.

2.16.4 Drainage Structures

The design of box and pipe culverts and drains shall follow the requirements of Technical Specifications.

2.17 Landscaping

All areas disturbed by construction activities shall be restored to a natural condition by suitable landscaping, top soil spreading, grassing and planting of trees, as appropriate. All Contractor's temporary facilities, including batching and crushing plants, crane foundations, workshops, offices and other buildings shall be removed from site on completion.

Section 3: Technical Specifications – Civil Works Acceptance Testing

3.1 General

To allow commissioning of the overall scheme to occur the penstock systems shall be watered up.

During commissioning, compliance with the following rating curves produced at detailed design shall be demonstrated:

- Intake penstock head loss/discharge curve established by hydraulic calculations
- Tailrace headloss/discharge curve established by hydraulic calculations

Compliance with freeboard requirements shall be confirmed.

- Penstock

Initial watering-up of the penstock system shall be undertaken under slow rates of filling and controlled conditions. The penstock shall be subjected to normal static pressure to check water tightness of welds and joints and allow a full inspection of the penstock system to be undertaken.

Prior to watering-up, the following shall be completed:

- Baseline readings shall be taken of temporary survey points located on each anchor block and on the penstock conduit approximately mid-way between anchor blocks.
- The penstock valves shall be commissioned, tested, and fully operational.
- The interior of the penstock system shall be inspected to ensure that all construction debris has been removed and that all personnel have vacated the interior.
- The exterior of the penstock system shall be inspected to ensure that all manholes (if provided) and valves have been closed and that airways are open.
- The main inlet and by-pass valves in the powerhouse shall have been tested, commissioned and placed in the closed position.

During watering-up the filling rate shall not exceed 1/10 of the design discharge so that air can be more easily removed. This is of particular importance when horizontal or near horizontal sections are to be filled.

To ensure the safety of personnel involved in the inspection programme and to allow problem areas to be identified and quickly acted upon, the filling operation shall be undertaken during daylight hours. If practical, at least 4 to 6 hours of daylight shall be available after completion of filling.

Following completion of the filling process the penstock system shall be allowed to stand for 24 hours prior to any operational testing of the powerhouse equipment. During this time periodic inspections shall be made to identify and resolve any problems.

Inspection checks to be undertaken shall include, but not be limited to, the following:

- Inspect expansion joints/sleeve couplings.
- Inspect equipment (e.g. valves, manholes etc.)
- Surveying of temporary survey points.
- Check for structural cracking or displacement of the penstock support system.
- Check for leaks.

Following completion of the watered-up inspection, checking and operational testing, the penstock system shall be dewatered and structural checks on the penstock support system repeated along with inspections of the internal and external surface protection systems and final readings at temporary survey points.

In the event that any distress, leakage or permanent deformation is detected, remedial measures approved by the Employer shall be implemented and the penstock filling test repeated until complete freedom from signs of distress, leakage and further permanent deformation within C.E.C.T. (Comité Européen de la Chaudronnerie et de la Tolerie - European Committee for Boilermaking and Kindred Steel Structures) limits is demonstrated.

Section 4: Technical Specifications – Outline Civil Works Design Criteria

4.1 Basic Parameters for the Main Features of the Works

Intake:	
Design flow	0.68 m^3/s
Maximum design screen velocity	
Penstock:	
Design flow	0.68 m^3/s
Roofing and Pedestrian Areas:	In accordance with BS EN 12056-3 and BS EN 752 with rainfall run-off amount 0.06 $l.m^{-2}.s^{-1}$ and risk factor 3.0 (Tables 1 and 2 BS EN 12056-3) unless statistical analysis of rainfall is undertaken.
Road and Vehicular Area Culverts and Drains:	In accordance with BS EN 752 with 1 in 50 year return period rainfall. Gravity flow systems shall be used. Culvert design to be in accordance with the UK Design Manual for Roads and Bridges, Volume 4, section 2, Part 7, HA 107/04.
Seismicity:	As defined in Section 4.3 below
Design Life:	
Civil works	100 years
Building structures and works	50 years
Penstocks	50 years

4.2 Concrete Structures

Concrete structures shall be designed for all loads likely to be encountered during construction and whilst in service. Designs shall be undertaken using appropriate factors of safety.

Design assumptions shall be based on the applicable provisions of the current engineering manuals issued by BSI, ICOLD, CIRIA, USBR, ASCE and organisations of similar international standing.

Loading conditions shall be categorised as follows:

(a) **Normal loading** applies to loads that can be categorised as normal operating, long term or repetitive short term.

(b) **Exceptional loading** applies to loads that can be categorised as maximum, minimum, short term, one off, and operating basis earthquake loads applied pseudostatically in addition to normal loading.

(c) **Extreme loading** applies to exceptional loading conditions acting in conjunction with maximum design earthquake loads.

Stability of concrete structures shall be analysed in accordance with the appropriate USACE Engineer Manuals or other recognised analysis and design standards. Structures that retain water or resist water pressures shall be designed to tightness class 2 under BS EN 1992-3.

Safety factors used to assess stability against sliding, overturning, flotation and foundation bearing pressure under normal, exceptional and extreme conditions shall be the ones specified in the applicable standard used in the design.

Detailed reinforcement drawings and bar bending schedules shall be prepared. Reinforcement detailing shall be in accordance with Section 9 of BS EN 1992-1-1:2004. When the structural design for earthquake loading relies on ductile behaviour of structural elements, then anchorage, splicing of bars and shear provision shall additionally comply with current earthquake detailing recommendations. Scheduling of reinforcement shall comply with BS 8666:2005 or equivalent standard.

4.3 Seismic Activity

For the seismic design of a dam project, the two design events motions defined are for serviceability limit state (termed the OBE) and the other for ultimate limit state (termed the MDE). These events are defined as follows:

Operating Basis Earthquake (OBE)

The OBE is the earthquake which is expected to occur in the structure's lifetime. The dam and appurtenant structures should remain functional and damage from the occurrence of earthquake shaking should be easily repairable. It is assumed that the structures will function within the elastic range. There are no fixed criteria for the determination of return period for this event although ICOLD has proposed an average of return period of 145 years (50% probability of being exceeded in 100 years). Industry practice indicates that commonly return periods of 200 or 500 years are adopted. For this project a 200 year return period was assumed.

Maximum Design Earthquake (MDE)

The MDE will produce the maximum level of ground motion for which the dam should be designed or analyzed. It is a requirement that the impounding capacity of the dam be maintained when subjected to this seismic load. For a dam of this size industry practice indicates a return period of 1000 years.

At Chipota Falls different levels of earthquake shaking were adopted for different classes of structure. This is described below.

Operating Basis Earthquake

The adopted OBE event for the appurtenant structures was 1 in 200 years, which relates to a Peak Ground Acceleration (PGA) of 0.045g for the site. This design earthquake load (E) is further factored by 1.5 to determine the ultimate capacity of the structure.

The structures shall also be designed for a Maximum Design Earthquake (MDE) in which case the structures may be damaged but retain their integrity.

Maximum Design Earthquake

The adopted MDE event for the dam and appurtenant structures is 1 in 1,000 years, which relates to a PGA of 0.10g for the site.

For the appurtenant structures only the MDE event (E) is factored as follows $U = D + L + 1.1E/Rm$ where Rm is a moment reduction factor = 1 for shear and thrust and 2 for moment.

The above combination appears to provide a ductility factor of $\mu = 2$ for the appurtenant structures ensuring that any damage will occur in a reasonably ductile (flexural) manner.

For the unreinforced (non ductile) concrete dam structures no reduction in the moments should be allowed for.

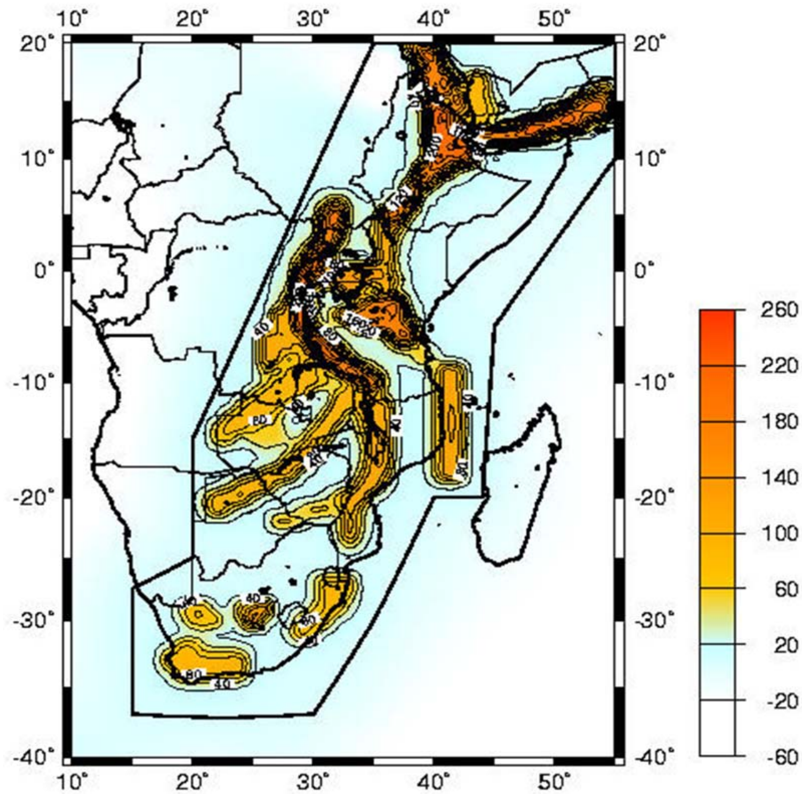


Figure 9: Peak Ground acceleration (PGA) contour map in gals cms-1 for 10% probability of exceedance periods of 50 and 100 years, (after Lombe, 1997)

High values are concentrated along the Zambezi at Kariba to the south ,east African Rift Valley System (EARS) to the east and the Kibaran Belt trending NE-SW to the NW of the country.

Reservoir Induced Seismicity

Because the Chipota Falls reservoir area lies in the Muchinga escarpment area which is quite stable.

4.4 Storm Water Drainage

Design of storm water drainage systems shall use flows computed using the "Rational Method" as defined in BS EN 752.

4.5 Penstock

The design of steel pressure conduits shall be in accordance with the loading cases, design stress levels and other provisions published by Le Comité Européen de la Chaudronnerie et de la Tolerie (C.E.C.T.), in the most recent revision of "Recommendations for the Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydro Electric Installations". Design methodologies for assessing stress levels and practical details shall be in accordance with the following:

(a) Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments, Volume 2 Waterways by the American Society of Civil Engineers (ASCE).

(b) Steel Penstocks, ASCE Manuals and Reports on Engineering Practice No. 79.

Section 5: Technical Specifications - Geotechnical and Preparatory Works

5.1 Site Investigations

5.1.1 General

Preliminary geological surveys were conducted in 2016 for the proposed Chipota Falls Mini Hydro power station project site. A geotechnical survey plan was prepared to obtain sufficient information for the project feasibility stage but no detailed geological evaluation of the foundation conditions and levels, the strength of the rock mass to support the concrete and rockfill structures, sources and quality of construction materials and the groundwater conditions was done.

The Contractor shall undertake any further investigations that he requires in order to complete his design and meet his contractual obligations.

5.1.2 Definitions, Equipment and Procedures

The definitions, equipment and procedures used in respect of all ground investigation activities, in situ testing, sampling and recording of results shall be in accordance with BS 5930 and be carried out using accepted standards of engineering practice.

5.2 Drilling and Grouting

5.2.1 Definitions

The following terms whenever used in this section shall have the following meanings:

"Depth" means the distance measured from the start of the hole regardless of direction.

"Stage" means a partial or complete length of hole in which grouting is performed.

"Grouting in descending stages" means drilling to a limited depth, setting a packer and grouting the hole, permitting the grout injected around the hole to set sufficiently to prevent its entering the hole when the hole is cleaned, cleaning out the hole, drilling to a deeper stage, setting a packer at the bottom of the previously grouted stage, grouting the new stage; and thus continuing in as many cycles of drilling and grouting as are required.

"Grouting in ascending stages" means drilling a hole to the full depth in one operation and grouting from the end of the hole towards the surface in successive stages by setting the packers at predetermined depths.

"Split-spacing" means the system of locating an additional grout hole approximately midway between two grout holes which have previously been drilled and grouted.

"Curtain grouting" means grouting of rock in one or more lines of holes spaced to form a curtain barrier.

"Blanket grouting" means drilling and grouting of rock with a pattern of holes spaced, drilled and grouted as directed in order to achieve grout saturation throughout the rock contained in the volume treated.

"Primary holes" are initial grout holes drilled at suitable spacings before any grouting has taken place.

"Secondary holes" are holes drilled midway between primary holes and parallel thereto.

"Tertiary holes" are grout holes drilled midway between adjacent primary and secondary holes and parallel thereto.

"Cavity grouting" means grouting to fill any voids at rock/concrete interfaces around structures.

"Contact grouting" means grouting to fill any voids at steel/concrete interfaces.

5.2.2 General

The following Clauses relate to certain methods of geotechnical ground treatment. Where the ground treatment proposed by the Contractor relates to a method not specifically referred to in these clauses, precise details of all materials and methods shall be provided in a Supplementary Technical Specification to be prepared by the Contractor. Methods and techniques that this would apply to include the following:

- Consolidation grouting, generally in underground works;
- Cavity grouting around concrete and steel lined conduits and certain concrete structures including any necessary drilling of grout holes;
- Skin grouting around the penstock steel liners, the steel frames of gates and similar hydraulic steel structures controlling the discharge of water and around other areas where steel linings etc. are set in the surface of the concrete;
- Grouting into preformed holes or pipes placed into concrete work for any reason;
- Grouting to control water seepage;
- Diamond core drilling to investigate the state of rock, either from the ground surface or ahead of the excavated face in underground works;
- Drilling cored check holes to determine the results of grouting operations and grouting such holes;
- Water testing grout holes and check holes;

- Foundation Grouting;

Wash water and waste grout resulting from all grouting operations shall not be allowed to contaminate any fill, backfill, steel lining or other permanent Facilities, and such water or grout shall not be allowed to flow into any watercourse until it has passed through settling ponds or tanks.

Where hazardous materials are used in grouting operations, the Contractor shall demonstrate, with appropriate testing, that these materials are not escaping to the surface or entering water courses and will not have any deleterious long term effect on the environment.

In hot climates precautions shall be taken to reduce the possibility of premature setting of grout through overheating. The consistency and temperature of the grout shall be checked using flow cones and thermometers.

5.2.3 Materials

Grout for injection under pressure into rock shall consist of cement, water and, where required, sand, pozzolan, bentonite or other additives.

Cement for grouting shall be as specified for concrete.

Water for grouting shall be as specified for concrete.

Sand for grouting shall be as specified for fine aggregate for concrete except that all particles shall be finer than 1 mm.

When bentonite is used for grouting it will normally be used in the range 2-7 per cent by weight of cement. Bentonite for grouting work shall be the sodium montmorillonite type and shall be as specified by the American Petroleum Institute. Bentonite must be mixed thoroughly with clean water before cement is added to form the grout. It may be necessary to have a special mixer when bentonite is used to avoid difficulty in mixing this very fine-grained material.

5.2.4 Equipment

5.2.4.1 Drilling Equipment

Drillholes may be drilled with either rotary type diamond drills or percussion type drills provided that, where holes satisfactory for subsequent grouting cannot be drilled by percussion type drills, rotary type diamond drills shall be used.

The drilling equipment shall be capable of drilling at any angle, of being set up to an accuracy of 1° and of drilling to an accuracy of 3°.

5.2.4.2 Grouting Equipment

Grouting equipment shall be capable of effectively batching, mixing and maintaining grout mixtures in suspension as specified, and of delivering and pumping grout into the grout holes and concrete joints through grout connections in a continuous uninterrupted flow at any constant pressure up to the limiting pressure required.

The arrangement of the grouting equipment shall be such as to provide a continuous circulation of grout of uniform consistency throughout the grouting system and to permit accurate pressure and flow control at the collar of the hole being grouted at all rates of grout acceptance.

5.2.5 Drilling

5.2.5.1 General

Holes shall be drilled from within 150 mm of the stipulated locations and grouted in stages. Casing of the hole is to be expected when drilling through loose overburden or difficult ground. In cases where water loss occurs during drilling, or for other reasons, holes may be grouted in descending stages.

Lubricants or other additives to drilling water shall not be permitted as an aid to drilling grout holes or check holes except as a combined air/water flush for deep holes.

Where packers are to be used in any hole for grouting or water testing, every precaution shall be taken to maintain a smooth wall in the hole in order that packers can be set at any location and seal the hole in the required fashion.

5.2.5.2 Holes in Structures

Where holes are required through concrete these shall be preformed, through which the rock behind can be drilled. If, however, holes are drilled through concrete and steel reinforcement is encountered drilling shall be discontinued immediately and new holes shall be drilled nearby. Holes shall be backfilled with concrete or mortar and the surface repaired. No drilling shall be carried out in concrete less than 7 days old.

5.2.5.3 Cored Check Holes

Cored check holes to check the effectiveness of grouting operations shall be drilled within the range of the adjacent grout holes.

5.2.5.4 Core Drilling

When diamond core drilling is being carried out, best practise techniques such as triple tube core barrels, face discharge bits and foam flush shall be used where appropriate. The rods shall be withdrawn and the core removed as often as is necessary to recover the maximum amount of core. The cores from such holes shall be packed in sequence in boxes. The boxes and their contents shall be adequately labelled to identify the hole location. Soils should be sealed where appropriate.

5.2.6 Water Testing

In conjunction with the drilling and grouting operations, water tests shall be carried out in grout holes and check holes to determine the permeability of the rock and the effectiveness of the grouting operations.

Water tests shall be conducted immediately after drilling each stage has been completed in all curtain grout holes, cored check holes and in holes for cavity grouting.

5.2.7 Particular Requirements for Cavity and Contact Grouting

5.2.7.1 Contact Grouting

During all grouting around steel linings, hydraulic gate frames etc., grouting pressures shall be controlled and the internal surface of the lining continuously monitored so that grouting can be stopped if any localised pressure causes the steel to deflect.

Following installation and encasement of any steel lining, a low pressure grouting operation will be required over the full length of the lining, or lesser length depending on void sounding tests, to seal any voids at the steel/concrete interface. No drilling will be required for this operation but grout nipples will be required to suit and protect the grout sockets.

Grout sockets in steel linings will generally be arranged so that it should be possible for grout to flow from one socket to another behind the lining.

Sockets shall be grouted at low pressure with adjacent holes being capped after the emerging grout has displaced any water from behind the lining and the pressure has been brought up to the required value.

Grouting will start with a water test to gauge the size of the cavity and lubricate the concrete/steel interface; and will proceed starting with a thin mix which will be thickened once interconnections between sockets have been established.

Where sounding tests indicate that there are still voids behind the steel despite grout refusal at an adjacent socket, the lining shall be drilled and further grout sockets installed and grouted.

If a pipe has been cast into the concrete to facilitate future cavity grouting, the pipe shall be plugged during the contact grouting. The plug shall be removed and the pipe flushed out as soon as the contact grout has taken up its initial set.

5.2.7.2 Cavity Grouting

The rock/concrete interfaces around concrete surface structures shall be grouted from within. Normally, it will be required to drill 300 mm into the rock prior to grouting.

In the case of areas faced with steel, cavity grouting will normally be carried out after contact grouting of the steel/concrete interface. Packers shall be used to prevent grout pressure being applied to the steel lining.

5.2.8 Repair and Clean-up

Concrete surfaces and foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition.

Upon completion of the grouting and checking of any area, the holes shall be washed and then backfilled with a thick grout mix.

On completion of grouting in areas of concrete with a steel lining which is to be painted, the steel surface shall be cleaned to a condition suitable to receive paint when dry. In order to minimise damage to earlier protective coatings, this cleaning work will normally be carried out by the supplier of the steel lining.

5.2.9 Records and Progress Assessment

Records of the drilling, grouting and water pressure tests, pressures, flow rates, the quantities used in the grouting operations and any other general records shall be kept. These will be required for the control of the grouting operation and shall therefore be available for inspection by the Employer at any time. The Contractor shall detail the procedures which will be undertaken in order to record and assess the progress of the grouting works in the Quality Plan.

The Contractor shall, in a manner prescribed by the Employer, keep records of the drilling for grouting, the quantities used in the grouting operations and any other general records required by the Employer, and shall submit such records daily in duplicate to the Employer. The presence of the Employer's inspector keeping a record of the operations shall not relieve the Contractor of his responsibility to produce these records.

The Employer will keep technical records of the grouting operations and the Contractor shall render such co operation and assistance as is necessary in this regard, as directed by the Employer.

5.3 Preparatory Works

5.3.1 Site Clearance

Trees, bush and vegetation shall be cleared from areas to be occupied by the permanent structures required for the Facilities. Topsoil shall be stockpiled for re-use.

All borrow areas and other areas where it is intended to use the material below for construction purposes shall be cleared by removing all trees, roots, stumps, topsoil, vegetable matter and other debris which is unsuitable for fill.

At borrow areas topsoil shall be set aside and replaced on completion of the Facilities.

Clearance for temporary facilities shall be kept to a minimum.

Material shall not be left lying around just outside the periphery of the area to be cleared, but shall be properly disposed of or removed completely.

Felled timber shall not be allowed to float down the river.

5.3.2 River Control Cofferdams

The cross-section and the materials used in the construction of the cofferdams shall be as shown on the Drawings. Materials for constructing embankment type cofferdams may be obtained from either nearby borrow areas subject to the approval of the Employer or required excavations to form the Facilities. Cofferdam foundations shall be shaped to reasonably smooth contours before placing cofferdam fill.

The Contractor shall be responsible for taking such precautions as are necessary to avoid overtopping of the cofferdams and to prevent or minimise damage to the permanent Facilities or to downstream properties.

The Contractor shall be responsible for the adequacy of all cofferdams and for any damage resulting from the failure or washing out of cofferdams, except as hereinafter provided.

5.3.3 Gabions

5.3.3.1 General

Gabions shall be constructed to protect excavated slopes or elsewhere as directed by the Employer. The gabions shall comprise selected rock fragments packed into wire baskets pre formed to the shapes and sizes required.

The gabion baskets may be either made up on Site, and assembled in accordance with manufacturer's instructions or supplied by local agents of manufacturers specialising in this item.

5.3.3.2 Baskets

All wire for baskets and tying shall be manufactured in compliance with BS 1052 and shall be galvanised in compliance with BS EN 10244-2.

The mesh for gabion baskets and diaphragms shall be welded steel fabric of mesh size not exceeding 100 x 100 mm and wire diameter not less than 2.5 mm. The same wire size shall be used for selvedges, edge binding and bracing wires. Wire for connecting baskets together shall be 16 gauge (metric).

Adjacent baskets shall be wired together before placing the rock.

Gabion baskets more than 1 m long shall have mesh diaphragms such that no compartment is more than 1 m long.

Wire baskets made on Site shall be bound, tensioned and stitched to contain the rock fill and all openings closed off to ensure that rock particles cannot be dislodged. Unless otherwise agreed, gabion baskets made up on Site shall not exceed 2 m long x 1 m x 1 m.

Pre manufactured standard gabion baskets shall have overall dimensions as follows:

Type A -	2 m x 1 m x 1 m
Type B -	3 m x 1 m x 1 m
Type C -	4 m x 1 m x 1 m
Type D -	2 m x 1 m x 0.5 m
Type E -	3 m x 1 m x 0.5 m
Type F -	4 m x 1 m x 0.5 m
Type G -	6 m x 2 m x 0.3 m

The ends, sides and internal diaphragms of gabion baskets shall be securely wired up with the correct binding wire. The basket will then be positioned on a prepared working platform.

Wiring of baskets shall start at the top by securing the end of the wire by twisting it around the selvedge and lacing the two edges together, passing the wire around the vertical selvedges and through each mesh in turn. The binding wire shall be secured at the bottom.

Each unit shall be wired securely to all adjacent units along all the selvedges and, where applicable, to adjacent concrete.

It is essential that tightness of the mesh is achieved. This can be done by securing one side of the empty basket to stakes driven into the ground and then stretching the bottom and the opposite side of the gabion by means of a stake in each corner of the basket secured at the bottom and pulled back by guy wires. The undersides of the baskets should be propped during filling.

5.3.3.3 Rockfill for Gabions

Rockfill for use in the gabion baskets shall be obtained from quarries established by the Contractor or from other approved sources. Rock pieces shall be of competent, fresh, approved rock graded in size within the range 250 mm to 100 mm with at least 60 per cent of the total not larger than 150 mm. The individual pieces shall be sound, hard, dense and durable.

5.3.3.4 Filling of Gabions

The rock shall be hand placed and packed to form a dense fill with a minimum of voids.

Vertical bracing wires shall be provided between bottom and top wire meshes at nominal 500 mm centres. Each vertical bracing wire shall be kept straight during the filling and securely fastened to the top mesh. On gabions which are more than 1 m thick, horizontal bracing wires shall also be introduced. Rock filling shall proceed to one third of the total height, when two horizontal bracing ties per metre will be positioned, then to two thirds of the height, when a second set of horizontal ties will be positioned. Filling may then be completed.

Gabion baskets should be filled to a level of 25 to 50 mm above their tops, the last 75 to 100 mm being in the smaller rock sizes.

The lids of the gabion baskets are then to be tightly stretched over the filling using a crow bar, and securely wired down.

5.3.3.5 Mattress Units

Mattress units shall be laid so that the movement of rock inside the mesh due to gravity or flow of water is minimised. Unless otherwise directed, units on side slopes shall be placed with the long side at right angles to the direction of the slope, and on inverts with the long side at right angles to the direction of flow.

5.3.3.6 Repairs

Repairs to gabion baskets shall be undertaken by preparing and fixing replacement wire mesh panels over any damaged panels.

Where gabion fill has been lost, new fill shall be placed as directed by the Employer.

5.3.3.7 Separation Geotextile

To prevent loss of fine fill material, a separation geotextile shall be placed between gabions and fill materials as indicated on the drawings.

The separation geotextile shall be 400g/m^2 non woven needle punched polypropylene fabric or equivalent and shall be installed in accordance with the manufacturer's instructions.

Section 6: Technical Specifications - Excavation and Filling

6.1 General Excavation Clauses

6.1.1 Scope

These clauses cover general excavation including excavation in borrow areas, excavations for structure foundations and excavation in cuttings down to formation level for roadworks.

The following are dealt with in other Parts of this Section:

- Requirements specific to excavation in rock;
- The preparation of excavated surfaces in particular areas of the Facilities immediately prior to the next stage, such as placing fill; and
- The quality of materials required for filling.

6.1.2 Definitions

The following definitions of earthworks materials shall apply to this Specification:

(a) 'Top soil' shall mean the top layer of soil that will support vegetation.

(b) 'Suitable material' shall comprise all material other than "unsuitable material".

(c) 'Unsuitable material' shall include:

(i) Material from swamps, marshes and bogs (wet muddy ground too soft to support a heavy weight);

(ii) Peat, logs, stumps and perishable materials;

(iii) Materials susceptible to spontaneous combustion;

(iv) Clay of liquid limit exceeding 90 and/or plasticity index exceeding 65 both determined in accordance with BS 1377 Part 2;

(v) Materials having a moisture content greater than the maximum permitted for such materials in the Contract, unless otherwise permitted by the Employer;

(vi) Materials containing chlorides, sulphates or other chemicals in quantities which will be injurious to the Facilities;

(vii) Refuse and man-made materials.

(d) 'Rock' shall mean geological strata or deposits and any hard natural or artificial material requiring the use of blasting or approved pneumatic tools for its removal.

(e) 'Artificially hard material' shall mean placed material such as foundation bases and buried previous works encountered, requiring the use of approved pneumatic tools for its removal.

(f) 'Hardcore' shall consist of hard dry stone, broken concrete blocks and bricks, coarse gravel or other sound hard material approved by the Employer. It shall not exceed 100 mm in any dimension, be free from clay, dust, rubbish, wood, harmful chemical substances and other deleterious matter and be graded so that when compacted, filling is dense without voids.

6.1.3 Dewatering of Excavations

Excavations shall remain free from water, irrespective of its source, to the extent necessary for the execution of the Facilities and in the interests of safety.

6.1.4 Adjustment of Methods to Suit Grading Requirements for Fill

When the Contractor is required to produce different materials from excavations for re use in the Facilities, he will be required to adjust his excavation and blasting techniques in order to produce material of suitable grading.

6.1.5 Remedial Work

Any damage resulting from the Contractor's operations during excavation, including damage to foundations and excavated surfaces, shall be repaired at the expense of the Contractor and to the satisfaction of the Employer.

6.1.6 Safety of Excavations

Precautions shall be taken to ensure the stability and safety of all excavation works and methods of construction including temporary support of excavated surfaces, diversion of water, pumping etc. Safety provisions shall comply with Zambian law and internationally recognised regulations.

Where a permanent excavation reaches rock, a horizontal bench shall be provided at the interface. The width of the bench shall be such as is necessary for safety reasons. Furthermore in Class 2 material where excavation exceeds 10 m in depth, 1.5 m wide horizontal benches shall be excavated at maximum vertical intervals of 10 m.

Handrails, toeboards and all necessary temporary supporting works such as timbering, shoring, anchorages and the like shall be installed wherever such support is required.

Timbering and shoring shall be so designed and constructed that if necessary it can be inserted as excavations proceed and safely withdrawn as backfilling is raised. Walings and struts shall be suitably positioned to permit pipes and other materials to be installed in the excavations. No temporary supports shall remain in excavations after backfilling.

6.1.7 Classification of Excavated Material

Excavation shall be classified for payment purposes only as follows:

(a) **Class 1**: All soil overburden, weathered and shattered rock, or cemented sand in river terrace areas and other material which can be removed by hand, by single shank ripping and bull dozing with a track mounted tractor at least equivalent to a Caterpillar D8L in weight and horsepower or, in confined areas, by a mechanical excavator equivalent to a Caterpillar 325 L fitted with a 1 m wide rock bucket.

(b) **Class 2**: Rock and artificial hard materials which cannot be removed effectively by the methods described in (a) above and which normally require recognised rock excavation methods such as drilling and blasting or use of hydraulic breakers.

6.1.8 Limits of Excavation

6.1.8.1 General

The surfaces exposed by open cut excavation against which concrete is to be placed shall be excavated to predetermined lines and levels. No material shall remain within the outline of structural concrete.

6.1.8.2 Excavation Beyond Limits

If excavation is carried out beyond predetermined lines and levels, backfilling shall be done with concrete or material similar to the fill to be placed against the excavated surface. The concrete used for filling excessive excavation shall have quality/strength sufficient to comply with the bearing load necessary for the foundation excavation for the structure. Beneath load bearing structures, foundations and other reinforced concrete work, the filling to any over-excavation shall be of the same quality concrete as that required for the associated concrete structure.

6.1.9 Sources of Fill Materials

The Contractor shall obtain the necessary fill materials for construction of the Facilities from borrow areas, quarries or other areas approved by the Employer.

The Contractor shall undertake all sub surface investigations, sampling and testing necessary to assess the suitability of materials for use as fill. The Contractor shall keep accurate records of any test pits, trenches or drillholes which he makes for the purpose of investigating fill materials.

6.1.10 Operation of Excavations and Borrow Areas

All excavations and borrow areas shall be cleared, grubbed and stripped. The top 200 mm of topsoil and a further 600 mm of sub-soil shall be separately stored and shall be returned in neat uniform layers to borrow areas and other areas disturbed by construction activities which will be visible on completion.

Borrow areas shall be reinstated by grading slopes to less than 45°, re-vegetation where topsoil can be stockpiled before construction, and removal of all construction equipment, including foundations, rendering quarry areas safe.

6.1.11 Use of Material from Excavations for the Facilities

6.1.11.1 General

Depending on its nature and quality, excavated material, including that from underground works, will either be:

- re-used as fill or backfill
- re-used to produce graded aggregate
- stockpiled as directed for re-use by others if surplus to the requirements of this Contract.
- taken to spoil.

The Contractor shall select materials as required and use his skills to avoid unnecessary waste of potentially usable materials.

6.1.11.2 Material for Re-Use

The Contractor's design shall maximise the re-use of excavated material elsewhere in the Facilities. The Contractor shall ensure that his excavation techniques result in material suitable for the particular re-use requirement.

In order to achieve particular materials the Contractor shall be prepared to select materials to different stockpiles, which he must maintain in an uncontaminated condition. Any contaminated material shall be abandoned and replaced.

In the case of rock for re use, the Contractor's blasting techniques shall produce rock fragments of suitable gradings. Secondary blasting shall be applied to oversize fragments. If in the opinion of the Employer the Contractor's rock excavation techniques and progress are not satisfactory, the Employer will require the Contractor to take expert advice on methods of blasting to ensure that the requirements are met or to revise his excavation programme.

6.1.12 Requirements Specific to Excavations for Particular Parts of the Facilities

6.1.12.1 Trenches, Manholes and Confined Foundations

Confined and narrow excavations, such as for trenches and manholes, shall be excavated with particular care and attention to adequacy of temporary strutting. Continuous dewatering may be necessary in water-bearing ground. Appropriate measures shall be taken when entering confined spaces such as manholes.

6.1.12.2 Structures

Excavation shall be carried out such that concrete and other structures may be formed to predetermined lines and levels. Dimensions shall be increased above the minima required in the interest of safety. In the course of the excavation work, the surrounding material shall be preserved in the soundest possible condition.

Excavated surfaces which will remain permanently exposed shall be finished off in a neat and workmanlike manner and graded to provide adequate drainage. Rocky material liable to become detached from such surfaces shall either be removed (and holes backfilled where practicable) or anchored.

Excavated surfaces on or against which concrete structures will be cast shall be trimmed so that there are no projections within the permissible limits and cleaned to remove loose soft or foreign materials by hand, air and water jets or other effective means. In situ concrete structures shall be cast against the excavated side surface in Class 2 material. Thus, when excavating in Class 2 material, excavation lines shall be kept as close as possible to the actual structural requirements.

6.1.12.3 Roads

The Contractor shall so order his construction programme that the timing of the excavation, culverts and drains does not adversely affect earthworks operations.

In swampy or waterlogged areas, the Contractor shall construct his haul roads, cut drains and ditches, and carry out any other work necessary to assist in draining the ground or otherwise to facilitate subsequent fill placing in earthworks operations.

6.1.13 Disposal of Excavated Material

Material which has to be excavated in order to execute the Facilities, but is unsuitable for construction purposes, shall be kept separate from other materials and not allowed to cause contamination of material required for use in the Facilities. Such unwanted material shall be disposed of by spreading the material in layers in designated spoil areas. The material shall be compacted to the maximum practicable extent by routing the haulage traffic over the area. Permanent spoil areas visible after completion shall be shaped to follow existing contours such that the tips blend in with the local topography. Such disposal areas shall be kept neat and tidy. Surfaces shall be finished and graded to the extent necessary to provide surface drainage, and grassed to prevent future erosion of the materials.

Disposal areas for unsuitable material encountered in borrow areas will be within or adjacent to the borrow areas.

6.1.14 Dust and Noise Prevention

Water bowsers, hoses etc. shall operate routinely as necessary to prevent the production of excessive quantities of dust. These measures shall be augmented near to occupied buildings and dust-sensitive areas.

Masks and ear mufflers shall be available to those personnel engaged on drilling, operating inherently noisy equipment and other work entailing long-term exposure to dust and noise and the consequent danger of contracting ill effects therefrom.

6.1.15 Specialised Sub-Surface Activities

Supplementary Technical Specifications shall be produced by the Contractor for specialised sub-surface activities (e.g. sheet piling, caisson construction).

6.2 Drilling and Blasting

6.2.1 General

The use of explosives shall at all times be in all respects in accordance with BS 5607, or equivalent, and relevant Zambian regulations. The more stringent regulation on any particular topic shall prevail.

Where there is a possibility of shattering the rock to an unacceptable degree or damaging concrete already placed, blasting shall cease and alternative methods shall be used.

No bench height in rock shall exceed 6 m. Blasting shall be carefully controlled to preserve the rock beyond the required lines and levels in the soundest possible condition by such means as limiting the size of the charges, varying the size and spacing of the drill holes, and using delays. Any unstable or shattered material beyond such lines and levels shall be removed immediately.

6.2.2 Communications

Site telephones or radios shall be used to ensure that the personnel in charge of each area where explosives are being used can at all times communicate effectively and rapidly with the central site management office. Radio signal strengths shall have no influence on the performance of electrical detonators.

6.2.3 Blasting near Other Works or Structures

Blasting charges shall be kept to a minimum at all times to prevent damage to existing structures or plant and equipment and to new works or future excavations.

For buildings and structures, the criteria to be observed to prevent damage shall be the limitation of peak particle velocity (PPV) of the shock wave at the structure. For plant and equipment the criteria shall be the limitation adjacent to the equipment of acceleration and amplitude. Arriving shock waves shall not exceed the following:

Structure	Peak particle velocity (mm/s)	Acceleration	Amplitude (mm)

Building containing operating electro-mechanical plant	10		
Operating plant or equipment	-	0.2 g	0.25
All other buildings and concrete on site, existing or under construction	50		
Previously grouted rock or shotcrete in permanent structures	50		
Excavations under construction and constructed fills	100		

During operations on Site, the size of instantaneous charge weights and total blasts shall be reduced where the possibility exists of sympathetic detonation, either through water or along joints and weathered seams in rock, particularly where water-bearing.

Where the level of shock waves is anticipated to approach the maximum limits specified, instrumentation to monitor the shock waves reaching structures, plant and equipment shall be provided. All recordings of shock waves shall be made available for inspection on request and shall not exceed the specified limits.

Blasting within 15 m of any fill or building or concrete or shotcrete previously placed in any permanent structure or any previously grouted rock will only be undertaken when instrumentation to monitor the shock waves has been set up.

Where blasting is required within this 15 m limit, the weight of explosive instantaneously detonated by each delay shall be restricted.

In the event of monitoring instrumentation not being operable for any reason blasting shall be restricted or prohibited in the vicinity of the adjacent works or existing structures.

6.2.4 Production of Accurate Final Profiles in Open Excavation

6.2.4.1 General

Pre-splitting or line drilling techniques shall be used for faces at angles of 30^{o} or more to the horizontal excavated in the open in hard rock which will be permanently exposed. Such methods shall also be considered for areas which will be covered with concrete or sprayed concrete.

Trim blasting shall be used on all horizontal surfaces or faces sloping at less than 30^{o} to the horizontal at the bottom of rock excavations required for concrete structures or unlined channels.

6.2.4.2 Pre-Splitting

Pre-splitting comprises drilling a line of holes of appropriate diameter, spaced at centres not more than 10 hole diameters or 500 mm, whichever is the lesser, and charging the holes with the minimum amount of explosives to split the rock in a surface along the line of drill holes. The drilled holes are charged lightly at intervals along their length.

Either all holes in a pre-split 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 pre-split holes to fire first. The first row of production holes adjacent to the pre-split face shall be lightly charged to ensure that no damage occurs to the pre-split face when the main charge is detonated.

6.2.4.3 Line Drilling

Line drilling comprises forming excavated rock faces by drilling a single line of closely spaced holes not less than 50 mm in diameter in the plane of the required rock surface to provide a plane of weakness along which the rock will break. The distance between the centres of holes for line drilling shall not be greater than 6 hole diameters and such holes shall be drilled at closer spacings down to 2 hole diameters if required to achieve satisfactory fragmentation on the desired plane.

Blasting will not normally be permitted in line drilled holes and only light charges for blasting will be permitted in the first row of production holes adjacent to line drilled holes.

6.2.4.4 Trim Blasting

Trim blasting comprises separate removal of a protective zone of rock which has purposely been left within the required limits of excavation for flat and sloping areas. Drilling for trim blasting shall consist of a regular pattern of parallel holes drilled at centres not greater than 1 m with holes dipping at approximately 60° to the final required surface.

The holes shall be lightly charged and detonated in relays to lift the rock progressively and form the final excavated surface.

The thickness of the protective zone in which trim blasting takes place shall be 1 m.

6.2.5 Stability of Exposed Rock Faces

The Contractor's support measures shall be approved by the Employer. Such approval will not relieve the Contractor of any of his contractual responsibilities.

As rock excavation proceeds, the Contractor shall scale and remove from the surfaces of any excavation all loose, overhanging or otherwise dangerous rock. Permanent excavated slopes shall be carefully scaled to stabilise the surfaces to the satisfaction of the Employer, and berms shall be maintained free of fallen rock.

Additionally, natural and excavated surfaces of rock shall be supported by the most appropriate of rock bolts, gunite or shotcrete where required or approved by the Employer. Temporary support measures shall be applied as soon as possible after excavation and in any case within 2 days of agreement that they are required.

The general intention is that rock bolts will be used where necessary to tie back unstable rock. However, ground anchors may be required in locations requiring greater restraint.

Whether the support measures are to be of a temporary or permanent nature shall be agreed beforehand with the Employer.

For permanent applications sprayed concrete shall include mesh and be associated with rock bolts.

6.3 Preparation of Excavated Surfaces

6.3.1 General Procedures

6.3.1.1 Procedure for All Surfaces

As a general rule, foundation areas upon which fill is to be placed without any special measures are to be of material of at least equal competence to the initial layer of superimposed fill material.

After completion of excavation the exposed surfaces shall be cleared of all loose, softened or otherwise unsuitable material.

Where filling or concrete is to follow, such work will be carried out immediately before covering the excavation. All necessary measures to prevent any subsequent damage to or contamination of a cleaned and prepared surface shall be taken, and the surface shall be maintained in an acceptable condition until the commencement of the next stage of work.

Cleaning of foundation surfaces to the extent that they can be mapped geologically, followed by mapping, following by further cleaning and preparation in advance of fill or concrete placement.

6.3.1.2 Further Procedures for Class 1 Materials

Where the surface exposed at foundation level is Class 1 material suitable to receive whatever is to be placed upon it, no further treatment will be required.

Where, however, the replacement of unsuitable material below the nominal founding level is required, the foundation shall be brought back to the correct level. The replacement material will depend on the type of works concerned.

6.3.1.3 Further Procedures for Class 2 Materials

Where grouting is to be carried out, exposed surfaces shall be cleaned of all loose material and loose rock shall be scaled and removed. Such cleaning will be required prior to grouting so that grouting can proceed efficiently and all surface leaks can be located and quickly plugged. On completion of grouting, the surface shall again be cleaned of all loose material and loose mortar shall be removed. It is expected that an air/water jet will be necessary to achieve the required standard. The surfaces shall be left in a condition sufficiently even to allow compaction where fill is to be placed on the surface.

Where the surface is to be prepared to receive fill or concrete, surface cracks, crevices and fissures shall be cleaned by using hand tools, air hoses and water jets to remove loose material to a depth where sound material is encountered or until the depth cleaned out is at least four times the width of the surface opening, whichever is the lesser. After cleaning, the surfaces shall be prepared using appropriate methods.

6.3.1.4 Slush Grouting

Grout for slush grouting shall consist of cement and sand thoroughly mixed in the proportions of 1 part cement to 3 parts sand by volume, with sufficient water to produce a mixture which can be poured and broomed into cracks and fractures in the surface of rock to fill completely all open joints, crevices and minor imperfections in the rock surface.

After completing the slush grouting, either water shall be applied to keep the surface continuously wet or the slush grouted area shall be covered with polythene or hessian and kept damp for a period of not less than 7 days.

6.3.1.5 Dental Concreting

Dental concrete required for profiling the rock surface and infilling larger cavities or fissures in foundations shall be Class 20 to 40. Concrete shall be shovelled into cracks and fissures and compacted by small vibrators, or hand punned where vibrators cannot be used. The surface of the concrete shall then be trowelled smooth. Thin layers or feather edging will not be permitted and edges of dental concrete shall be finished by forming a small fillet at 45° to the rock surface. On completion the Contractor shall keep traffic away and cover the area with polythene or damp hessian such that the concrete surface remains damp for 7 days.

6.3.2 Particular Requirements for Concrete Structures

Where the excavated surface is Class 1 material the procedure shall be as already described.

Where the excavated surface is Class 2 material, such measures as brushing, washing and air hosing to clean the surfaces shall be employed. After completion of excavation and any necessary foundation grouting and support of side slopes etc. required at this stage the surfaces shall be prepared as already described except that slush grouting will not normally be used for structures. Where overbreak below foundation level occurs, backfilling shall be carried out using concrete having the same grade as that of the adjoining part of the structure.

6.3.3 Particular Requirements for Roadworks

Methods and materials shall comply with the following:

- South African Transport and Communications Commission – Code of Practice for the Design of Road Pavements, Division of Roads and Transport Technology, July 2001.
- South African Transport and Communications Commission - Standard Specifications for Roads and Bridge Works, Division of Roads and Transport Technology, July 2001.

6.3.4 General Requirements for Placing of Fill

6.3.5 Scope

These Clauses give requirements which are common to all permanent earthwork fill areas. However, for roads particular additional requirements will apply as described in clauses which follow after this Part of this Section.

The following clauses cover all necessary subsequent operations leading to and including compaction of fill materials.

6.3.6 Methods and Equipment

Storage and transport of materials shall be such that they do not segregate and that they arrive at the point of deposition fit to be spread and compacted, subject only to any necessary final moisture conditioning.

Adequate survey control shall be provided.

6.3.7 Materials for General Filling

6.3.7.1 Unsuitable Material

Unless otherwise indicated material will be classified "unsuitable" for filling if it is:

(a) clay or silt of organic content exceeding 12% under Test 8 of BS 1377 for roadworks;

(b) clay having a liquid limit exceeding 90 and/or plasticity index exceeding 65;

(c) susceptible to spontaneous combustion;

(d) domestic or industrial refuse and any other material which, by virtue of its physical or chemical composition or moisture content, will not compact to form a long term stable fill;

6.3.7.2 Suitable Material

"Suitable Material" shall comprise all that which is acceptable in accordance with the requirements of the Contractor's design and will compact to form a long term stable slope. Where grading envelopes are given, the material shall lie within the grading zone required for the proposed location and shall moreover have a grading curve reasonably parallel to the given envelope ie it shall be neither gap-graded nor single-sized except where specifically required by the design.

6.3.8 Backfilling and Minor Fill Areas

6.3.8.1 Scope

These Clauses cover backfilling but also apply to minor earthworks and embankments, such as dozed bunds for landscaping, which will not be subjected to continual imposed loads after completion. Particular clauses will follow when the Contract includes earthworks which are subject to such loads, i.e. road embankments.

6.3.8.2 Materials

Backfilling of areas excavated to remove unsuitable material below formation level shall normally be with Class 1 material. In marshy areas suitable methods shall be employed to produce a surface which will remain stable when fill is placed on it and compacted.

Fill material used for work described in this Part of the Specification shall be approved Class 1 material free from large clods, large rocks, rubbish and other unsuitable material. Where free-draining material is required, all layers thereof shall be of consistent quality.

Backfill material shall normally be selected from excavated material at the Site which has been set aside for this purpose. When suitable backfill material cannot be obtained in this manner, it shall be obtained from another borrow source and brought to the Site.

6.3.8.3 Procedure

Unless otherwise agreed with the Employer, backfilling shall be carried out in layers not exceeding 150 mm after compaction. Each layer containing cohesive materials shall be watered to the approximate optimum moisture content and thoroughly compacted uniformly over the full area of each layer to the density of the surrounding ground. Unless otherwise instructed, vibrating plate or similar compaction equipment shall be used in confined areas. Where appropriate the final layer of backfill shall be neatly finished to accord with the surrounding ground levels and any settlement which occurs shall be made good by re compacting and the addition of further compacted backfill.

In areas where fill is built up above the surrounding ground level, compaction shall be effected by routing bulldozers, haulage traffic etc. uniformly across the whole area until it is clear that no further compaction is being obtained.

Care shall be taken to ensure that the type of material, the method of compaction and the arrangement of the work do not cause any damage to structures. Rockfill shall not be used adjacent to structures.

6.3.8.4 Special Compaction

In areas which are inaccessible to the normal compaction equipment or which require special compaction for other reasons, eg around structures or instrumentation, special hand or other suitable compactors shall be used to achieve the desired compaction. In general such compaction shall be used near concrete structures, against irregular rock surfaces or in zones of very limited area. The fill shall be forced into all irregular depressions and corners.

Where special compaction is required, the fill material shall be placed in layer thicknesses not exceeding 150 mm. Compaction by special methods shall be carried out to achieve dry densities equivalent to those being achieved in adjacent areas by normal compaction methods.

Equipment used for special compaction shall be front-end loaders, hand-guided heavy duty mechanical tampers, hand-guided vibratory rollers, hand methods or other such compaction arrangements suited to working in confined spaces.

The compaction of stabilised fill in areas such as a cut off trench shall be carried out by a vibratory roller 600 mm wide with a static weight of at least 0.8t.

6.3.9 Trial Embankments

Trial embankments shall be carried out to verify the maximum layer thicknesses and number of passes for the particular material and items of equipment intended to be used.

6.3.10 Testing

6.3.10.1 General

All necessary testing equipment shall be available to ensure that at all times the moisture and density characteristics of fill materials can be monitored. In addition to the laboratory method of moisture determination, suitable field apparatus which will give a quick reading shall be employed. With this equipment a constant check shall be made on the moisture contents of all materials about to be placed or compacted. Duplicate samples shall be tested in the laboratory for correlation purposes.

The methods of testing outlined in BS 1377 shall be used.

It will be necessary to adjust the frequency of testing as work proceeds in order to suit the variations in fill placing rates and areas covered.

Further control tests in borrow areas and stockpiles shall be carried out as necessary to check that the material being placed, or about to be placed, meets the requirements of the Specification, to optimise placing destinations and to identity unsuitable material.

6.3.10.2 Compaction Definitions

Unless otherwise stated, earthworks compaction will be assessed with respect to the values of maximum dry density and optimum moisture content as determined by the 2.5 kg rammer method described in BS 1377.

6.3.11 Construction Joints in Fill

Construction joints shall not be used in embankments where there is a practicable alternative.

The sloping face of construction joints shall not be steeper than 1 in 1.75 and, during placement, the material shall be compacted as close as practicable to the exposed face of the construction joint.

Prior to placing a layer of fill materials against previously placed fill in any construction joint, the surface of the material previously placed in the area of the joint shall be cut back a horizontal distance of not less than 1.5 m beyond that required to expose a dense face.

Materials placed against a construction joint shall be matched and bonded into the previously placed material in order to achieve a dense homogeneous fill across the construction joint.

6.3.12 Suspension and Resumption of Operations

Fill placing operations shall be suspended whenever inclement weather conditions are such that the material cannot be placed and compacted at the moisture content and to densities equal to those which would be achieved under normal conditions. If fill placement is suspended because of precipitation or impending precipitation or for any other reason, the surface of impervious fill materials shall be graded and rolled smooth to seal the surface and to avoid unnecessary absorption of moisture.

Where operations have been suspended, the effects of rain or other adverse conditions shall be assessed before placing is resumed. Prior to resumption of fill placement, any material not conforming to the specified requirements shall be removed or reconditioned until it is suitable. Equipment shall not otherwise be allowed to travel or work on the fill, except for necessary removal, until it has dried sufficiently to prevent excessive rutting and to allow the equipment to operate satisfactorily.

6.3.13 Dressing of Outer Faces

Outer faces of embankments shall be dressed to form a neat, uniform, workmanlike appearance. The dressing of the faces shall be completed as the work proceeds.

6.3.14 Tolerances

Embankments and fill areas shall be constructed such that maximum local deviations from the finished outside slope surface of the embankment do not exceed a dimension related to the largest stone size measured at right angles to the surface. In addition:

- The finished outside slope surface shall not be uniformly lower than the required lines;
- The crest width shall not be less than the required width;
- Where an embankment has berms, the levels of the berms shall not be lower than the required elevations;
- All finished slopes shall drain effectively;
- The level of the finished crest shall nowhere be lower than that prescribed; and
- The dimensions of core zones and filter zones shall not be less than the required dimensions.

6.3.15 Protection and Maintenance

All fill shall be maintained in a satisfactory condition until the completion of the work.

The surface shall be shaped and necessary steps taken to avoid ponding of water on the fill or contamination of the fill by traffic or other causes, and shall at all times keep the surface and slopes of the embankment free from rubbish, rejected or unsuitable material, and waste materials.

6.4 Particular Requirements for Road Embankments

The placing of fill up to formation level shall comply with the "South African Transport and Communications Commission - Standard Specifications for Roads and Bridge Works, Division of Roads and Transport Technology, July 2001".

6.5 Particular Requirements for Substation Surfacing

The area of the substation shall comprise a 450 mm thick layer as described in the UK Highways Agency Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works, Series 600, Table 6/2, Type 1A or 1C fill overlain with 75 mm of 20 mm single sized stone chippings.

Section 7: Technical Specifications - Roadworks and Pavement

7.1 General

Access roads, parking areas and turning circles within the power station environs shall be surfaced as follows:

- In general a single gravel-wearing course suitable for the constructional plant shall be placed on the prepared formation during the construction period.
- Once construction traffic has ceased to operate, the contractor shall refurbish the road base accordingly.

All roadworks shall comply with the requirements of the following:

1. Government of the Republic of Zambia - Recommendations on Road Design Standards Geometric Design of Rural Roads, Roads Department, December 1994.
2. South African Transport and Communications Commission – Code of Practice for the Design of Road Pavements, Division of Roads and Transport Technology, July 2001.
3. South African Transport and Communications Commission - Standard Specifications for Roads and Bridge Works, Division of Roads and Transport Technology, July 2001.

All roads shall be Type III in accordance with reference 1 above and shall comprise a single carriageway having a width suitable to accommodate power scheme service vehicles.

7.2 Materials Available at Site

7.2.1 Coarse Aggregates

Coarse aggregates for concrete pavement and road sub base etc. shall be provided either by crushing suitable rock obtained by quarrying in any designated borrow areas or by acquisition from suitable quarries or hard stone suppliers.

When crushed rock is produced as described above from excavated rock, the rock intended for such use shall be separated from stockpiles of quarried rock and all activities necessary to obtain the required specified standard (e.g. handling, haulage, crushing and screening) shall be undertaken.

In the event that suitable material is unavailable at the site, measures shall be taken to obtain the required aggregates by either opening up a quarry or purchasing aggregate of the specifications required from suppliers in the area.

7.2.2 Fine Aggregates

Fine aggregate shall be produced by excavating from any approved deposits in river beds, by crushing rock or by using such other approved sources. All operations to produce the required quality and grading of fine aggregate specified shall be carried out e.g. haulage, washing and screening.

Section 8: Technical Specifications - Steelwork

8.1 General

The Contractor shall be responsible for the design, supply of materials, fabrication, installation, testing and commissioning of all steelwork.

Steelwork shall conform to the requirements of BS EN 1993 and BS EN 1090-2. In general the Contractor shall follow the recommendations of The National Structural Steelwork Specification for Building Construction, 5th Edition, British Constructional Steelwork Association (BCSA) and Steel Construction Institute (SCI) publication 203/07, London 2007.

8.2 Design

The Contractor shall design all steelwork in accordance with the Applicable Standards.

8.3 Materials

8.3.1 General

Steel plates, rolled and hollow sections and similar products used for structural and other purposes shall be from an approved manufacturer and shall comply with BS EN 10025.

All structural steelwork shall be designed, fabricated and erected in accordance with BS EN 1993, BS EN 1011 and BS EN 1090-2.

Hot rolled structural steel sections shall comply with BS 4 and BS EN 10056.

Steel tubes shall comply with BS EN 10297.

Material selection shall consider corrosion, galvanic and other mechanisms and suitable precautions taken in order to provide a durable structure requiring minimum maintenance.

8.3.2 Bolts, Nuts and Washers

Bolts for structural and other purposes shall unless otherwise noted be hot dip galvanised metric black bolts to BS 3692 Grade 8.8. Where required, ISO metric precision bolts shall be to BS 3692. Metal washers shall be to BS 4320. ISO metric black cup and countersunk head bolts and screws with hexagon nuts shall comply with BS 4933.

8.3.3 High Strength Friction Grip Bolts

High strength friction grip bolts shall be galvanised and shall comply with BS EN 1993-1-8:2005 as specified. Hardened steel washers shall be provided under both the head and nut of each bolt.

8.3.4 Test Certificates

The Contractor shall supply a manufacturer's test certificate for each consignment of steelwork delivered to the site together with a delivery note stating the weight, type, length and place of origin of the steelwork.

8.3.5 Foundation Bolts and Anchorages

All necessary anchorages and foundations bolts to be built into foundations and all templates required for correct location of anchorages and foundation bolts shall be provided.

Foundations bolts shall be complete with tubular steel sleeves to permit adjustment in position and with anchor frames, washers, washer plates and nuts.

After foundation bolts and anchorages have been cast into concrete, the bolt ends shall be protected by greasing and wrapping with suitable protective material.

After fixing the base plate, bolt holes shall be grouted with neat cement grout. Base plates shall be bedded in accordance with BS EN 1993. Temporary erection packers under base plates shall be arranged to be removable on completion of bedding.

8.4 Fabrication

8.4.1 General

Steel sections shall be new and fabricated to BS 4: Part 1 or BS EN 10056 as appropriate and shall comply with the following standards:

- BS EN 10025 Hot-rolled non-alloy structural steel
- BS EN 10029 Tolerances for hot-rolled steel plates
- BS EN 10210 Hot-finished non-alloy and fine-grain structural hollow sections
- BS 7668 Hot-finished weldable structural hollow sections in weather-resistant steel

Sections which are heavily pitted or rusted shall not be used.

Cuts and holes shall be made neatly and accurately. Burrs, sharp edges and dross caused by flame cutting shall be removed.

Prior to commencement of fabrication, details of proposed quality control for all shop work including welding shall be provided.

Erection marks shall be stamped or painted on all members.

8.5 Workmanship

Steelwork shall be fabricated in accordance with BS EN 1090-2 except as modified herein.

Exposed cut edges of steelwork shall be rounded off by grinding. Ends of members bearing in compression shall be machined so that loads are transmitted over the entire area of contact.

Plates, rolled and hollow sections required to be cut to exact lengths shall be accurately cold sawn or machined. Hot sawing or machine gas cutting is permitted for the ends of beams and other parts in compression.

Tube ends, other than those cold sawn, shall be hand flamecut and dressed to fit accurately the profile of the tube, etc, to which they are to be jointed.

Burrs left by a cold or hot saw shall be removed and gas cuts shall be dressed free from oxidised metal to a neat and workmanlike finish.

Ends of tubes welded to plates, etc, shall be formed so that the tubes butt over their entire area.

The ends of the members shall be prepared generally in accordance with the foregoing requirements and the maximum gap allowable between ends will be 2 mm.

Fitted stiffening tubes, angles or plates to brackets, flanges to joists, tubes, etc. shall be accurately shaped to fit the profile of the member stiffened.

Landing cleats shall be provided for all beam to column connections.

In tubular structures the ends of all tubes shall be sealed to be airtight.

Frames of tube or box connections shall be jig assembled and the ends of all tubes shall be sawn and not flame cut, except for irregular profiles. The minimum thickness of box or tube sections for main members shall be 4 mm.

Sealing the ends of tubes shall be carried out under ambient conditions and the trapping of excessive moisture shall be avoided.

Any holes in steelwork shall be drilled.

8.6 Welding

8.6.1 General

Welds shall have 6 mm minimum legs and they shall be designed in accordance with the requirements of BS EN 1993 to resist the loads and forces to be transmitted by the various members. The arrangement of welds of joints shall be designed to take into account the distribution of all stresses and any eccentricities arising from the welds relative to the axes of the members.

Welding shall comply with BS EN 1090-2 and BS EN 1011. The layout, procedure and sequence of all welding operations shall be arranged to so as to eliminate any distortion, residual stress or accidental stress. Approved written welding procedures shall be available in accordance with BS EN 1011 and tested in accordance with BS EN ISO 15607.

Welding shall be undertaken using the metal arc method to BS EN 1011 to form fully fused joints with mechanical properties not less than those of the parent metal. On Site welding of structural steel sections is not permitted.

8.6.2 Standards

Welding procedures, tolerances, welding consumables, weld testing and proficiency testing of welders shall comply with the appropriate British Standards listed below for the grades and thicknesses of steel and the types of weld specified:

BS EN 1090-2 Technical requirements for the execution of steel structures

BS EN 287: Approval testing of welders for fusion welding Part 1: Steels

BS EN ISO 15607: Specification and approval of welding procedures for metallic materials

BS EN ISO 2560: Welding consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels classification

BS EN 571: Non destructive testing. Penetrant testing

BS EN 756: Welding consumables – Solid Wires

BS EN 760: Welding consumables – Fluxes for submerged arc

BS EN 970: Non destructive examination of fusion welds

BS EN 1011: Welding, recommendations for welding of metallic materials

BS EN 1435: Non destructive examination of welds

BS EN 1714: Non destructive testing of weld joints

BS EN ISO 9934:	Non destructive testing magnetic particle testing
BS 4872:	Approval testing of welders when welding procedure approval is not required. Part 1: Fusion welding of steel

8.6.3 Equipment

Welding equipment shall be sufficient to comply with the required welding procedures and shall be capable of depositing the various types of electrodes used under the conditions of current and voltage specified by the manufacturer of the electrodes. Equipment, accessories and connections shall be maintained in proper working order.

8.6.4 Welds

The arrangements of the runs in multi run welds shall avoid the formation of slag traps and ensure adequate root penetrations and correct shapes of the welds. The sizes of the electrodes and the number of runs necessary to make each welded joint shall conform to the electrode manufacturer's recommendations. All welds shall be continuous and welds with blowholes or similar defects will be rejected. Penning of the welds involving deformation of the weld surface whether during de-slagging, or subsequently, shall not be allowed.

Butt welding shall not be interrupted until at least 50% of the weld depth is complete.

No welding shall take place in rain or in areas intermittently wetted by flowing or turbulent water.

8.6.5 Temporary Support

To achieve the required weld fit-up clamps, jigs and manipulators shall be used. They shall remain in position until the entire length of the root run(s) and the first pass is complete for all butt welds. They shall be used in such a way that welding can be carried out in the most suitable position. Tack welds shall not be used for butt welds. Welded temporary attachments shall not be made in areas subject at any time to tensile stresses. Temporary securing welds, where used, shall be to the same specification as for permanent welds. The attachments shall be removed with care and the area of the temporary weld ground down and dressed-up as required.

8.6.6 Testing of Connections

Non-destructive testing of welds shall be carried out as necessary by an approved testing organisation to demonstrate compliance with the specified acceptance standards. Acceptable methods of testing are magnetic particle testing (BS EN ISO 9934), penetrant testing (BS EN 571), radiographic examination (BS EN 1435) and ultrasonic (BS EN 1714) as appropriate and as agreed with the Employer. At least 16 hours shall elapse between completion and the non-destructive testing of a weld.

Every weld shall be inspected visually over its full length following the recommendations given in BS EN 970, before non-destructive testing is carried out.

Non destructive testing of welds shall be carried out in accordance with all the requirements of the relevant British Standard or equivalent.

For tests on butt welds the percentage of examinations refers to the total number of butt welds.

For tests on fillet welds the percentage of examination refers to the total length of fillet welds.

8.6.7 Acceptance Levels - Butt Welds

Acceptance levels for butt and fillet welds shall be as stated in BS EN 1712 with inspection and testing in accordance with BS EN 1011.

8.6.8 Weld Failure

If the results of any 10% weld length examined by radiographic or ultrasonic methods do not conform to the required acceptance levels, two additional 10% lengths from the same weld shall be examined. In the case of failure of one or both of these additional examinations the weld will be rejected.

8.6.9 Remedial Work

Remedial work shall be as described in BS EN 1011.

8.7 Bolted Connections

8.7.1 General

Bolted connections shall generally comply with the requirements of BS EN 1090-2.

The minimum size of bolt used on all standards connections shall be 12 mm diameter. Single bolt connections will not be permitted. Bolts in tension will not be allowed, the only exception being foundation bolts and high tensile bolts in haunch connections of portal frames. All bolted joints shall be over-designed by 20%. Where pin bolting is used for assembly and erection of joints which are finally welded, pin bolts shall be omitted from the strength calculations of the joint.

Holes shall be drilled accurately using a template. Burrs and arises shall be removed from the edges of holes before the parts are assembled and holes shall not be punched. No holes shall be gas cut, either during fabrication in shops or during erection at site.

Bolt holes shall be accurately aligned so that all bolts can be inserted without force. Bolts shall not be driven home. Drift pins used to draw members into alignment shall not be used in a manner which distorts or enlarges bolt holes.

Bolts shall be of sufficient length to show at least two clear threads beyond the nut when fully tightened. When bolts are used in bearing, members shall not bear on the threaded part.

Open bolt ends shall be protected by a suitable covering and grease.

8.7.2 Joint Preparation

Joint interfaces shall be clean and free from loose scale, loose rust, oil, grease, paint and all other deleterious matter before any joint is assembled.

The members to be connected shall be clamped together to achieve contact over the full bearing area. If there is a remaining gap which may affect the integrity of the joint, the connection shall be taken apart and a suitable pack inserted to achieve contact over the full bearing area.

8.7.3 High Strength Friction Grip Bolts

High strength friction grip bolts shall comply with the following:

(a) Non-load indicating connectors shall be installed in accordance with BS EN 1993-1-8;

(b) Load indicating connectors shall be installed in accordance with the manufacturer's recommendations but the minimum shank tension shall be in accordance with BS EN 1993-1-8;

(c) The Contractor shall demonstrate on site by means of sample bolts and a calibrated bolt load meter that the minimum shank tension is obtained with the type of fastener chosen and the equipment proposed for tightening. All tools used for measuring tightness shall be regularly calibrated on the types of bolts actually being used.

Facing surfaces shall be prepared in accordance with the Painting and Surface Protection section. They shall at the time of assembly be clean and free of loose scale, loose rust, oil, grease, paint, masking tape and all other deleterious matter and of burrs and other defects, unless otherwise specified. Lubricant applied to the bolts shall not be permitted on the facing surfaces.

Parts to be connected shall be firmly drawn together with all bolts partially tightened. The joint shall be examined and if there is a remaining gap which may affect the integrity of the joint, it shall be taken apart and a pack inserted before recommencing the tightening procedure.

High strength friction grip bolts which have been tightened and subsequently released shall not be used in permanent Design Build Services.

8.8 Transport and Storage

8.8.1 Handling and Storage

All wire ropes and chain slings used for hoisting and securing loads shall be covered to prevent scoring, chaffing and other damage.

Softwood timber bearers with a sufficient contact area to prevent crushing shall be provided at all stages of transport and storage. Bearers shall be level and sufficient in number to prevent distortion of members. Beams used to support external steelwork shall be sufficiently high to ensure that the lowest parts of the stored members are above the rainwater splash zone and splashing from passing vehicles.

Members shall be stacked to permit free drainage of rainwater from the surfaces and to avoid ponding. If covers are provided to steelwork, timber bearers or other form of support to ensure that covers are not in contact with steel surfaces, arrangements for ventilating under covers to minimise condensation shall be acceptable.

Projecting stud bolts and cleats shall be avoided where possible.

8.8.2 Prevention of Contamination

Precautions shall be taken at all stages to prevent steelwork being contaminated by oil, cement, soil, chemicals or other deleterious agents. Should any contamination occur, the contaminant shall be removed immediately by swabbing or brushing and the surfaces washed clean with clean water.

8.9 Erection

8.9.1 General

Erection procedures shall generally comply with the requirements of BS EN 1090-2.

The Contractor shall provide and be responsible for all necessary lifting tackle, gear, lifting beams and selection of points for the erection of the works. The structures shall be designed for the erection loads to which they will be subjected

Erection drawings shall show size and location of all members, and shall give complete location and details for setting anchor bolts. They shall show elevations of bottom of all bases, bearing plates, top of masonry to receive these plates, extent of all connections and all details necessary for erection.

During erection the work shall be securely bolted or otherwise fastened and, if necessary, temporarily braced to make adequate provision for all erection stresses, wind, temperature and other conditions, including those due to erection equipment and its operation. The Contractor shall design and provide all temporary bracing and supports required for the method of erection.

8.9.2 Lifting and Runway Beams

Any crane or lifting beams shall be installed and tested in accordance with the requirements of BS 2853/BS EN 1993-6 - Design and Testing of Steel Overhead Runway Beams and Travelling Trolleys. Any crane or lifting beams shall be certified by the Zambian Government Inspector. The Contractor shall submit to the Employer three copies in English of test certificates for all test readings. The test certificates shall state the condition under which each test was carried out.

8.9.3 TOLERANCES

Tolerances for erection of steelwork shall be in accordance with BS EN 1090-2 and BS 5606 "Guide to accuracy in building", except as modified below:

(a) Tops of beams at ground level shall be within ± 6mm of specified level

(b) Tops of beams above ground shall be within the tolerance in (a) above plus 1/4000th of the height above ground level

(c) Difference in level of tops of beams at any storey or frame level shall not exceed 3mm

(d) Columns shall be plumb within 3mm in 3 metres or 5mm in 10 metres.

8.10 Protective Coatings

Preparation for, selection and application of protective coatings shall be in accordance with the Employer's Requirements section, Painting and Surface Protection.

8.11 Miscellaneous Steelwork

8.11.1 Stairways, Stepladders, Platforms, Walkways and Flooring

To permit access to all parts of the plant stairways, stepladders, platforms and walkways complete with guard-rails shall be provided in accordance with BS EN ISO 14122.

Lugs and fixing bolts shall be supplied for fixing into concrete etc. Complete fabricated stairways and stepladders with all lugs and fixings attached shall be protected from corrosion as specified elsewhere.

Stairways, stepladders, platforms and walkways shall be designed to a headroom of 2.3 m and an imposed load of 7.5 kN/m^2.

Where panels are designed to be removable for inspection and maintenance purposes each removable piece shall weigh no more than 25kg.

8.11.2 Guard-rails

Guard-rails shall be provided for staircases, well openings, platforms, walkways etc.

At ends of guard-rails unjointed loops between the rails shall be added and at stair intersections suitable connections and bends shall be provided.

Guard-rail standards shall be securely fixed to the main structural members with bolts of ample size and strength. All standards shall be fixed perfectly upright with the railing horizontal or to the dimensioned slopes. Where necessary, semi-dry grout shall be packed beneath the base plates of standards to ensure perfect contact with concrete surfaces and straightness of the railing.

Tubular guard-rails shall be formed from tube with a minimum external diameter of 34 mm.

All members shall be designed to fail before their end fixings.

Guard-rails that provide protection around trenches, pits etc., and elsewhere as directed by the Employer, shall include toe plates in accordance with BS EN ISO 14122.

8.11.3 Floors, Platforms etc.

Non-slip covers and suitable mild steel angle support kerbing around the perimeter of trenches and catchpits in floors shall be provided. Panels shall be of convenient size for handling purposes. Cutting of individual pieces is to take account of the direction of the pattern.

The angle kerbing shall generally consist of 40 x 40 x 5 mm angle (or otherwise to suit) with fixing lugs welded on at approximately 400 mm centres. Rebates and cores shall be provided in the floor to receive the angle kerbing where required.

Chequer plating shall have a thickness of at least 6 mm of plain metal and shall be of an approved non-slip raised pattern type. In certain cases it may be necessary to fix stiffening angles to the underside of the chequer plating. Where shown on the Drawings, chequer plating shall be fixed to supports with flush bolts.

Open grid flooring shall be an approved type of approximate 38 mm square pattern weighing approximately 50 kg/m^2, with bearing bars and transverse bars. All panels shall be trimmed with bars of corresponding depth, welded to the bearing bars at cut sections. The deflection shall not exceed 1/200 of the span or 8 mm, whichever is the lesser, under the design working load.

Stair treads shall be to BS EN ISO 14122, with approved sight strips. The treads shall be attached to the steel staircases in an approved manner.

Landings and other elevated areas of flooring shall have 8 mm thick angle kerbing or similar as toe plates around the perimeter. The toe plates shall not be fixed to the flooring panels.

8.11.4 Floor Plating

Floor plating including kerbs and supports shall be provided as required around plant, equipment, access pits and trenches. Hooks for lifting the floor plates shall also be provided.

8.11.5 Anchor Bolts

Mild steel, high strength and stainless steel anchor bolts shall be provided and installed.

Mild steel anchor bolts shall comply with BS 4190. High strength anchor bolts shall comply with BS 4395. Stainless steel bolts shall comply with BS EN ISO 3506.

Anchor bolts shall be complete with nuts, standard washers and turnbuckles if required. Expansion or adhesive type anchor bolts may be used in place of anchor bolts and shall comply with manufacturer's instructions.

Mild steel and high strength anchor bolts shall be galvanised in accordance with the appropriate specification, where required.

Anchor bolts to be embedded in concrete shall be positioned with a template before the concrete is placed and the Contractor shall ensure that the anchor bolts are maintained in the correct position to the specified tolerances during the placing of concrete.

Adhesive anchor bolts shall be stainless steel Rawplug Chemical Anchors, Hilti Adhesive Anchors or equivalent.

8.11.6 Miscellaneous Embedded Metalwork

Miscellaneous embedded metalwork including, but not limited to, that listed in this sub clause shall be provided and installed.

(a) embedded metal frames for floor plate covers, walkways, gratings and hatchways, ventilation openings, manholes and precast panels;

(b) anchoring and handling hooks and sockets and miscellaneous screwed anchors for eye bolts, in walls and ceilings, to facilitate erection of equipment;

(c) handrail post sockets;

(d) bearing plates, sole and anchor plates not listed in other items;

(e) step irons;

(f) brass strips and angles in floors.

8.11.7 Miscellaneous Non-Embedded Metalwork

Miscellaneous non-embedded metalwork including, but not limited to, the items listed in this sub clause shall be provided and installed.

(a) non-embedded supporting structural framework and cover plates, floor plates, gratings and hatch covers;

(b) removable steel floor panels, each removable piece not to weigh more than 25kg;

(c) pipe hangers and supports;

(d) manhole and inspection pit covers;

(e) cable pit covers.

Section 9: Technical Specifications - Concrete

9.1 Concrete Materials

9.1.1 Scope

This Clause 9.1 deals with the materials, workmanship, production, placing and testing of concrete.

Associated aspects of general concrete work such as the following are specified in Clause 9.2:

- Reinforcement
- Built-in Items
- Formwork
- Surface Finishes
- Tolerances.

Clause 9.3 refers to specialised concrete work that may be required for this Contract, i.e.

- Pre-casting
- Pre-stressing
- No-Fines Concrete
- Super-plasticised Concrete
- Sprayed Concrete.

9.1.2 General

The Contractor shall operate a quality assurance system to BS EN ISO 9001 which implements procedures of supervision, inspection, testing, maintenance and calibration to ensure the specified characteristics of the concrete will be achieved. Concrete mixes shall be specified, produced, transported and tested for compliance in accordance with BS EN 206-1 and within any additional criteria described herein.

9.1.3 Durability

9.1.3.1 General

The concrete must perform satisfactorily in the working environment during its anticipated service life. The materials and mix proportions specified and used should be such to maintain its integrity and protect any embedded metal and reinforcement from corrosion. Among the inter-related factors affecting durability, the environmental conditions to which the concrete will be exposed, the structural form, strength grade, cover to steel and possibly cement type will be defined at the structural design stage.

The quality of concrete shall comply with the durability requirements of Sections 4 and 5.3 of BS EN 206-1:2000, Section 4 of BS EN 1992-1-1:2004, and Section 2.4 of BS EN 1990:2002.

The quality of construction workmanship, levels of control and inspection of construction shall comply with the requirements of BS EN 13670:2009.

The required design life is indicated in Section 2 of this specification.

9.1.3.2 Chloride Content of Mixed Concrete

The mix design shall comply with Section 5.2.7 of BS EN 206-1:2000.

The total chloride content of the concrete mix, expressed as a percentage by weight of chloride ions, shall not exceed 0.35% for concrete made with cement to BS EN 197, BS 4550, BS 1370, and 0.20% for concrete made with sulphate resisting Portland cement, to BS 4027. The chloride content shall be measured in accordance with BS 1881: Part 124.

9.1.3.3 Alkali-silica Reaction

Aggregates shall be inert when tested chemically in accordance with ASTM C289.

Precautions to prevent alkali-silica reaction shall be taken in accordance with BS EN 206-1. In addition, opal, tridymite and cristobalite will not be accepted in aggregates. Quartz aggregate shall not contain quartzite, nor more than 30 per cent by weight of highly-strained quartz (defined as giving an average undulatory extinction of more than 25^o in thin sections). The amount of equivalent sodium oxide in mixed concrete shall not exceed 3 kg/m^3.

The possibility of alkali-silica reaction will always be minimised if ingress of water into the body of the concrete is itself minimised. Therefore, good practice shall always be used so as to produce uniformly-compacted concrete with a dense surface and (on flat slabs) minimum laitance.

9.1.4 Materials

9.1.4.1 Cement

"Cement" shall mean Portland cement and other approved materials used as partial replacement for Portland cement complying with BS EN 197, BS 1370, BS 3892, BS 4027, and BS EN 15167 when tested in accordance with BS 4550 and BS EN 196.

High alumina cement or extra rapid hardening cement shall not be used.

The total acid soluble alkali content (Na20 + 0.658 K20) of cement shall not exceed 0.60% by weight.

If it is found necessary to use cement from different factories the various makes of cement must be stored separately and never mixed. The use of different makes or brands of cement in any one pour or batch shall be prohibited. To the fullest extent possible, each unit of concrete shall be made entirely with cement obtained from one factory.

9.1.4.2 Aggregates

Aggregates shall comply with the requirements of BS EN 12620 and/or BS EN 13055 when tested in accordance with BS 812, BS EN 932 and BS EN 933.

Coarse aggregates for concrete shall be provided either by crushing suitable rock obtained by quarrying in any designated borrow areas or by acquisition from suitable quarries or hard stone suppliers.

When crushed rock is produced as described above from excavated rock, the rock intended for such use shall be separated from stockpiles of quarried rock and all activities necessary to obtain the required specified standard (e.g. handling, haulage, crushing and screening) shall be undertaken.

In the event suitable material is unavailable at the site, measures shall be taken to obtain the required aggregates by either opening up a quarry or purchasing aggregate of the specifications required from suppliers in the area.

Fine aggregate shall be produced by excavating from any approved deposits in river beds, by crushing rock or by using such other sources as are approved by the Employer. All operations to produce the required quality and grading of fine aggregate specified shall be carried out e.g. haulage, washing and screening.

Additional Requirements for Coarse Aggregate

The coarse aggregate shall be crushed natural stone or gravel and have the following characteristics over and above the requirements of BS 882/BS EN 12620 when tested according to BS 812, BS EN 932 and BS EN 933:

(i)	Clay, silt, dust and other deleterious matter (by weight):	max 1%
(ii)	Flakiness index: BS EN 933-3	max 30%
(iii)	Elongation index: BS EN 933-3	max 30%
(iv)	Apparent relative density: BS EN 1097-3	min 2.6
(v)	Water absorption: BS EN 1097-3	max 3%

(vi)	Impact value: BS EN 1097-2		max 30%
(vii)	Crushing value: BS EN 1097-2		max 30%
(viii)	Drying shrinkage:	BS EN 1367-4	max 0.065%

(ix) Soundness: loss after 5 cycles of immersion and drying shall not exceed 18% when tested for soundness using magnesium sulphate in accordance with BS 812: Part 121.

Additional Requirements for Fine Aggregates

Fine aggregates shall have the following characteristics over and above the requirements of BS EN 12620 when tested according to:

(a) BS 812/ BS EN 1097

Apparent relative density:	min 2.6
Bulking:	max 20%

(b) ASTM C125

Fineness modulus:	min 2.3, max 3.1

(c) BS 812:Part 121

Soundness: (loss after 5 cycles of immersion and drying):

using sodium sulphate	max 10%
using magnesium sulphate	max 15%

9.1.4.3 Water

Water used for concrete manufacture shall be clean and free from harmful amounts of acids, alkalis, organic matter or other substances which will impair the strength or durability of the concrete.

If it is intended to utilise river water arrangements shall be provided to ensure that the silt content is within acceptable limits.

9.1.4.4 Admixtures

Admixtures shall comply with the requirements of BS EN 206-1, BS EN 934 and BS EN 12878 where appropriate.

9.1.4.5 Storage of Materials

Generally storage and handling of cement, cementitious materials, aggregates, admixtures and water shall comply with Section 9.6.2 of BS EN 206-1.

Cement shall be stored so that each delivered batch is clearly identifiable. It shall be kept dry, off the ground in covered and watertight stores, and used in order of delivery. Loose or split bags or air set cement shall not be used.

Aggregates shall be stored on a concrete or screeded surface, or in bins. The storage area shall have a fall away from the mixer. Contamination of stockpiles by foreign matter or other aggregates shall be prevented. Segregation of sizes in any stockpile shall be avoided and spillage of material from one pile into another shall be prevented by the provision of adequate bulkheads.

9.1.5 Concrete Mixes

Concrete mix types shall be either "designed" or "standardised prescribed" as defined by BS EN 206-1. Designed mixes are specified by their required performance in terms of strength grade, subject to any restriction on materials, minimum or maximum cement content, maximum free water/cement ratio and any other properties required. The designs of all mixes shall be based on the particular type and brand of cement to be used on the site. The type of cement, aggregates and mix proportions shall be selected in accordance with BS EN 206-1 and BS 8500 : Parts 1 and 2, BS EN 1992-1-1 and for water retaining structures BS EN 1992-3 to achieve a durable concrete for the exposure conditions it will encounter in its particular working environment. Strength grades so specified shall not be less than the characteristic strengths assumed for the structural design.

Standardised prescribed mixes are selected from the restricted range given in BS 8500: Part 2: 2006. They may be used in non structural or minor structural applications in accordance with Section 6.4 of BS EN 206-1: 2000 and shall conform to BS 8500-1: 2006.

The required concrete mixes shall be identified on drawings of each structure. For designed mixes concrete will be identified by class comprising the compressive strength grade, the maximum aggregate size, and a numeric mix number. Thus, designed concrete Class C20/25/40/2 identifies concrete having characteristic 28 day cylinder/cube strengths of 20/25 N/mm^2 respectively, a maximum size of coarse aggregate of 40mm and a mix number of 2. Full details of materials and mix proportions for all classes of designed mixes for use in the Facilities shall appear on one key drawing.

9.1.6 Trial Mixes and Assessing Conformity

9.1.6.1 Trial Mixes

Trial mixes shall be prepared for each mix reference of designed mix concrete in accordance with BS 1881 and BS 12350 (unless there are existing data showing that the proposed mix proportions and method of manufacture should produce a concrete of the strength, quality and workability required).

The Contractor's programme shall allow for a minimum of 35 days before the commencement of concreting to successfully carryout preliminary trial mixes prepared and tested.

No structural concrete shall be placed in the Design Build Services until the design of the mix and sources of materials have been agreed.

Trial mixes shall be prepared before Facilities commence preferably under full-scale production conditions or, if this is not possible, in an approved laboratory using a sufficient number of samples to be representative of the aggregates and cement to be used.

9.1.6.2 Sampling

A set of six cubes shall be made from each of three batches for each mix reference of concrete. From each sample of six cubes, three shall be tested at an age of 7 days and three at 28 days.

This procedure shall be followed when accelerated testing is posted for Works cubes, but an additional three cubes from each batch shall be made, cured and tested in accordance with the accelerated regime.

The average of each of three cube strengths shall be taken as the test result.

9.1.6.3 Trial Mixes after commencement of Facilities

Once the proportions of the mix ingredients for each class of concrete, including the water content, have been agreed, they shall not be varied unless it fails to meet specified requirements.

However, if it is found when concreting is commenced that any particular grade of concrete does not meet the specified requirements, the Contractor shall modify or re-design the mixes. Where a trial mix is required after the commencement of the Facilities, the foregoing preliminary trial mix procedure shall be adopted. The Contractor will not be entitled to extra payment if the amended mix designs should prove to be more expensive than those on which his tender was based.

9.1.6.4 Conformity

For designed mixes compressive strength testing shall form an essential part of the assessment of conformity to the specification. Sampling, testing and compliance requirements shall be in accordance with the requirements of Section 8.2 of BS EN 206-1: 2000.

For prescribed standardised mixes compliance shall be determined in accordance with Section 8.3 of BS EN 206-1: 2000.

Additional cubes may be required for special purposes. These should be made and tested in accordance with BS EN 12390-1, BS EN 12390-2 and BS EN 12390-3 but the methods of sampling and the condition under which the cubes are stored should be specified according to the purpose for which they are required. These include:

a) the strength of concrete in pre-stressed concrete at transfer;

b) the time at which to strike formwork;

c) the strength of concrete under cold and hot weather conditions;

Sampling should preferably be at the point of placing and any such cubes should be stored as far as possible under the same conditions as the concrete in the members.

The cubes should be identified at the time of manufacture and should not be used for the conformity procedures of BS EN 206.

9.1.6.5 Action to be taken in the Event of Non-conformity

Remedial action to be taken in the event of non-conformity shall be determined after consideration of the location and quantity of concrete involved and the possible consequences of any reduction in concrete quality and strength on the durability and structural performance of the Facilities.

The structural requirements of the concrete in the Facilities will be satisfied provided that (i) no 28-day Test Result is less than 85 per cent of the specified characteristic strength and (ii) no individual 28-day cube strength is less than 70 per cent of the specified characteristic strength.

If either of (i) or (ii) is not satisfied, the volume of concrete represented by the sample shall be considered structurally suspect. Where structural performance is critical further actions shall include one or more of the following:-

(a) Cores shall be drilled from the suspect portions of the structure to determine whether the equivalent cube strength of the in situ concrete satisfies the strength required for the particular part of the structure.

(b) Non-destructive testing, e.g. ultrasonic examination, of the suspect portions may be carried out to assess the equivalent cube strength of the in situ concrete.

(c) Full scale load tests.

(d) If load tests are impracticable, or if a tested portion of the structure fails to pass the tests, the Contractor shall either replace or strengthen each section that failed or which contains concrete that failed, as relevant.

(e) The work shall be demolished and reconstructed.

9.1.7 Surface Finish Trials

Where the surface finish of concrete is permanently exposed to view and its appearance is aesthetically important practical surface finish tests shall be made using trial formwork or surface finishing processes. In these tests all equipment and formwork shall be exactly as intended for use in the permanent Facilities and the samples shall be retained for future reference until the relevant work is completed.

9.1.8 Batching

Batching of concrete constituents shall be in accordance with Section 9.7 of BS EN 206-1: 2000.

9.1.9 Mixing

9.1.9.1 Preparation

Coarse aggregate shall reach the point of mixing in a saturated, surface-dry condition. The temperature of cement at the time of mixing shall not exceed 60ºC.

Before the start of each period of mixing, the inner surface of the mixer shall be cleaned and all hardened concrete shall be removed. An initial charge of 1:2 cement/sand slurry of sufficient quantity to coat the entire drum shall be mixed and discharged.

9.1.9.2 Procedure

Mixing shall be in accordance with Section 9.8 of BS EN 206-1: 2000. Adequate stand-by mixing capacity shall be available at all times.

The mixing time shall be sufficient to ensure that a thoroughly blended, homogeneous mixture is produced. The minimum mixing times shall be not less than 1½ minutes for a drum mixer and 1 minute for a pan mixer. The period of mixing shall be measured from the time when all the materials are in the mixer to the commencement of discharge. During this period the mixer shall be rotated at the speed recommended by the manufacturer.

The maximum mixing times shall be 20 minutes for drum mixers and 10 minutes for pan mixers.

The discharge of concrete shall be carried out such that there is no segregation of constituent materials.

9.1.9.3 Delays

In the event of delay in the concreting operations, the concrete may be retained in the mixer for the period the concrete remains adequately workable but not exceeding 90 minutes provided that during this time the mixer is restarted for short periods of 2-3 minutes at intervals of 10-15 minutes.

9.1.10 Transportation of Concrete

Concrete shall be transported from the mixers to the place where it is required in such a manner that segregation, loss of ingredients and adulteration are prevented and that the batch is uniform and of the required workability at the point and time of placing. All equipment shall be of suitable size and proven design and maintained in first-class working order. Adequate stand-by equipment shall be available at all times.

Where agitator trucks are used, the drum shall rotate continuously during the journey and shall be run at maximum speed for 30 seconds immediately before discharge.

Each delivery of concrete shall be accompanied by a delivery ticket issued at the batching plant and collected at the point of discharge.

9.1.11 Placing of Concrete

9.1.11.1 General

The concrete shall be placed in its final position and fully compacted before loss of workability occurs. In no case shall concrete be placed in the permanent Facilities more than 20 minutes after discharge from the mixer unless it is carried in agitator trucks, operating continuously, in which case the placing time shall be within 90 minutes of the introduction of the cement to the mixers or within 20 minutes of discharge from the agitator.

Concrete shall not be re-tempered by the addition of water or other material. All contact surfaces of an absorbent nature, including any previously placed concrete, shall be left damp but no free water shall be permitted to remain on these surfaces.

The concrete shall be placed in such a manner that the exposed area of fresh concrete against which further concrete is to be placed is kept to a minimum. When concreting closed circuits, therefore, work shall proceed from one or more points on the periphery in both directions at the same time so that closing junctions are always made between newly-cast faces. When layers of concrete are used in large areas such as thick slabs and foundations, the compacted layer thickness shall not exceed 0.5 m.

9.1.11.2 Prevention of Segregation

Concrete shall be handled and deposited using approved equipment in such a manner as to prevent segregation. Particular attention shall be paid to the following points:

Precautions shall be taken at all points of discharge of concrete. For example, suitable spouts or baffles shall be provided at the ends of chutes;

Concrete shall drop vertically into the centre of whatever container receives it;

Falling concrete should be closely confined in a downpipe of the proper size to within 1 m of the place of deposition in the forms or other container, and the final drop shall be vertical. The maximum distance through which concrete may be dropped without downpipes is 2 m;

Concrete shall not be dropped through reinforcing steel or into any deep form, whether reinforcement is present or not, in such a manner as to cause separation by repeated impacts on the reinforcing bars or the sides of the form. For placing in such conditions hoppers, vertical ducts or other means shall be used to prevent the concrete from either reaching the final place of deposition in a state of segregation, or coating the reinforcing steel and the forms with mortar which will dry out before it can be covered with concrete;

Use of external vibrators shall generally be avoided. Where unavoidable the formwork must be designed specifically for their use.

In general it cannot be assumed that segregation occurring in handling will be eliminated in the course of other operations. Segregation shall be prevented, not corrected after its occurrence.

9.1.11.3 Internal Temperature Rise in Concrete

Note should be taken of the effect on the ultimate temperature rise of the cement content and if necessary allowance shall be made to compensate for this. As a guide it may be assumed that in pours of large cross-section there will be a potential temperature rise at the core of approximately 12°C due to the effect of hydration for each 100 kg of Ordinary Portland cement per cubic metre of the mix, but this temperature rise may be subject to review during the course of the Contract.

Suitable measures and monitoring shall be adopted to limit to 20°C temperature differentials between the core of a concrete pour and the surface of the concrete.

9.1.11.4 Concreting in Hot Weather

For hot weather concreting, concrete mixes employing admixtures should be considered in order to retard the hydration and/or increase the initial workability, or using a cement or combination that has a low heat evolution. All reasonable steps shall be taken to reduce to a minimum the placing temperature of concrete, such as spraying coarse aggregate with water, painting silos with a reflecting paint, insulating tanks and pipelines and protecting concrete ingredients from the direct rays of the sun. Fresh concrete having a temperature exceeding 32°C shall not be placed in the permanent Facilities.

The temperature of fresh concrete may be reduced by cooling the concrete ingredients.

When casting concrete in times of high ambient temperatures or hot drying winds, precautions shall be taken to prevent excessively rapid initial drying out of concrete which would otherwise occur before normal curing procedures can be undertaken. Shading and wind breaks consisting of plastic sheeting or several thicknesses of hessian, both fixed to suitable supports, or other approved protection may be used. Hessian screens shall be kept continuously wet and all such protection shall be kept in good repair.

9.1.11.5 Concreting in Wet Weather

Concrete shall not be placed during periods of heavy or prolonged rainfall. Suitable precautions shall be taken to protect concrete which has been placed and has not hardened sufficiently to resist damage from rainfall.

9.1.11.6 Concreting in Wet Ground

Concrete shall be placed in the dry except where this is impracticable. In locations susceptible to flooding, concrete shall not be placed in any excavation until a dewatering pump of adequate capacity to deal with maximum probable rates of inflow of water is installed and available for immediate operation, together with a standby pump of equal capacity and all necessary ancillary equipment. Pumps connected in parallel shall have a control valve on the discharge side.

During and after concreting in wet ground, pumping or dewatering operations in the immediate vicinity shall be suspended if there is any danger that they will extract cement or otherwise interfere with the newly-placed concrete before it has set and gained adequate strength.

9.1.11.7 Placing Concrete under Water

No concrete shall be placed in flowing water and concrete placed under water shall not be vibrated.

Before placing concrete under water, measures shall be taken to ensure that there is no accumulation of mud, silt or other deleterious materials. Concrete to be placed under water shall be placed by tremie and shall not be discharged freely into the water. Pumping of concrete is acceptable where appropriate.

The cement content of the mix shall be increased by 20 per cent over and above that required for an equivalent grade of concrete placed in dry conditions and for such a case it will be permissible to exceed the maximum cement contents for designed mixes. If necessary, the mix shall be re-designed with increased sand content and higher slump to ensure that it will flow satisfactorily. The concrete shall be a rich coherent mix of high workability, with a slump of 150 mm or more, placed in such a manner that segregation does not occur.

The hopper and pipe of the tremie shall be clean and watertight throughout. At the commencement of concrete placing the pipe shall extend to the base of the pour and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie pipe and the water. The pipe shall at all times penetrate the concrete which has previously been placed and shall not be withdrawn from the concrete until completion of concreting. A sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water. The internal diameter of the tremie pipe shall be not less than 150 mm for concrete made with 20 mm aggregate and not less than 200 mm for concrete made with 40 mm aggregate. It shall be so designed that external projections are minimised, allowing the tremie to pass within any reinforcement without causing damage. The internal face of the pipe of the tremie shall be free from projections.

9.1.11.8 Pumped and Pneumatically-placed Concrete

Pumped and pneumatically-placed concrete shall comply with the requirements of this specification except that a maximum slump limit of 100 mm will apply. Admixtures are permissible.

9.1.12 Compaction and Vibration

9.1.12.1 General

Compaction of concrete shall comply with the recommendations of BS EN 13670 and Section 6.2.2 of BS 8110: Part 1: 1997.

9.1.12.2 Slabs of Large Area

Concrete in slabs of large area and road slabs shall be vibrated initially by pokers or plate vibrators but when using poker vibrators it is essential to avoid displacing reinforcement. The surface shall then be struck off above the side forms and finally compacted using a steel-shod hardwood or metal tamping beam not less than 75 mm wide and 225 mm deep.

9.1.13 Protection

All newly-placed concrete shall be adequately protected from anything likely to interfere with the process of setting, such as vibrations from nearby machinery. After the removal of formwork no load of any kind shall be imposed on any reinforced concrete member until the concrete has attained its design strength.

9.1.14 Joints

9.1.14.1 Construction and Movement Joints

Construction joints and movement joints shall comply with the requirements of BS EN 13670 and Sections 6.2.9 and 6.2.10 of BS 8110: Part 1: 1997.

9.1.14.2 Emergency Construction Joints

In the event of a failure of the concrete supply lasting longer than 1 hour all concrete surfaces on which fresh concrete has still to be placed shall be covered from the direct heat of the sun. Wherever practicable on exposed faces, a timber of the same thickness as the cover to reinforcement shall be inserted between the formwork and the reinforcement and removed before further concreting, to form a neat straight joint conforming to the existing joint pattern.

If the initial set has commenced before the concrete supply is restored the pour shall be terminated. The surface of the concrete left in place shall be prepared as a normal construction joint to receive future concrete, with the additional requirement that concreting shall not be recommencing until 24 hours after the termination.

9.1.15 Curing

9.1.15.1 Methods

Methods of curing shall include:-

(a) maintaining formwork in place

(b) covering the surface with impermeable material such as polythene which must be well sealed and fastened

(c) spraying the surface with an efficient curing membrane

(d) covering the surface with absorbent material kept wet

(e) by continuous or frequent application of water to the surface avoiding alternate wetting and drying and the application of cold water to warm concrete surfaces.

Water curing, "method e" above, should be used preferentially whenever practical. Spray applied curing membrane should only be used if water curing or wrapping with impermeable material is impractical and if the membrane will not affect bond or other characteristics of subsequent finishes. It should comply with ASTM C309-74.

9.1.15.2 Periods of Curing

All exposed surfaces of concrete, other than sub-foundation carpets and mass concrete filling beneath or against foundations, shall be water cured. The period of curing shall be determined from BS EN 13670.

9.1.15.3 Particular Cases

Columns. In the case of columns, close wrapping with an impervious material such as polythene sheeting immediately after removal of the forms will be deemed to be equivalent to retaining the forms in position insofar as curing is concerned.

Slabs etc. Water curing of surfaces not cast against formwork shall be commenced as soon as possible after final set and shall normally be carried out by ponding or by covering the surfaces with sand, hessian, or similar material kept in a saturated condition. Sloping surfaces will require continuous application of water.

When the concrete has been subjected to prolonged mixing before deposition, as in the case where there has been a delay, surfaces which are not cast against formwork shall be covered up with polythene sheeting or similarly impervious material immediately placing is complete. The sheeting shall be removed the day following casting and the surfaces shall then be water cured for the full period specified by Tables F.1 to F.3 of BS EN 13670.

Walls etc. Water curing of surfaces other than horizontal top surfaces of concrete shall be carried out by laying out a perforated water pipe along the top of the pour where possible or spraying at sufficiently frequent intervals to ensure that the surfaces are always maintained in a moist condition. If climatic conditions are such that drying out would occur at night, the Contractor shall arrange for spraying to be carried out at night as well as during the day.

9.1.15.4 Prolonged Curing

In cases where the concrete may be subject to attack due to atmospheric pollution or aggressive groundwater, where the concrete may be subject to abrasion or where the concrete is required to be impervious to gases or fluids other than water, the curing period may have to be increased up to twice that specified above.

9.1.15.5 Effect on Appearance

Precautions shall be taken to ensure that the concrete is not permanently stained, marked, contaminated or otherwise damaged as a result of the curing operations and shall scrub down surfaces so affected if they will be visible on completion.

9.1.16 Watertight Concrete

9.1.16.1 General

Construction Drawings shall indicate those parts of the Facilities where watertight concrete occurs and the following provisions shall apply:

- No metal ties in formwork unless the watertight concrete requirements under "Formwork: Ties" are met;
- Expanded metal is not permitted in construction joints unless removed afterwards;
- Particular attention shall be paid to vibration, especially near construction joints.

9.1.16.2 Testing of Concrete Tanks

Concrete tanks for the storage of water or other liquids shall be tested with water in accordance with Section 3 of this specification.

9.1.17 Defects

The concrete shall be free from honeycombing and planes of weakness shall have the required standard of surface finish and shall be watertight where required. The surface of the concrete should be inspected for defects and for conformity to the surface finish specified and where appropriate, for comparison with approved sample finishes.

Subject to the strength and durability of the concrete being unimpaired, the making good of surface defects may be permitted by the Employer but the level of acceptance should be appropriate to the type and quality of the finish specified and ensure satisfactory permanence and durability.

On permanently exposed surfaces great care is essential in selecting the materials and the mix proportions to ensure that the final colour of the faced area blends with the parent concrete in the finished structure. Voids can be filled with a fine mortar, preferably incorporating styrene-butadiene rubber (SBR) or polyvinyl acetate (PVA), while the concrete is still green or when it has hardened. Fine cracks can be filled by wiping a cement grout, an SBR, PVA or latex emulsion, cement/SBR or cement/PVA slurry across them. Fins and other projections can be rubbed down.

9.1.18 Records

A daily record shall be kept of all concreting operations, which shall include, inter alia, records of:

(a) Each section of the work in which concrete has been cast, and the grade and quantity of concrete placed;

(b) All test cubes made during each day, allowing space for later entry of the cube crushing strengths, which shall be recorded in the appropriate space as soon as they become available;

(c) The daily maximum and minimum temperatures in the shade at the particular site;

(d) Any events which may affect the quality of the concrete, e.g. the occurrence of rain, high wind, breakdowns in weigh-batchers, mixers, cranes or other concreting plant etc.;

(e) Any emergency construction joints formed as a consequence of a breakdown in the supply of concrete.

In addition records shall be kept of calibration tests as carried out periodically on weigh-batching plant.

The records shall be available at all times during the progress of the work for inspection.

9.2 Ancillaries to Concrete

9.2.1 Reinforcement

9.2.1.1 General

Reinforcement specification and workmanship shall comply with BS EN 1992-1-1 and BS EN 13670. High yield strength reinforcement bars projecting from concrete shall not be rebent.

9.2.1.2 Butt Joints

The only acceptable form of butt joint comprises a proprietary mechanical coupler of proven design that satisfies the following criteria:

a) When a test is made of a representative gauge length assembly comprising reinforcement of the size, grade and profile to be used and a coupler of the precise type to be used, the permanent elongation after loading to 0.6 times the characteristic yield stress should not exceed 0.1 mm.

b) The tensile strength of the coupled bar should exceed the characteristic yield stress by 5%.

9.2.1.3 Welded Joints

Where welding is unavoidable material workmanship shall comply with BS EN 13670 and BS EN 1992-1-1. Welded joints should not be considered except in areas of extreme congestion where there is no other method available to achieve the design requirements.

9.2.1.4 Built-in Items

General

Construction drawings shall indicate all embedded items from any source, identifying each type of embedment, their location, the accuracy of positioning required and any special workmanship requirements. In all cases, with the exception of first stage concrete, built-in parts shall be within 5 mm of the position indicated on the drawings.

Built-in items shall be securely held in position to resist forces which will be imposed by the concreting activities. Large items of electro-mechanical plant for example may require restrictions on pour heights to keep flotation or other forces acting on restraints during concreting within designed limits.

Proprietary built-in items shall be assembled and installed strictly in accordance with the manufacturers' instructions, using appropriate tools, ancillaries and consumables supplied by or as recommended by the manufacturer.

Any built-in item which cannot subsequently be examined or replaced easily shall have a design life in its working environment not less than the anticipated lifetime of the structure it is built into.

Built-in items shall be protected as necessary to prevent damage, deterioration or loss of serviceability.

Pipes shall not be built-in unless they are connected to the remainder of the pipework system, properly aligned, and complete with valves and specials; or unless there is adequate flexibility in the pipework system not yet in place to accept all probable misalignments and positional errors. Otherwise box-outs shall be left in the concrete. The surfaces of box-outs shall be prepared as construction joints.

Void Formers over Turbine Casings

Where turbine casings are to be encased in concrete and it is necessary to allow the casing to expand and contract due to pressure variations in service, a void shall be formed over the top surface of the casing and elsewhere as required by the turbine manufacturer.

Where required by the turbine manufacturer the void former shall comprise 12 mm thick closed cell polyethylene foam board of appropriate density. The density, which affects compressibility, and permissible lift heights of embedding concrete are inter-related and shall be selected such that the compressive strain of the foam acted upon by the pressure of concrete prior to setting shall not exceed 10 per cent.

The foam board shall be glued to the surface of the casing to form a continuous surface which will not be dislodged during concreting. Every care shall be taken to prevent point loads occurring on the foam which would cause local crushing, i.e. from reinforcement spacers and the like. All joints shall be taped to prevent ingress of mortar.

9.2.2 Formwork

9.2.2.1 General

The Contractor shall design, supply and fix all necessary formwork, together with its attendant falsework, scaffolding, timbering, shoring, strutting, etc, required for the placing of concrete. The design construction and treatment of formwork shall be in accordance with the recommendations in BS EN 13670. Falsework shall be designed and constructed in accordance with BS 5975: 2008.

9.2.2.2 Ties

Where internal metal ties are used, they or their removable parts shall be extracted without damage to the concrete and the remaining holes filled with a suitable mortar. No permanently embedded metal part of a tie shall have less than 30 mm cover to the finished concrete surface.

Where the concrete is to be watertight, internal metal ties of any sort shall not be used unless they are in two parts, each screwed into a central metal or other block which remains in the concrete and in which the screwed lengths do not penetrate through the block. The void left after removal of the tie shall be filled by a mortar having the lowest practicable water/cement ratio.

Where tie bolts are used in concrete which is to pass high-velocity water flow, a proprietary system shall be used which enables the tie bolt to be completely removed, the void effectively plugged and the surface made flush with neither projection, depression nor feather edge. One possible system is a non-ferrous tube with a threaded end. After removal of the bolt the tube is filled with grout and a non-ferrous threaded plug is screwed in and ground off flush with the surface.

For other areas prominently and permanently visible on completion, ties shall be aligned in a regular symmetrical pattern and preformed cones shall be used at the ends. The cones shall be removed after striking the formwork and the resultant recesses filled to 10 mm back from the general surface with a smoothed mortar of the same water/cement ratio as that of the concrete.

In areas which will not be visible after completion, the cones may be filled flush with the concrete.

9.2.2.3 Exposed Corners

All exposed concrete shall have external angles chamfered 20 mm x 20 mm by means of moulding strips fixed to the formwork.

9.2.2.4 Erection of Formwork

The height of concrete lifts shall not exceed the Contractor's designed capacity of the formwork or falsework.

The formwork for successive vertical lifts must make good contact with the concrete in the preceding lift such that there will be no excrescences, bulges, tears and other outward signs of a faulty junction, e.g. significant grout leakage. Compressible grout strips or timber strips shall be used to ensure that such untidy irregularities at junctions between lifts are avoided.

The forms must be fixed in perfect alignment and securely braced in order to withstand, without displacement or deflection, the movement of men, materials and plant, and the pressure of the wet concrete whilst it is being cast.

Particular care shall also be taken with the fixing of stop ends to form construction joints so as to ensure that there will be no unacceptable leakage of mortar.

9.2.2.5 Removal of Formwork

Removal of formwork shall comply with the recommendations of BS EN 13670. Striking times shall be determined in accordance with the CIRIA Report 136. Particular care shall be taken when assessing striking times for striking vertical forms for higher classes of finish or elements subject to wind loads.

9.2.2.6 Surface Finishes obtained from Formwork

The classification of formed surface finishes shall be in the following categories. Finish classifications shall be indicated on the Construction drawings.

Class F1: Usually for areas which will not be visible in the completed Facilities:

Unwrought timber may be used.

Class F2: Usually for areas, except high velocity waterways, which will be visible in the completed Facilities:

Normal fair finish for exposed work, obtained from the use of steel shutters or forms lined with plywood, formboard, blockboard or hardboard of approved manufacture or other approved material. Upon removal of the formwork all fins and joint irregularities shall be ground smooth. Air holes shall be made good with mortar of the same colour as the concrete.

Wherever possible on large surface areas, large panels (generally 2.4 x 1.2 m approx.) of 5 or more ply timber shutter panels with a minimum number of joints between panels shall be used.

In areas prominently and permanently visible on completion, particular attention shall be given to the arrangement of joints and bolts (where used), so as to achieve a symmetrical pattern in the finished concrete surfaces. In general, panel and bolt lines shall be either, vertical, horizontal or parallel to the overall lines of the structure.

The finished face of concrete resulting from the use of Class F2 formwork shall be of an even light colour without significant colour variations between panels. Defects in finished surfaces shall be rectified.

Class F3: Special shuttered surfaces, including those for waterways subject to high velocity flow:

As F2 but the formwork is to be lined with materials of the highest quality and heavily strutted to ensure a particularly accurate line of finish within the given tolerances in which no filling of blemishes will be necessary. The only allowable remedial work will be grinding off to obtain required tolerances.

Class F4: Exposed aggregate finish for architectural purposes:-

As F2, but additionally an exposed aggregate finish shall be produced by painting the relevant areas of the forms with an approved retarding agent, followed by brushing the concrete surfaces immediately after the formwork has been struck. Formwork treated with a retarding agent shall be struck within 60 hours of casting the concrete. In order to achieve uniformity of finish, construction joints shall be kept to a minimum where the concrete aggregate is to be exposed and due allowance shall be made for temperature variations when estimating the time between casting and brushing the concrete surfaces to expose the aggregate.

The type of formwork used and care in placing concrete for areas which are to have an exposed aggregate finish shall be consistent with the need to produce a uniform finish in each area of exposed aggregate.

In order to obtain a uniform colour for the exposed aggregate, crushed rock sand shall be used.

Before forming any exposed aggregate surfaces, sample panels of 4 m^2 minimum area shall be cast to establish a mix with the desired appearance, uniformity and depth of aggregate exposure. The time lapse between casting and brushing the concrete surfaces, the method of brushing, types of brushes used, temperature effects etc. shall be established at this time and will then be used for all exposed aggregate surfaces. Sample panels shall be manufactured at least 3 months before any such permanent surfaces are intended to be formed, and must be allowed to weather for 2 months before selection.

9.2.2.7 Unformed Surface Finishes

9.2.2.8 General

Exposed surfaces of concrete not finished against formwork, such as horizontal slabs or slightly sloping surfaces, shall be brought up to a uniform surface and worked with screeds or other suitable tools to a smooth finish within the required tolerances.

If the concrete surface of any section of work is unsatisfactory and does not conform to the specified finish, such surfaces shall be rubbed down while still green or alternatively ground down with carborundum or other methods when hard in order to give a smooth clean finish. Honeycombed surfaces shall be cut back and re-cast to the specified finish.

9.2.2.9 Classification of Surface Finishes

The classification of surface finishes for concrete not cast against formwork shall be in the following categories. Surface finish classifications shall be indicated on Construction Drawings.

Class U1: Tamped Finish

Exposed surfaces of concrete not finished against formwork such as horizontal or slightly sloping surfaces shall be brought up to a uniform surface and worked to exact line and level using screeding boards or other suitable tools to a uniform finish without excessive laitance. Where these surfaces are to receive a secondary or finished screed or layer the concrete surface shall be sprayed with a water jet after the initial concrete set has taken place so as to loosen and remove the surface mortar and expose clean particles of the coarse aggregate.

This is the normal finish for ordinary work and construction joints. Additional measures for slabs of large area have been described under "Compaction and Vibration".

Class U2: Wood Float Finish

As U1 but after the concrete has hardened sufficiently the surface shall be floated by a wooden float to produce a uniform surface free from screed marks.

Class U3: Steel Float Finish

As U2, but using a steel float with great care to produce a particularly hard and smooth surface, while avoiding the development of excessive laitance.

This is for very high quality work.

Class U4: Specially-Required Quality in the topmost layers or at the surface of the fresh concrete.

When a particular treatment is to be applied to concrete before hardening it will be designated as follows and shown on the Drawings:

- U4.1: Small chippings applied to plastic concrete.
- U4.2: Applied chemical hardener.
- U4.3: Applied chemical sealer.
- U4.4: Power floating.
- U4.5: Vacuum process.

Various specialised treatments are available for differing requirements, mostly utilising proprietary equipment or products. The supplier's recommendations shall be strictly followed, along with any relevant provisions of BS 8204, and the work shall be carried out only by personnel experienced in the type of work concerned.

9.2.3 Tolerances

9.2.3.1 General

Tolerances shall be in accordance with BS EN 13670 and BS 5606, whichever is more onerous for any particular element, except in critical areas where plant or other service requirements are required for their proper performance over their design life.

9.2.3.2 Local deviations in planar surfaces

Local tolerances for slabs, walls and other flat surfaces will be designated as S1, S2 or S3 and indicated on the Construction Drawings. These categories are defined as follows:

(i) When a 3 m straight edge is laid on the surface the maximum deviation (valley) measured below the straight edge shall not exceed:

For S1:- 3 mm;

For S2:- 5 mm;

For S3:- 10 mm.

(ii) The local slope computed as the depth of a "valley" divided by its distance from the nearest "crest" (point where the straight edge touches) shall not be steeper than:

For S1:- 1 in 200;

For S2:- 1 in 120;

For S3:- 1 in 60.

(iii) Steps at joints shall not exceed:

For S1:- 1 mm;

For S2:- 2 mm;

For S3:- 2 mm.

Slabs which are to receive a screed as part of the finishing work shall be to S3 unless otherwise stated.

Category S3 shall be assumed where no tolerance is stated.

Remedial work by grinding of protrusions will always be preferred to filling of hollows.

9.2.3.3 External Slabs and Road Slabs

Concrete road slabs shall be to S2 both longitudinally and transversely.

All external slabs across which stormwater will flow and other slabs laid to falls shall always be able to shed water effectively even if this suggests a tighter tolerance.

9.2.3.4 High-Velocity Water Conduits

Abrupt protrusions, steps and hollows in conduits which will carry water at high velocity are likely to lead to cavitation immediately downstream of the defect, with potentially very serious consequences. Accordingly, concrete surfaces in such conduits shall be to S1 parallel to the flow and S2 transversely, except that at joints transverse to the flow no projection at all of the downstream edge into the flow will be accepted.

9.2.3.5 Members

The tolerances for precast reinforced or pre-stressed concrete members shall comply with the recommendations of BS EN 13670.

9.3 Specialised Concrete Techniques

9.3.1 Precast Concrete

9.3.1.1 Scope

This Clause 9.3.1 applies to all concrete cast away from its position in the permanent Facilities, whether reinforced or pre-stressed. It also applies if the pre-casting is carried out within the main limits of the work site or at a factory.

9.3.1.2 Marking

Every precast unit shall be marked with a unique identifying number and the date of casting. The marking shall be made with indelible paint on a surface which will not be visible on completion.

9.3.1.3 Handling

Precast concrete units shall be lifted and supported during manufacture, transport and erection only at specific lifting or supporting points and these shall be clearly identified on drawings and marked on the units. Transportation, site handling and erection shall be carried out only by experienced personnel using methods and equipment which will not overstress the units.

Where precast units are stored on the ground, the supporting area shall be strengthened as required to avoid settlement which could adversely affect the precast units.

Erection will include the placing, precise alignment and levelling of members in final position in the structure. The correctness of line and level shall be ensured before erection by careful levelling and preparation of the bearing details. Joints between precast elements shall be grouted, pointed, glued or caulked as required.

9.3.1.4 Bearings

Bearings other than steel details shall be proprietary items obtained from a manufacturer specialising in this type of equipment.

Bearings shall be set to the exact detail shown on the construction drawings to the designated tolerance using the manufacturer's recommended fixing and seating arrangement, shims and special grouts as required.

9.3.2 Pre-stressed Concrete

9.3.2.1 Scope

This Clause relates to in situ and precast pre-stressed concrete. For precast work the requirements given for Precast Concrete shall apply in addition.

It is assumed herein that post-tensioning will be used. The use of pre-tensioning however is not excluded.

9.3.2.2 General

Pre-stressing operations shall be carried out only under the direction of an experienced and competent supervisor and all personnel operating the stressing equipment shall have been properly trained in its use. Special precautions shall be taken when working with or near tendons which have been tensioned or are in the process of being tensioned.

Formwork which will be in place during stressing shall be designed to allow for the horizontal and hogging movements which will take place during stressing.

Tendons, anchorages and stressing equipment shall all be compatible. Under no circumstances shall apparatus designed for use with one system of pre-stressing be used in conjunction with apparatus designed for use with another system.

9.3.2.3 Pre-stressing Tendons

The specification and workmanship for pre-stressing tendons including materials, handling, tendon arrangement, anchorage, the tensioning apparatus and the tensioning procedure shall comply with BS EN 1992-1-1 and BS EN 13670.

Full records shall be kept of all tensioning operations including the measured extensions, pressure gauge or load cell readings and the amount of pull-in at each anchorage. Copies of these records shall be supplied to the Employer.

9.3.2.4 Grouting of Ducts

Ducts shall be grouted with cement grout as soon as practicable after the tendons have been stressed. Grout for pre-stressing tendons shall comply with BS EN 447: 2007. Grouting procedures all comply with BS EN 14605: 2005. Testing of grout shall comply with BS EN 445: 2007.

Pre-stressed beams shall be load tested selecting 1 in 10 for the first 50 of a particular type of unit and 1 in 25 thereafter.

The test load shall exceed the maximum design load (unfactored) but will not be such as to exceed either 40 per cent of the specified cube strength in compression or 10 per cent of the required cube strength at transfer in tension.

Units intended for composite construction may have to have a temporary top slab of reinforced concrete for purposes of the test. This will be debonded from the pre-stressed concrete.

Loads shall be measured to an accuracy of + 2 per cent (or 0.05t if greater) and deflections to + 0.5 mm. Loading jacks and gauges shall be calibrated together.

Loads for beams and like items shall be applied equally to the third points of the span. For other structural units the load shall be applied at the centre of the span. Loads shall be increased in 10 stages, held for 15 minutes at each stage and released in 5 stages.

The initial hog shall be measured together with the load/deflection curve during the test. At least 85 per cent of the maximum deflection shall be recovered on completion of the test.

Any pre-tensioned unit which fails the test shall be rejected. Other units cast in the same line shall also be rejected unless tested and found to be satisfactory.

Full records shall be supplied to the Employer of the test showing age of unit, initial hog, loads, deflections and calculated value of Young's Modulus of Elasticity.

9.3.3 Concreting of Canal Linings

The power canal shall be concrete lined for its entire length. Forms for canal linings shall be designed in such lengths as will allow each placement to be completed without interruption.

9.3.4 No-fines Concrete

No-fines concrete will be used where required to produce a stable porous foundation or for other applications.

The aggregate shall be gap-graded such that all particles pass a 37.5 mm sieve but not more than 10 per cent pass a 20 mm sieve; alternatively, all particles shall pass a 20 mm sieve but not more than 5 per cent shall pass a 10 mm sieve. The aggregate/cement ratio shall be between 8 and 10.

The water/cement ratio shall not exceed 0.45 and shall be a minimum such that each particle of aggregate is completely coated with a smooth grout paste, but at the same time the paste shall be sufficiently wet that the mortar coatings run together at the point of contact (without filling the interstices between the particles) to form a fillet which will bond the particles together.

Trial mixes shall be carried out to establish optimum mix proportions before any no-fines concrete is used in the permanent Facilities.

The aggregate shall be thoroughly saturated immediately before batching.

No-fines concrete shall not be moved from its point of deposition other than to strike off to the correct level.

Where no-fines concrete is to be covered by normal concrete a layer of building plastic, or preferably mortar, shall be placed over the surface of the no-fines concrete to prevent mortar of the concrete from filling the interstices of the no-fines concrete.

9.3.5 Super-plasticised Concrete

It is envisaged that super-plasticised concrete may be required in areas where reinforcement is very congested and access is very difficult.

Super-plasticised concrete is a normal concrete to which a super-plasticising admixture has been added as a workability agent to increase the workability considerably during the first 30-60 minutes after mixing without adversely affecting the required properties of the hardened concrete.

Trial mixes shall be carried out to verify the extent of the increase in workability and to prove that it is not accompanied by excessive bleeding or segregation. It may be necessary to increase the sand content from the equivalent grade of un-plasticised mix in order to meet these requirements. The flow table spread of the mix before addition of super-plasticiser shall not exceed 44 cm.

In the production concrete the super-plasticiser shall be added by a calibrated gravity-feed dispenser and mixing shall continue for 2-5 minutes thereafter. If there is a delay such that the effect of the plasticiser wears off significantly, the concrete shall be used elsewhere or discarded; a second dosing shall not be permitted.

It shall be assumed that vibration will still be necessary.

9.3.6 Sprayed concrete

9.3.6.1 Scope

The term "gunite" will be used for sprayed concrete where the maximum aggregate size is less than 10 mm and the term "shotcrete" where the maximum aggregate size is 10 mm or greater. The use of gunite may be expected to be restricted mostly to work of a cosmetic nature of which the visual appearance is important.

Any aspects of sprayed concrete work not covered by the Specification shall be in accordance with the relevant clauses of ACI Standard 506.

9.3.6.2 General

Areas to which sprayed concrete is to be applied and the thicknesses to be applied shall be identified on construction drawings and, where necessary, supported by structural calculations before work on a particular area commences.

The dry mix process, in which water is added at or adjacent to the nozzle, shall not be used unless the Contractor (a) can demonstrate that he has successfully used the dry mix process in comparable conditions elsewhere and (b) has suitably experienced operatives available for such work on this site.

The primary use of sprayed concrete will be as a means of preventing disintegration of a rock mass during the first few hours after its exposure following excavation. In such cases the first layer of the sprayed concrete shall, therefore, usually contain an accelerating admixture and will normally be applied after blasting but before removal of spoil. This layer may be expected to have a nominal thickness of around 30 mm.

Temperature restrictions on concrete placing shall apply also to sprayed concrete.

9.3.6.3 Preparation of surfaces

The surfaces to which sprayed concrete is to be applied are to be barred down and descaled of all large loose material and cleaned down with a mixture of water and air applied at high pressure.

Where the inflow of groundwater renders the surface too wet for the normal application of sprayed concrete, the water shall be suitably drained so that the surface is free of running water. Alternatively, grouting may be necessary to reduce water inflow to acceptable limits.

All surfaces to receive sprayed concrete shall be moist but free of dirt, oil, rebound or other deleterious material. Where sprayed concrete is to be placed over a previous layer, that layer shall first be allowed to reach its initial set and then cleaned of all laitance, rebound or other loose material by brooming or sluicing.

Pins at suitable spacings shall be inserted into the surface to receive sprayed concrete to facilitate the verification of the applied thickness.

9.3.6.4 Reinforcement

Where required, steel mesh reinforcement shall be incorporated in sprayed concrete. Minimum reinforcement shall comprise a single layer of welded steel mesh fabric of 5 mm wires at 150 mm centres. Where heavier reinforcement is required, a built up system made from steel reinforcing bars shall be used.

In areas where mesh is to be used, a first application of sprayed concrete shall be made before fixing the mesh fabric, with the object of filling fissures and pockets to form a more uniform surface against which the mesh can be placed satisfactorily.

The steel mesh shall be securely fixed at maximum centres 800 mm both ways at the optimum distance from the surface for the application process such as to minimize rebound and prevent voids. The minimum cover between the reinforcement and the exposed face of the sprayed concrete shall be 30 mm. Laps shall be 250 mm minimum for mesh and 50 diameters for steel bars, and bars in lap areas shall be at centres exceeding 50 mm.

If two layers of reinforcement are required, each layer of reinforcement shall be contained in a separately-applied layer of sprayed concrete.

9.3.6.5 Equipment

Equipment used for the application of sprayed concrete shall comprise compatible components of established design in proper working order. Water needed for the process shall be supplied at a steady pressure of 3-6 bars. Air for the equipment is to be clean, dry and oil free and should be provided at the equipment within the pressure range 4-6 bar.

The nozzle shall produce a conical discharge stream of uniform appearance throughout.

9.3.6.6 Experience of operatives

Nozzle men employed on this Contract shall have experience of similar work on previous projects. Supervisors shall have adequate background specialist experience.

9.3.6.7 Protection of personnel

Sprayed concrete generates considerable dust and this is particularly aggravated when powdered additives or admixtures are used. The situation is made more severe when the additive is siliceous. Personnel other than the spraying operatives must be suitably warned and protected if need be. Nozzle men and assistants must be issued with adequate protective clothing to prevent excessive dust entering ears, nose and mouth; respirators shall be used if necessary. Hands must also be protected against prolonged contact with cement.

9.3.6.8 Materials

Water and reinforcement shall be as specified for concrete.

Cement shall be Ordinary Portland Cement as specified in the Concrete Section. Uniformly fine-grained cement is preferable.

Where an accelerating admixture is necessary in order to apply the sprayed concrete successfully or to maintain safe conditions, the amount used shall be within limits recommended by the manufacturer but within the range 2-7 per cent by weight of cement. In the case of cement containing a pozzolan, the advice of the manufacturer of the additive (and of the cement, if necessary) shall be sought to determine the suitability of the combination. The objective in adding such an admixture should be to obtain high early strengths appropriate to the conditions.

Depending on the materials available on Site, it may be possible to use 10 mm and 20 mm aggregates as used for ordinary concrete works. Aggregates with a high proportion of flaky particles may prove to be unsatisfactory. Suitable tests shall be carried out to determine the optimum type and grading of aggregate.

There are quite wide variations in 10 mm aggregate gradings which appear satisfactory for gunite. It is to be expected that a grading within and parallel to the following band will be satisfactory, but the exact grading used is likely to be subject to trial and error and will vary depending on whether crushed rock or naturally occurring materials are used.

BS Sieve Size (mm)	Percentage Passing
14	100
10	93-100
5	65-90
1.18	30-60
0.6	17-41
0.3	8-23
0.15	0-10
0.075	0-2 (mandatory)

In the case of the combined grading of 20 mm aggregate for shotcrete there appears to be reasonably close agreement on practicable gradings and it is suggested that a grading within and parallel to the following band is likely to be satisfactory:-

BS Sieve Size (mm)	Percentage Passing
37.5	100
28	97-100
20	90-100
14	76-96
10	62-87
5	45-70
1.18	18-40
0.6	12-32
0.3	5-20
0.15	0-12
0.075	0-5 (mandatory)

9.3.6.9 Mixes and properties

There shall be sufficient over-design strength to allow for rebound, variation in workmanship and other relevant factors.

The mixes as sprayed shall lie within the following limits unless otherwise agreed by the Employer:

- Cement content (kg/m^3)	300-450
- Aggregate/cement ratio for gunite	1.0-3.0
- Aggregate/cement ratio for shotcrete	3.0-5.0
- Water/cement ratio	0.35-0.45

In determining the water/cement ratio, account shall be taken of the water content of the aggregate, which should normally be in the range 3-6 per cent.

Water shall be added in sufficient quantities to minimize rebound while simultaneously avoiding any slumping of the layer of sprayed concrete during placing.

The specified 28-day compressive strength of 100 mm diameter cores 100 mm long shall be 30 N/mm^2.

When the mix incorporates an accelerator the following properties shall be the objective:

- Maximum time of Initial Set:	3 minutes
- Maximum time of Final Set:	12 minutes
- Core strength at 8 hours:	3 N/mm^2
- Core strength at 72 hours:	12 N/mm^2

9.3.6.10 Test panels

Sprayed concrete shall only be carried out by experienced nozzle men.

At least 2 weeks before any sprayed concrete is expected to be produced, not less than 3 test panels for each mix for testing shall be prepared. Sets of test panels shall comprise one shot downwards on to a horizontal surface, one shot on to a vertical surface and one shot on to an overhead horizontal surface. The panels shall be obtained by securely attaching 500 x 500 x 120 mm deep timber boxes to appropriately aligned surfaces and applying sprayed concrete to the areas contained in the boxes using the same mixing and placing equipment to be used in the Facilities.

All the panels shall be a minimum thickness of 80 mm. When the final set has taken place the test panels shall be transported to the laboratory where the crushing strength will be determined by testing cylindrical cores cut from the panels. No trial core strength, after adjustment for length of core, shall fall below the minimum specified.

During sprayed concrete operations, routine test panels shall be prepared beside the application zones for the purpose of quality control. Three panels shall be supplied for approximately each 25 m^3 of sprayed concrete and shall be tested as described above.

The quality of the sprayed concrete will be considered satisfactory if every test result is at least 80 per cent of the specified strength and if at least 80 per cent of all results exceed the specified strength.

9.3.6.11 Batching

Materials shall be batched by weight and cement shall not be added more than 1 hour before the anticipated time of placing the sprayed concrete.

9.3.6.12 Placing

Unless trials have demonstrated otherwise, the nozzle shall discharge 1-1.5 m from the surface. There shall be no significant inclusion of rebound in the finished work, no hollow areas, good adherence to the rock and a reasonably smooth surface finish. Rebound shall be kept clear of sprayed concrete being placed and an air jet shall be provided for this purpose.

Sprayed concrete should be available for application immediately following the scaling of the excavation.

The thickness of sprayed concrete applied in one pass shall be at least 25 mm. In general an initial layer sufficient to stabilize the rock immediately after excavation is to be expected, followed by any remainder at some convenient later time. It is not intended that the finished exposed surface will present the same appearance as a concrete lining placed behind formwork; large radius irregularities will be permitted, but local roughness and re-entrant angles are to be avoided.

Construction joints in the layer shall be formed at 45° to the face and precautions shall be taken to prevent weak and unsightly edges at construction joints. If necessary, timber strips may be temporarily fixed in place to give a neat, strong edge. Before placing the adjoining work the edge shall be cleaned and thoroughly wetted.

The sprayed concrete after completion is not to be touched up, trowelled, smoothed off or worked in any way, but left undisturbed. Before a succeeding layer is placed the existing work shall be checked for hollow or non-adhering areas and these shall be cut out and replaced.

9.3.6.13 Curing

The sprayed concrete shall be kept moist continuously for 7 days. Spraying with a fine mist of water is to be anticipated at intervals not exceeding 4 hours unless the area of application is one of high humidity.

Section 10: Technical Specifications – Pipe work

10.1 Scope

This section of the Specification deals with pipes prefabricated at the manufacturer's works and intended to carry:

- Potable water in water supply systems, both in pumped supply lines and gravity feed lines.
- Stormwater by gravity (or pumping if need be).
- Sewage and foul water by gravity or pumping.

It therefore deals primarily with pipe runs formed from stock manufactured items which are not special to this Project.

Small diameter plumbing pipes within domestic and office buildings are covered in the Building Works Section, together with foul water outlet pipes as far as collecting gullies immediately outside the buildings. The recommendations of BS 6700 and BS EN 806 shall be followed for potable water pipework within buildings.

The excavation and backfilling of pipe trenches is dealt with in the Earthworks section.

The building of steel pipes into concrete work is described in Concrete Works section.

The internal protection of potable water pipes is covered in the Painting section.

10.2 General

The workmen engaged on laying and joining pipes shall be suitably experienced in the type of pipe which is being installed.

In general the materials, workmanship and testing shall conform to BS 6700 as appropriate when used for water supply pipelines, BS EN 752 and BS EN 1610 for drainage and sewerage adjacent to buildings, and also for sewage disposal systems.

All pipes and specials shall be clearly marked so that the BS or equivalent standard, the type, grade and pressure designation of the pipe can be easily identified to ensure that the correct pipe is installed in each section.

The laying and jointing of foul sewers shall be in accordance with all relevant requirements of BS EN 752 and BS EN 1610.

10.3 Materials

10.3.1 Precast Concrete Pipes and Specials

Pre-stressed and reinforced concrete pipes shall be to BS EN 1916/BS 5911-1 Strength Class 120 unless expressly required otherwise.

Concrete pipes shall be of the spigot and socket type with rubber sealing rings. Ogee joints shall not be used.

Precast concrete manhole units etc. shall be to BS EN 1917/BS 5911 Part 3 and Part 4.

Precast pipes and specials shall be free from cracks, fractures and unacceptable surface roughness. No faulty pipes shall be used in the permanent Design Build Services.

10.3.2 Plastic Pipes

For polyethylene and unplasticised PVC (uPVC) pressure pipes, BS EN 13244 and BS 5955-8 shall apply. Joints and fittings shall be to BS EN 1452.

Where uPVC pipes are used for stormwater drainage, BS 4660/BS EN 13598 shall apply.

Where uPVC pipes are used for gravity sewerage, they shall be to BS EN 1401-1 and installation shall be to BS EN 1601.

Plastic pipes shall not be installed above ground in locations subject to sunlight unless they are certified by the manufacturer to be suitably resistant to ultra violet light. Pipes which are not so resistant but which are to be used below ground shall be stored under cover.

Where perforated uPVC pipes are used for foundation and land drainage, they will be drilled or slotted with hole sizes to suit the particle size of the surrounding medium and perforation area to suit inflows.

Structured wall thermoplastic pipes shall comply with BS EN 13476 or equivalent.

10.3.3 Pitch Fibre Pipes

Pitch impregnated pipes and fittings shall not be used for pressurised pipelines.

10.3.4 Vitrified Clay Drain and Sewer Pipes

Clay drain and sewer pipes shall be in accordance with BS EN 295.

10.3.5 Steel Pipes

10.3.5.1 General

Steel pipes shall be to the pressure ratings required for each particular application. They shall be sound and free from cracks, surface flaws, laminations and rough, jagged and imperfect edges.

All pipes and fittings shall be made in accordance with BS EN 10224, BS EN 10255, BS EN 10253, BS EN 10216, BS EN 10217 and BS 2633, as appropriate, using the minimum number of individual pieces of plate.

Pipes are to conform dimensionally to BS EN 10220.

10.3.5.2 Joints

All jointing materials shall be supplied by the Contractor.

Pipe ends shall be prepared for field welding where necessary. Welded joints shall have an ultimate tensile strength at least equal to 95% of the minimum tensile strength of the parent plate.

Where flanges are required they shall be in accordance with BS EN 1092 for the required design pressure and they shall be square to the axis of the pipe, truly plane on the machined faces and faced full across.

Loose steel flexible and half flanged couplings for use with plain ended and flanged pipework and fittings are to be installed at the required positions. They are to be of approved quality and manufacture, and capable of withstanding the required test pressures without exceeding a stress of 75% of the guaranteed yield stress of the steel. The couplings are to be supplied with all rubber rings and central locating registers, capable of easy removal by unscrewing. Whatever type is offered the Contractor must state the maximum deflection angle which is possible without affecting the water-tightness or effectiveness of the joint.

All components of rubber rings and gaskets shall be in accordance with BS 7874/BS EN 681 & 682. Rubber rings and insertions shall be of homogeneous material, free from blemishes and porosity, uniform in shape to the specified dimensions and such as to achieve watertight joints. The rubber shall be vulcanised by an approved process and any joints therein shall have a minimum of 90% of the tensile strength of the uncut section. The rubber shall be suitable for operating temperatures from 5°C to +70°C.

10.3.5.3 Protection against Corrosion

The protection of steel pipes against corrosion is specified under Employer's Requirements section - Painting and Surface Protection.

Galvanised pipes shall be supplied as required.

10.3.5.4 Small Bore Steel Tubes

Screwed and socketed steel tubes shall be to BS EN 10255.

10.3.5.5 Ductile Iron Pipes

All pipes, fittings, joints and accessories shall comply with BS EN 545 for water pipelines or BS EN 598 for sewerage applications.

10.3.5.6 Valves

Valves shall be of steel or cast iron with appropriate corrosion protection. Sluice type valves shall be to BS 5163. Air valves shall be of the double-duty kinetic type, capable of releasing air quickly during filling and emptying, and of discharging automatically any entrained air accumulating in the pipeline during normal working conditions.

All valves are to be supplied with operating keys and shall turn clockwise to close unless specifically required otherwise. The direction of turning to increase/decrease the flow shall be marked by a symbol as well as "open/close" such that the direction to turn is clear.

The manufacturers' instructions for installing and building of valves shall be followed in all respects.

10.4 Laying of Pipes and Fittings

10.4.1 General

Sight rails and boning rods shall be used for the laying of pipes to falls. Pipes shall be evenly bedded and the bores shall be concentric. There shall be no projections at the joints inside the pipes. Each pipe or fitting shall be thoroughly cleaned and examined for damage or defects before being laid and, while pipelaying is proceeding, the mouth of the last pipe laid shall be plugged to prevent foreign matter from entering. Where required pipes shall be cut, in which case the cut edges shall be finished off square and the edges trimmed.

A sight line shall be used along the outside of the pipes to ensure correct alignment. Pipelaying shall commence at the lower end of a grade and shall proceed uphill. Spigot and socket pipes shall be laid with the direction of flow from socket to spigot.

Before a metal pipe is placed in the trench the internal and external protective coatings shall be examined, both visually and by means of a "holiday" detector.

Pipes shall be jointed in the trench and all relevant manufacturers' instructions regarding the procedure to be adopted for this work shall be followed.

After a sufficient length of trench has been excavated to the required depths, the pipes, which shall have been previously strung out along the side of the trench, are to be carefully lowered into place on to the prepared trench bottom or bedding. Immediately before being laid, each pipe and fitting is to be carefully examined both inside and out for any damage or defects, and all stone, dirt, grease or any foreign matter must be removed from the inside of the pipe.

The pipes must bear evenly on the prepared trench bottom or special bedding. Where hollows, bumps or irregularities of the trench bottom occur which prevent the pipe from being supported on the solid along its entire length between joint recesses, the pipe is to be lifted from the trench or moved to one side while the trench is regraded in the manner specified. Where such regrading or packing is rendered necessary by reason of any error on the part of the Contractor for this Contract, it must be carried out at his expense.

Damaged or defective pipes or fittings shall not be used. Pipes damaged after laying shall be replaced.

On no account may hard objects such as stones, bricks or blocks be used to bring pipes up to the required level. Any temporary packing wedges which are used during jointing shall be removed before backfilling.

Where jointing solutions or lubricants are used, they shall be those recommended by the manufacturers.

A "badger" on a sound rope is to remain in the bore of the pipe previously laid and jointed and is to be drawn forward as the work proceeds, throughout the whole length of the pipelines. The "badger" and ropes used are to be of soft material which will not damage the internal surface of the pipes.

All pipes and fittings are to be laid true to line and level. Pipes and fittings must be well butted together, except in the case of pipes laid with flexible joints. Pipes must be concentric so as to give a uniform joint.

Special care shall be taken to prevent water from draining into open and partially backfilled trenches.

10.4.2 Cut Pipes

Pipes that have been cut shall be dressed square and to a smooth even finish, which shall not be inferior to that of the uncut pipe. The finished dimensions of the ends cut at Site must be within the tolerances applicable to the spigot ends of the particular type of pipes to be laid.

Closure lengths of lined and sheathed or coated steel pipes shall be flame cut on Site and the edges of the cut pipe ground smooth. All damage to the lining and external protection shall then be made good.

For pitch fibre pipes which have been cut a snap-ring joint shall be used.

Closure lengths of uPVC pipes shall be cut on Site with a saw and edges chamfered and made smooth with a file.

10.5 Jointing of Pipes and Fittings

10.5.1 General

Before jointing, each pipe, bend or special shall be thoroughly cleaned out and carefully examined for possible damage. The ends of each item and of all flanges are to be inspected and cleaned to ensure that all parts forming the joint are undamaged and clean.

All pipes shall be solidly and evenly bedded, true to line and level, concentric and well butted so as to give a uniform joint.

At manholes, flexible joints shall be used for gravity drains and sewers to connect the pipe built into the manhole wall with the main pipe run. These joints shall not be more than 1.5 pipe diameters from the external face of the manhole wall. Similar rocker pipes, complying with Table NA.23 of BS EN 752:2008, shall be used where pipework passes through structures and be of sufficient number to allow for expected differential settlement.

Flexible joints are to be expected for some or all lengths of metal, uPVC and AC plain ended pipes in particular. These joints will usually comprise a proprietary flexible detachable coupling unit and flexible rings. Such materials shall be assembled strictly in accordance with the manufacturer's instructions.

10.5.2 Concrete Pipes Jointed using Rubber Rings

The method for making the joint for spigot and socket pipes is as follows:-

After laying and bedding both pipes, the new pipe is slid away just far enough to allow the rubber ring to be inserted. The rubber ring is placed over the pipe end, centred, and rolled to the extreme end of the pipe. The pipe is pushed into the socket with the rubber ring rolling evenly into the collar. The pipe is then pulled back approximately 6mm and firmly haunched with rammed selected backfill to prevent subsequent movement.

A 45^{o} fillet of 1:3 cement/sand mortar shall be added to prevent ingress of foreign matter into the joint. If mortar is used it shall be kept damp for 7 days.

10.5.3 Integral Mechanical Spigot and Socket Joints for uPVC Pipes

These joints shall be made with materials and special tools obtainable from the pipe manufacturer, whose instructions shall be strictly observed.

10.5.4 Joints in Pitch Fibre Pipes

Joints in pitch fibre pipes depend entirely on the fit of the manufactured tapered joints surfaces. It is, therefore, necessary to provide snap ring joints in areas where differential movement may be expected.

10.5.5 Caulked Joints in Vitrified Clay Pipes

Caulked joints shall be made of 1:2 cement/sand mortar, mixed thoroughly first in a dry state then with only sufficient water added to make the mixture damp enough to hold together. A ring of tarred yarn soaked in liquid cement shall be put around the end of the spigot, or another suitable arrangement employed, to ensure that it is concentric with the socket. The yarn shall be well caulked home with a proper metal caulking tool, and the remainder of the socket filled with mortar well rammed home with the caulking tool and finished off to a fillet at the socket. Any mortar or other material which has found its way into the barrel of the pipe shall immediately be removed with a badger or other approved tool.

After jointing, the pipes shall be protected with damp sacking until they are tested and after testing they shall again be protected until backfilling is commenced.

10.5.6 Jointing of Metal Pipes

Jointing of plain-ended metal pipes, depending on the material, shall be by butt-welding or by using proprietary couplings such as Viking Johnson. Welding of pipelines shall be in accordance with BS 2633.

Jointing of flanged metal pipes shall incorporate the use of rubber insertion gaskets. All bolts used shall be mild steel black bolts with hexagonal heads and nuts in accordance with BS 4190. Bolt projection from the nut shall be neither greater than 12mm nor less than 4mm.

Any bitumen coating on the face of the flanges or on the spigot ends of metal pipes in excess of a thin film must be removed by scraping or similar process.

In jointing flanged metal pipework, valves, etc. the face of the flanges shall be cleaned thoroughly. The jointing material, cut properly to full-face size and with holes for bolts, is to be inserted immediately before bringing the flanges together.

Before closing the joints, the flanges must be parallel to each other, with at least two thirds of all bolts inserted in the boltholes. After the fittings have thus been aligned and well supported, the joint shall be closed by bolting up all bolts to uniform thickness. The new pipe shall be adequately supported to avoid overstress during bolting up.

10.6 Associated Concrete Work

Where there are tees, bends, terminal valves or end caps in pressurised pipe lines, concrete anchor blocks shall be designed and constructed. Holding-down bolts and anchor straps shall be provided and installed where required.

In general standardised prescribed concrete will be used for haunching and surround in trenches. The concrete shall be well rammed round the pipe and, if in trenches, against the wall of the trench, care being taken that the joints are left accessible.

10.7 Testing

10.7.1 Pressure Pipelines

The Contractor shall test pressure pipelines by hydrostatic pressure as the construction progresses. No one section of laid pipeline may exceed 600m in length until it has been satisfactorily tested. A further test of the entire pipeline will be required on completion.

Testing under air pressure will not be permitted. Pumps, water, power units, water meters, piping, valves, pressure gauges of certified accuracy and any other equipment necessary shall be supplied for the testing of individual sections of the pipeline and for the final completion test.

The Contractor shall provide blank ends, closure pieces and couplings and satisfactory means of supporting the end thrusts at the ends of the pipe sections under test.

The pipeline shall be tested to pressures not exceeding 1.5 times the maximum allowable working pressure for the particular class of pipe under test.

Before filling the pipelines checks shall be undertaken to ensure all required anchor blocks are in position. The Contractor shall be responsible for isolating or closing of valves and any arrangements deemed necessary to check on leaks from valves. (However, where possible, testing against a valve should be avoided).

Pipework shall be filled with water in such a manner as will give rise to no shock and also prevent the accumulation of air after satisfactory filling. When all air has been expelled, the pipeline shall gradually be pumped up by means of a pump equipped with a suitable pressure gauge to the desired pressure and the pump disconnected for a period of not less than 6 hours. At the end of this period, the pressure reading is to be noted and the main pumped up to its original pressure. Water shall then be released from a pet cock fitted to one of the test ends of the main until the pressure has fallen to that obtained at the end of the test period. The quantity of water released shall be measured by using a suitable container. The test will be deemed satisfactory if the amount of replacement water does not exceed 0.1 litres per mm internal diameter of pipe per km tested per 6-hour test period per 100m head of test pressure. At the completion of the test, the pressure in the pipeline shall be reduced gradually.

If the amount of make up water exceeds the specified quantity leaks shall be located and repaired and the length of pipeline re-tested. Any joint which leaks under the test pressure shall be located and made watertight or, where necessary, shall be entirely cut out and re-made. Any pipe or pipes or part of a pipe which, as a result of a test or during the course of the work or during the Defect Liability Period, is found to be split or otherwise defective, shall be cut out and replaced.

10.7.2 Tests of Protective Coating

Protective coatings shall be examined by means of a "holiday" detector of an approved type and rating for the particular coating system.

10.8 Repairs to Steel Pipes

Repairs to pipes shall be in accordance with BS 2633.

Should a weld repair be required on a pipe subsequent to hydraulic testing, the pipeline shall be re-tested to the pressure specified.

Where "holidays" have been found in protective coatings they shall be made good.

Where the protective coating has been damaged it shall be repaired by removing an entire band the width of the damaged section and replacing with a full wrapping band of reinforcing mat. Where the damaged area exceeds 0.5 % of the pipe surface area the entire relevant area shall be stripped and the pipe re-coated.

Where internal linings have been damaged they shall be re-coated with the full existing lining system.

10.9 Gravity Drains and Sewers

Stormwater drains may be tested by air or water but foul sewers shall be tested by water. The criteria for testing and acceptance shall be as laid down in BS EN 752. Any length which fails the test shall be rectified and re-tested.

All lengths of foul sewers and storm water drains shall be tested.

10.10 Wrapping of Metal Flanged Joints, Couplings and Unpainted Sections of Metal Pipes

After installation and testing on Site, the exposed joint areas of metal pipes and any adjacent unprotected lengths shall receive two coats of bituminous paint which is to be supplied by the steel pipe manufacturer; the second coat not being applied until the first has dried. Once the second coat has dried a layer of approved primer paste is to be applied followed by a layer of approved mastic to provide a more even contour for the wrapping of the joints which follows.

The wrapping is to be in two layers. Firstly a proprietary overlapping tape fully impregnated with a compound based on saturated petroleum with inert siliceous fillers is to be applied, followed by an overlapping similarly impregnated tape totally resistant to termite attack.

10.11 Backfilling

10.11.1 Solid Pipes

Backfilling shall not commence within 24 hours of placing any concrete surround or haunching.

The material for backfilling up to 300mm above the top of the pipe or concrete surround shall be approved sand or selected granular material well graded from 0.075 to 20mm. It shall be compacted with hand tools in layers not exceeding 150mm. Around pipes which do not have a concrete haunch or surround, this first backfill shall be brought up simultaneously on both sides of the pipe.

The backfill material which follows the hand compacted material shall be approved suitable material less than 80mm size, placed in 150mm layers and compacted to a density not less than that of the surrounding ground.

10.11.2 Porous Pipes

The backfilling for porous pipes shall be clean broken stone or other approved materials and shall not be larger than 80mm nor smaller than 20mm. It shall be carefully packed around the pipes and brought up and consolidated to required levels.

10.11.3 Corrugated Steel Pipe Culverts

No particles larger than 80mm shall be used in the backfill material within 600mm of the culvert.

The backfilling shall be placed and compacted in 150mm layers to 100% of optimum density. No construction equipment shall be driven over the culvert until the cover to the crown exceeds 600mm. Thereafter construction shall proceed as for filling in road embankments.

10.11.4 Trench Supports

Trench supports shall be eased up in stages as the level of backfill rises such that there are no associated uncompacted areas.

10.12 Manholes, Catch-pits, etc.

10.12.1 Brickwork

Where brickwork is used in manholes, catchpits, trenches and other adjuncts to drainage works it shall be built in hard pressed or wire cut bricks of approved quality showing a minimum of crazing on the exposed faces. The brickwork shall be built in "English" bond using 1:3 cement/sand mortar flush pointed on internal exposed surfaces. Where, in foul sewer manholes, mortar rendering is to be applied, brickwork joints on internal surfaces shall be raked out 6 mm to provide a key.

10.12.2 Benching

In sewerage manholes the channels shall be lined with half round clay pipes.

Benching, i.e., the forming of pipe channels, junctions and similar curved formations in the bottom of manholes, junction pits and similar drainage structures, shall be formed in concrete in accordance with the Concrete section and then plastered true to specified shape with 1:3 cement/sand mortar steel trowelled to a smooth hard finish.

10.12.3 Step Irons and Covers

Step-irons shall be of hot-dip galvanised malleable iron complying with BS EN 13101.

Manhole covers and frames shall be to BS EN 124 and of a class to suit the expected loading conditions. Covers shall be accurately set in concrete in accordance with the Concrete section.

The covers shall be interchangeable wherever feasible, shall fit in any position without rocking and shall be supplied with a hot dipped bitumen coating.

10.12.4 Particular Requirements for Septic Tanks

Septic tanks are to be constructed in accordance with the requirements of BS 6297. They are to be constructed of reinforced blockwork or reinforced concrete for the design population and capacity as noted on the drawings. Two chamber septic tanks will be required where noted.

10.13 Particular Requirements for Maintenance of Drainage Works

All pipes shall be maintained in a sound, clean and watertight condition and any subsidence of backfilling made good until the expiration of the Defects Liability Period.

When connecting to an existing drainage system care shall be taken that cement mortar, spoil or building debris is not carried into the existing pipelines. Should this nevertheless occur, pipelines shall be cleared of all debris.

Section 11: Technical Specifications - Building Works

11.1 General

This Section deals with work of a decorative or ancillary nature, which is generally executed after structural completion. Notwithstanding the fact that the work specified herein may constitute only a small part of the Facilities as a whole, much of the work described in this Section will be in highly visible locations. It is, therefore, essential that the high standards of quality and workmanship required elsewhere are maintained in respect of the work headings described in this Section. Accordingly, trial panels and examples of important work items shall be required in order to establish an acceptable standard by which completed permanent Facilities will be judged.

A significant proportion of the work discussed in this Section requires the use of proprietary materials. The storage, use, installation and subsequent protection of completed work involving such materials shall be strictly in accordance with the manufacturer's instructions.

All building construction and finishing work shall be performed by experienced tradesmen or accredited specialists and site workmanship shall be to the standards described in the relevant parts of BS 8000.

All incidental flashings, damp proofing, weather seals or other approved materials which are necessary to render the buildings completely watertight and weather-proof shall be provided and fixed.

Finishing work shall not commence until:-

- all construction, including installation of permanent Plant, fittings and equipment has been completed
- the concrete or other materials have dried out sufficiently
- for internal work, the area concerned and such adjacent areas which may affect the finishing work have been weatherproofed.

Tiles and sheet materials which are to be of a particular colour or type shall be purchased from one source and at the one time.

Contact between dissimilar metals in the finished structure shall be prevented by the provision of approved, permanent, separating material. In particular, the following precautions shall apply to aluminium items:

- Aluminium which abuts steel or copper shall be protected by a 0.20mm thickness of black polythene fixed with an approved adhesive. Alternatively, zinc chromate primer may be used, taking care not to mark exposed aluminium faces.

- Where aluminium abuts onto concrete, the aluminium shall be protected by coating with bituminous paint, taking care not to mark exposed aluminium surfaces.

11.2 Brickwork, Blockwork and Stone Masonry

11.2.1 General

These clauses deal with burnt clay brickwork, concrete blockwork and stone masonry. If one of these materials is used as cladding as well as for the exposed face of normal wall construction, the final appearances of both shall be the same.

All reinforced and unreinforced masonry shall be designed and executed in accordance with all parts of BS EN 1996 as appropriate and BS 8000:Part 3.

For work which will be permanently exposed to view, sample panels of 6 m^2 minimum size shall be constructed for inspection with regard to appearance and bonding. The panels shall be retained under cover as the standard for production work.

Completed work shall be protected from harmful effects of weather for at least 3 days.

11.2.2 Burnt Clay Bricks

Burnt clay bricks shall comply with, BS EN 771-1.

Burnt clay bricks used in the permanent Facilities, whether engineering, facing or other bricks, shall be hard, sound, well burnt, square, free from crazing, and uniform in size.

All backing bricks used in conjunction with facing bricks shall be of the proper size to ensure that no difficulty is experienced in building the walls to the bonds specified.

In terms of BS EN 771-1, burnt clay bricks shall satisfy the following criteria:

	Exposed externally	**Other Locations**
Soluble salt content	S2	S2
Compressive strength (N/mm^2)	Min. 7.0	Min. 7.0
Water absorption (%)	Max. 4.5	Max. 4.5

11.2.3 Precast Concrete Blocks and Bricks

Those clauses of BS EN 771-3 which can reasonably be applied to the methods and practices commonly in use in the country where the Facilities are to be executed shall apply to concrete blocks and bricks. Generally the following shall apply:

- solid blocks shall be used below damp proof course level.

- the nominal height of blocks shall be 200 mm.
- the mix shall not be leaner than 1:9 by volume.
- the maximum size of aggregate shall be 10 mm.

As defined in BS 6073/BS EN 772, compressive strengths shall not be less than the following values:

	Exposed externally	**Other Locations**
Bricks (N/mm^2)	10	7
Blocks (N/mm^2)	3.5	2.8

It should be noted that the areas used for these calculations differ in BS 6073/BS EN 772, in as much as the contact area is used for bricks so the strength is basically of the material of which the brick is made. For blocks, however, the gross area including voids is used in the calculation.

Notwithstanding the above criteria, the material of which blocks are made shall not have strength less than that given above for bricks for the same exposure designation.

11.2.4 Stone for Masonry Work

Stone for masonry walling shall be an approved, selected natural material and shall be hard, clean and free of cracks, fissures, soft beds, veins and other defects liable to affect durability or structural soundness. It may vary in size from 150 mm to 500 mm minimum and maximum dimensions and shall be roughly dressed. Stones for walls shall have a minimum width in the range 25 - 75% of the wall thickness.

11.2.5 Mortar

Materials used in mortar shall comply with the following:-

Cement	as for Concrete
Lime (semi-hydraulic)	BS EN 459-1
Sand	BS EN 13139

All mortar shall be mixed by machine and used within 1 hour of being mixed.

When lime mortar is used, the lime, sand and water shall be mixed in a machine and stored for 48 hours before the addition of cement; loss or gain of moisture shall be prevented during that time.

11.2.6 Ancillary Items

11.2.6.1 Air Bricks

Materials and details for air bricks shall be to BS 493.

External faces of air bricks shall be provided with a louvred pattern cover in terra-cotta, cast iron or pressed galvanised sheet metal, complete with attached insect screen.

Internal faces of air bricks shall be provided with cast plaster gratings.

The air passage in solid walls shall be rendered with cement mortar.

The air passage in cavity walls shall be lined with terra-cotta, natural slate tiles or another approved material cut to size.

11.2.6.2 Lintels

All openings shall have specially manufactured lintels. The minimum end bearing length shall be 200mm.

11.2.6.3 Metal Ties

Metal ties used in cavity walls and for linking two leaves of walls laid on stretcher bond shall comply with BS EN 845.

Ties of the "Butterfly" type shall be formed from 3.5mm galvanised wire and have a length to suit building in by a minimum of 60mm at both ends.

In cavity walls, ties shall slope outwards and be provided at centres not exceeding 900mm horizontally and 450mm vertically.

11.2.6.4 Damp-Proof Courses

Damp-proof courses for brick and block walls shall be three ply bitumen felt conforming to BS 6398 and weighing at least 3.2kg/m^2.

Damp-proof courses for masonry shall be formed in lead sheeting to BS EN 12588, weighing approximately 30kg/m^2 and built in to mortar bedding within the joint. All surfaces of stone which come into contact with concrete or other materials shall, prior to installation, be given two coats of bitumen or approved bituminous paint of heavy consistency.

11.2.6.5 Water Repellent Treatment

Where a water repellent silicone treatment is required, the facing work shall be sprayed to saturation with one coat of an approved solution containing a minimum of 5% silicone by mass. The solution shall be applied only to dry surfaces which have not been wet for 2 days and the application shall be made during fair weather so that the solution may mature for at least 4 hours before exposure to rain. Spraying shall be carried out at low pressure to avoid backspray and the surfaces shall be flooded so as to produce at least 150mm run-down. If, however, manufacturer's instructions differ from the above they shall have precedence. Breathing of the vapour arising from the silicone water repellent solution must be avoided and the Contractor shall ensure that adequate ventilation is provided during the spraying operation. Where necessary, the workmen engaged in spraying shall be provided with painters' spray masks.

11.2.7 Constructional Procedures

11.2.7.1 Brickwork and Blockwork

All relevant clauses of BS EN 1996-2 shall apply. Bricks and blocks may be damp when laid but shall not be saturated.

The bond shall be such that vertical joints in adjacent courses are separated by at least 25% of the length of the wall unit. In mass work the proportion of headers shall be at least 25%. Care shall be taken that the colour of headers will not produce unsightly bands on exposed faces.

Brickwork and blockwork shall not rise more than 1.5 m per day. Corners and other advanced work shall be stepped back but the rise from the adjacent section shall not exceed 1 m. Facing work shall not be brought up more than 0.6 m in advance of the backing.

Overhand work will not be permitted except where unavoidable.

Joints shall be 6-10 mm wide. Contact surfaces shall be laid on a full bed of mortar and single frogged bricks shall be laid with the frog uppermost. Courses shall be perfectly horizontal and even in width. Vertical joints shall be filled before the next course is laid and shall line up. Facing bricks shall be undamaged and quoins shall be kept truly vertical, with unchipped arises.

Damp proof courses (DPC) shall be laid on a 12 mm mortar layer and stepped as required. The DPC shall be the full width of the wall with 100 mm laps, sealed with an approved bituminous compound. A mortar layer shall be laid on the DPC as bedding for the next course.

Extreme care shall be taken to prevent mortar droppings remaining in cavities or on wall ties. Occasional joints in the outer leaf shall be left open at the bottom of the cavity, just above the damp proof course.

The work shall be built tightly against concrete columns, soffits and other structural parts except where otherwise specified. Where compression joints are required they shall, unless otherwise detailed, be formed using 12 mm Flexcell or other approved waterproof softboard.

Blockwork built against concrete columns, beams etc. shall be tied to the concrete with approved, 2 mm thick galvanised ties associated with dovetailed grooves cast into the concrete. They shall fit snugly into the grooves and shall be spaced at 1 m centres (to the nearest course) or closer in particular cases where appropriate. These ties shall be built into the joints in the blockwork and the dovetailed groove shall be filled solid with mortar as work proceeds. Any other wire ties provided in the concrete shall be straightened out and built into the wall in an approved manner.

As well as holes for windows and doors, other holes and chases shall be left in the walls where required, including provision for any sub contractor's making good. Holes shall not be cut out unless there is no alternative.

Fixings for window and door frame shall be approved inserts or plugs. Wooden pallets shall not be used. Such fixings shall wherever possible be built in as work proceeds but otherwise shall comprise drilled holes and proprietary fixings installed in accordance with the manufacturer's instructions.

Joints shall be finished as the work proceeds. Where there is no plastering or other finish of significant thickness to follow, joints shall be flush internally and weather struck externally. Joints shall be raked out and pointed at flashings, aprons, drips, etc. to match the adjoining wall. Where cement rendering is to follow, joints shall be raked out 10 mm to form a key. Exposed surfaces below shall be protected from falling mortar or other debris.

Where brickwork or blockwork is reinforced, the reinforcement shall be completely embedded in the mortar with adequate cover.

All walling, at final completion, shall be washed down and cleaned if necessary. In extreme cases a 5% solution of hydrochloric acid for the cleaning of exterior brickwork shall be used; this shall be preceded and followed by copious baths of fresh clean water.

11.2.7.2 Stone Masonry

All relevant clauses of BS EN 1996-2 shall apply.

Stone masonry shall be uncoursed random rubble masonry.

All stratified stone possessing bedding planes shall be laid with its natural bed as nearly as possible at right angles to the direction of load. Thus in the case of arch rings, for example, the natural bed shall be radial.

For dry random rubble walling, the stones shall be carefully shaped to obtain a close fit at all beds and joints, any interstices between the stones being filled with selected stone chippings or spalls.

When it is required to construct coursed masonry, the stonework shall be brought to courses at regular intervals not exceeding 0.5 m and no vertical joints shall be carried through the courses.

Squared masonry shall be as for coursed masonry with the additional requirement that all stones be truly squared and dressed on the beds and joints for at least 100 mm from the exposed face. Vertical joints shall not include more than 3 consecutive stones and horizontal lapping shall exceed 100 mm.

Block in course masonry shall be as for squared masonry except that the squared and dressed distance shall be 200 mm and bond stones shall form not less than one sixth of the exposed area and be at least 800 mm long rather than 400 mm long.

A further refinement is ashlar masonry, in which the stones are dressed to form accurate rectangular blocks of uniform size on the exposed face, which shall be tooled and have joints of uniform width.

Facework quoins shall be built to a height not exceeding 1 m in advance of the main body of the work and adjacent walling stepped down on either side. Stone facework between the quoins shall then be built to a height not exceeding 0.5 m above the backing masonry, which shall then be brought up level with the completed facework. At no time shall the backing masonry be built up higher than the facework.

Except for dry random rubble walling, all joints shall be sufficiently thick to prevent stone to stone contact and shall be completely filled with mortar, each stone being tapped home. The general objective should be that each stone supports and is supported by two others and the volumetric proportion of mortar should be of the order of 20%.

Sills and coping stones shall be dressed and squared as required. No section of stone masonry shall be permitted to rise more than 1 m per day.

Bond stones shall be provided at least once per square metre of exposed face. They shall measure at least 150 x 150 mm on the exposed face and be at least 400 mm long provided that they shall not extend to the full wall thickness.

Expansion and compression joints shall be formed with Flexcell or other approved softboard and shall be raked out, left open during construction, pointed using suitable, approved mastics and cleaned off as required on completion. Testing of mastics shall be in accordance with BS 3712. Sealants shall be two part polysulphide sealants to BS EN ISO 11600 applied in accordance with the manufacturer's instructions, with a backing of polyethylene foam strip.

Stone masonry built against concrete columns, beams etc. shall be tied to the concrete with approved 20 gauge stainless steel ties associated with stainless steel dovetail slots cast into the concrete. The ties shall fit snugly into the slots and shall project 60% of the wall thickness up to a maximum of 350 mm. In coursed masonry, ties shall be provided at courses. For cladding, the spacing of ties shall not exceed 1m in any direction.

Completed stone masonry shall be protected against weather or staining by other trades. Care shall be taken to prevent staining from timbers, oil, wet straw, washings from steelwork or scaffolding and other injurious or disfiguring substances. All facing stonework shall be washed down, cleaned, pointed and protected as the work proceeds.

11.3 Timber and Allied Work

11.3.1 General

In the absence of local standards the following shall apply:

Non-structural cut timber shall comply with BS EN 942 and workmanship shall comply with BS 1186:Part 2 and BS 8000:Part 5.

Timber for structural work such as roof trusses shall be in accordance with BS 4978 and BS EN 1995.

Moisture contents at the time of delivery to the Site shall be in the range 11-15% for external work and 8-12% for internal work. Appropriate measures shall be taken to prevent excessive loss or gain of moisture due to hot, dry or rainy weather conditions during and after delivery of timber to the Site.

All timber shall have been seasoned for at least 12 months (or approved equivalent) before being made up for use in the permanent Facilities. It shall be sawn die square to within 2 mm of the sizes required and shall be free of all active insect attack and any other defects known to be deleterious in the local environment.

11.3.2 Wood Based Panel Products

The Standards applicable to board and similar products shall be as follows:-

Softboard insulation board for ceilings etc. shall have a density not exceeding 350kg/m^3. This and other fibre building boards including hardboard shall be to BS EN 316/622-4 as appropriate and marked for compliance therewith by the manufacturer.

Plywood shall be to BS EN 636. For exterior use it shall be of an approved, moisture-resistant type and for extreme exposure may have to be marine plywood to BS 1088-1.

Chipboard shall be to BS EN 300/309/312/633/634 as appropriate and marked for compliance therewith by the manufacturer, but shall not be used where water may come in contact with the material, even for short periods, because of the severe swelling effect exhibited by this material when wet.

Laminated plastic surfacings shall be Formica single-sided decorative laminated plastic sheet to BS EN 438, 1.6 mm thick and bonded as recommended by the manufacturer. Other plastic sheeting shall consist of layers of paper impregnated with phenolic and/or melamine resins and subjected to heat and pressure to form a solid, homogeneous fire-resisting sheet.

Plasterboard shall be at least 12 mm thick and comprise a core of plaster of Paris between two sheets of heavy paper.

11.3.3 Preservation

All timber shall be treated with preservatives except western red cedar (thuja plicata), jarrah and greenheart, which will be accepted without preservative treatment. The preservative treatment given to timber shall be consistent with its absorption capacity and place of installation. Whatever method of preservation is used, it shall accord with established local practice and be suitable for subsequent varnishing or painting with normal household paints.

Preservatives shall be applied to softwoods using systems described in BS 4072 and BS 5589. Hardwoods shall be treated with a colourless preservative suited to local conditions and compatible with intended subsequent finishes.

11.3.4 Preparation

Knots, pitch pockets and sappy spots shall be treated with shellac.

Exposed woodwork shall be wrought to a smooth, even surface free from machine or tool marks.

11.3.5 Workmanship

Workmanship for timber shall generally conform to BS 1186-2 and BS 8000-5.

Finished sizes shall be such as to ensure that required finished dimensions are obtained. All joinery must be framed together in the best known method of joining woodwork together, i.e. by mortice, tenon, dovetail or other approved method.

Joinery work must be framed up as soon as full details are obtained but shall not be glued, wedged or otherwise fixed together until immediately prior to bringing on to Site ready for fixing.

Joints shall be perfectly formed and fitted, and secured against movement and stresses by the use of approved glue in addition to other fixing methods. Timber on exposed faces, and where exposed to water, shall be formed with suitable weatherings and with joints formed to check or prevent capillary or other penetration by water.

Pins shall be punched and stopped. Glazing beads and beads to solid panels shall be secured with brass countersunk screws and cups.

Mouldings and lippings shall be preferably of hardwood timber and worked on the solid. All lock rails shall be double tenoned. Edges shall be slightly rounded. The work shall be planed as required and then sandpapered and cleaned of dust prior to being painted.

All work wherever possible shall be secret fixed. The Contractor shall provide all necessary beads, fillets, steps, grounds, backings, linings, castings and furrings and all rebating, tenoning, grooving, scribing, housing, mitreing, mortising, framing, planing, dovetailing and other work necessary to complete the whole in the best workmanlike manner according to the required details.

Timber work shall be protected from scratching or other damage after installation.

Any nail holes, cracks, open joints etc. at completion shall be closed with putty or stopping and made good.

Should any joint of any timber work shrink, give or open, or any timber warp or twist before the end of the Defect Liability Period, such defective timber must be taken out, refitted and redecorated or replaced. Any work disturbed around the items removed must be made good.

11.3.6 Particular Requirements for Timber Roofs

11.3.6.1 General

The principles of BS EN 1995-1-1 shall be followed wherever applicable in any design work.

Roof timbers shall be suitable for the structural requirements and shall receive approved preservative treatment. Timbers of roof trusses shall as far as practicable be in full lengths and no jointing within the lengths of structural members shall be allowed.

Each truss shall sit on a timber wall plate on top of the wall and be adequately tied down to the wall.

All roof spaces shall receive anti-termite/insect treatment before being occupied or taken over.

11.3.6.2 Jointing in Roof Trusses

The lengths of bolts at joints shall be such as to leave between 2 and 10 mm projecting from the nut when the bolt is tightened. Bolts shall be fitted with square washers at both ends and shall be positioned to comply with BS EN 1995. Particular attention shall be given to ensure that no bolt is too near the end of a tension member.

Where joints within the lengths of structural members are allowed, the timbers shall be butted together and joined with two pieces of timber of the same size 500 mm long placed on each side and bolted together with six 20 mm bolts and square washers.

Joints between structural truss members shall be made with 20 mm dia. Bolts.

11.3.6.3 Secondary Roof Timbers

Secondary timbers shall have the minimum number of joints and such joints shall be scarf joints coinciding with a roof truss.

Wall plates shall be 50 x 100 mm unless otherwise indicated. They shall be adequately fixed to the wall by galvanised ties or other approved method.

Intermediate ceiling joints at least 40 mm wide shall be added parallel to roof trusses at centres not exceeding 1 m. Such ceiling joists shall be adequately supported against sagging as either by bearing onto longitudinal walls, by longitudinal stringers between trusses or by hangers nailed between the joists and purlins.

Purlins shall be fixed with the long edge square to the sloping rafter. Adequate support members shall be provided to purlins, which shall be fixed to every rafter and joined only over rafters. Purlin centres shall not exceed 1 m.

Valley boards, gutter boards, barge boards and fascia boards shall be 25 mm thick. They shall be fixed to every rafter and joist which they cross. Suitable similar edging boards shall be added around chimney stacks and similar interruptions to the general line. Fascia boards and barge boards shall be twice grooved on the rear face.

An opening through the ceiling into the roof space and all necessary trimming timbers shall be provided in every building. The opening shall be 600 x 750 mm and shall be provided with a blockboard cover which can be lifted from underneath.

11.3.7 Ceilings

Suspended ceilings shall be a proprietary system erected in accordance with the manufacturer's instructions and BS EN 13964.

11.4 Doors, Windows and Louvres

11.4.1 Frames

11.4.1.1 Materials

Frames of internal windows and personnel doors shall be of timber, proprietary steel or aluminium in which case BS 1245/BS 6510/BS 4873 shall be followed where applicable. Frames of external windows and doors shall be proprietary steel or aluminium.

Metal window frames shall wherever necessary be supplied complete with metal surrounds of width equal to the overall finished width of the wall.

Louvre surrounds and panels shall be of aluminium or other rustproof material. The head and sill sections shall match and be fitted with dual softness PVC or neoprene insert weather-strips. Metal insect screens will be required to all louvre panels and opening windows.

Burglar bars to windows, where required, shall be of wrought iron or steel, painted the same colour as the window frame.

11.4.1.2 Installation

Frames shall generally be built in during construction of the walls and securely fixed. Wooden supports shall be used around window frames. Frames shall be set plumb and true, braced wherever necessary to prevent deflection during fixing and protected from damage during other work.

Metal frames shall be set plumb and true with the sill bars resting on wedges to ensure that they are perfectly level. All lugs shall be tightly bolted up and solidly built in as the brickwork proceeds. Where frames have to be fixed in concrete openings, holes shall be formed for the fixing lugs and coupling bars. The windows shall be carefully placed and set in the exact positions required, and the lugs tightly bolted up.

Frames or parts to be coupled shall be bedded against mullions and transoms with approved waterproof mastic, all strictly in accordance with the instructions of the manufacturer.

No load is to be imposed on window frames during building in. Suitable clearances are to be provided between head of window and underside of lintel.

Door frames and similar components shall, unless otherwise agreed, be fixed with countersunk screws or bolts with heads set into the frames and covered with a plug of the same material as the frame.

Walls shall be built as close as possible to the frames and the gap filled solid with mortar at each course. Where frames are positioned before the completion of adjacent walling, the wall construction shall be bedded solidly against jambs and any projecting heads or ties of the frame.

Junctions between frames and walls shall be tightly caulked with approved mastic sealant and/or lime/cement mortar as directed, and pointed up neatly all round. Mastic so used shall have long-term resistance against weather, insects and ultra-violet light. Sealants shall be to BS EN ISO 11600.

Where adjacent walls are plastered, the plaster shall be neatly brought up to the frame and well tamped into any remaining cavities.

11.4.2 Doors

Timber doors shall comply with BS 4787:Part 1.

Steel security doors shall be press formed from 1.25 mm thick mild steel sheet supplied as a proprietary system.

Doors, other than security doors shall be of a proprietary design. They shall comply where relevant with BS 6510 for steel doors.

Steel roller and folding shutter doors shall be proprietary systems installed in accordance with manufacturer's instructions. They shall be manually operated except where fire resistance is required, when they shall be fitted with automatic closing facilities.

All fire resisting doors shall comply with BS 476.

Door frames for rooms requiring the exclusion of dust (the Control Room and computer and electronic equipment rooms) shall employ air seals.

Doors wider than 860mm shall have three 100mm x 2mm thick steel hinges. Other doors may have two hinges.

Door stops shall be fitted by screwed fixings where necessary.

11.4.3 Door and Window Furniture

All doors shall be complete with ironmongery including locking arrangements, handles and where appropriate, emergency escape facilities. Special security locks, hinges and padlocks shall be provided on doors leading to secure areas.

Fittings shall comply with the following:

- Locks and latches — BS EN 1906 and BS EN 12209
- Wood screws — BS 1210
- Hinges — BS EN 1935
- Fixing accessories — BS 1494

Locks and any padlocks which may be required shall be mastered and sub-mastered to suit a master key system.

11.5 Glazing

11.5.1 General

Glass shall be of best quality, to BS 952 and free from bubbles, scratches, waviness or other imperfections.

Glazing to aluminium alloy windows shall comply with BS 4873.

Glazed panels shall be fitted in accordance with the principles of BS 6262.

The installation of patent glazing systems shall comply with manufacturer's instructions.

For any glazing in doors or partitions forming a fire-barrier, polished Georgian wired glass or laminated safety glass shall be used.

Generally 6mm clear float glass shall be used however, for bathrooms, lavatories and other appropriate locations, rough cast obscured glass of approved pattern and quality shall be used instead of clear glass.

Glass in louvres shall be 6 mm thick and shall be adjustable.

The glass blades shall be 150 mm wide with 25 mm overlaps and polished edges. Vertical mullions shall be used at such centres that no louvre blade is longer than 1100 mm.

The blades shall be set into interlocking metal clips fixed to the surrounds and of the same metal as the surrounds.

Tests shall be carried out to establish that the finished louvre will keep rainwater out.

11.5.2 Putty

Putty for wooden frames shall be linseed oil putty to BS 544.

Putty for metal frames shall be gold size tropical quality metal window putty to BS 544 or other cement putty of approved manufacture.

11.5.3 Fixing of Glazed Panels

Workmanship shall be in accordance with BS 8000-7.

Rebates shall be cleaned and painted with an approved primer suitable for the material forming the frame.

The glass shall be either sprigged to wooden frames or fixed to metal frames with approved proprietary glazing clips. Glass panes to timber doors and fanlights shall be set in putty and secured with timber glazing beads. Putty shall be worked to produce fillets of adequate cross-section without projecting into sight lines. It shall be applied to both sides where necessary, neatly finished to line and mitred at corners. Any putty failing to show proper signs of setting within seven days shall be replaced.

The finished surface of the putty shall be true in line and level with straight edges, sharp mitres, smooth surfaces and neatly cut in against the glass. The rebate of the sash shall be touched up with paint where necessary to ensure adhesion of the putty.

All putty must first form a "crust" and have a smooth finish before any paint is applied. Putty shall, however, be painted soon enough to ensure that no cracks develop, and before the bond with the steel and glass is destroyed. Any putty which is found to be loose, cracked or unsatisfactory in other respects shall be replaced at the Contractor's expense.

Glazing shall be cleaned after other trades in the area have completed their work. Broken panes shall be replaced.

11.6 Roof Finishes

11.6.1 Tiles on Pitched Roofs

Clay tiles shall be locally-manufactured and to BS EN 1304 where consistent with local practice. Concrete tiles shall similarly be to BS EN 490.

The provisions of BS 5534 shall apply to the arrangements of laps, battens and details where relevant to the local situation.

Tiles shall be laid on battens on a waterproof underlay. The tile underlay shall be reinforced bitumen felt to BS EN 13707.

Ridges, hips and valleys shall be formed from purpose-made tiles.

Tiles shall be laid and fixed in accordance with BS 8000:Part 6.

11.6.2 Finishes on Flat Roofs

Where a screed is to be placed directly onto a concrete roof the finish of the concrete surface shall be appropriate for a screed. Screeds shall be of minimum thickness 25 mm and be laid in alternate bays of area not exceeding 8 m^2 and length of side not exceeding 3 m.

Two layers of screed shall be used where the thickness of screeds to falls exceeds 150 mm; feather edges shall be avoided.

Normal-weight screeds shall be of a 1:4 cement:sand mix by volume.

Where lightweight screeds are applied on concrete roofs, the lightweight screed shall be preceded by a proprietary two-coat cold-applied bituminous vapour barrier, laid in accordance with manufacturer's instructions. The lightweight screed shall be mixed and applied in strict accordance with manufacturer's instructions.

Lightweight screeds to timber roofs shall be vermiculite based, mixed and applied in accordance with manufacturer's instructions.

Felt roofing will not be permitted.

Where a concrete roof is to be covered with mastic asphalt, the concrete shall have a wood float finish and the mastic asphalt shall be preceded by one layer of bituminous black sheathing felt to BS 747/BS EN 13707. Materials and workmanship shall comply with BS 6229 and BS 8218.

Asphalt shall be of tropical quality and shall comprise a mechanical mixture of properly selected and graded limestone aggregate with asphalt in such proportions as will yield a plastic, voidless mastic which can be trowelled to any form and contour.

Precast concrete slabs for use on roofs shall be 38 mm thick and shall be to BS EN 1339 and BS 7533-4.

Proprietary finishes to flat roofs shall comply with manufacturer's instructions.

11.6.3 Metal Cladding to Roofs and Walls

Metal cladding shall be a proprietary system comprising profiled steel or aluminium sheets. Protective coatings, installation and fixings shall comply with manufacturer's instructions.

11.6.4 Roof Drainage

All flat roofs with parapets shall be finished to falls to rainwater outlets, which shall be proprietary systems built strictly in accordance with the makers' instructions and special care shall be taken to ensure a perfectly watertight joint with the waterproofing layers.

Where external down pipes and rainwater heads are required, suitable openings shall be made through the parapets for discharging the rain water into the heads. All such openings shall be lined with galvanised sheet metal, flashed and made perfectly waterproof.

Gutters and downpipes shall be installed in accordance with BS 8000:Part 13.

11.7 Wall and Ceiling Finishes

11.7.1 Plastering and Rendering

11.7.1.1 General

Cement shall be Ordinary Portland cement to BS EN 197-1.

Gypsum plaster shall be to BS EN 13279 and shall be lightweight where applied on plasterboard and on ceilings. Gypsum plaster shall not be used on external faces.

Sand for final coats shall be to BS 13139. For the first coat in two-coat work the sand may be to BS 13139 or as specified for concrete, or a mixture of the two types.

Plastering and rendering systems shall comply with the requirements of BS EN 13914-1 and BS 8481.

Bagwash finish will generally be used for blockwork walls which are to be painted. To make a bagwash finish, a 2:1 sand cement mortar having the consistency of thick paint shall be smoothed onto the wall to fill all open pores in the blockwork and mortar.

Where required, a Tyrolean finish shall be used for external surfaces. Wall surfaces to which Tyrolean finish is to be applied shall first receive a first coat as described above for brickwork and blockwork.

11.7.1.2 Preparation of Surfaces

Concrete surfaces shall be roughened, wire brushed and thoroughly cleaned. All traces of oil or grease shall be removed by washing down with a 5% dilute solution of hydrochloric acid, the treated surface afterwards being washed with clean water. A cement mortar slush, composed of 1 part cement to 4 parts concrete sand, shall then be thrown on to the wetted concrete surface by trowel so as to cover it completely and provide a strong key. The finish coat shall be applied soon after slushing.

Brickwork and blockwork walls which are to receive cement mortar plaster shall have the joints raked out 10mm to form a key for the plaster and be thoroughly cleaned and wetted before the plaster is applied. If necessary, dilute hydrochloric acid shall be applied as for concrete walls.

In two-coat work the first coat shall be heavily scratched with a metal paddle or other suitable tool before the first coat has set, in order to provide a good mechanical key for the finish coat. Any projecting fins shall be removed.

All surfaces shall be dampened before plaster is applied.

11.7.1.3 Junctions

At exposed corners, Expamet or similar galvanised beads and stops with galvanised fixings shall be used. For external work or internal work exposed to wetting, stainless steel beads, stops and fixings shall be used.

Where walls with plastered finishes abut concrete columns, beams etc. without such finishes, a 3mm open joint shall be formed through the full depth of the finish. Junctions between other different background materials shall be covered by an expanded metal scrim.

Each day's work shall be formed to a neat edge or vee-groove.

11.7.1.4 Workmanship

The plaster shall be applied uniformly and all reveals, junctions and splay sections shall be formed to exact line and level. Intersections between walls and ceilings shall be formed to a true line and angle. Arrises to reveals, openings, columns, etc., shall be laboured to produce a pencil round finish.

All walls shall be finished from top to bottom in one operation in order to ensure a complete absence of joints showing at the various levels.

Each coat shall be trowelled sufficiently to obtain an efficient bond with the underlying surface and shall be worked up to a perfectly true surface with a straight edge and wood float so that it is smooth and true.

Finish coats shall additionally be worked over lightly with a steel float.

For two-coat work the first coat shall be kept moist to avoid excessive drying out and the finish coat shall be applied within 48 hours of the first coat.

Finish coats shall be kept moist by spraying or other approved process for at least 4 days after completion.

All plastered surfaces shall be finished perfectly true and free of projections, hollows, irregularities, or other imperfections. All plaster shall be sound and free of cracks or crazing. Every plaster coat shall be perfectly bonded to the underlying material over the entire area plastered, and any plaster which, after hardening, rings hollow when tapped shall be replaced.

11.7.2 Wall Tiling

Wall tiles shall preferably be 200 x 300mm

Wall tiles shall be glazed ceramic wall tiles to BS EN ISO 10545 . The tiles shall preferably have spacer lugs and cushion edges, and exposed edges of tiles and matching fittings shall be rounded if available but glazed otherwise.

Tiles shall be fixed in accordance with BS 5385-1/BS 8000-11.1 using an approved tile adhesive after cleaning all dust, etc. from the wall.

The tiles shall be fixed throughout to a true and level line and grouted on completion with approved tile grout.

On completion of tiling work, all surplus grout shall be removed and the tiling thoroughly cleaned.

11.8 Floor Finishes

11.8.1 Preparation of Underlying Concrete

When it is necessary to add a wet-placed cementitious or similar layer to the surface of a concrete floor, the layer may be placed in either of two ways:

(a) The layer shall be placed within 3 hours of completing the concrete floor.

(b) The concrete must be left after being cast for a few days until it is sufficiently strong to be roughened as required in the Concrete Works section for surfaces which are to receive further concrete. Shortly before adding the further layer, the prepared surface shall be thoroughly cleaned, washed down and brushed with a stiff broom. After cleaning and washing, and immediately ahead of adding the layer, the concrete surface shall be slushed over with a 1:3 cement/sand mortar and this shall be worked and brushed into the concrete with stiff brooms.

The above procedure will be required for screeds, granolithic floors and similar finishes.

11.8.2 Mortar Screeds

Mortar screeds where required shall be put down in accordance with BS 8000-9.

The screed coat shall be a cement/sand mixture using concreting sand with a sand/cement ratio in the range 3.2 - 4.2 by weight.

Mortar screeds for floors shall be broken to coincide with structural movement joints and shall be laid in bays not exceeding 15 m^2 in area and with no side longer than 5m.

The surface of the screed shall be graded to any required fall, additional layers being used where the thickness would otherwise exceed 60 mm per layer. The accuracy shall be within 3 mm of a 3 m straight edge.

Where a further wet-finish layer is to follow the screed, a wood float finish shall be used, after which the surface shall be scratched to form an acceptable key.

Where a dry finish such as PVC or similar floor covering is to follow, a particularly smooth finish shall be obtained by using a steel trowel after the wood float operation.

The screed shall be properly cured with moist sand or otherwise for a period of at least 7 days and protected against damage until covered by the final surface finish, if any. Any hollow areas shall be replaced.

11.8.3 Granolithic Finish

A granolithic finish will be required in areas subject to hard wear and will normally be placed directly on to the prepared surface of a concrete floor. It shall comply with all relevant clauses of BS EN 13318 and have a drying shrinkage not exceeding 0.045%.

Granolithic concrete shall be a cement/sand/aggregate mixture using 6 mm down chippings of granite, basalt, flint or hard limestone as aggregate and coarse river or other suitable sand. Neither all-in crushed material nor unprocessed crushed rock sand will be permitted.

The proportion of sand shall not exceed 15% and the sand shall comply with BS EN 12620. The cement shall be Ordinary Portland cement as used for plastering. The sand and aggregate shall be well mixed before the addition of cement and water.

The aggregate/cement ratio shall be 2.5 by weight unless another ratio is agreed. The consistency of the mix shall be as dry as practicable, with a water/cement ratio of approximately 0.40.

Where granolithic finish is to be coloured, the tinting pigment shall be of approved quality and shall be mixed with the cement before the latter is mixed in with the aggregate; it should not be merely dusted on the surface whilst spreading and trowelling.

Granolithic layers shall be broken to coincide with structural movement joints and shall be laid to falls where required and in bays with no side longer than 2.5m. Panel edges shall be defined by brass, ebonite or other approved strips set accurately to levels and left in place. If ruled joints are used, the depth thereof shall be half of the layer thickness. The accuracy shall be within 3 mm of a 3 m straight edge.

The granolithic material shall be laid, thoroughly compacted, levelled with a screeding board and wood floated, care being taken not to work the granolithic more than is necessary. When the surface becomes tacky, it shall be finished off with a steel trowel to a smooth hard finish. Excessive trowelling must, however, be avoided as this tends to bring the cement to the surface, thus weakening the granolithic and causing rapid disintegration of the floor under heavy wear. No additional cement shall be dusted on the surface of the laid granolithic, nor applied in the form of a slurry.

The granolithic layer shall be cured by being kept continuously damp for 7 days.

Granolithic coved skirtings shall be provided around the edges of paving against walls, partitions, machinery, plinths, etc. A flush skirting, approximately 150 mm high, shall be provided against walls which are plastered or tiled, the thickness of the skirting being equal to that of the wall finish, with a ruled joint between the skirting and the wall finish. For skirtings around plinths and unplastered walls, a projecting skirting with a rounded top edge shall be provided, to a thickness of 18 mm. The radius of the cove at junction with floor shall be 50 mm throughout. Angles, stops etc. shall be neatly finished.

Granolithic work shall be tested for hollow areas and all such areas shall be replaced.

Wheeled traffic shall be kept off for 4 weeks unless otherwise agreed by the Employer.

11.8.4 In Situ Terrazzo Finish

An in situ Terrazzo finish creates dust during its execution but has the virtue of being dust-free after completion. In any Terrazzo areas in the vicinity of sensitive electro-mechanical Plant which is in operation or being erected the Contractor shall programme his Terrazzo work to minimise any adverse effects on such Plant.

Sample panels will be required in advance of Terrazzo work, which shall comply with all relevant clauses of BS EN 13318.

The aggregate shall be clean, granular, approved marble chips graded between 2 mm and 12 mm and free from dust. The mix proportions shall be one part of white Portland cement to 2½ parts of marble chips by volume and the ingredients shall be thoroughly mixed dry, before the addition of water, to obtain absolute uniformity of colour.

The surface of the underlying screed shall be cleaned and hacked to provide a good bond for the Terrazzo. Unless shown otherwise, the minimum thickness of the Terrazzo shall be 18 mm and that of the combined Terrazzo finish and underlying screed shall not be less than 25 mm.

In situ Terrazzo floor finishes shall be laid in panels approximately 1.2 m square cast in alternate bays and separated by 3 x 20 mm ebonite, brass or aluminium dividing strips. Breaks in the screed and structure movement joints shall be followed. The accuracy shall be to within 3 mm of a 3 m straight edge.

A suitable amount of the dry mix shall be sieved and retained in a dry condition for patching voids during subsequent grinding.

The consistency of the mix shall be plastic and as dry as is practicable; a water/cement ratio of approximately 0.50 is to be expected.

After the Terrazzo has been laid it shall be tamped to ensure consolidation and then lightly trowelled. Any undue working which may draw the cement to the surface shall be avoided. After the cement has taken its initial set, the surface shall be covered with sand and kept damp for 8 days, including the following polishing operation.

Terrazzo floors shall be polished to expose the aggregate, the first stage being to saturate the floor with water and grind with a coarse carborundum brick or disc at a minimum of 3 days after casting. The floor shall then be scrubbed clean and any holes or pores made good with material previously reserved from the original mix, following which the mortar shall be allowed a further 5 days to harden before the Terrazzo is ground to its final polish, using a fine-grained stone or disc.

All angles, stops, etc., shall be neatly finished off as directed and ground and polished to expose the aggregate as specified above.

Terrazzo skirtings shall be provided around the edges of floors against walls, partitions, machinery, plinths etc. The skirting shall be 12 mm thick by 150 mm high with a 50 mm radius at the corner between skirting and borders, and shall be of approved colour and texture.

Any bays containing hollow sections on completion shall be replaced.

As soon as the curing material is removed a thick bed of sawdust or similar approved protective material shall be laid. Wheeled traffic shall be prevented from travelling on the floor surfaces until 4 weeks after laying and the protection shall be maintained and renewed until occupation of the room concerned.

11.8.5 Epoxy Floor Coating

The scope of the work comprises the Supply and Application of a self-leveling smooth Epoxy Floor Coating as per appropriate ASTM standards. The epoxy floor coating shall be laid on an adequately prepared 50mm concrete screed.

The epoxy floor coating shall meet the requirements as set out in ASTM standards for heat, resistance limitation, thermal coefficient of expansion, indentation, coefficient of friction and abrasion resistance.

The epoxy floor coating shall have:

A flexural strength >25MPa,

Tensile strength > 13MPa,

Bond Strength > 2.7MPa,

Minimum thickness of 2.5mm.

The epoxy coating shall be self-extinguishing and impervious with maximum water absorption rate of 0.2%.

11.8.5.1 Surface Preparation

An epoxy floor coating shall be laid on a 50mm floor screed. The contractor shall diamond grind the screed to remove any protrusions and to provide a dust free open textured surface.

11.8.5.2 Priming

The contractor shall supply and apply two coats of appropriate solvent-free primer for priming purposes

11.8.5.3 Blinding

The Contractor Shall supply and pull an epoxy scraper coat, to fill pitted and eroded areas and seal the surface by means of a trowel and spike roller before applying the adhesive compound.

11.8.5.4 Adhesive application

The Contractor shall supply and skim blow with an appropriate multi-purpose epoxy adhesive to the required floor profile before applying the epoxy floor layer.

11.8.5.5 Application of Epoxy

The Contractor shall supply and place an appropriate smooth epoxy flooring by means of a 6mm notched trowel and spike roller to provide an easy to clean chemical impact and scratch resistant flooring surface at a minimum thickness of 2.5 mm , Light grey in colour(preferably).

11.8.5.6 Cutting of Joints

The Contractor shall saw cut to reflect joints through overlay and seal joints with appropriate industrial joint sealant.

11.8.6 Surface Sealing of Cementitious Surfaces

Exposed cementitious surfaces shall be treated by applying a proprietary oil resistant hardener applied in accordance with manufacturer's instructions.

11.8.7 Tiled Floors

11.8.7.1 General

All relevant clauses of BS 8203 and BS 8000-11.1 shall apply.

Tiled floors shall be finished to a tolerance of 3 mm from a 3 m straight edge.

Tiles shall not be laid on a concrete or cementitious screed surface until at least 21 days after the surface has been cast.

11.8.7.2 Terrazzo Tiles

Where Terrazzo tiles are required, they shall be hydraulically pressed tiles to BS EN 13748, polished to a fine grit finish. Such tiles may also be used on walls.

Terrazzo tiles shall be laid on a 1:4 semi-dry cement/sand mortar bed with joints arranged to coincide with structure movement joints, and shall be pointed with 1:1 mortar using white Portland cement.

11.8.7.3 Other Tiles

Other types of tile shall comply with the following:

- PVC tiles BS EN 649 or BS EN 654
- Thermoplastic tiles BS EN 649

- Ceramic tiles BS EN ISO 10545

All these types of tiles shall be laid in accordance with BS 8203 or BS 8000-11.1, as appropriate, by suitably specialised workmen and set on an adhesive layer known to be compatible with the material of both the tile and the underlying surface.

Any joints which require to be grouted shall be filled with a material known to be compatible with the tile, the adhesive and the use which will be made of the completed floor.

11.9 Plumbing and Allied Work

11.9.1 Scope

A building will normally have an external stopcock on the branch from the mains water supply pipe and an internal stopcock immediately after entry of the supply pipe into the building. This Section covers internal plumbing work beyond the internal stopcock.

Waste water will normally be fed into a gully trap immediately outside the building. This Section covers the discharge pipework to and including the gully trap.

For external pipework beyond the cut-off points described above, reference is to be made to other appropriate Sections of this specification.

11.9.2 General

Plumbing work shall comply with relevant local authority regulations.

Pipes shall be fixed with approved pipe clips at centres not exceeding 1 m on walls and 2 m in roof spaces.

11.9.3 Supply and Distribution Pipes

11.9.3.1 Galvanised Steel Tubes and Fittings

Galvanised tubes and tubular fittings shall be galvanised seamless mild steel to BS EN 10255, "Medium" weight. Fittings not covered by the foregoing standard shall be galvanised malleable cast iron of an approved make.

Such tubing and fittings shall have screwed and socketed joints put together using plumbing tape or other approved method in common use for such materials.

11.9.3.2 Copper Tubes and Fittings

Copper tubes used for internal plumbing shall be seamless tube to appropriate clauses of BS EN 1057/12449/12451. Joints shall be made with approved compression or capillary fittings complying with BS EN 1254. Fittings and specials shall be brass of similar quality.

11.9.3.3 Bends in Metal Pipes

Pipes shall be cut by hacksaw or other method which neither reduces the diameter of the pipe nor forms a bead or feather which might restrict the flow of water. Easy bends in the tubing shall be made with an approved bending machine; heating to facilitate bending will not be permitted. Elbows shall be round pattern.

All made bends on copper tubing are to be formed with approved mechanical means without diminishing the internal bore of the tube and when it is impossible to use a bending machine, the bend shall be made by sand loading and bending in an approved manner.

11.9.3.4 Chromium-Plated Items

Where chromium-plated pipes and fittings are required, BS EN ISO 1456 shall apply. Steel shall be heavily coppered, heavily nickelled, and finally, chromium-plated. Copper and brass shall be heavily nickelled and then chromium-plated.

11.9.4 Taps and Valves

Taps and valves up to 50 mm shall be to BS 1010-2 and BS EN 12288. Stop-valves and taps on pipes smaller than 50 mm in diameter in domestic areas shall be chromium-plated where exposed to view. External taps shall have outlets suitable for hose connections and shall be to BS 2879.

Valves on pipes larger than 50 mm in diameter shall be cast iron gate valves from an approved manufacturer. Similar valves shall be fixed on the branch supply to all buildings in an external brick-lined chamber at least 300 mm deep with an approved cover.

Ball valves shall be high-pressure "Portsmouth" pattern with copper or plastic ball, the whole to BS 1212.

Internal stop-valves shall be supplied at the following locations as a minimum:

- at the beginning of each branch off the rising main
- on each pipe as it leaves a storage tank
- to isolate taps.

11.9.5 Storage Tanks

Water storage tanks shall be rectangular and of galvanised mild steel to BS 417-2 or of an approved heavy duty plastic type unless expressly required to be otherwise. They shall be supplied complete with cover, inspection arrangements, ball valve consistent with supply pressure, overflow pipe and scour pipe. The overflow and scour pipes shall discharge externally. Internal surfaces of tanks shall be painted with two coats of non-toxic, grey bituminous paint.

11.9.6 Hot Water Cylinders

Hot water cylinders shall be of cylindrical pattern and shall be of copper to BS 1566-1. Suitable inlets, outlets and overflow fittings and a 3 kW immersion heater shall be provided. Any cylinder heaters which operate direct from the mains shall be fitted with variable pressure reducing valves and relief valves or standpipes. Cylinders shall be insulated and fitted with an integral thermostat and isolating valves.

11.9.7 Flushing Cisterns

WC cisterns shall be of the low-level type.

Urinal flushing cisterns shall be to BS 1876.

11.9.8 Bathroom and Sanitary Fitments

Workmanship shall be in accordance with appropriate clauses of BS 8000-13.

All such fitments shall be of best quality by Armitage Shanks or similar approved. Basins shall have overflows. All taps and fittings shall be chromium-plated. Fitments shall be white unless otherwise instructed.

Wash basins shall be glazed earthenware to BS 1188 or BS 5506, complete with fittings. The size shall normally be 550 x 400 mm and provision shall be made for 12 mm taps and 30 mm outlet. A wall mirror, towel rail and nearby coat hook shall be provided.

Shower trays shall be in situ or proprietary vitreous china. Shower rails, curtains, and a vitreous china soap holder shall be provided in shower cubicles.

11.9.9 Steel Sinks and Wash Basins

Sinks shall be of seamless 20 gauge stainless steel to BS EN 13310 and shall be in one piece with the draining board, which shall have an adequate fall towards the sink. They shall be of the upstand type with 40 mm deep edge complete with 12 mm taps and 40 mm overflow and outlet. Bottle traps shall be fitted.

Metal wash basins shall be to a similar standard.

A sink for use in a battery room shall be fitted with acid-proof plastic trap and waste fittings. An adjacent raised hardwood slatted platform at the same level as the sink shall be provided to facilitate handling of the batteries. A spillage outlet in the floor shall be connected to the waste outlet of the sink.

11.9.10 Disposal System

11.9.10.1 Materials

Waste pipes shall be as follows:

- External waste pipes from toilets:
  - uPVC.
- Waste pipes from baths, sinks etc. both above and below ground:
  - muPVC to BS EN 1329-1, BS EN 1455-1 and BS EN 1519-1.
- Soil and vent pipes above ground:
  - uPVC to BS 4514.
- Soil pipes below ground:-
  - uPVC to BS EN 1401.

Bottle traps shall be used for sinks and wash basins. They shall suit the adjoining pipework and have coupling nuts and a screwed base, and shall comply with BS EN 274 if made of plastic.

Other waste fitments shall comply with BS EN 274.

11.9.10.2 Workmanship

The installation, method of jointing and fixing shall comply in all respects with the manufacturer's instructions and BS 8000-13. The method of jointing plastic fitments shall be that of solvent welding using the manufacturer's approved cement. Seal rings, conforming to BS EN 681/682, shall be used where necessary to accommodate internal movement.

Pipes shall be fixed in straight runs at nominally 1 m centres on horizontal pipes and 2 m centres on vertical pipes. All horizontal runs shall be laid to gradients in accordance with BS EN 12506-2. Expansion joints shall be provided at a maximum of 4 m centres for soil pipes, 2 m centres for waste pipes and adjacent to fixed points.

Where pipes pass through walls and floors, a 6 mm annular space for sealing shall be allowed for between the external surface of the pipe and the internal surface of the hole or built-in pipe.

11.9.10.3 External Items

Workmanship shall be in accordance with BS 8000-14.

Back inlet gully traps of approved pattern will be used at each building to collect waste water from bathrooms and kitchen sinks. The traps shall have removable gratings, and the traps fitted on kitchen waste pipes shall have an integral grease trap which may be removed for cleaning. Rainwater downpipes shall not be discharged into these gully traps.

A ventilation pipe of approved pattern, fitted with wire basket to the outlet, shall be fitted at the most suitable and highest point of the soil pipe system from each building. The pipe shall be not less than 100 mm diameter and shall protrude above the eaves by a minimum of 900 mm. It shall be securely fixed and flashed if it passes through a roof overhang at the eaves. If made of cast iron the pipe shall be to BS 416. No waste pipe shall discharge into the vent pipe.

11.9.11 Inspection and Testing

The work shall be inspected and tested during installation and all work which will be concealed shall be tested before it is finally enclosed. A final test shall be made upon completion for soundness and performance in accordance with BS EN 12506-2. Any defective work, damaged fittings etc. shall be taken out and replaced.

11.10 Grouting Around Fixings

11.10.1 Grouting Holding-Down Bolt Holes

After holding-down bolts for steelwork, machinery etc. have been set in position grouting up of holding-down bolt holes shall be required. Where such holes are accessible the grout shall be of a semi-dry consistency and shall be rammed into place with suitable hand tools. Where holes are inaccessible, as far as the ramming operation is concerned, liquid grout shall be run into the tubes or holes, which shall be shaped and chamfered to facilitate this operation.

Generally, grout shall be composed of 1 part cement and 2 parts sand.

Before grouting operations are undertaken tubes and holes shall first be thoroughly cleaned using compressed air or a water jet. If the hole has been cleaned with compressed air it shall be moistened before grouting; if with a water jet, the superfluous water shall be removed.

Where the holes pass right through the structural member, or where the grouting tubes are horizontal, steps shall be taken to ensure that the grouting hole is sealed off so that no leakage of grout occurs.

11.10.2 Grouting under Steelwork Base plates

Where grouting up under structural steel base plates and similar structures is required the gap under the base plate shall be at least 20 mm. All such grouting is to be done with cement mortar mixed in proportion of 1 part cement to 2 parts sand. Wherever possible the grout shall be of damp consistency and shall be rammed into place with suitable hand tools. Grout must be rammed in progressively, and care must be taken that the entire area under each base plate is completely filled with grout.

Where bolts pass right through the structural member either vertically or horizontally it may be necessary to fill the space between the anchor plate and the concrete member to provide adequate bearing. For such cases grout of a plastic consistency shall be provided.

Before any grouting is done, the top and bottom surfaces between which the grout is to be placed must be made absolutely clean and the concrete surface must be soaked with water.

11.10.3 Non-Shrink Grout

Where required an approved proprietary non-shrink grout shall be used. The grout shall be placed in accordance with the manufacturer's instructions with particular attention being given to the requirements for grouting in hot climates.

11.11 Fencing

11.11.1 General

Fencing shall have reinforced concrete posts and struts with 10 mm diameter holes for wires and shall be erected with a smooth top profile following approximately the ground profile.

Class C20/25/20 concrete shall be used for posts. Holes around posts shall be backfilled with standardised prescribed concrete in accordance with the Concrete section.

Fencing shall be to BS 1722-10.

All bolts to fencing shall be burred over.

11.11.2 Security Fencing

11.11.2.1 Overall Height

The finished vertical height to the top of the crank shall be 3.2 m unless another height is required.

11.11.2.2 Mesh

The mesh shall be diamond mesh of size 50 mm and the wire shall be 3.55 mm diameter galvanised steel wire, supported on four line wires of 4 mm diameter galvanised wire, surmounted by a 45° overhang comprising three strands of galvanised barbed wire to BS 4102 and BS EN 10223 at 200 mm centres. Galvanised stirrup wire of 3.55 mm diameter shall be used to tie the line wires to posts. Wire of 1.6mm diameter shall be used to tie the mesh to the line wires.

11.11.2.3 Supports

Supports shall be set 750 mm into the ground.

The fence shall be carried on 125 x 100 mm intermediate posts 3m apart with holes for wires and a bend at the top to form a 45° overhang.

Struts shall be 100 x 100mm and shall be used at all gate posts, corner posts and straining posts to resist otherwise unbalanced forces. They shall be bolted to the post to which they add support within the top third of its height. Reinforcement of struts and intermediate posts shall be four 10 mm bars and a 3 mm spiral wire link.

Straining posts shall be used in place of the normal standards at corners and at intervals not exceeding 100 m. They shall be 150 x 150 mm, also bent to give the required overhang at the top. Reinforcement of straining posts shall be four 10 mm bars and a 3 mm spiral wire link. Holes for fixing eyebolts shall be 12 mm diameter.

Cranked tops shall be cast with the post and shall taper to 100 x 85 mm for intermediate posts and 150 x 85 mm for straining posts.

11.11.2.4 Bottom Edge Detail

Either the bottom 150 mm of the mesh shall be concreted into a 225 x 150 mm Class C20/25 concrete ground beam or the bottom 450 mm of the mesh shall be dipped into bituminous paint and 300 mm buried, with the ground reinstated.

11.11.2.5 Gates

Gate posts and gates shall be of welded galvanised steel. The gate frame shall be square with all corners mitred or saddled. Vertical braces shall be added to gates at 1.2 m centres and there shall be one horizontal brace.

Gate posts shall be either of 150 x 150 x 5 mm rectangular hollow sections or 168 mm dia. x 5.4 mm thick tubes, with base plates, and they shall be coated with bituminous paint below ground.

Gates shall be of the sliding type, preferably and shall follow the same pattern as the fence and match the 45° overhang of barbed wire. They shall be fitted with adequate rail and support slam plate and locking facility. The bottom hinge shall be of the heel and socket type. The plate shall be 25 mm thick and the pin 25 mm diameter. The bottom of the gates shall have a ground clearance of 75mm and, when closed, the space between meeting stiles shall not exceed 25 mm.

11.11.3 Strained-Wire Fencing

11.11.3.1 General

Strained-wire fencing shall be 1.2m high as Type SC120 of BS 1722-2, with concrete posts and struts, unless another height or type is instructed or shown on the Drawings.

11.11.3.2 Wire

Plain galvanised mild steel wire 4 mm in diameter to BS 4102 shall be attached at 170, 320, 470, 700, 950 and 1200mm above ground level, and shall be strained using winding brackets at the straining posts.

An additional top strand of galvanised mild steel barbed wire to BS 4102 shall be added and securely attached to the posts.

11.11.3.3 Supports

Intermediate posts shall be provided at intervals not exceeding 3.5 m. The posts shall be 125 x 125 mm members set into the ground to a depth of at least 600 mm. Reinforcement shall be four 6 mm bars and a 3 mm spiral wire link.

Straining posts at the ends of the fencing and at 100 m intervals shall be 125 x 125 mm members, placed vertically 750 mm into the ground. Reinforcement shall be four 8 mm bars and a 3 mm spiral wire link.

A 100 x 75 mm strut shall be added at 45° to each straining post. The struts shall be attached to straining posts with mild steel 10 mm diameter bolts. A 700 mm length of the strut shall be buried below ground level. Reinforcement shall be four 6 mm bars and a 3 mm spiral wire link.

11.12 Landscaping and Miscellaneous Works

11.12.1 Precast Paving

Precast paving slabs shall be in Grade C20/25/10 concrete with a wood float finish and shall be 50 mm thick.

Topsoil shall be removed and the subsoil shall be scarified to a depth of 150 mm and compacted to 93% of modified AASHTO density. Locally soft areas where the above compaction cannot be achieved shall be removed. The excavated material shall be replaced with approved backfill compacted to the above density.

Where slabs are to be laid on sand, the area to be paved shall be trimmed to falls, compacted and overlain with 50 mm of sand which shall be watered and raked to a true surface. The paving slabs shall then be laid and bedded down using a light vibrating-plate compactor. Concrete edge strips shall be provided on the perimeters of such paved areas to prevent loss of sand.

Where slabs are to be laid on a concrete bedding, the area to be paved shall be trimmed to falls, compacted and overlain with 75 mm of dry mix concrete complying with the Concrete section. The dry mix concrete shall be spread out dry and raked to a true surface. The paving slabs shall then be laid and bedded down using a light vibrating-plate compactor. Joints between slabs shall be filled and pointed with 1:4 cement/sand mortar.

11.12.2 In Situ Concrete Paved Areas

In areas for concrete paths etc. the surface shall be prepared as required for precast paving and compacted as specified to falls. The concrete shall be grade C20/25/20, shall have a tamped finish and be 75 mm thick.

11.12.3 Gravel Surfacing

If areas of gravel are used for parking areas etc., the gravel shall be tough, durable, clean stone of maximum size 20-40 mm.

External gravel, hardcore and similar areas adjacent to new buildings shall on completion be sprayed with an approved anti-termite treatment.

Section 12: Technical Specifications - Painting and Surface Protection

12.1 Materials

12.1.1 General

This specification applies to the painting and surface coating of civil works structures and structural steel work of the Facilities. For painting and surface protection of electrical and mechanical equipment refer to Employer's Requirements, Section M&E General.

The supply shall include the surface treatment, priming, corrosion protection and painting of the materials and equipment furnished. Such work shall include work in manufacturer's facilities and on site including touch up painting.

Painting systems shall be selected in accordance with site conditions and knowledge of the operational aspects of the respective materials and equipment. Equipment which is not specifically manufactured for this project may be to the manufacturer's standard painting system provided that it is an Employer approved system and that the finished colour is acceptable.

Final painting shall be done to a colour code, the details of which will be advised by the Employer. The painting system and finish used for both internal and external surfaces shall be suitable for the particular conditions to be experienced in shipping, storing, erection, commissioning and operation. Where the surfaces to be painted are subject to heat or attack by chemicals, oils, etc., special paints having the appropriate resistant qualities shall be used. The different paints used for priming undercoat and finish at works and at site shall all be mutually compatible. Protection of steelwork by painting or any other finish shall not be considered as a substitute for any corrosion allowance specified for a particular application.

Different shades of colour shall be used for separate coats of paint in order to most easily verify complete coverage.

All paint shall be delivered from the manufacturer in sealed containers clearly labelled with the product name, batch number and use-by date and accompanied by the manufacturer's application instructions.

Fungicidal paints shall be used wherever practicable.

12.1.2 Restrictions

Chlorinated rubber paints shall not be used on areas subject to repeated handling, such as handrails.

All paints shall be ultra-violet stabilised when they are to be used externally in areas which will be exposed to sunlight for prolonged periods.

Where coal-tar epoxy paints are to be applied in two or more coats, the time interval between coats shall be in the range 12 - 48 hours unless the manufacturer recommends otherwise for the particular temperature and climatic conditions at the time.

12.2 Workmanship

12.2.1 General

All finished surfaces shall have a neat, pleasing appearance. All pigmented primers and paints which will be used for priming and painting at the site shall be delivered in sealed containers packed by the manufacturer.

Painting shall be carried out only by suitably experienced personnel, under cover except where impracticable, and in accordance with the manufacturer's instructions for each material used.

Paint materials shall not be diluted in any way unless specifically stated and agreed by the manufacturer.

All dust, grease and other deleterious matter shall be removed before the next coat is applied.

Protective coatings shall not be applied to damp surfaces or when condensation is expected soon after application. At the time of application the relative humidity shall not exceed 60% and the temperature of steel shall be at least 3°C above the dew point. The painting shall be suitably timed, and the work suitably shaded or enclosed, to avoid detrimental effects caused by dust or (particularly for steelwork) extremes of temperature beyond the recommended application range for the paint.

12.3 Procedures

12.3.1 General

The relevant provisions of BS 6150 and BS EN ISO 12944 shall be applicable.

Metallic surfaces to be coated shall be prepared by methods in accordance with BS 7773 as appropriate. If BS 7773 is used all ferrous surfaces to be painted shall be abrasive blast cleaned to the specified quality of finish in accordance with BS EN ISO 8503.

The maximum amount of protective coating work on items to be delivered to the Site shall be carried out at the manufacturer's works.

In the case of items to be sent by sea, the last coating applied before shipment shall be suitably resistant to the marine environment. These items shall be washed down and dried before any further coating is applied at the Site. For transit by sea and delivery to the Site, all open-ended tubular and hollow steel sections shall have temporary air-tight caps or plugs of approved design to avoid internal corrosion.

Machined surfaces required to be left bright in service shall be protected during transport, storage and installation by a tough coating readily removable during erection.

Where equipment is stored on site, the protective coatings shall be periodically inspected. Any damaged coatings shall be immediately repaired.

Cleaned surfaces shall be kept free of contamination and shall be coated as soon as practicable after cleaning. Cleaned surfaces shall not be allowed to stand overnight without being coated.

Surfaces of non-ferrous components, active iron, insulation and other parts for which there are special finishing requirements shall be painted or protected by approved methods.

Surfaces to be embedded in concrete shall be free of loose material but shall not be coated except that coatings of exposed sections of embedded surfaces shall extend to 75 mm into the concrete or the full depth where this is less than 75 mm.

Dry film thicknesses for coatings on steelwork will be considered as minima, and in the case of blast cleaned surfaces will be considered as measured from the peaks.

In addition to providing all necessary access facilities for painting work, the Contractor shall supply dustsheets, screens etc. to prevent nearby work by others or other trades being adversely affected by the painting operations. He shall moreover protect and clean up adjacent areas as may be necessary during and after painting.

12.3.2 Painting in Enclosed Areas

In confined and enclosed areas, adequate protective measures such as breathing apparatus shall be provided for all personnel where necessary. Adequate ventilation (if necessary by forced draught) shall be provided to produce an acceptably dry surface on which to apply the protective coatings.

12.3.3 Painting near Electrical and Mechanical Plant

It may be necessary to execute painting work adjacent to Electrical and Mechanical Plant which is either being erected, under test or operating productively. In these cases particular care shall be taken to minimise dust. All directions regarding safety adjacent to live and moving machinery shall be strictly observed.

Specific precautions are to be taken at all times to prevent the ingress of dust and scale into the working parts of the Plant and all cleaning in the vicinity of completed machinery shall as far as possible be carried out with electrically operated tools with vacuum attachments for the collection of dust and scale.

The Contractor shall be responsible for the removal and correct replacement of all labels and nameplates where necessary for the proper execution of the work and care should be taken that no damage to same is incurred.

Care is to be taken to keep grease nipples, dials, gauges, sprinkler valves, window control gear, and similar items such as moveable parts which are not intended to be painted, clean and free from foreign matter. Any inadvertent painting is to be removed at once before it commences to dry. Any large area so painted by spillage is to be cleaned at once. Particular attention is to be given to masking the work where spraying is permitted.

Where it is necessary to remove floor plates, trench covers or gallery panels for painting, these items shall be replaced, including clipping down. Temporary holes formed in floors and walkways are to be securely fenced.

12.3.4 Final Finish

The whole of the work shall be executed to give a uniform finish. Adjacent and similar surfaces of the same colour and to which the same paint is applied are to have a uniform finish.

All finishes shall be such as to completely cover and obscure the base construction and priming coats such that additional coats of paint will not effect a significant improvement in appearance. They shall be consistent in colour and free from brush marks, irregularities and defects in the paint surface.

Defective areas shall be touched up or recoated. Additional coats shall be applied if the finish of any part of the work is not equivalent to its counterpart in similar painted surfaces carried out elsewhere in the Facilities.

12.4 Particular Requirements for Steelwork

12.4.1 Basic Requirements of Protection Systems

Steelwork drawings will be annotated with the system categories required, which are designated below, primarily in respect of use and ease of access. The systems shall be compatible with the durability requirements stated herein and be selected on the requirements given in BS EN ISO 12944-5.

Protective treatment applied to fasteners, welds and joint areas (excepting mating areas for high-strength friction-grip bolts) shall be of at least the same quality as that of the adjacent steelwork.

The durability requirements in the table below are to be:

- No maintenance for A years
- Minor maintenance thereafter until major maintenance after B years.

12.4.2 Designation of Systems

System Designation	Primarily for	Durability (years) A	Durability (years) B	Equivalent BS EN ISO 12944-1 Approx. durability
P1	Internal with ready access.	6	10	M
P2	Internal with difficult access; and External with ready access	8	12	M
P3	External with difficult access.	8	12	M
P4	Subject to silt-laden fresh water flow	10	15	H
P5	Fresh water immersion and adjacent spray zone	10	15	H
P6	Painting on galvanised surfaces	8	12	M

Other designations which may appear on Drawings are:

- PO unpainted
- PG galvanised.

Steel which is to be encased in concrete need not be painted, but all loosely-adhering rust, grease and other deleterious materials shall be removed. The only coating which is likely to be required for such surfaces is bituminous paint.

In the above list, "difficult access" means areas immersed in water or where access thereto involves scaffolding and/or other temporary arrangements, additional to ladders, and which significantly disrupt the normal use or production process.

12.4.3 Preparation of Bare Steel to Receive Paint

Except for system P1, steelwork shall be blast cleaned at the fabricator's works to remove oxide, mill-scale etc. before application of the primer.

For blast cleaning the abrasive shall be either chilled cast iron shot or steel shot of not less than 40 Hardness Rockwell C, of grade consistent with the profile to be produced. No oversize abrasive shall be used because this will tend to produce excessive peaks.

The abrasive shall be free of matter which could leave deleterious contaminants.

Particular attention shall be paid to joint areas because breakdown of surface protection will otherwise commence in such areas. Weld spatter and alkaline deposits from welding shall be removed before blast cleaning.

The arrangements for blast cleaning shall be such as to ensure that dust and stray abrasive do not contaminate nearby wet paint or surfaces waiting to be primed.

After blast cleaning any "hackles" and "rogue peaks" shall be rubbed down mechanically and the surface freed from abrasive residue, including embedded particles, by high pressure air dusting and/or vacuum cleaning. Where extensive grinding has been necessary to remove the defects it may be necessary to re-blast the affected areas to remove rust and provide an adequate key for the paint.

All crevices shall be cleaned out and steel sections thoroughly degreased using approved cleaners followed by thorough rinsing with water.

12.4.4 Application of Primer

12.4.4.1 General

As soon as the blast cleaning and removal of abrasive has been completed, any mating surface to be connected by high strength friction grip bolts shall be masked. The primer may penetrate the HSFG joint area by up to 10-15 mm.

The first application of primer paint shall take place as soon as possible after blast cleaning, and in any case before visible deterioration takes place.

At areas to be welded, either the primer shall be kept back from the areas or else approved temporary protection such as taping may be provided as an alternative to priming the weld areas. The edges of shop coats exposed on removal of the tape shall be treated in accordance with the paint manufacturer's instruction to ensure adhesion to further coats.

In highly-corrosive conditions the bolts, washers and other fastenings shall be protected and primed before insertion.

12.4.4.2 Stripe Coats

After erection, at a suitable time prior to the first undercoat, a stripe coat of primer shall be applied to all welds, fasteners, bolts, washers and to external corners other than those of RHS sections.

Before the final coat a stripe coat of the last undercoat shall be applied to the same areas.

12.4.4.3 Weld Areas and Damaged Areas

All painted surfaces which have incurred damage during stockpiling or delivery to Site prior to erection shall be made good.

Weld areas and areas previously primed in the manufacturer's works shall be thoroughly washed down with clean fresh water and all oil, grease, dirt or any other matter which may affect the painting process shall be removed by use of approved cleaning agents. Any deteriorated or otherwise faulty paintwork including mechanical damage shall be cleaned down to bright bare metal using mechanically operated abrasive discs and such surfaces shall then be cleaned of dust and immediately primed to the same standard as the undamaged adjacent area.

12.4.5 Application of Undercoat and Finish Coats

Where concreting and pressure grouting are carried out adjacent to erected steelwork prior to Site painting, all grout, waste and associated deleterious materials shall be satisfactorily removed before painting at Site.

In highly-corrosive conditions, joints between mating surfaces connected with friction grip bolts shall after erection be sealed with an approved flexible sealer applied by pressure gun and knife to a weather fillet pointing.

12.5 Particular Requirements for Steel Pipes

12.5.1 Scope

This Clause applies both to ex-factory pipes delivered to Site for installation and to large fabricated pipework, e.g. penstocks, which are welded up on Site after being delivered as flat plates or smaller items.

12.5.2 External Surfaces of Pipes

External surfaces of pipes to be encased in concrete need not be painted, but all loosely adhering rust, grease and other deleterious materials shall be removed. Protective coatings applied to adjacent surfaces not in contact with the concrete shall extend a minimum of 200 mm inside the concrete.

Exposed external pipe surfaces shall be painted in accordance with the system designated for other steelwork of equivalent exposure. In cases where the Employer has a need to distinguish the contents of pipes by their colour, it will be necessary to have particular colours of finish coats. Where finish coatings with a limited colour range are proposed, e.g. micaceous iron oxide, the shade of system which is nearest to that requested shall be nominated.

Buried external pipe surfaces which are not encased in concrete shall be protected by either:-

(a) Clean and prime as for System P3 (external with difficult access) followed by glass-fibre protection comprising bituminous materials to BS EN 10300. The glass-fibre coating shall be in two layers with minimum overlaps of 30 mm and a total thickness of at least 5 mm: or

(b) Works application of sprayed metallic zinc at 130g/m^2 followed by bituminous coatings totalling 0.070 mm. In areas of aggressive groundwater polyethylene sleeving may be required, in which case the material shall be to BS 6076 and the strictest control shall be applied in order to avoid gaps or perforations and consequent corrosion.

12.5.3 Internal Surfaces of Pipes

Internal surfaces of pipes shall, unless protected by mortar lining or other non-paint system, be painted to System P4.

12.6 Metal Coatings

12.6.1 Galvanising

12.6.1.1 Processes

All galvanising shall be by the hot-dip process in accordance with BS EN ISO 1461. Electro-galvanising, "cold" galvanising paints or zinc metal sprays shall not be used.

Bolts, washers and associated fasteners for galvanised work shall be either sherardised, galvanised and centrifuged, or electro-galvanised.

12.6.1.2 Preparation

All deleterious substances which will not be removed by the galvanising process itself shall be removed by pickling before galvanising takes place.

Pickling shall be carried out using inhibited hydrochloric or sulphuric acid with a strength not exceeding 14 percent. The temperature of the acid shall be 15-25^{o}C for hydrochloric acid and 60-80^{o}C for sulphuric acid. The immersion time shall be the minimum required for cleaning in order to avoid (for example) excessive uptake of hydrogen, which could cause embrittlement of the steel. All traces of acid shall be washed off and the surfaces dried before immersion in the galvanising fluid. Materials likely to resist the pickling liquid shall be removed beforehand.

Steelwork with "difficult access" (as defined in the section for Painting of Steelwork) shall be blast-cleaned to BS EN ISO 8503/BS 7079 Sa 2 medium profile using chilled cast iron shot of grade G24.

12.6.1.3 Requirements

The work shall be carried out in accordance with BS EN ISO 1461.

The minimum average coating weights of steelwork and fasteners etc. shall be in accordance with BS EN ISO 1461 except that for steelwork to be submerged for long periods or with "difficult access" the coating weight on the steelwork shall be increased by 25%. However, the thickness shall not be increased by an excessive amount such as to affect adversely the adherence of the coating.

All steel ladders, platforms, duct covers and associated fixings will be galvanised.

Adequate provision shall be made for venting and draining hollow sections and specially provided vent holes shall be suitably plugged after galvanising.

12.6.1.4 Procedure after Galvanising

Newly-galvanised parts shall be stored off the ground under cover using timber spacers such that air can circulate between them. They shall be handled with care at all times and shall not be bent significantly during further assembly work. Damaged or defective areas shall be repaired by thorough wire brushing followed by either two coats of a zinc-rich paint or the application of a low melting point zinc alloy repair rod or powder to the damaged area, which shall be heated to 300°C.

Galvanised surfaces to be joined by high-strength friction-grip bolts shall be roughened before assembly to obtain the required slip factor. Roughening shall not extend beyond the minimum area needed.

Direct contact between non-ferrous metals and galvanised parts shall be prevented by tape or other approved means.

12.6.2 Electroplating

Electroplating shall be nickel plus chromium plating in accordance with BS EN ISO 1456 or zinc or cadmium plating in accordance with BS EN ISO 2081 and BS EN ISO 2082. Nickel planting alone shall not be used.

12.7 Painting of Galvanised Steel (System P6)

Where it is necessary to paint galvanised surfaces, a "T" wash in accordance with BS EN ISO 12944 shall first be applied and the surface made free of dirt, grease and oil and then dried.

All galvanised surfaces to be surrounded by concrete shall receive two coats of bituminous paint before installation in order to prevent damage to the coating by abrasive particles in the wet concrete.

12.8 Particular Requirements for Timber

12.8.1 Preservative Treatment

Timber shall receive preservative treatment as specified in the relevant Section elsewhere for Timberwork.

12.8.2 Preparation

In areas which are to receive emulsion or other water-based paints, all nail heads and similar items shall be first painted with zinc phosphate primer.

All nail holes, cracks, open joints etc. shall be filled to the general surface level with putty or approved stopping and smoothed over to tie in with the surface.

Knots, pitch pockets and sappy spots shall be treated with knotting.

All deleterious materials such as dust, dirt, grease etc. shall be removed.

Door fittings and similar items shall be removed before painting the timber.

12.8.3 Method

12.8.3.1 General

Built-in parts shall be primed before being fixed.

12.8.3.2 Softwoods

One coat of wood primer shall be applied. A self-knotting aluminium primer is preferred. Primer shall not be omitted from locations such as the bottom edges of doors. Built-in parts shall be primed before being fixed.

After priming, there shall be two undercoats followed by one coat of a hard gloss finish paint on surfaces exposed to view on completion.

12.8.3.3 Hardwoods

Exterior hardwoods shall be protected unless otherwise instructed. The protection shall comprise two coats of a low-solid, exterior-quality wood stain.

Interior hardwoods shall receive three coats of clear polyurethane rubbed down with fine steel wool and wax polished.

12.9 Particular Requirements for Cementitious Surfaces

12.9.1 Scope

This clause covers concrete, plaster, brickwork, blockwork and similar surfaces with cement or lime bonding. Plaster surfaces shall always be painted.

12.9.2 Preparation

Plaster and concrete surfaces shall not be treated until they have dried out to an acceptable degree and have been cleaned of all deleterious efflorescence, dirt, oil, etc.

Cracks shall be raked out and filled with material compatible with both the cracked material and the treatment coatings to be applied.

Rough areas of concrete shall be ground smooth by means of a rotary carborundum disc with cement slurry as a lubricant.

12.9.3 Method for Walls

12.9.3.1 Primer

The primer shall comprise one coat of an acrylic emulsion or other alkali-resistant primer compatible with the coatings which are to follow.

12.9.3.2 Normal Finish

Two coats of a coloured acrylic coating compatible with the primer shall then be applied. Emulsion will be acceptable internally.

If the appearance is not uniform after two coats provision shall be included for application of a third coat.

12.9.3.3 Gloss Finish

In some areas, a gloss finish may be required on such surfaces. In this case the gloss paint shall be an approved coating additional to the work described for Normal Finish.

12.9.4 Methods for Floors

If it is required that coatings be applied to floors, they shall be epoxy-based and supplied by an approved manufacturer. The floor surface shall be further prepared, and the application carried out, strictly as recommended by the manufacturer of the coating.

Painted finishes on battery room floors shall comprise an epoxy-based two-pack acid-resistant compound applied by brush or roller.

Section 13: Technical Specifications – Penstock

13.1 General

This section covers the detailed specification for the design, manufacture, supply, erection, commissioning and testing of the steel Penstock and any other large diameter fabricated pipework.

Such steel pipework shall be designed and manufactured to the shapes required, transported to Site, installed, tested and commissioned in accordance with the requirements of the Specification. All necessary permanent and temporary supports, anchorages, stiffeners and fittings are to be included.

Manholes, tees and small diameter outlets are to be provided with all necessary reinforcement of the main pipe shell in accordance with BS EN 13445/PD 5500.

Shear connectors, anchorages or stiffening rings are to be provided to resist external pressure as required. They shall be fully welded to the exterior of the pipe wall and be so shaped as to offer little obstruction to the placing of the concrete encasement.

Temporary dished ends and all necessary pumps, valves, air bleeds, pressure and temperature gauges shall be provided for pressure testing with water and designed in accordance with BS EN 13445/PD 5500.

The materials to be used in fabricated pressure pipework, and the requirements applicable to the manufacture, shall be in accordance with the C.E.C.T. (Comité Européen de la Chaudronnerie et de la Tolerie) Recommendations for the Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydro Electric Installations.

The structural design for the penstock shall be supported by detailed calculations, having due regard to the complexity of the shapes required and the stiffening necessary for their support. The pipewall thickness so calculated shall be increased as required to include an allowance for corrosion protection.

Consideration must be given to control of distortion and temperature effects during welding of the elements of pipework and account must be taken of rail and road loading gauges to be traversed by the pieces travelling to the site. Heat treatment after assembly and welding on Site for relief of "locked up" stresses may be required.

13.1.1 Design

The design, fabrication, manufacture and installation of the pipes and all bends, reducers, anchorages, connections and details shall be the responsibility of the Contractor. Due account shall be taken of discontinuity stresses at points of restraint in the pipe wall.

The materials to be used in the fabrication of pipework and the requirements for manufacture and installation shall be in accordance, as appropriate, with BS EN 10025, and the following list:

C.E.C.T.	Recommendations for the Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydro-Electric Installations.
BS EN 10025	Hot-rolled products of structural steels
BS EN 10028	Flat plate products for pressure purposes
BS EN 10029	Tolerances for hot-rolled steel plates
BS EN 10210	Hot-finished non-alloy and fine-grain structural hollow sections
BS 7668	Hot-finished weldable structural hollow sections in weather-resistant steel
BS EN 10216	Seamless steel tubes for pressure purposes
BS EN 10217	Welded steel tubes for pressure purposes
BS 2633	Class 1 arc welding of ferritic steel pipework for carrying fluids
BS EN 13445/PD 5500	Specification for unfired fusion welded pressure vessels
BS EN 1092	Flanges and their joints

Steel shall be of a readily weldable grade, preferably less than 50 mm thick.

Care shall be taken in laying out bends and reducers to reduce turbulence and hydraulic losses to a minimum. They are to be formed by the smooth intersection of conical pipes, with care and attention given to the avoidance of sharp corners and internal obstructions. Crotch stiffening girders may intrude slightly within the branch pipe provided they do not generate significant separation of flow from the pipewall and turbulence.

13.1.2 Basic Technical Requirements

The working head shall be measured at the centreline of the pipe. These values shall include an allowance for permissible pressure increases. The internal test pressure shall apply to the centreline of the pipe.

Shear connectors, anchorages or flanges provided to resist thrusts and pressure shall be fully welded to the exterior of the pipe wall and be so shaped as to minimise obstruction to the placing of concrete encasement.

Temporary internal stiffening devices shall be provided to withstand a 2 m head of wet concrete unless the Contractor's method of working require otherwise. A 25% overstress above normal working stress will be accepted for this condition.

Design stresses on the net thickness (excluding the corrosion allowance) shall not exceed the yield stress divided by the appropriate factor of safety given in the C.E.C.T. recommendations for design.

Steel stresses used for design shall be as follows:

(i) Membrane stresses are defined as stresses which are essentially constant throughout the thickness.

(ii) Equivalent stresses are determined from the biaxial stresses at a point by Hencky von Mises theory.

(iii) Uni-axial stresses are the combination of bending and direct stresses in a given direction.

(iv) Local stresses are defined as those which occur over a small area and which are essentially bending stresses varying throughout the thickness of the pipe shell.

(v) The bending stresses in the reinforcing girders and bending stresses across the pipe diameter are not classified as local stresses.

(vi) The local stresses under any combination of loading shall not exceed those in BS EN 13445/PD 5500, where 'f' is the appropriate allowable stress as per C.E.C.T.

In any case the stress concentration factor at points of local stress under any combination of load and under any condition of operation shall not exceed 2.25. The stress concentration factor is defined as the ratio of the local stress to the adjacent membrane stress.

13.1.3 Materials

All plates, as well as rolled sections, shall be milled or sawn to exact length and to a smooth surface at right angles to the axis of the member or exactly as otherwise required.

Stiffeners shall be machined or otherwise formed to the required profile to ensure full bearing contact.

Test certificates are required and the Contractor shall make copies available to the Client before steel covered by the Certificates is accepted.

Material tests and analysis shall be undertaken as follows, unless otherwise agreed by the Employer:

(i) Ladle analysis in accordance with ASTM E1019.

(ii) Product analysis in accordance with ASTM A370.

(iii) Impact tests carried out at a temperature of -20°C in accordance with BS EN 10045-1, shall give an energy not less than 27 Joule.

Tests shall be undertaken to ensure that all sections are free from piping, laminations, blisters, scale and other unacceptable defects. Test certificates shall be supplied.

Stiffeners shall be machined or otherwise formed to the required profile to ensure full bearing contact.

All pipes, bends, reducers etc., shall be fabricated using the minimum number of individual pieces of plate. Longitudinal seams in adjacent sections of pipe shall be staggered.

Welding consumables (e.g. electrodes, filler wires etc.) shall be to BS EN ISO 14341.

Grout sockets shall be threaded to BS EN 10226-1 unless the Contractor's grouting equipment requires another thread.

13.1.4 Welds

13.1.4.1 General

This Clause is additional to Employer's Requirements section – Structural Steelwork, Clause - Welding and shall prevail in the event of a discrepancy.

Welding shall be metal arc welding in accordance with all appropriate clauses of BS EN 13445/PD 5500 and BS EN 1011.

Fabrication of straight penstock sections, bends, bifurcations, reducers and other special sections shall be undertaken under workshop conditions away from the site. Longitudinal welding at site shall not be undertaken.

13.1.4.2 Inspection and Testing

Non destructive testing including radiographic examination shall be carried out on Site as well as at the manufacturer's works. Radiographic examination shall be carried out in accordance with BS EN 1435. Ultrasonic examination shall be carried out in accordance with BS EN 1714. The type of test to be used for each weld shall be the most suitable for the particular case.

Welds made at a fabrication shop away from the Site shall be examined and passed before despatch to Site and the inspection reports and X-ray films shall be available on Site before installation commences. Installation welds made on Site shall be examined and passed before concrete encasement commences. If checks on site welds reveal previously undetected faults in shop welds, then examination on the full extent of the welds in which the fault occurs shall be undertaken.

Welds on fabricated steel pipework shall be examined by non destructive testing and assessed as follows:

(i) All shop welds shall be 100% X-ray tested. All circumferential site welds shall be 100% ultrasonic tested. In the case that defects are found the full weld shall be 100% X-ray tested.

(ii) Examination, assessment and rectification of welds shall generally be in accordance with the C.E.C.T. recommendations, BS 2633 and BS EN 13445/PD 5500.

(iii) Where a section of a weld is shown by initial examination to be defective but the limits of the defect are not fully defined, additional examination shall be carried out until the limits of the unacceptable weld are fully determined.

(v) All repaired welds shall be inspected using the same method by which the defect was revealed. The same section of weld shall not be repaired more than twice in view of the changes, which are to be expected in the structure of the metal, as a result of repeated heating.

13.1.5 Tolerances

All fabrication tolerances shall be in accordance with C.E.C.T Recommendations for Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydro Electric Installations.

13.1.6 Installation

Only approved, competent workers, carefully supervised by qualified installation staff shall be permitted to carry out the installation work on site.

Consideration must be given to control of distortion and temperature effects during welding of the elements of pipe work. Heat treatment after assembly and welding on Site for relief of "locked up" stresses may be required.

Upon completion of the installation new and existing steel surfaces that will be grouted against, shall be clean, dry, and free from oil, grease and any other loosely adherent or deleterious material.

The alignment and levelling of the penstock shells and all associated equipment shall be carried out accurately.

Flat bottom rails or similar section shall be provided in order to facilitate moving the penstock section and segments into position, and to assist in erection and alignment in view of the limited space available and the steep slope in the penstock area. These rails shall be complete with fish plates and all anchor bolts etc.

Due regard shall be given to the effect of erection stresses on Site, and neither bolting nor welding shall be undertaken until proper alignment has been obtained.

The penstock shells shall be made up in convenient lengths for handling. All material necessary for temporary internal bracing, prevention of movement during concreting, etc. shall be provided. Welding of any temporary steelwork to the steel shells shall not be permitted.

All penstock sections and associated pipe work shall be free of dents and defects.

Where the penstock sections are to be finally built into anchor blocks, anchor sections with suitable anchor stiffening rings shall be provided, where required, to carry all loads imposed on the anchors during erection and testing.

Forces imposed on the first stage concrete of the anchor blocks shall be limited to safely maintain the stability of the blocks in both sliding and overturning.

All installation tolerances shall be in accordance with C.E.C.T Recommendations for Design, Manufacture and Erection of Steel Penstocks of Welded Construction for Hydro Electric Installation.

13.1.7 Hydraulic Testing

Sections of large diameter pipework comprising structural complexity (i.e. complicated weldments, such as wye branches/bifurcations) shall be hydraulically tested with water on completion of welding and prior to shipment from the workshop.

For the hydraulic test specially domed or other approved blank ends shall be supplied and removed afterwards. The domed ends shall be welded on the extremes of the penstock sections to be tested, which shall be over length so that there will be no material affected by repeated welding in the completed work. All domed ends shall be designed in accordance with BS EN 13445/PD 5500.

Fabricated pipework under test shall withstand the test head for 6 hours without loss of pressure (allowance for temperature variations and creep excepted). This period is longer than that given in the C.E.C.T. Recommendations but shall nevertheless apply. The amount of any water added to maintain the pressure shall be recorded. If any defects in design, materials or workmanship are revealed by the test, they shall be made good.

The test pressure shall be 1.25 x maximum operating pressure as defined in the C.E.C.T. Recommendations.

Section 14: Technical Specifications – M&E General

14.1 General Requirements

14.1.1 Scope

This Section gives the General Technical Specifications for the mechanical and electrical Facilities. If the provisions of this Section conflict with the requirements of particular Technical Specifications given in these Employer's Requirements then the requirements of the particular Technical Clauses shall prevail.

The M&E General Technical Specification defines the workmanship and material requirements. The Contractor may propose variations from these Employer's Requirements by demonstrating, to the approval of the Employer, that such variations are equal to or better than the Specified requirements.

The approval by the Employer of any variations from these specified requirements shall not relieve the Contractor of any other of his obligations under the Contract.

14.1.2 Quality of Design, Materials and Manufacture

As far as possible the equipment to be supplied by the Contractor shall be of the Contractor's standard design, provided that this design is in accordance with the requirements of these Employer's Requirements. Components used shall have proven satisfactory service and shall be new and unused.

All equipment performing similar duties shall be of the same type. All identical machined parts shall be interchangeable.

All parts subject to reservoir head shall be designed for fully developed resonant water hammer at twice maximum static head at a stress not exceeding 90 percent of yield stress.

All parts of the turbines and generators shall be designed for the maximum transient runaway speed, the value of which shall be nominated by the Contractor.

All plant shall be designed for the area seismic requirements.

All design shall be appropriate to the climatic conditions at the power station.

All Plant shall be designed to minimise the risk of fire and consequential damage, to prevent ingress of vermin, dust and dirt, and accidental contact with electrically energised or moving parts, and collection and condensation of water. The Plant shall be capable of continuous operation with minimum attention and maintenance in the exceptionally severe service and climatic conditions.

All rotating shafts and couplings shall be fitted with rigid guards of wire mesh or plate so designed that accidental contact with the rotating parts is not possible.

The Contractor shall provide all auxiliary and/or distribution transformers, and associated connections and switchboards, necessary for the successful implementation of the Design-Build Services and such transformers, connections together with associated switchboards shall be deemed to be included in the Contract.

The design and materials shall be such as to achieve service life, operational reliability, ease of maintenance, inspection and adjustment.

Items of proprietary equipment to be incorporated into the plant shall be of high quality produced by reputable manufacturers and of adequate capacity to perform the required service under all normal operating conditions.

To avoid the possibility of galling or friction occurring on close tolerance moving components the material selected for the components shall be such that the difference in surface hardness between adjacent surfaces shall be not less than 50 Brinell.

All wearing parts and all joint rings, seals and gaskets shall be replaceable.

The method of rectification of manufacturing errors, material defects and performance shortcomings shall be to the approved concession procedure.

14.1.3 Applicable Codes and Standards

Plant and equipment shall comply with the following general groups of Standards. The Contractor shall refer to Standards within these general groups in defining the characteristics of the plant and equipment in his supply. These groups of Standards (or the approved equivalent thereof) shall be referenced in the contractual information presented for Approval by the Contractor:

Dimensions and units	ISO
Ferrous and non-ferrous material for fabrication	ASTM BS
Pressure Vessel design and manufacture	ASME and BS
Welding procedures and welder qualifications	ASME and BS
Structural welding	AWS and BS
Non destructive testing	AWS, ASME, ASTM and BS
Materials testing	ASTM
Pipework supports	ANSI

Pipe flanges and valves	ISO
Noise and vibration	ISO
Fastenings	ISO
Pumps and fans	ISO
Painting	SSPC and BS
Electrical equipment	IEC
Cables	IEC or BS
Diesel engines	ISO and BS
Fire Protection and detection	NFPA
HVAC	ASHRAE or BS
Hoisting and handling equipment	BS or FEM
Hydraulic Gates and equipment	DIN
Equipment Identification Coding	KKS

Where:

ASHRAE = American Society of Heating & Air-Conditioning Engineers
ASME = American Society of Mechanical Engineers
ASTM = American Society for Testing and Materials
AWS = American Welding Society
BS = British Standards
DIN = Deutsches Institut für Normung
FEM = Fédération Européenne de la Manutention
IEC = International Electrotechnical Commission
ANSI = American National Standards Institute
ISO = International Standards Organisation
KKS = Kraftwerk-Kennzeichensystem
NFPA = National Fire Protection Association
SMACNA = Sheet Metal and Air-Conditioning Contractor's National Association.
SSPC = Structural Steel Painting Council

14.1.4 Seismic Design

The New Facility plant and equipment shall be designed to withstand an Operating Basis Earthquake (OBE) for a design life of 50 years and probability of exceedance, without damage and without interruption to operation, as defined in Employer's Requirements Section 4 Technical Specification - Outline Civil Works Design Criteria.

14.1.5 Labels for Equipment

14.1.5.1 Warning Notices

The Contractor shall provide movable warning notices and signs for the Facilities of a form and wording to be determined by the Employer to suit the Employer's high-voltage and other safety regulations. The Employer will provide the Contractor with copies of these relevant regulations.

14.1.5.2 Labels

(a) All plant and items of equipment shall be identified using the KKS system.

(b) The Contractor shall provide labels of a size and detail to permit rapid and positive identification to be made for operational and maintenance purposes of all pieces of equipment including enclosures, power outlets, switches, luminaires and devices whether enclosed in cubicles or separately mounted. The Contractor will provide to the Employer a complete list of items provided under the Contract.

(c) Labels not in direct sunlight shall be engraved in a plastic laminate composed of white and black layers. When engraved they shall have black letters not less then 3 mm high on a white background. Alternatively, labels may be machine engraved aluminium with lettering filled with black paint of not less than 0.5 mm line thickness. Letters shall be neat in appearance not less then 3 mm high and engraved not less than 0.2 mm deep.

(d) Labels exposed to sunlight shall be of matt stainless steel with engraved letters filled with black paint.

(e) Pipe labels shall comply with BS 1710 using adhesive markers.

(f) All steel and plastic labels more than 100 mm long and used indoors shall be fastened by nickel-plated brass screws. Fixings for long labels cater for expansion. Indoor labels of length less then 100 mm shall be fastened by epoxy adhesive.

(g) Labels for cubicles and equipment mounted within 2.0 m above floor level shall be positioned so that they can be read by a person of average height standing in front of the cubicles.

(h) Labels for devices mounted on or in enclosures shall be provided on the inside of the enclosure adjacent to the device as well as on the device. Device labels shall not be located on removable covers of the device.

(i) Valve labels shall be fastened to a galvanised sheet steel bracket, held in place by the valve flange bolts or by two galvanised steel straps around the pipe adjacent to the valve.

(j) Warning labels shall be provided on or in all electrical equipment where terminals at dangerous voltages (including 400/230 V) may be exposed during maintenance. Warning labels shall be of plastic laminate with white lettering on a red background.

(k) MCBs, MCCBs and links shall be identified by their function, voltage, polarity, phase colour and rating. Equipment not covered such as luminaires, switches and power outlets shall be identified by L, S or P followed by a consecutive number and the supply circuit identification.

(l) The wording of warning labels shall be in the English language.

14.1.5.3 Rating Plates

A rating plate complying with the requirements of the appropriate Standard shall be provided on each item of plant. A drawing of the rating plate for major items of plant shall be submitted, during the design phase, to the Employer for approval.

Where the rating plate is affixed to an item of plant, but not an individual component of an item of plant, of a mass in excess of 100 kg, it shall also specify the mass of the item. The rating plates shall be of engraved or stamped matt stainless steel, brass or of other approved metal.

14.1.5.4 Supply of Warning Notice, Labels and Rating Plates

Failure to complete the supply and fixing of warning notices, labels and rating plates shall be sufficient reason for the Employer to withhold the issuing of an Operational Acceptance Certificate in accordance with the Conditions of Contract.

14.1.6 Assembly during Manufacture

All parts of the plant shall be assembled during manufacture at the Contractor's discretion, unless specified, to the full extent necessary for the purpose of inspection, testing and otherwise ensuring that they will function satisfactorily and are mutually correct as regards dimensions. During such assembly, all parts shall be correctly dowelled and match-marked to facilitate erection at site.

14.1.7 Painting and Coating Systems

14.1.7.1 General

(a) The Contractor shall carry out surface preparation and apply surface protection as specified in this Clause.

(b) All parts of the Facilities shall be protected against corrosion during transport, storage and erection and in service by surface treatment appropriate to the particular material and service. Machined surfaces required to be left bright in service shall be protected during transport, storage and installation by a tough coating readily removable during erection, to the approval of the Employer.

(c) Where items of plant are stored on site, the protective coatings shall be periodically inspected. Any damaged coatings shall be immediately repaired.

(d) Surfaces of non-ferrous components, active iron, insulation and other parts for which the Contractor has special finishing requirements shall be painted or protected by methods to be proposed by the Contractor for approval.

(e) Surfaces to be embedded in concrete shall be free of loose material but shall not be coated except that coatings of exposed sections of embedded surfaces shall extend to 75 mm into the concrete or the full depth where this is less than 75 mm.

14.1.7.2 Painting of Plant

(a) The Contractor shall submit to the Employer, for approval, proposed painting systems including the following details:

- makes and types of the proposed coatings schedules including the following details;
- methods of preparation, application and inspection;
- sequences and intervals of all procedures;
- standards to which procedures or products conform;
- precautions and restrictions to be observed; and
- methods of protection of factory applied coatings during transport to Site.

(b) All coating products shall be supplied from reputable manufactures. The Contractor shall supply samples of the products proposed.

(c) Erection marks shall remain visible after coating where the coating is applied prior to erection.

14.1.7.3 Surface Preparation

(a) Surfaces to be coated shall be prepared by methods in accordance with SSPC or BS 7773 as appropriate. If BS 7773 is used all ferrous surfaces to be painted shall be abrasive blast cleaned to the specified quality of finish in accordance with BS 7079.

(b) Cleaned surfaces shall be kept free of contamination and shall not be touched by bare hand. If any areas become contaminated they shall be cleaned bearing coated.

(c) Cleaned surfaces shall be coated as soon as practicable after cleaning. Cleaned surfaces shall not be allowed to stand overnight without being coated.

14.1.7.4 Paint Systems

(a) The paint systems shall comprise approved sequences of surface preparation, primer coating, under coating where appropriate and finish coating. The various coats of each system shall be of the same brand. Paint systems shall comply with BS EN ISO 12944 part 5. Details of manufacturer's test records to substantiate this selection shall be submitted to the Employer for approval.

(b) Equipment which is not specifically manufactured for this project may be to the manufacturer's standard painting system provided that the system has been agreed to by the Employer and that the finished colour is acceptable.

(c) Finish coat colours shall be as nominated by the Employer. Successive coats shall be distinguishable by colour.

(d) Paint may be applied at the Factory or at Site, providing the products and procedures are suitable for the intercoat exposure and the environment during application.

(e) All paint shall be delivered to the point of use in sealed containers clearly labelled with the product name, batch number and use-by date and accompanied by the manufacturer's application instructions.

14.1.7.5 Metal Coatings

(a) All galvanising shall be by the hot-dip process in accordance with BS ENO 1461 Parts shall be pickled thoroughly before being galvanised, with all materials likely to resist the pickling liquid removed beforehand.

(b) Where possible, fabrication and de-burring of the material shall be carried out prior to galvanising. Where the galvanising has been damaged, the exposed surface shall be painted as soon as possible in accordance with the following system:

(c) clean back to bright steel;

(d) feather the edges of the surrounding galvanising coating;

(e) degrease in accordance with BS 7773 and

(f) apply two coats of a zinc rich primer for a total film thickness of not less than 0.075 mm.

(g) Electroplating shall be nickel plus chromium plating in accordance with BS EN 12540 or zinc or cadmium plating in accordance with BS 1706. Nickel planting alone shall not be used.

14.1.8 Locking Facilities

14.1.8.1 General

The Contractor shall provide locking facilities for a security locking system and an isolation locking system for cubicles, equipment and rooms together with padlocks for access gates and doors. The Contractor shall also provide sufficiently sized lockable key racks to accommodate all such keys. Below are the locking systems to be provided:

14.1.8.2 Security Locking System

The Contractor shall provide a security locking system for all elements of the Facility. A minimum of five sets of keys for each element of the Facility shall be provided by the Contractor, together with at least two spare sets of each type of lock, including keys. Security locking system shall be of the standard lock and key design.

14.1.8.3 Safety Isolation Locking System

The Contractor shall provide a complete safety isolation locking system for the secure isolation of plant and equipment during maintenance procedures to ensure the safety of personnel. The safety isolation system shall include, but not be limited to the following:

(a) The safety isolation locking system shall be a padlock system completely independent from the master key security locking system. Padlocks shall be provided in sufficient number and suitable to lock every electrical and mechanical isolating device which may be required to be isolated and locked in accordance with the Employer's access permit system for equipment maintenance and operation.

A suitably sized lockout box shall be provided that shall be operated by a combination of one master key and at least three other keys able to be withdrawn individually to enable effective lockout. Equipment requiring isolation padlocks includes but is not confined to electrical disconnectors, earthing switches, lockable circuit-breakers, other lockable electrical devices and all isolating valves.

(b) The padlocks shall be high quality locks with a number operated cylinder mechanism and manufactured from brass or unhardened steel. All padlocks shall preferably be identical in type and shall be of a size suitable to fit the locking facility of every device required to be locked. The keying system shall be a simple independent system in which each lock shall be able to be operated by its own key only and without any master key facility.

(c) The Contractor shall formally hand over, directly to the Employer, two keys for each lock, together with all lock manufacturers' authorisation papers to enable the Employer, and no one else, to purchase additional copies of the keys. Each key shall be fitted with a blank label tag suitable for the Employer to add his own label.

14.1.9 Material Protection

(a) In choosing materials and their finishes, due regard shall be given to the range of conditions under which the Plant is to operate, and the recommendations of BS CP 1014 shall be observed unless otherwise approved.

(i) Metals

Iron and steel generally shall be painted or galvanised. Indoor parts may alternatively be electroplated or have other approved protective finish. Small iron and steel parts (other than rustless steel) of all instruments and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent rusting. Cores, etc., which are built up of laminations or cannot for any other reason be anti-rust treated, shall have all exposed parts thoroughly cleaned and heavily enamelled, lacquered or compound. When it is necessary to for dissimilar metals to be in contact, these shall be so selected that the potential difference between them in the electrochemical series is not greater than 0.5 V. If this is not possible the contact surfaces of one or both of the metals shall be electroplated or otherwise finished in such a manner that the potential difference is reduced to within the required limits, or, if practicable, the two metals shall be insulated from each other by an approved insulating material or a coating of approved varnish compound.

(ii) Screws, nuts, springs, pivots, etc

The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws, when used, shall be electroplated, or when plating is not possible owing to tolerance limitations, shall be of corrosion-resisting steel. All wood screws shall be of dull nickel plated brass or of other approved finish. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g. phosphor-bronze or nickel silver, as far as possible.

(iii) Fabrics, cork, paper, etc

Fabrics, cork, paper and similar materials, which are not subsequently to be protected by impregnation, shall be adequately treated with an approved fungicide. Sleeving and fabrics treated with linseed oil or linseed oil varnishes shall not be used.

(iv) Wood

The use of wood in equipment shall be avoided as far as possible. When used, woodwork is to be thoroughly seasoned teak or other approved wood which is resistant to fungal decay and shall be free from shakes and warp, sap and wane, knots, faults and other blemishes. All woodwork shall be suitably treated to protect it against the entry of moisture and from growth of fungus and termite attack, unless it is naturally resistant to those causes of deterioration. All joints in woodwork shall be dovetailed or tongued and pinned as far as possible. Metal fittings where used shall be of non-ferrous materials.

(v) Adhesives

Adhesives are to be specially selected to ensure the use of types, which are impervious to moisture, resistant to mould growth, and not subject to the ravages of insects. Synthetic resin cement only shall be used for joining wood. Casein cement shall not be used.

(vi) Rubber

The use of natural rubber-based materials is not acceptable.

Neoprene or similar synthetic compounds, not subject to deterioration due to climatic conditions, shall be used for such items as gaskets, sealing rings and diaphragms.

(b) All plant shall be designed to prevent entry of vermin, dust and dirt. Where wiring, piping or ductwork passes through openings in equipment housings, such openings shall be constructed to prevent entry of vermin. Wiring and piping enclosures and ductwork shall also be vermin-proof.

14.1.10 Miscellaneous Metal work

(a) The Contractor shall provide and install the following miscellaneous metal work required for the necessary completion of the Facilities. Where applicable it shall be designed, manufactured and installed in accordance with the regulations and statutory requirements of Zambia.

(i) support structures, brackets and fittings for support of pipes, cable and equipment;

(ii) soleplates, bedplates, foundation bolts and anchor bolts;

(iii) floor plates and kerbing required for completing the floors around and over the Plant;

(iv) platforms, stairways with toe and kick plates, ladders, guards, handrails necessary for easy and safe access to items of the plant requiring access for operation, maintenance and testing;

(v) safety guards at each point where normal access would permit personnel to come within reach of any moving item of plant; and

(vi) lifting lugs, eyebolts or other lifting attachment points in each item having a mass of more than 40 kg.

(b) All miscellaneous metal work shall be hot-dipped galvanised.

14.1.11 Noise

The noise pressure level emanating from any part of the Works measured by the method to be selected by reference to BS EN ISO 3740 shall be less than LAeq = 80dB(A) as an average level measured over a working day with an upper limit of LAeq = 135dB(A) during any plant starting or stopping sequence. Noise pressure levels above the 135dB(A) limit curve shall not be permitted, unless otherwise specifically agreed by the Employer.

During commissioning or when requested by the Employer the Contractor shall measure the noise pressure levels as defined above from all major sources and submit curves of decibel versus frequency for the Employer's approval. If the noise pressure levels measured exceed the specified levels the Contractor shall take the necessary steps to reduce the levels to a value below those specified in this Clause.

14.1.12 Position of Instruments, Controls and Hand-wheels

Instruments shall be located conveniently for access and reading. Instruments which must be read frequently shall be located between 750 mm and 1800 mm from the floor. Those which are read occasionally may be located between 500 mm and 2000 mm from the floor.

Controls and valve hand-wheels shall be located conveniently for access and operation. In general, controls should be within the range 750 mm to 1500 mm and valve hand-wheels 1000 mm to 1500 mm above floor level.

14.2 General Mechanical Requirements

14.2.1 Fabrication and Welding

All welding carried out by the electric arc processes.

All welding design, procedures, welder qualification, consumables and Non-Destructive Testing (NDT) shall as required by the relevant ASME, and BS Codes and Standards or approved equivalent and the Contractors Quality Assurance requirements.

Prior to any fabrication and welding being carried out the Contractor shall prepare and submit details of weld procedures to the Project Manager for approval.

The welding procedures shall include details of weld preparation, weld, fill material, flux, preheating temperature, arc current and voltage, welding speed, weld heat input, groove conditions, post weld treatment and subsequent NDT. Implementation of the procedure shall be demonstrated with the test plates.

The test plates made shall be stamped to indicate the welder and date welded. The Contractor shall provide all test plates, equipment, apparatus, supplies and labour required for the tests.

Following approval, the welding shall be carried out in accordance with the approved procedures

Non-destructive testing (NDT) including radiographic and ultrasonic, shall be carried out by the Contractor when required by the standards, these specifications or the design criteria employed. All important welds, which, in the opinion of the Project Manager may be fully stressed, or which in the opinion of the Project Manager do not appear to conform to the welding standards, shall be subject to NDT when required by the Project Manager.

Suitable meters shall be provided to show the welding current and the arc voltage at all times during the welding operations. Unless otherwise specifically stated, welded parts requiring machining shall be completely welded before being machine finished.

The preparation all joints for welding shall be such as to allow thorough fusion and full weld penetration. The surfaces of materials adjacent to the welds for a distance of at least 30 mm shall be thoroughly cleaned of all rust, grease and scale, to bright metal.

All electrodes shall be stored at temperatures recommended by the manufacturer and portable heating storage canisters shall be issued to each welder or group of welders and proper discipline shall be maintained in storage and of electrodes

The welding technique employed, the appearance and quality of the welds made, and the methods used in correcting any defective work, shall conform to the requirements of the approved procedures.

14.2.2 Piping, Valves, Pressure Gauges and Strainers

14.2.2.1 General

The Contractor shall provide all oil, air and water services required for the plant forming the Contract Facilities.

For these services the Contractor shall provide the pipe connections, take off straining grids, isolating and guard valves, service strainers, filters, particle traps, section valves, and other equipment as necessary.

All piping, flanges, sockets, joints, seals, gaskets, etc. shall be of materials to withstand pressure and temperature conditions involved in the operation of the equipment and provide a positive seal under all operating conditions (including water-hammer) and shall incorporate an ample factor of safety.

Provision shall be made for the drainage of the system by means of suitable falls and allowing for full expansion that can take place under all conditions of operation. Drainage falls are to be arranged, as far as possible, in the same direction as the operational flow of the medium contained therein and special attention is to be given to the design to minimise the risk of corrosion fatigue. The installation is to be designed to prevent the collection of pockets of water. For this reason drains are to be installed at all obstructions such as flow orifices.

Where necessary, provision shall be made for the draining and release of air in systems by the use of valves and in addition plugged drain and air release bosses should be welded to pipes at appropriate points to facilitate hydraulic testing.

14.2.2.2 Sizing of Pipes

The maximum allowable velocities of flow in pipes shall be as follows:

Water	4.5 m/s
All other pipework	0.6 m/s per 25 mm bore up to a maximum of 4.0 m/s

In any case, the overriding design criteria shall be to prevent erosion of pipes. Higher velocities may be approved in special applications or for systems used intermittently.

The Contractor shall demonstrate if required that the velocities finally selected offer the optimum combination of material and pump costs.

Notwithstanding the maximum velocities permitted above, the noise levels in the pipe work systems shall comply with the appropriate clauses of the Specification.

14.2.2.3 Pipes

All piping under internal pressure exceeding 15 bar, whether water, oil or air, shall be seamless. Piping of 50 mm inside diameter and over shall be of steel unless otherwise specified. In any one system, or pipe service, all pipe work and fittings shall be of the same materials or similar unless otherwise specified or agreed by the employer.

All piping shall be routed to provide a neat and economical layout having the shortest possible run and requiring the minimum number of fittings. Piping shall be arranged so that full access is provided for the maintenance of equipment can be achieved with the minimum dismantling of piping. All piping shall be installed as closely as possible to walls, ceilings, columns, etc. so as to occupy the minimum of space.

Oil pipes shall not be embedded in concrete but shall be run in trenches and ducts with adequate supports and restraints. Sleeves shall be provided where pipes pass through walls, floors, beams or columns. The internal diameter of the sleeves shall be adequate to allow sections of the piping to be removed through them.

Pipes shall accurately cut to length and shall be installed without springing or forcing. Due allowance shall be made for expansion and contraction of pipes.

All pipes, pipe bends and tees shall be truly circular in the bore and uniform in wall thickness, with the number of joints kept to a minimum necessary for efficient maintenance of the equipment. Tees and bends shall be to standard dimensions. Hot bending with packing may be used for larger sizes according to facilities available, but not bends in alloy or stainless steels, which may be made after permission by the Employer. Where bends are formed, no crimping or flattening of the pipe will be accepted.

As far as possible all pipework shall be shop-welded, particularly for branches, headers and bends, and shall be assembled and tested before dispatch. An adequate number of loose flanges and trimming allowances shall be provided to facilitate site erection. All pipes shall be fitted with temporary blank flanges or plugs before dispatch to site, and these shall not be removed until just before coupling up.

Pipes to be laid in the first phase concrete shall be readily available at the Site, properly shaped, flanged and surface-treated when concreting starts.

Oil pipes shall be thoroughly cleaned and flushed, throughout installations and immediately before setting to work with the same type of oil to be sued in the system. Necessary precautions must be taken to ensure that the contamination does not enter pumps, filters and other sensitive equipment. Compressed air pipes must be sufficiently flushed with dry air to remove any debris and condensation before connecting to the equipment.

14.2.2.4 Flanges and Joints

For piping and valves 50 mm or smaller in diameter, an approved type of high pressure joint ring compression coupling may be used, provided that outside diameter of pipes or tubes are as recommended by the coupling manufacturers, and provided that pipes are carefully aligned prior to connection are adequately supported and restrained to prevent vibration. For air services, flanged couplings shall be used between the compressor and the solenoid valve. Screwed running joints shall be used.

All couplings of pipes and valves 50 mm or larger in diameter shall be by flanged joints. The Contractor shall standardise the type of flanges on pipework throughout the plant to one of ASME, DIN or equivalent standard. Piping permanently embedded in concrete except piezometer pipes shall not be smaller than 75 mm in diameter and shall be stainless steel pipes without flanged joints inside the concrete. Any necessary bends in embedded pipe work shall be of generous radius.

Flanges shall be machined across the full face diameter and shall be square with the bore of the pipe. Edges shall be machined and the back shall be cutter-faced or spot-faced so that bolt-heads, washers and buts will bed down appropriately. For medium and high pressure services where thin joining material is used flange faces shall be appropriately finished. In general all flanges shall comply with the relevant requirements of the ISO standards.

After welding of site welded flanges, the joint faces shall be machined to ensure that any distortion is eliminated. A suitable machine shall be supplied by the Contractor to machine flanges welded at the Site. No butt welding of pipes at site is allowed where internal treatment is not possible.

Jointing material shall be so proportioned that when the joint is tightened-up no part of it will protrude into the pipe bore.

14.2.2.5 Pipe Supports and Hangers

All pipe work and accessories shall be mounted and supported in a safe and neat manner.

All brackets, stays, frames, hanger and supports for carrying and staying the pipes, including their fasteners, shall be included in the supply and completed by the Contractor at the site. Pipes and fittings shall be supported at or near flanges wherever possible.

Supports and hangers shall be designed and arranged so that any pipe can be withdrawn without disturbing the others.

All heavy valves, and others, where necessary, shall be supported independently of the pipes to which they connect.

The Contractor shall supply drawings showing the location of each major anchor and support and the weight to be carried by that support.

14.2.2.6 Pipework Identification Colours

After erection at site and final painting, each of the pipework ranges shall be colour coded by the Contractor as follows:

Lubricating oil	Light brown
Oil drainage	Dark brown
Hydraulic Fluid	Dark red
Cooling Water	Sea green
Water drainage	Black
Air pressure	White, grey rings

Air vacuum	White, primrose rings
CO_2	Light Buff

The coding shall consist of coloured bands only, suitable bands being provided at approved positions along individual pipes.

14.2.2.7 Valves

All valves shall be readily accessible for both operating and maintenance, and where necessary for ease of operation the spindles shall be extended and an approved form of pedestal hand wheel provided at convenient operating floor level. Valve of same make, size and type shall be interchangeable.

As far as possible, valves shall not be fitted in an inverted position and of flanged type. An indicator or approved type shall be fitted to each valve and each extended spindle shall clearly show the position of the valve.

Shut-off valves shall be suitable for opening and closing against full unbalanced pressure, including closure against free discharge. If necessary, bypasses are to be provided to meet these requirements. It should be particularly noted that all connections to the main water passages (e.g. to the penstock upstream of the main inlet valve or to the draft tubes) shall be provided with guard valves in addition to isolating valves. Guard valves shall be mounted as close as possible to the point of connection, and any associated with the penstock shall be equipped with extension spindles and headstock in approved positions. Where provided, back flushing connections for taking off straining grids positioned between the associated guard and isolating valves, and shall be equipped with their own isolating and non-return valves.

Special attention shall be given to the operating mechanism and correct lubrication of all valves to ensure a minimum of maintenance and ease of operation.

Any gear or bevel wheels used to transmit motion shall be of cast steel or approved quality cast iron with machine cut teeth. No thrust from the valve shall be transmitted to the extension spindles and valve supports shall not be mounted directly on floor plating.

Any floor steel work trimmers for supporting pedestals shall be provided by the Contractor.

All the valves shall be provided with means for padlocking.

All valves over 300 mm bore for pressures exceeding 15 bar shall be of forged or cast steel valves for such pressures but of 30 mm bore or less may be of bronze.

Valves for lower pressures may be if modular cast iron.

Valves for water over 50 mm bore shall be of external rising spindle type.

Valves for oil shall be of the non-rising spindle type.

On all water services the valve gate operating screws shall be external and not immersed in water. Means shall be provided to protect the operating mechanism of all valves against mechanical damage and dust or dirt.

All valve body seats shall be of the separate ring type in an approved material so fitted to preclude loosing or leakage behind the seat ring. Disc faces of valves below 50 mm shall be integral with the gate and valves of 50 mm and above shall be screwable wearing parts fitted to disc. When in full opened position disc faces shall be clear of the net bore while, when fully closed, the guard shall be in proper alignment with the seat.

All valves shall be arranged so that the hand wheel moves in a clockwise direction to close the valve. The face of each hand wheel shall be permanently and clearly marked with the words "open" and "close" and shall be provided with an arrow to indicate the directions for opening and closing. Hand wheels shall be of metal and spokes and rims shall be ground smooth.

Non-return valves shall be of the non-slamming type preferably incorporated with means of adjusting the closure rate with damping towards the "close" end of the stoke. The valve bodies shall have removable access covers to permit internals to the examined or replaced without removing the valve from the pipeline. If appropriate, provision shall be made for draining the pipe work on each side of non-return valves.

The direction of flow should be permanently marked on the valve body.

Pressure reducing valves must be of relay operated globe valve or piston type. Use of orifices is permitted only in pipe systems below 25 mm in diameter.

All safety valves shall be tested at the manufacturer's works and the blowing pressure must be clearly stamped on the valve body. The safety valves must be fitted with a manual test handle.

Motor operated valve enclosures must be water tight and explosion proof and shall have torque and travel limiting devices. The valve should be capable of manual operations and change-over device shall return to motor drive mode automatically.

Valves shall be tested in the factory to twice the maximum working pressure which will occur in service, and the test pressure shall be legibly and permanently marked on the valve.

All actuated valves and all manually operated valves requiring operation during normal or emergency conditions shall be accessible from floor level or a permanent platform.

All brackets, stays, frames, supports, etc. necessary for carrying and steadying valves shall be included in the supply and completed by the Contractor at the Site.

The Contractor shall provide a valve schedule summarising the duties of all valves provided under the Contract and quoting the relevant mechanical and electrical device numbers, the associated drawing number, and the class, working pressure and test pressure.

14.2.2.8 Drains

Pipe systems, vessels, receivers, tanks, coolers, heat exchangers, filter and strainer casings and similar equipment subject to periodical or occasional rinsing, cleaning or refilling shall be provided with drain pipes or orifices. All such pipes and orifices shall be located at the respective equipment's lowermost point so that in connection with the venting complete evacuation is warranted.

All drains shall be equipped with easily accessible and perfectly sealing valves, cocks or threaded plugs. Materials used shall be non-sticking. All drains requiring periodical use shall be routed to the nearest drain.

14.2.3 Pumps

All pumps to be supplied for the Facilities shall be of reputable make and of a type suiting best the purpose and duty. They shall be furnished complete with electric motor drive and be self priming.

All pumps shall be capable of maintaining their required duty continuously for an extended period without requiring replacement of impeller and / or labyrinth and wearing rings. They shall be capable of continuous operation without over-heating, cavitation, excessive noise or vibration, surging or instability when working singly or in parallel with other pumps.

All positive displacement pumps shall have factory calibrated safety valves integral with the pumps or adjacent to the delivery ports of the pumps.

No pumps shall be supplied with specific suction head and speeds outside normally accepted ranges, and the Contractor shall be entirely responsible for advising the pump manufacturer of the inlet and outlet conditions and arrangement of each pump.

As far as possible, tests on pumps in manufacturer's works shall be carried out with the actual suction pipework to be used on the plant or alternative, the suction pipework shall give flow conditions identical with those existing during the tests.

Metallic seals may be used of the type which may be replaced without disturbing the pump shaft. All large pumps shall be provided with both impeller and casing labyrinth and wearing rings and replaceable gland sleeves.

Pumps shall be designed to have reasonable margins available in head and capacity to compensate for any normal slow rate of wear anticipated. Care must be taken to ensure that such margins do not increase velocities in the associated system to erosion levels.

14.2.4 Fixings and Fasteners

14.2.4.1 Nuts, Bolts, Studs and Washers

All fasterners in contact with water shall be made of stainless steel.

All seal retaining plates and fasterners shall be made of stainless steel.

All bolts, nuts, studs, eyebolts and screw threads throughout the Contract Facilities shall be to approved standard metric dimensions as recommended by ISO-272-1982. Nuts and bolts shall be of bright high tensile steel and heads shall be hexagonal in shape and truly faced. Rolled threads are acceptable provided that they comply with an approved standard. Black grade bolts and buts are not acceptable. Where jacking screws are supplied they shall be of high tensile steel with fine threads.

Bolts, studs and nuts shall be of free machine quality stainless steel when subject to frequent adjustment or removal, such as the adjusting bolts for gland rings on stuffing boxes, removable screens, screen elements and adjustable bearings, or if used for securing internal components in contact with water, such as the runner nose cone etc., or is subject to removal when associated with bolts projecting from concrete, or in any situations liable to corrosion.

Nuts, tap bolts, set pins and bolt heads on items subject to vibration shall be provided with a positive locking device.

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

Any special tools such as jacking tools, torque multipliers etc., shall be included in the supply of special tools.

Great care must be taken in application of bolting with respect to corrosion. Galvanic and other corrosion mechanisms must be taken into account when bolting is applied. On installed bolts, open ends on bolts should be covered with grease and plastic caps to avoid corrosion and damage.

14.2.4.2 Rivets

For general use, pin-headed rivets to the appropriate Standard or equivalent shall be used, nut rivets on bearing surfaces shall be flat countersunk, driven flush. When practicable, riveting shall be done by hydraulic tools and the rivets must completely fill the holes when closed. If loose, or if the heads are badly formed, cracked or eccentric to the shank or do not bear truly on the plate or bar, such rivets shall be cut out and replaced. All surfaces to be riveted must be in close contact throughout.

14.2.4.3 Dowels

At all stages of assembly, where accuracy of fit has to be assured on the Site, dowel holes shall be provided with dowels to assist re-assembly.

14.2.4.4 Erection Marks

All shop assemblies shall, before dismantling for packing, be clearly scribed with reference lines and match marked to facilitate correct assembly.

All members comprising multipart assemblies, e.g. steel framework, piping installations, etc. shall be marked with distinguishing numbers and / or letters corresponding to those of the approved drawings or material lists. These erection marks, if employed before painting or galvanising, shall be clearly readable afterwards.

Colour banding to an approved code shall be employed to identify members of similar shape or type but of differing strengths or grades.

14.2.4.5 Foundation Fixings

All necessary foundation fittings, built in items, fixing bolts, packers, and similar items shall be supplied by the Contractor and delivered in sufficient time to be incorporated in the foundations while they are being cast.

14.2.5 Oils and Lubricants

Points requiring grease lubrication shall be provided with ample and easily accessible greasing nipples or grease boxes.

Oil and grease used throughout the Facilities shall be of a make and grade readily commercially available in Zambia.

The first filling of lubricating and grease, including flushing oil for all equipment supplied plus an excess of 10% of the overall net amount required shall be included in the supply.

Where lubrication is effected by means of grease, preference will be given to pressure-gun system with a separate nipple to each point. Where necessary for accessibility, the nipple shall be placed at the end of extension piping and, when a number of such points can be grouped conveniently the nipples shall be brought to a battery plate mounted in a convenient position.

A complete schedule of recommended oils and other lubricants required for all components of the plant shall be furnished by the Contractor. The number of different types of oils and lubricants used throughout the plant shall be minimised.

All oils and lubricants must comply with international standards and be of an environmentally friendly nature. All oils and lubricants must be documented by the Contractor and approved by the Employer.

14.2.5.1 Self Lubricated Bearings

Self lubricated bearings shall be of a proven proprietary make approved by the employer. The finish of the surface in contact with the bearing and loadings shall be accordance with the manufacturer's recommendations.

14.3 General Electrical Requirements

14.3.1 Insulation Levels and Clearances

Electrical equipment shall have insulation levels in accordance with IEC 60071. Electrical clearances shall be in accordance with IEC 61936.

14.3.2 Auxiliary Power Supplies

14.3.2.1 A.C. Supplies

The nominal a.c. auxiliary supply voltage is 400 V, 3-phase, 4-wire, 50 Hz.

3-phase a.c. supply shall be used for power circuits, and single-phase a.c. supply for lighting and small power circuits such as cubicle heaters.

Unless otherwise specified elsewhere in these Employer's Requirements, the equipment provided under this Contract shall be capable of operating reliably at continuous voltages and frequencies between 80% and 110% of the nominal voltage and between 95% and 102% of the nominal frequency, with extreme values of voltage and frequency occurring coincidentally, without deterioration. Precautions shall be taken to ensure that plant does not mal-operate during transient disturbances to the above supply systems and to ensure that essential instrumentation and indications are available after loss of a.c. supplies.

14.3.2.2 D.C. Supplies

The nominal d.c. supply voltages are 220 V, 2-wire and 48 V, 2-wire.

The 110 V, 2-wire d.c. supply shall be used in the Powerhouse and Substation for circuit breaker control, tripping and closing supplies, d.c. actuators, and emergency lighting.

The 48 V, 2-wire d.c. supply shall be used for telecommunications.

Unless otherwise specified elsewhere in these Employer's Requirements, all d.c. equipment provided under this Contract shall be capable of operating reliably at continuous voltages between 80% and 120% of the nominal voltage, without deterioration.

14.3.2.3 Short-time Voltage Ratings

All electrical equipment shall be so designed as to withstand abnormal system voltages as required by IEC 60071.

14.3.2.4 Current Ratings

Continuous current ratings

Current ratings in accordance with IEC 60059 shall be adopted, unless otherwise agreed with the Project Manager.

Every current carrying part of the equipment shall be capable of carrying its site rated current continuously under the site ambient conditions as specified.

Temperature rise

Full provision shall be made for solar heat gain on all outdoor apparatus and any differential temperatures attained as a result of the impingement of solar heat.

The maximum temperature attained by components under the most onerous service conditions shall not cause damage or deterioration to the equipment or to any associated or adjacent components.

Short-time current ratings

Electrical equipment shall be adequately supported and braced to withstand the forces associated with the maximum short-circuit currents specified or pertaining, whichever is the greater, and assuming that the inception of the short-circuit is at such a time that gives maximum peak currents. No provision for current decrement shall be made unless specifically permitted by the appropriate Standard, or elsewhere in these Employer's Requirements.

Equipment shall be so constructed as to withstand the specified maximum short-circuit currents for a duration of 3 seconds, unless otherwise specified, without the temperature exceeding the specified maximum short-time temperature or value stated in the relevant Standard, under these conditions. The equipment shall be considered as being operated at the maximum permitted continuous temperature prior to inception of the short circuit.

The final temperature attained as a result of the passage of short-circuit current shall not cause permanent damage, or deterioration sufficient to reduce the normal operating characteristics below the specified or most onerous operating requirements whichever is the highest.

14.3.2.5 Electrical Insulation

Insulating materials shall be suitably finished so as to prevent deterioration of their qualities under the specified working conditions in accordance with IEC 60085.

The insulation of all machine windings, solenoids, etc. other than those immersed in oil or compound, shall be of Class F materials.

All cut or machined surfaces and edges of resin-bonded laminated materials shall be cleaned and then sealed with an approved varnish as soon as possible after cutting.

Wherever practicable, instrument, apparatus and machine coil windings, including wire wound resistors, shall be thoroughly dried in a vacuum or by other approved means and shall then immediately be impregnated through to the core with an insulating varnish. Varnish with a linseed oil base shall not be used.

No material of a hygroscopic nature shall be used for covering coils. Where inter-leaving between windings in coils is necessary, manila paper, thoroughly dried, which permits penetration by the insulating varnish or wax, shall be used.

Polychlorinated Biphenyl (PCB) type materials shall not be used anywhere in the equipment or in any component.

14.3.2.6 Earthing and Bonding

All non-current carrying metal parts of electrical equipment shall be bonded to an earth terminal or terminals mounted on the equipment and readily accessible.

All equipment terminals provided for an external earth connection shall be identified by indelible means unless such terminals are directly and visibly mounted on metallic equipment frames or earth bars, when such marking may be omitted.

Identification marks for earth terminals shall comprise the colours green/yellow in combination or a reproduction of the symbol No 5019 in IEC 60417.

Assemblies containing electrical equipment, including switchboards, control boards and control and protection panels, shall be provided with a separate copper earth bar running the length of the assembly. All metal parts and the earth terminal or terminals shall be bonded to this earth bar. Earthing connections shall not depend upon the bolting of steel or steel joints between adjacent panels or cubicles.

Earth bars shall be of adequate size and suitably supported and braced to carry the rated short circuit current for the associated electrical circuits for the rated short-circuit current duration, without damage or excessive heating likely to damage joints, associated or adjacent components.

Switchgear and control gear assemblies shall be provided with two or more earth terminals unless otherwise specified. The copper earth bar shall be sized to withstand the maximum system earth fault current for 3 seconds without deterioration.

The size of the copper earth bar in control panels, or similar enclosures containing low voltage apparatus shall be such as to comply with the specified requirements for withstanding prospective short-circuit currents. The size of this bar shall in no case be less than 100 mm^2 cross-sectional area, shall be such as to provide sufficient mechanical integrity, and shall be not less than the size of the largest incoming power supply conductor.

The metal cases of all instruments, relays and the like shall be connected to the panel earth bars by copper conductors of not less than 2.5 mm^2 cross-sectional area, or by other means subject to the approval of the Project Manager.

14.3.3 Electric Motors

14.3.3.1 General

Motors shall comply with the requirements of IEC 60034 and IEC 60072 as amended and supplemented by these Employer's Requirements.

14.3.3.2 Type and Rating

Except where specified otherwise or economically justified, all a.c. motors shall be of the constant speed, cage induction type with windings adequately braced for direct-on-line starting at the rated voltage. They shall be suitable for control by either circuit breaker or contactor.

Motors shall be continuously rated, Duty Type S1. Exceptions shall be permitted only when the intermittent or short time duty cycle can be accurately defined by the Contractor.

Three phase a.c. motors shall be rated for the a.c. auxiliary system voltages specified above.

14.3.3.3 Insulation

Motors shall be insulated with materials complying with IEC 60085. All motors shall have Class F insulation but temperature rise shall not exceed the limits applicable to Class B.

14.3.3.4 Conditions of Operation

A.C. motors shall be capable of continuous operation under the service conditions within the Zone A voltage and frequency variations specified in IEC 60034-1 Figure 13.

In the event of loss of supply, all motors shall be suitable for restarting against the full residual voltage in the motor winding during motor run-down.

14.3.3.5 Starting Performance

Unless otherwise specified or required, cage induction motors up to and including 40 kW shall have a starting performance better than or equal to Design N in accordance with IEC 60034 Part 12. Above 40 kW Design D shall apply.

The starting torque at 80% rated voltage shall be adequate for starting the driven load under the most arduous conditions. The accelerating torque at any speed and 80% rated voltage shall be not less than 10% of motor rated torque. In any event the motor starting torque at 100% rated voltage, and at all speeds between standstill and the speed at which breakdown torque occurs, shall be not less than 1.7 times the torque obtained from a load curve which varies as the square of the speed and is equal to 100% motor rated torque at rated speed.

The margins between the torque of the motors and driven plant shall include suitable allowances for wear, fouling etc. during the life of the Plant.

Electric motors shall be suitable for two successive starts with the motor already at full load working temperature, subject to the motor being permitted to decelerate to rest under operating conditions between successive starts.

After a cooling time of 30 minutes at rest another starting sequence of two successive starts shall be possible.

14.3.3.6 Bearings

The type of bearing, bearing numbers and re-greasing interval shall be stamped on each motor rating plate.

In general grease lubricated rolling element bearings shall be used.

Bearings shall comply with the applicable ISO Standards.

Bearings shall be designed to exclude the ingress of dust and water and sealed to prevent leakage of lubricant along the shaft.

Grease lubricated rolling element bearings shall have grease nipples located in accessible positions and shall preferably be provided with dust-proof grease escape valves on the bearing housings.

Sleeve bearings shall preferably be lubricated by two oil rings or other approved device running in an oil bath having filling, inspection and draining facilities, together with an oil level indicator.

Motors supplied with independent bearings shall be mounted with the bearings on a common bedplate.

Rolling element bearings shall have a minimum L10 lifetime of 40,000 h, as determined in accordance with ISO 281-1 under the worst operating conditions.

Sleeve bearings shall have a minimum lifetime of 25,000 h.

14.3.3.7 Enclosures and Methods of Cooling

The degree of enclosure protection for motors shall be as follows unless otherwise specifically approved by the Project Manager:

- IP 54 to IEC 60034-5 for indoor locations not subject to hosing,
- Not less than IP 55 to IEC 60034-5 for outdoor locations, and indoor locations subject to hosing or escape of water under head.

The cooling classification for motors shall be as follows unless otherwise specifically approved by the Project Manager:

- IC4A1A1 or IC5A1A1 or IC6A1A1 to IEC 60034-6 for LV motors, or IC4A1A0 for small power LV motors,

Ferrous metals shall be used for the frames and end shields of all ratings of motors. Aluminium and its alloys shall only be used when the Contractor can demonstrate that it is entirely suitable for the particular application at its installation location.

Fans of identical motors shall be interchangeable without affecting motor balance.

14.3.3.8 Anti-condensation Heaters

To minimise condensation in all motors above 11 kW when out of service, heaters of an approved type and rating, suitable for operation from the station auxiliary LV a.c. single phase supply, shall be fitted inside the lower half of the stator frame.

The control of anti-condensation heaters shall be so arranged that they are normally energised when the motor is not running. Controls shall be of the automatic thermostatic type to limit temperature rise when the heater circuits are energised.

14.3.3.9 Motor Winding Temperature Detectors

All motors with cooling classification IEC 60034-6 IC6A1A1 shall have their stator windings equipped with six embedded temperature detectors wired to a motor mounted auxiliary terminal box. In addition to the winding temperature detectors, temperature sensors shall be positioned in the closed air and external cooling medium circuits at the inlet and outlet ducts of the heat exchangers.

Temperature detector terminals shall also be provided in a separate terminal box on the motor.

Connections shall be taken to an external device to continuously monitor all temperature detectors in a particular motor. The monitoring device shall be complete with alarm contacts which shall operate when any single detector exceeds prescribed limits, these limits being adjustable and capable of being set at site.

14.3.3.10 Terminals and Terminal Boxes

Winding terminations shall generally comply with IEC 60034-7 and -8. Separate non-compound filled terminal boxes shall be provided for each of the following, as applicable:

- Main (line) connections,
- Star point (neutral) connections,
- Anti-condensation heater connections,
- Instrumentation and alarm devices.

All terminal boxes with the cables terminated shall have an enclosure classification not less than that of the motor itself. All terminal boxes shall be of an adequate size for the satisfactory termination of the cable(s) required or specified, including all applicable termination components.

Terminals and terminal leads shall be substantially designed for connection to a system having the symmetrical short circuit rating of the source switchboard.

The clearances and creepage distances shall apply also to insulated terminals and connectors.

Porcelain terminal bushings and insulators shall not be used.

Where pressure relief terminal boxes are used, they shall be designed to relieve the products of an internal fault safely to the outside, and not into the interior of the motor.

Provision shall be made for earthing the cable armour, and the cable insulation screens, where applicable, in accordance with the cable termination method being used.

In auxiliary cable boxes either stud terminals or clamp terminals shall be provided.

The anti-condensation heater terminal box shall have a warning label adjacent to it, stating "Motor heater - terminals live".

14.3.3.11 Earth Terminal

All motors shall be provided with a means of earthing the frame.

14.3.3.12 Performance Tests

Complete performance tests as detailed in IEC 60034 shall be carried out at the manufacturer's works on the first motor of each type and rating being supplied under this Contract. The motor shall be tested for temperature rise at full rated output. The maximum temperature which would be obtained at the specified ambient temperature shall be estimated from this value, and shall not exceed that stated in IEC 60034 for the appropriate class of insulation. Where there is more than one machine identical in all essential details, the remainder shall be given routine tests.

14.3.3.13 Local Control Panels at Motors

A control panel or emergency stop push-button, as appropriate, shall be provided for mounting alongside each motor where the motor is installed remote from the motor starter panel. It shall be a totally enclosed metal-clad weather-proof type suitable for mounting on a wall or stanchion with a minimum enclosure classification of IP 55, and shall be designed for bottom cable entry.

Each control panel shall be equipped with one start and one stop push-button. The emergency stop push-button shall be provided in the same box or a separate box to the approval of the Project Manager. Where no local control is called for, the control panel is to be provided only with the emergency stop push-button.

Emergency stop push-buttons shall have a large "mushroom" head, be coloured red and incorporate a protective cover or guard to avoid accidental operation. The buttons shall automatically lock in the depressed position. Contacts shall be provided to cause tripping of the associated circuit, prevent restart of the circuit and bring up an alarm.

Emergency stop push-buttons shall trip the associated circuit breaker or contactor regardless of the control position selected.

The contacts of all push-buttons shall be shrouded to minimise accidental contact and the ingress of dust, and shall be suitably rated for voltage and current for the circuit in which they are provided.

Control panels shall be clearly labelled showing the duty or drive to which they are applicable.

14.3.3.14 Starters and Contactors

Motor starters shall comply with IEC 60947-4-1 where the motor starter is assembled from discrete components or shall comply with IEC 60947-6-2 where the motor starter is integrated. All motor starters shall be supplied by one manufacturer.

Each a.c. motor shall be equipped with a direct-on-line, three-pole motor starter, unless otherwise specified, providing the following facilities:

- Fully shrouded triple-pole lockable isolator rated to break stalled motor current and mechanically interlocked with the compartment door.
- Instantaneous short-circuit protection by means of air circuit breaker or MCCB rated to break the circuit rated short circuit current.
- Contactors to IEC 60947-4-1. These shall have an uninterrupted duty rating mechanical endurance cycle number 0.3 and making and breaking utilisation category AC-3 with a capacity for the circuit rating except where short duration motor operation or inching is required when the category shall be AC-4. Each contactor shall be provided with a minimum of four auxiliary contacts. Electrically held-in type shall be provided for non-essential auxiliaries. For essential auxiliaries mechanically latched or electrically held-in delayed release devices shall be provided.
- In addition to short circuit protection overload and fault protection shall be provided as follows:
    - for drives below 10 kW, thermal overload.
    - for drives from 10 kW to 90 kW, thermal overload with single phasing feature, and earth fault.
    - for drives of 90 kW and above, overload relay, single phase, and earth fault.
    - Relays shall have sufficient contacts for remote direct wire alarm and data processing alarm circuits.
- Ammeter with compressed overload scale.
- Red and green lamps to indicate 'running' and 'stopped' respectively.

Control circuit supply shall be 110 V a.c., single phase, with one leg earthed, from an integral 400/110 V transformer connected across two 400 V phases and protected by MCCB. The control supply shall be isolated by the motor circuit isolating switch which can be by-passed by an internal test switch interlocked with the door to allow operation of the starter without energising the motor.

Motor starters shall provide Type 2 coordination to IEC 60947-4-1 and shall be type tested to the full range of tests provided for in that standard including the high current short circuit and make and break tests. Motor starters to IEC 60947-6-2 shall be type tested to the full range of tests provided for in that standard.

Where two or more starters are contained in the same cubicle they shall be segregated. The cubicle shall be complete with all necessary wiring terminal boards, cable sealing and terminating arrangements and mounting facilities.

All a.c. motor starters shall be capable of operating for not less than five minutes at 75% of the nominal voltage at normal frequency without exceeding the temperature rise limits specified in IEC 60947.

Where d.c. starters are provided, they shall incorporate the above features as appropriate together with any accelerating contactors/relays for progressive cut-out of motor resistors. All d.c. starters shall be capable of operating reliably with the range of supply voltage as specified.

All equipment such as contactors, starters, relays and the like where the normal operation is such that interruption of low frequency or direct current occurs, shall be fitted with means of suppressing all interference frequencies in accordance with EN 55011.

14.3.4 Instrumentation

14.3.4.1 General

All equipment shall be designed and type tested to demonstrate reliable operation over the temperature range 0°C to 55°C with a relative humidity range 5% to 95%.

Control and indication equipment shall meet the requirements of IEC 61000. Compliance shall be demonstrated by type test.

Instruments shall be supplied from one composite range. All indicating, measuring and recording instruments shall be of the flush mounted pattern to IEC 60051 (Direct acting indicating analogue electrical measuring instruments and their accessories) with dust and moisture proof covers tested to IEC 60068 (Environmental testing). Where hinged covers are necessary they shall be provided with locks.

The scales of all instruments shall be in SI Units.

The movements of electrically actuated instruments shall be of the dead beat type.

All indicating instruments shall be fitted with non-reflecting glass. Instrument scales shall be in accordance with BS 3693 (Recommendations for design of scales and indexes on analogue indicating instruments) printed in black figures on a white background. Scale pointers shall be clearly visible at 2 m distance. Major scale markings shall be separated by not more than five minor marks. Minor scale marks shall be half the height and the width of the major scale markings. Scales shall be provided with red coloured marks at points corresponding to the normal working values (or full load current of the equipment in the case of ammeters). Pointers shall be black other than in the case of instruments with two pointers in which case only one shall be black.

Indicators shall be chosen such that the maximum steady state value is approximately at 75% full scale deflection. Instruments with circular scales shall have not less than 240° total pointer deflection.

Instruments shall be supplied with a readily accessible zero adjustment.

Repeatability shall be maintained to within ±0.5% without adjustment for a period of not less than 12 months. Accuracy class of all the instruments shall be 1.

14.3.4.2 Pressure

Each tapping point for pressure measurement shall be fitted with an isolating valve at the point of connection. Where pressure gauges are mounted in panels the isolating valves shall be suitable for the connection of a test gauge. All pressure measurement tappings shall be provided with an air bleed and drain connection.

Pressure gauges shall comply with BS EN 837 (Specification for Bourdon tube and vacuum gauges). The gauges shall have a dial size of 150 mm. Unless otherwise stipulated in the specification as absolute, pressure gauges shall indicate gauge pressure. Gauges indicating water pressure shall be graduated both in Pascals and metres of water column.

For locations subject to vibration the gauge shall be mounted either on anti-vibration mountings at the tapping point and be glycerine filled or mounted in a non vibrating location elsewhere, connected by flexible tubing to the tapping point.

Pressure transducers shall comply with BS 6447 (Specification for absolute and gauge pressure transmitters and electrical outputs).

14.3.4.3 Temperature

Temperature measuring devices shall generally be in accordance with the recommendations of BS 1041 (Temperature Measurement).

Liquid-in-glass thermometers shall be in accordance with ISO 1771 (Enclosed scale general purpose thermometers). They shall be protected against accidental damage by a metal casing. Thermometer pockets shall comply with the requirements of BS 2765 (Specification for dimensions of temperature detecting elements and corresponding pockets). Where physically possible a thermometer pocket shall be fitted adjacent to each remote temperature indication sensor.

Dial type thermometers shall be in accordance with BS EN13190 (Specification for dial type expansion thermometers). The dial size shall be 150 mm diameter. They shall be fitted with contacts for alarm indication and trip if required and shall be equipped with hand reset maximum indication pointers.

Resistance Temperature Detectors shall be Pt100 type conforming to IEC 60751 (Industrial platinum resistance thermometer sensors).

Thermocouples shall comply with IEC 60584 (Thermocouples). Extension leads for all thermocouple devices shall run in compensating cable up to the point of the cold junction compensation.

14.3.4.4 Limit Switches

Limit switches shall be industrial standard with proven service in dust laden, damp and wet oily and humid conditions and shall generally meet the requirements of IEC 61020 (Lever switches).

Limit switches shall be arranged such that they will not be damaged by over-travel of the drive. They shall have snap action.

14.3.4.5 Level Indicators

Level indicators shall be fitted to all liquid filled containers. Level indicators shall be in accordance with BS 3463 (Specification for observation and gauge glasses for pressure vessels). For oil containers level indicators shall be marked with normal levels at 20°C. Level indicators shall be equipped with isolating valves and shall be designed for ease of cleaning. Connections shall be provided at the top and bottom of the gauge glass for draining and flushing purposes. All tubular glass type gauges shall be furnished with stainless steel safety protective shields.

14.3.4.6 Level Measurement

Level measurement shall generally be by displacement or differential pressure measurement. However capacitance, electrodes or ultrasonic devices may be used with the approval of the Project Manager where function and circumstances dictate.

Where detection of discrete levels is required, float operated magnetic switches shall be used. Each switch shall have snap action with minimum hysteresis.

For water duty materials in contact with the water shall be of stainless steel.

14.3.4.7 Instrument Piping

Instrument piping shall be of copper or stainless steel.

14.3.5 Cubicles and Panels

14.3.5.1 General

Cubicles and panels shall be provided to house all relays, control modules, printed circuit boards, etc. and to accommodate all indicators, alarm annunciators, push-buttons, control switches, indicating lamps, etc. They may be of modular construction and can be of the Contractor's standard type if they meet the other requirements of these Employer's Requirements. They shall be provided complete with all necessary relay mounting frames and module and printed circuit board shelves. Where pneumatic or hydraulic equipment is supplied in a cubicle, physical separation from the electrical equipment and associated wiring shall be arranged. In the case of hydraulic equipment, suitable trays and drainage points shall be provided for the collection and disposal of any leakage.

Cubicles shall be rigid and shall be of sheet metal, all welded construction formed on a framework of standard rolled sections. The minimum thickness of the sheets employed shall be 2 mm and they shall be braced to give adequate rigidity for the mounting of instruments and controls.

Each floor mounted cubicle shall be provided with a 75 mm channel foundation member (which shall be continuous over more than one cubicle when such are grouped) to serve both for levelling and to act as a kicking strip.

Cubicles more than 300 mm deep shall be provided with permanent internal lighting, supplied independently of all other electrical services in the cubicles. Suites of cubicles shall be provided with a suitable isolating MCB for this purpose. Lighting supply shall be from the Station LV a.c. single phase auxiliary supply. Door-operated switches shall be provided to control the lighting.

Hinged and lockable doors shall provide access to the interior of cubicles. Each door shall be fitted with suitable dust-tight sealing strips. No equipment shall be mounted on access doors unless specifically permitted elsewhere in these Employer's Requirements.

The cubicles shall be complete with internal supports for wiring, and terminal boards and suitable isolating switches and protection for a.c. and d.c. supplies.

Cubicles shall be well ventilated top and bottom through vermin-proof louvres with a brass gauze screen attached to a frame and secured to the inside of the louvre openings. Cable and piping entries shall be made through glands in a removable plate separate from the base of the cubicle. Gland plates for bottom entry to floor mounted cubicles shall be at least 250 mm above the floor of the cubicle.

All cubicles shall be provided with a natural air circulation ventilation system. All control equipment shall be designed to operate without forced ventilation.

All cubicles or panels shall be fitted with automatic thermostatically controlled anti-condensation heaters.

The internal wiring of all cubicles shall be complete in the manufacturer's works. For connection to electronic and related or miniature equipment, wires not smaller than 16/0.20 mm may be used and terminated by wire wrapping, subject to the approval of the size and the wrapping process by the Project Manager.

For suites of panels inter-panel wiring shall be routed through apertures in the sides of panels and not via external multicore cabling looped between the panels.

Instrument and control devices shall be easily accessible and capable of being removed from the panels for maintenance purposes.

Panels for mounting on a wall or stanchion shall be a totally enclosed metal-clad weather proof type with a minimum enclosure classification of IP 55 and shall be provided with a bottom entry cable gland.

All panels, whether individually mounted or forming part of a suite, shall incorporate a common internal copper earthing bar onto which all panel earth connections shall be made. Suitable studs or holes to the Project Manager's approval shall be left at each end of the bar for connection to the main station earthing system. Earth connections between adjacent panels shall be achieved by extending the bar through the panel sides and not by interconnecting external cabling.

Cubicles shall be drilled for all mounted equipment and cubicle construction screws before surface preparations are carried out.

14.3.5.2 Panel and Wiring

All control panel wiring, secondary control wiring in circuit breakers, motor starters, control gear and the like shall be carried out in a neat and systematic manner with cables supported clear of the panels and other surfaces at all points to obtain free circulation of air. The electrical equipment shall have readily accessible connections and shall be wired to terminal blocks for reception of external cabling.

The sequence of the wiring terminals shall be such that the junction between multi-core cables and the terminals is achieved without crossover.

All electrical equipment mounted in or on switchgear, panels and desks, shall have readily accessible connections and shall be wired to terminal blocks for the reception of external cabling.

The wiring shall be capable of withstanding without deterioration the conditions at Site, due allowance being made for such temperature conditions as may arise within any enclosure. The insulating material shall not assist the spread of fire; that is it shall not continue to burn once the source of flame is removed.

All wiring shall be of adequate cross-sectional area to carry prospective short-circuit currents without risk of damage to conductors, insulation or joints.

The following classes of conductor, as defined in IEC 60228, shall be used for panel wiring:

- Class 1 conductors up to a maximum of 0.9 mm diameter where necessary for wire-wrapped terminations and similar techniques

- Class 2 conductors except where specified otherwise
- Class 5 conductors between points subject to relative movement

The following minimum conductor sizes shall be used:

- 4.0 mm^2 for current transformer secondary circuits
- 2.5 mm^2 for control circuits
- 1.5 mm^2 except where specified otherwise
- 0.5 mm^2 for alarm and indication circuits with a continuous or intermittent load current not exceeding 1 A.

Where an overall screen is used, this shall be a metallic screen or low resistance tape.

Wiring shall be supported using an insulated system which allows easy access for fault finding and facilitates the installation of additional wiring.

Small wiring passing between compartments which may be separated for transport shall be taken to terminal blocks mounted separately from those for external cable connections.

Connections to apparatus mounted on doors or between points subject to relative movement shall be arranged so that they are subjected to torsion rather than bending.

Ribbon cables or similar preformed cables with plug and socket connectors may be used for light current wiring. Plug and socket connectors shall be polarised so that they can only be inserted into one another in the correct manner.

If so required, the Contractor shall submit for the Project Manager's approval samples of the types of wire, numbered ferrules, and terminal washers or lugs as appropriate which he proposes to use.

Wires shall be colour coded in accordance with IEC 60446 and as follows:

Colour	**Type of circuit**
Brown	L1 phase connections in current and voltage transformer circuits only
Black	L2 phase connections in current and voltage transformer circuits only
Grey	L3 phase connections in current and voltage transformer circuits only
Green/ yellow	Earthed neutral connections and insulated earth wires

Colour	Type of circuit
Blue	A.C. neutral connections earthed or unearthed connected to the secondary circuit of current and voltage transformers. A.C. connections other than those above and connections in a.c./d.c. circuits
White	Connections in 24 V d.c. alarm and indication circuits

Wiring diagrams shall indicate wire colours and be drawn as viewed from the back of the panel.

All wires shall be fitted with numbered ferrules of approved type at each termination. At points of inter-connection between wiring, where a change of numbering cannot be avoided, double ferrules shall be provided. Such points shall be clearly indicated on the wiring diagram. Ferrules shall be of white insulating material indelibly marked with black characters, complying with BS 3858.

An additional ferrule shall be provided on all wiring directly connected to circuit breaker trip coils, tripping switches, etc., which shall be marked "trip" or "T" in red.

No wires may be teed or jointed between terminal points.

Electrical wiring and instruments shall be located so that they are not affected by leakage of oil or water.

Bus wiring between control panels etc. shall be fully insulated and segregated from the main panel wiring.

All metallic cases of instruments, control switches, relays etc., mounted on control panels or in cubicles, steel or otherwise, shall be connected by means of copper conductors of not less than 2.5 mm^2 section to the nearest earth bar. These conductors may be bare or have insulation coloured green/yellow.

14.3.6 Electrical and Electronic Components

14.3.6.1 General

Except where otherwise specified, electrical and electronic components shall comply with the relevant IEC Standard. Each component shall have a temperature/humidity classification suitable for the conditions stated elsewhere in these Employer's Requirements.

The Contractor shall submit to the Employer, for approval, the manufacturer's name, type and catalogues of all types of electrical and electronic components that he proposes to use.

14.3.6.2 Plug-in Units

Wherever possible, the design of electronic equipment shall be based on sub-units interconnected by flexible connectors using approved plugs and sockets. The flexible connectors shall be of sufficient length to allow the unit to remain connected when it is withdrawn for adjustment.

The laminates used for copper-foil printed wiring or printed circuit boards shall be suitable for the climatic conditions specified and shall be of an approved non-hygroscopic base material of high insulation resistance, preferably non-inflammable or flame resistant, and of adequate strength. The basic dimensions for printed wiring shall be as required by IEC 61188 and IEC 60130.

For printed circuit board multi-contact plug and socket connectors, the contact-making surfaces shall be of the same or compatible metals. If the contact surfaces are plated, the plating shall be non-porous, free from pinholes and of thickness to ensure low contact resistance for the life of the plant. Sockets shall preferably be of the 'floating' type, be tolerant of board thickness and shall not cause excessive wear on the board connectors.

To minimise the deposition of dust on the boards they shall, wherever possible, be mounted in the vertical plane. The printed wiring side of each board shall be finally protected against dust and moisture by an approved varnish suitable for use under tropical conditions.

All electronic equipment and plug-in units shall be housed in cubicles.

14.3.6.3 MCCBs and MCBs

Facilities shall be provided for the protection and isolation of circuits associated with protection, control and instrumentation. They shall be of approved type and grouped as far as possible according to their functions. They shall be clearly labelled, both on the panels and the associated wiring diagrams.

Facilities shall be provided to enable the control circuit for any circuit breaker to be individually isolated for maintenance purposes. For d.c. circuits, isolation is required on both poles. For a.c. circuits, the phase shall be protected and the neutral connected to earth. Where a link is required for test purposes, the link bar shall be a bolted connection.

Facilities for protection and isolation of control and tripping circuits are preferably to be mounted on the outside of control panels, except for panels installed outside control rooms.

Moulded case circuit-breakers (MCCBs) shall be provided as required according to the load requirement and shall be in accordance with IEC 60947-2.

Each complete MCCB together with its operating mechanism and any auxiliary switches shall be arranged to permit full accessibility for inspection and maintenance.

The MCCBs shall be manually operated with trip free mechanisms. Each circuit-breaker shall have a mechanical position indicator positively driven from the operating mechanism.

Each MCCB shall be equipped with at least two normally open and two normally closed spare auxiliary contacts. Spare contacts shall be wired up to the terminal block. Each circuit-breaker shall be provided with thermally operated trips for overload protection and instantaneous magnetic trips for short-circuit protection.

Miniature Circuit Breakers (MCBs) shall comply with IEC 60898 and shall be high speed fault energy limiting thermal/magnetic trip.

MCBs shall be equipped with quick make and quick break trip free mechanisms which prevent the breaker being held in against overloads or faults.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by de-ionising arc chutes.

The actuator shall have three positions, "on", "off" and "tripped". To reset from the tripped position the actuator shall first pass into the "off" position.

The rupturing capacity of the MCB shall be not less than that of the switchboard itself.

14.3.6.4 Electrical Relays

Relays shall be provided with non-flammable dust and moisture proof cases.

Relay elements shall be of the plug-in or withdrawable type and the plug-in connections shall be made and broken by pressure contacts. Where appropriate, the Project Manager will approve the use of cases containing multiple plug-in relay elements.

The coils shall be continuously rated and shall have a tropicalised finish. Alternating current operated coils shall be suitable for operation at 110 V a.c. + 10 percent to -15 percent and d.c. operated coils of control and trip relays shall be suitable for operation at 110 V d.c. in the range of 80 percent to 120 percent of nominal voltage for control relays and 60 percent to 130 percent for trip relays. For the control systems, relays and coils shall be suitable for operation at 24 V d.c., within IEC tolerances.

Time delay relays shall be of the solid-state type, wherever practicable. It shall be possible to adjust the timing delays easily and the relays shall hold the adjustment. The timing range of the relays shall overlap the expected setting by at least ±50 percent. The setting adjustment shall be calibrated clearly.

At least one spare normally-open contact and one spare normally-closed contact shall be provided on each relay in addition to the contacts required by the control scheme. Relay contacts shall be adequately rated for the service conditions.

14.3.6.5 Control and Selector Switches and Push Buttons

Control and selector switches and push buttons shall comply with IEC 60947.

Circuit breaker control switches shall be of the three position type with a spring return action to a central neutral position and without a locking feature.

Circuit breaker control switches shall be labelled open/N/close or (O/N/I) and arranged to operate clockwise when closing the circuit breakers and anti-clockwise when opening them, and shall be of the pistol grip type. They shall be designed to prevent accidental operation.

When switches of the discrepancy type are approved, operation shall be effected by two independent movements and shall be arranged in the lines of the mimic diagram. Such switches shall include lamps and be of the manually operated pattern, spring loaded such that it is necessary to push and twist the switch past its indicating position for operation. The lamps shall be incorporated in the switch base and shall flash whenever the position of the controlled device is at variance with the position indicated by the control switch. Hand dressing of the control switch to the correct position shall cause the lamp to extinguish.

Push-button test switches shall be provided on the control panel which will illuminate all discrepancy lamps on the control panel. The scheme shall be complete with all necessary diodes and other equipment required for satisfactory operation.

Switches for other apparatus shall be operated by push-buttons, shrouded or well recessed in their housings in such a way as to minimise the risk of inadvertent operation.

Multi-position selector switches shall have a lockable stay-put action. Each position of the selector switches shall be suitably labelled to signify the functions in accordance with the approved wiring diagrams.

It shall not be possible at any time to close any switching device from more than one location simultaneously, and suitable interlocking shall be provided to meet this requirement.

The contacts of all control and selector switches shall be shrouded to minimise accidental contact and the ingress of dust and shall be suitably rated for voltage and current for the circuits in which they are used.

All control switches shall be provided with labels to identify function in addition to clear indication as to the direction of each operation, for example, "open", "raise", "lower", etc.

14.3.6.6 Auxiliary Switches

All auxiliary switches and mechanisms shall be mounted in accessible positions clear of the operating mechanisms and shall be protected. The contacts of all auxiliary switches shall have a positive wiping action when closing.

Auxiliary switches shall conform to IEC 60947-5-1. Auxiliary switches shall be provided to interrupt the supply of current to the trip coil of each circuit breaker immediately the breaker has opened. These auxiliary switches shall make before the main contacts, during a closing operation.

A minimum of four spare auxiliary switches, two normally open and two normally closed, shall be provided for each circuit breaker and contactor.

All auxiliary switches, whether in service or not in the first instance, shall be wired up to a terminal board and shall be arranged in the same sequence on similar equipment.

Auxiliary switches mechanically operated by the circuit breakers, contactors, isolators, etc. shall be approved type and the contacts mounted in accessible positions clear of the operating mechanism of the circuit breaker, contactor, isolator, etc.

Banks of auxiliary switches and associated terminal boards shall be arranged to facilitate extension when required.

14.3.6.7 Limit Switches

Limit switches shall be provided on all power operated valves, actuator drives, manually operated valves for which monitoring of position is specified or is necessary for indication and control functions, and at other locations as specified. The switches shall be arranged so that they will not be damaged by over-travel of the drive, and shall have a snap-action. The electrical rating of the switches shall be adequate for service conditions.

14.3.6.8 Indicating Lamps and Fittings

Indicating lamps fitted into the fascias of switch and instrument cubicles or panels shall be adequately ventilated.

Lamps shall be easily removed and replaced from the front of the panel by manual means preferably not requiring the use of extractors.

Where lamp extractors are necessary the Contractor shall supply at least four of each type of extractor required.

The bezel holding the lamp glass shall be of metal or other approved material and shall be easily removable from the body of the fitting.

The lamps shall be clear and fit into a standard form of lamp holder. The rated lamp voltage shall be at least 20% in excess of the auxiliary supply voltage, whether a.c. or d.c. Alternatively, low voltage lamps with series resistors will be acceptable.

The lamp glasses shall comply with IEC 60073 and shall be in standard colours, red, green, blue, white and amber. The colour shall be in the glass and not an applied coating and the different coloured glasses shall not be interchangeable. Transparent synthetic materials may be used instead of glass, provided such materials have fast colours.

The variety of indicating lamps provided shall be rationalised to reduce maintenance and spares requirements. The lamps shall have an operating life of at least 10,000 hours, under site conditions.

A lamp test facility shall be provided for all switchboards, control panels etc. to enable all lamps to be tested whilst the equipment is in service. Operation of the lamp test facility shall not cause any other device to operate.

14.3.6.9 Light Emitting Diodes (LEDs)

LEDs shall comply with EN 120001 (Harmonised system of quality assessment for electronic components). Numerical displays incorporating LEDs shall be not less than 20 mm high.

14.3.6.10 Terminal Boards

All terminal boards shall be mounted in accessible positions and, when in enclosed cubicles, shall be inclined towards the door. The spacing of adjacent terminal boards shall be not less than 100 mm and the bottom of each board shall be not less than 200 mm above the incoming cable gland plate. Separate terminations shall be provided on each terminal board for the cores of incoming and outgoing cables including all spare cores. Requirements of terminal boards shall be in accordance with IEC 60947.

Terminal assemblies shall be of the unit form suitable for mounting collectively on a standard assembly rail, secured from the front and giving the required number of ways plus 10% spare.

Terminal boards for multicore cable connections shall incorporate a disconnecting link to facilitate circuit isolation during testing.

Adjacent terminals to which wires of different voltage, polarity or phase are connected shall be segregated from other terminals and shall be fitted with non-flammable plastic covers, with warning labels to prevent contact with any live parts. This requirement also applies to terminals carrying wires of the same voltage but originating from different sources.

Wires shall be grouped on the terminal boards according to their functions.

All connections shall be made at the front of the terminal boards and no live metal shall be exposed at the back.

No more than two wires shall be taken to any common pair of terminals, unless specifically approved by the Project Manager. Where more than 2 wires are required to be connected to a common pair of terminals bridging straps shall be provided.

All terminal blocks shall provide a degree of protection of not less than IP2X installed, either inherently or by provision of insulating covers.

Sufficient terminals shall be provided to permit all cores on multi-core cables to be terminated. Terminals for spare cores shall be numbered and be located at such position as will provide the maximum length of spare core.

The tails of multi-core cables shall be bound and routed so that each tail may be traced without difficulty to its associated cable.

When two lengths of screened cable are to be connected at a terminal block (i.e. junction box) a separate terminal shall be provided to maintain screen continuity.

14.3.7 Electronic Equipment Assemblies

14.3.7.1 General

All inputs to electronic equipment which are derived from sources in close proximity to other equipment operating at voltages higher than the breakdown voltage of the electronic equipment shall be suitably isolated.

All cabling to electronic equipment shall be terminated on links equipped with test sockets arranged to allow for testing input condition with the links in-situ. Visible indication of input conditions should, where possible, be displayed on LEDs in series with the input circuit.

All outputs from electronic equipment which are routed in close proximity to other equipment operating at voltages higher than the breakdown voltage of the equipment shall be suitably isolated.

14.3.7.2 Printed Circuit Card Frames and Wiring

The printed circuit (PC) cards shall be assembled in frames, which when mounted in racks or cubicles shall give full clear front and rear access to the cards and their connectors. Where it is necessary to mount equipment at the rear of card frames, the mounting shall be arranged on hinges to facilitate access to the card frames and wiring.

Card frames shall be equipped with locking devices to prevent the unplugging of boards due to vibration or accidental disturbances.

If plugs are connected to the front of PC cards or in any case where there is movement of the plug socket relative to the attached cable, the cable shall be of a stranded type designed for this purpose.

Wires shall not be soldered onto wire wrap or similar pins not designed for soldering.

Joints in cubicle internal wiring and in wiring between cubicles are not permitted.

Withdrawable cards, modules and cable plugs shall be keyed, coded or otherwise marked to ensure there is no possibility of replacement in the wrong position.

14.3.7.3 Printed Circuit Cards

Printed circuit cards shall be of good quality fibreglass. They shall be flow soldered and covered with a protective varnish. Components and test points shall be clearly labelled. Type number, serial number and a reference to the relevant drawing number shall be clearly labelled on the PC card. Such labelling shall be of a permanent nature and shall withstand cleaning with Freon or similar solvent.

Preference shall be given to printed circuit cards equipped with modular edge connectors rather than those using an extension of the printed circuit track as a male plug.

Components shall not be used as through-connectors. If through-hole plating is not employed, separate through-connectors shall be provided by track connecting pins.

14.3.7.4 Components

The following information shall be supplied prior to installation for each replaceable component or module used:

- name of manufacturer/distributor;
- name of second source manufacturer / distributor; and
- data sheet giving the complete specification for the component.

At least one spare replaceable component or module of each type shall be kept on Site during the entire period of erection at Site.

All components shall be conservatively rated. The surface temperature of any component shall be at least 5ºC lower than the maximum test temperature of the equipment.

Where possible, components shall be of standard ranges which can be expected to be freely available from more than one source.

14.3.7.5 Programmable Controllers

Where programmable or pre-programmed circuits are employed, the Contractor shall supply the following in addition to the information required above.

- Flow charts;
- Programme listings in the programming language used by the designers;
- Copies of all information required to programme the system or to replace components or modules;
- A control panel or work station allowing testing of all functions performed (with facilities to run, single step, display register, display memory, change programme counter, etc.).

14.3.8 Cable Boxes

Electrical equipment supplied under this Contract shall be fitted with all necessary cable boxes, which shall be complete with all required fittings.

All cable boxes shall be of adequate size to allow for the correct termination of the cable sizes required or specified, taking into account the crossing of cores to achieve the correct phasing. The cable entry into the cable box shall be arranged so that there is adequate space to manipulate the cable for glanding and termination.

Cable boxes shall be of adequate proportions and designed in such a manner that they can be opened for inspection without disturbing the gland plate or incoming cable.

Where cable boxes or gland plates are designed for the termination of single core cables, they shall be fitted with non-magnetic gland plates.

The body of each cable box shall be earthed.

The enclosure classification of main and auxiliary cable boxes with the cable(s) terminated shall not be less than that of the associated plant, subject to a minimum classification of IP 54.

Clearance and creepage distance shall be adequate to withstand the specified a.c. voltages and impulse voltages for service under the prevailing site conditions.

All cable boxes shall be designed to withstand the high voltage d.c. cable tests prescribed in IEC 60502 or other applicable Standard.

14.3.9 Instrument Transformers

14.3.9.1 Current Transformers

Current transformers shall conform to IEC 60044 unless specified otherwise. Current transformers shall be to class 0.2M for performance guarantee measurements, class 0.5M for general measurements and generally to class 5P for protection unless the form of protection requires otherwise.

The current transformer ratings shall be suitable for the system conditions. The rated continuous thermal current shall be equal to the rated normal current of the primary circuit. The accuracy limit factor shall be calculated on the maximum through fault current unless the relays and devices supplied from the transformer are designed to operate correctly under saturation.

The Contractor shall take any necessary precautions against proximity effect in the design, to ensure that the accuracy and class designation are maintained with the current transformers installed in service and under conditions of rated current or fault current as appropriate. The Contractor shall provide to the Project Manager a statement of the precautions taken, or of the reasons why precautions are not necessary, in respect of each current transformer.

Power transformers may be fitted with bushing type current transformers, which have a sufficient number of secondary cores for protection and instrumentation.

Current transformers for low voltage installations shall be air insulated ring type and the secondary leads shall be brought out to terminals at the back of the switchgear.

The secondary winding and core of each current transformer shall be encapsulated in epoxy resin, to exclude moisture and suitable to withstand dielectric and thermal and mechanical stresses in service.

The primary polarity designation and secondary terminals shall be clearly marked on the appropriate faces of each current transformer.

The cores shall not be earthed. An earthed shield shall be provided, where appropriate, between primary and secondary windings to protect the secondary windings and connected equipment against breakdown of insulation between the windings. All external metalwork of the current transformer shall be earthed and insulation shall be provided to prevent circulating currents in clamping frames for multiple stacked secondaries. If the earthing shield referred to above is supplied, it shall be separately earthed; a common shield shall be provided where secondaries are stacked together. Any metallic parts in the primary insulation and adjacent to the primary conductor shall be connected to the primary conductor by flexible conductor.

Current transformers shall be supported independently of the primary conductor. Each encapsulated secondary winding shall be securely held in place to withstand dielectric and thermal and mechanical stresses in service. The tails of secondary windings shall be anchored separately from the windings, so that stresses applied to the tails do not affect the windings proper. The arrangement shall be such that secondaries which are stacked together are free of stresses due to differential expansion.

A local junction box shall be provided for each group of current transformers located near each other. Connections from the secondary terminals shall be taken via these junction boxes.

14.3.9.2 Voltage Transformers

Voltage transformers shall be suitable for the system conditions and shall conform to IEC 60044 unless specified otherwise. Voltage transformers shall be to class 0.2 for performance guarantee measurements, class 0.5 for general measurements and the appropriate class for protection.

Voltage transformers shall be single-phase units each with one primary and one secondary winding (unless otherwise specified) without tappings. The primary windings shall be earthed via a removable link to a common terminal for earthing the core and frame.

The windings shall be insulated with and encapsulated in silica-filled epoxy resin by a full vacuum impregnation process that has proven penetration of the arrangement proposed. The total cross sectional area of wire used for the high-voltage windings shall not be less than 0.07 mm^2.

Terminal markings shall be permanent and shall be as shown on the drawings. One rating plate shall be provided with each unit and shall be fixed to the enclosure. A separate label identifying the voltage transformer phasing and group shall be fixed on the enclosure.

A local junction box shall be provided for each voltage transformer. The secondary terminals shall be connected to these junction boxes which shall contain devices for secondary circuit protection. Sub-circuits shall be individually protected.

For capacitor voltage transformers, transient oscillations produced at the output terminals of the secondary winding when the primary is subjected to a sudden reduction in applied voltage at rated frequency should be so damped that at 10 milliseconds after the instant of change and thereafter:

(i) the peak value of any transient oscillation shall not exceed 5 percent of the peak value of the rated steady state output voltage;

(ii) the frequency of the transient oscillation should be lower than 10 Hz or greater than 250 Hz; and

(iii) the ratio error at the fundamental frequency of applied voltage should not exceed 5 percent.

During impulse tests on the high-voltage winding, the transferred overvoltages to the secondary winding shall not exceed 3 kV between secondary terminals, or between secondary winding and earth when one phase secondary winding is earthed through another phase secondary winding in series. If necessary to achieve this, an earthed screen shall be designed into the voltage transformer between the primary and secondary windings.

The neutral end of the primary windings shall be brought out externally through a 2 kV rated bushing with a separate earth connection that can be disconnected for test purposes.

Withdrawable side connected voltage transformers shall be cast resin encapsulated together with the main spouts and shall be accommodated in a separate tank at the rear of the unit. When the voltage transformer is isolated an automatic shutter shall cover the fixed spouts. The voltage transformers shall be mounted on guide rails. All necessary handling equipment for voltage transformer removal shall be provided.

14.3.10 Control and Monitoring System (CMS) Interface Requirements

In general all plant and equipment shall be equipped with facilities to permit monitoring by the Control and Monitoring System (CMS) whether or not the initial installation of the CMS requires these indications. Where specified, equipment shall also be provided with facilities to permit control by the CMS.

The following indications shall be made available to the CMS:

- Measured quantities, current, voltage, temperature, pressure, level, etc.
- Status of medium and low voltage circuit breakers and disconnectors. Status shall be open or closed and, where appropriate, withdrawn to the service position, locked out, charged, etc.
- Status of valves.
- Operation of all protective devices and alarms.

For each assembly of equipment, or suite of cubicles, all signals intended for the CMS shall be wired to a single dedicated terminal board. The terminal board shall be located within the equipment cubicle or where more particularly specified elsewhere in these Employer's Requirements or where approved by the Project Manager shall be housed in a separate dedicated marshalling cubicle.

Section 15: Technical Specifications – Hydro Mechanical Equipment

15.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the hydro mechanical equipment.

The hydro mechanical and associated equipment shall be provided to control and regulate water flow from the Mulembo River to the turbine generator units.

Scope

The scope of supply shall include trash racks, manual trash rakes, gates, valves, and reservoir water level sensors but not be limited to the following:

- Provision of trash racks, manual trash rakes, gates, valves, stop logs and level sensors;
- Operating mechanisms including hydraulic systems where appropriate;
- Controls and status inputs to the station Control and Monitoring System;
- All associated pipe work, valves and controls;
- All hoists, lifting beams and specialist maintenance equipment;
- Installation, testing and commissioning;
- Spare parts;
- O&M manuals.

15.2 Design - General

The trash screens, screen raking mechanisms, gates, valve and level sensor installations shall be complete in all respects, including all materials, equipment and parts, to provide fully functioning systems and shall be fit for purpose for the intended use.

The design for the hydraulic gates shall be to the requirements of DIN 19704 and DIN 1705. Hoisting equipment shall be designed for the full weight to be lifted including any gate or stop log assemblies and lifting devices together with maximum hydrodynamic forces, seal face friction and an overall safety factor of 50 percent.

All plant and equipment shall be designed and manufactured to provide high reliability in operation and for ease of operation and maintenance. It shall also be designed for long periods of operation between overhaul, routine service and or component replacement.

The design, dimensions and materials of all parts shall be such that they will not suffer damage under the most adverse conditions nor result in deflection or vibrations which might adversely affect the operation of the plant. Mechanisms shall be designed to minimise the potential for mal-operation due to rust or other corrosion.

All parts, which require dismantling, or which may require dismantling for the purpose of servicing or replacement, shall be retained with anti-corrosive fasteners. The type, materials and size of all fasteners shall be selected to safely withstand the maximum superimposed direct, alternating, kinetic, thermal loads and all loads including those imposed during installation and subsequent maintenance of the plant during its life time.

The design shall be such that the replacement and general maintenance may be undertaken with the minimum of down time and expense. The tolerances used for dimensions and finishes shall be selected with due consideration to the particular properties and functions of the parts and the corresponding accuracy required to obtain proper operation and tight sealing.

Wherever possible, all similar parts, including spare parts, shall be interchangeable. Such parts shall be of the same materials and workmanship and shall be manufactured with tolerances to enable the rapid and simple substitution of replacement from spare parts as necessary.

Suitable structural steel bases or frames shall be provided where necessary to transmit to the concrete foundations all loads imposed by the various parts of the Plant. Such bases or frame shall be supplied complete with suitable bolts and shall be so proportioned that the bearing loads imposed on the concrete foundations will do not exceed those specified.

All gates, screens, structures and plant shall have protective coatings applied appropriate for the specific environment in which they operate and to give effective protective coating life of not less than 15 years operation.

All gates screens, structures and plant shall be provided with access ladders, platforms and railings to ensure the safety and security of the operations and maintenance personnel.

All plant and equipment shall be designed to minimize the risk of fire and consequential damage, to prevent ingress of vermin, dust and dirt, and accidental contact with electrically energized or moving parts, and collection and condensation of water. The plant and equipment shall be capable of continuous operation with minimum attention and maintenance even in the exceptionally sever conditions.

The detailed requirements for each specific trash racks, trash rakes, gates and level sensors and hoists installations follow below:

15.3 Test on Completion - General

15.3.1 Pre-commissioning Tests - General

Preliminary tests at site of the screens, gates, stop logs and associated equipment shall include but not be limited to the following:

- Checks that alignment of all screens, gates, guides seal faces are within the approved design tolerances;
- Radiographic or ultrasonic examination of any site welds in load carrying members, other than seal welds;
- Pressure testing of the installed pipe work and fittings;
- Checks on all seal clearances with feeler gauges;
- Rotational checks on all motors;
- Insulation resistance tests on all site installed wiring and electrical connections;
- Setting of limit switches, indicators and control equipments;
- Inspection of satisfactory installation of all components.

15.3.2 Commissioning Tests - General

Commissioning Tests of the screens, gates and associated equipment shall include but not be limited to the following:

- Test of water leakage from closed gate,

The requirements for each specific element are detailed in the following sections:

15.3.2.1 Tests on Completion - Reservior Level Sensor

Commissioning Tests

In addition to the Commissioning Tests – General the reservoir level measurement devices Commissioning Tests shall include, but not be limited to, the following:

- Functional tests of the continuous level monitoring device;
- Test to confirm functionality of level gauge board.

15.3.3 Intake Gate and Hoist –Intake to penstock

This section of the Employer's Requirements covers the specific requirements for the penstock intake, intake gate and hoist.

The penstock intake gate and hoist gantry shall be provided to facilitate the inspection and maintenance of the intake.

15.3.3.1 Principal Parameters - Intake Gate and Hoist

Number	1
Type of gate	Sluice gate
Type of hoist	Manual screw hoist
Operation (normal)	Balanced flow conditions

Principal Parameters – Sand flushing valve

Number of gates	1
Type	Sluice gate
Raising / lowering system	Manual actuator

15.3.3.2 Operating Conditions - Intake Gate, Sand Flushing and Hoist

Under normal operating conditions the intake gate is maintained in the fully open position.

Periodically the intake gate is closed to allow for inspection, maintenance or other purposes.

Design - Intake Gate, Sand Flushing and Hoist

The intake gate shall be complete with all associated handling equipment

The intake gate shall be arranged with seals and skin plate on the upstream face.

The gate shall be designed according to DIN standards.

The design of the intake gate embedded parts shall be on the basis of maximum loadings without consideration of load sharing with the structural concrete.

The design of the embedded intake gate parts shall be on the basis of maximum loadings without consideration of load sharing with the structural concrete.

The intake gate and associated structures shall be of fabricated steel with steel skin plates.

The plate thickness shall include a corrosion allowance of not less than 1 mm per face.

The intake gate stem shall be manufactured from corrosion resistant steel and shall be sized to for the worst loading condition and with a factor of safety of not less than 2.0.

Sparge pipe work shall be permanently installed in the gate slot to allow any material that may accumulate on the gate sill ends, preventing gate full closure, to be agitated and dispersed by means of fixed high pressure air jet nozzles. The high pressure air shall be provided by a mobile air compressor unit discharging into the sparge pipe work via flexible hose lines and 'quick' hose connection couplings.

Section 16: Technical Specifications - Inlet Valves

16.1 Scope of Work

This section covers the detailed specification for the design, manufacture, supply, erection, commissioning and testing of main inlet valves.

A main Inlet valve shall be provided for Turgo turbine unit and shall be complete with upstream make-up pipe, downstream dismantling/expansion joint and all associated equipment.

The inlet valves shall be a gate valve designed to manual close under emergency conditions. The valve shall have a bypass pipe and valve for pressure balancing before operation.

Scope

Each main inlet valve and associated auxiliaries shall include, but not be limited to, the following:

- Body;
- gate;
- sealing rings;
- Upstream flange connection with penstock drain pipe;
- Downstream flange connection with turbine;
- Downstream flanged make up pipe;
- Special maintenance tools and equipment;
- Spare parts.

16.2 Design

16.2.1 General

The valves shall be suitable for opening under equal upstream and downstream pressure and for closing without damage against the maximum flow and water hammer pressure that may arise from turbine runaway and associated emergency valve closure. Care shall be taken to avoid resonant water hammer due to seal movement or any other conditions. Means for suppression of resonance in the event of its occurrence shall be provided together with an alarm.

The Contractor shall ensure that cavitation does not occur under any operating conditions including emergency closure conditions.

The stress in the fixed and rotating parts of the equipment shall not exceed 2/3 of the material yield stress under worst conditions (emergency closure under turbine runaway condition).

The designs shall include a corrosion allowance of not less than 1mm.

The Inlet Valve assembly shall be made of cast or forged homogeneously welded steel; with the following material specification:

Body	Carbon Steel S 355 J2G3 or similar
Rotor…	Carbon Steel S 355 J2G3 or similar
Seats	Stainless Steel 304L or similar
Shafts	Stainless Steel NFA Z 20 C 13 or similar
Fixing Plates/Cover	Carbon Steel S 355 J2G3 or similar
Pins	Stainless Steel NFA Z 20 C 13 or similar

All flange connections will be drilled according to ISO 5752.

All equipment required for key selected local manual opening and closing together with a shrouded mechanical trip device shall be provided adjacent to each valve.

16.2.2 Downstream Dismantling /Expansion joint

The dismantling joint with forged steel flanges shall be designed in conjunction with the downstream part of the inlet valve so as to give access to the service seal for inspection, repair and replacement without removing the valve body. The joint flange which is in contact with the valve body shall be provided with a stainless steel surface where it is in contact with the movable sealing member.

The secured expansion joint shall be in the nature of a gland with substantial flanges, the sliding portions being sealed with approved packing and steel packing rings.

16.2.3 Valve Body

The valve body shall be of cast or fabricated design or a combination of both. It shall be of rigid construction so that undue distortion does not arise in operation or with the valve in the closed position and the seals engaged. Lifting eyes and base plate with holding-down bolts shall be included.

Substantial steel bearings with self-lubricating bushes shall be incorporated in the valve body together with readily renewable packings for the trunnions.

An indicator with scale and pointer shall be provided for valve to indicate (in percentage) the valve rotor position.

16.2.4 Lubrication

All bearings and trunnions shall be provided with self-lubricating bushes and shall be designed for easy replacement.

16.2.5 Inlet Valve Operation

Complete mechanical equipment shall be provided to ensure correct and safe sequences of inlet valve and seal operation.

16.2.6 Indications and Alarms

The following main inlet valve indications / alarms shall be provided at the turbine control panel.

Indications

- Inlet valve "closed/in transit/open"
- Inlet valve lock "on/off"
- Turbine pressure equalised with penstock (Differential sensor).

16.3 Factory Acceptance Tests

Factory acceptance test shall include but not limited to a hydraulic pressure test of the inlet valve to 1.5 the maximum operating pressure. The hydraulic pressure test shall be held for 30 minutes during which time there shall be no leakage.

16.4 Tests on Completion

16.4.1 Pre-Commissioning Tests

The Inlet Valves shall be subjected to the following but not limited pre-commissioning tests:

(i) Check of operation of service and manual seals in the dry; and

(ii) Opening and closing of the main inlet valve in the dry.

16.4.2 Commissioning Tests

Upon completion of the pre-commissioning tests and once all generating plant is ready, the following commissioning tests shall be performed on the MIV to be co-ordinated with the tests of other plant:

(i) Watering up and seal leakage checks;

(ii) Stroking of seals in the wet;

(iii) Opening and closing of the inlet valves in the wet under no flow conditions;

(iv) Emergency closure tests at 25%, 50%, 75% and 100% full load.

(v) Reliability Test

16.5 Spare Parts

Spare parts for the main inlet valves and associated equipment shall be provided for 10 years operation and maintenance and shall include, but not be limited to, the following:

• Valve seal – seal and seat	1 set
• Valves	2 of each type
• Pressure gauges	1 of each type
• Flexible hoses	1 of each type
• Nuts, bolts, fasteners etc.	1 set or 10% of each type

Section 17: Technical Specifications – Turbines and Governors

17.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the Turgo turbine unit together with the associated governor and auxiliary equipment.

17.2 Scope

The turbine unit with associated governor and auxiliary equipment shall include, but not limited to, the following:

- hydraulic turbine with a power output of not less than 100 kW, including inlet, turbine bearings, turbine shaft, turbine runner buckets/cups, turbine governor and all necessary controls;
- All lubricating and hydraulic systems pipe work and fittings;
- Pressure taps and all fixtures, fittings and facilities for efficiency tests;
- Specialist maintenance tools, lifting and , handling devices, access platforms together with associated equipment;
- Spare parts;

17.3 Turbine Design Data

17.3.1 Design Flow Rate

The total design flow rate through the turbine at rated output shall be **0.68** m^3/s.

17.3.2 Design Head

Design head – 45.38 m

17.3.3 Head Losses

Total head losses are to be determined by the Contractor at the total design flow rate.

17.3.4 Waterway Dimensions

The waterway dimensions are to be determined by the Contractor to provide the station total guaranteed output of 200 kW at the generator terminals, at the design flow rate.

17.3.5 Speed of Rotation

The specific speed of the proposed turbine shall be conservatively within the turbine supplier's limit of experience.

The Contractor shall ensure that there is a wide margin of safety between the first critical speed of the combined generator and turbine shaft system and the normal running and runaway speed.

The Contractor shall provide a report which demonstrates the design measures taken to sufficiently separate the natural frequencies of the unit components to avoid resonance between the unit and both the hydraulic system and the electrical power system, including the appropriate selection of turbine and generator parameters, the elimination of Von Karman vortices pressure pulsations and the prevention of water hammer resonance.

All rotating parts shall be accurately balanced at speeds up to that attained on full load rejection so that operation will be without excessive vibration. The Contractor shall measure any out-of-balance of the rotating portions of the unit and shall make such adjustments as may be necessary to achieve satisfactory dynamic balance at Site.

Vibration amplitudes measured at the bearing brackets and non-rotating parts shall be within the recommendations of VDI 2056 for machine group G. Shaft and rotating parts vibrations shall be within the recommendations of Zone A of BS ISO 7919. Field measurements shall be performed in accordance with IEC 60994.

17.4 Guarantees and Performance

17.4.1 General/

The turbine unit shall be directly coupled to the generator unit.

Each turbine shall be capable of continuous operation, without excessive vibration and the effective absence of cavitation damage to the turbine over the life of the plant over the entire range of net head of the Works and at flow rates from 110% to 25% of a turbine design flow rate (0.68 m^3/s).

17.4.2 Test Data Derived from the Scale Model

The Contractor shall provide the performance results from a previous scale model of a similar Turgo turbine of similar size to determine the prototype turbine performance together with justification for the transposition between the tested model and the proposed prototype turbine. The model test report shall demonstrate a guaranteed 15 percent margin on the value of model Thoma number (σ_m) for which a 0.2 percentage drop in model turbine efficiency is measured (i.e. $\sigma_{plant} \geq \sigma_{0.2m}$ x 1.15) under all conditions of prototype net head.

In determination of the plant sigma the static suction head shall be measured relative to the runner centreline.

The machines shall be designed to have their best efficiency under the net head corresponding to Unit Electrical Output Guarantee specified for this Contract. On test, at model output corresponding to the guarantee, the model turbine efficiency shall not be less than the specified efficiency for this Contract.

The Contractor shall also demonstrate the capability of the prototype turbine to operate down to 50% of full load for prolonged and continuous periods of time. These results shall be supplied in the form of tables accompanied by the associated test curves and a presentation note describing the transposition from model to prototype values for each guaranteed point.

Model acceptance test shall be in accordance with IEC 60193.

17.4.3 Operating Limits of the Prototype Turbine

The Contractor shall provide turbine 'hill' type curves, and Head – Flow (H-Q) diagrams and Head – Power (H-P) diagrams that shall give the flows and powers respectively, efficiency curves and operating limits.

17.4.4 Turbine Guarantees

In addition to the overall station output guarantee, combined turbine and generator unit guarantees for output and efficiency, specific turbine guarantees shall be provided including 'turbine speed and pressure rise, and 'turbine cavitation' as specified in these Specifications.

17.4.5 Maximum Runaway Speed

The Contractor shall guarantee the behaviour of the turbines (no permanent deformation, no loosening or play) at the worst runaway speed. All parts of the turbine shall be designed in accordance with requirements of ASME Boiler and Pressure Vessel Code Section VIII, Division 1 and Division 2. Division 1 criteria shall apply to simple stress analyses. Stress intensities specified in Division 2 and reduced by 20 percent shall apply for more detailed analyses such as finite element analysis (FEA), for stress concentrations and fatigue. The maximum runaway speed shall be determined from the model test report under "off-cam" conditions and with a cavitation factor (σ) yielding the highest runaway speed.

17.4.6 Maximum Over-Speed

The maximum over speed, as defined in the IEC code for in-situ acceptance tests, shall remain less than the guaranteed value under the worst operating conditions. The maximum speed rise of the Unit following load rejection under any conditions of normal operation, accident or emergency shall not exceed 40%. Stable operation under all conditions shall be ensured.

The Contractor shall submit the results of his hydraulic transient/regulation study demonstrating the design values, and the adequacy of the design values. The results shall include a description of the method, input data and sample calculations demonstrating the calculations and the output data in graphical form showing the behaviour of the Unit.

17.4.7 Minimum Flywheel Effect

Flywheel effect inertia shall be incorporated into the turbine and generator rotating mass to give stable governing and to maintain the specified speed and pressure rises during a full load rejection.

17.4.8 Runner Inspection

Following Tests on Completion, and for the duration of the Defect Liability Period, the Contractor shall undertake regular testing and inspection of the turbine runners for cavitation and or cracking, as Tests on Completion.

The testing and inspection shall be carried out on each turbine runner at intervals of 1,000 hours of operation and shall be conducted during unit outages, agreed with the Employer. The testing and inspection shall be witnessed by the Employer.

The Contractor shall prepare a detailed report on results of the tests and inspections for the Employer.

17.4.9 Cavitation

The Contractor shall design the turbine units to avoid cavitation as recommended by IEC 60609-2.

Any cavitation that may occur shall not exceed the guaranteed values. Should more weight of metal than this be removed within the guarantee period, the Contractor shall either replace the material by welding or replace the runner free of charge. The method of rectification shall be decided by the Employer taking into account the extent of damage.

17.4.10 Runner buckets/cups Cracking

The Contractor shall guarantee the runners against crack formation for a period of not less than 24 months or 16,000 operating hours which ever is the greater.

17.5 Operating Modes

The turbine unit and associated equipment shall be designed to safely withstand the loadings occasioned by fluctuating load conditions without excessive or undue degradation of performance or excessive maintenance requirements.

The Turbine generator unit shall be capable of sustaining satisfactory prolonged and continuous part load operation.

The governors shall be capable of controlling the turbines on the basis of headpond level control and/or to follow electrical load demand. Normal operation of the generating unit will be base load, run-of-river.

The turbine unit shall be operated from the powerhouse control room utilising the station Control & Monitoring System (CMS).

The turbine shall also have facilities for operation from the Unit Local Control Board located adjacent to the turbine generator unit.

17.6 Design

17.6.1 Turbine Dismantling

The turbine generator units shall be arranged to facilitate the dismantling and assembly of a turbine unit without the need to dismantle its associated generator unit.

Additionally, facility shall be provided for the removal of the turbine runner from without the need to dismantle and assemble the other main turbine components including shaft, bearings, head cover and guide vanes.

To facilitate turbine dismantling and assembly the Contractor shall provide all necessary equipment including, but not limited to, special tools, lifting and handling equipment.

17.6.2 Allowable Stresses

The stress in the fixed and rotating parts of the equipment shall not exceed 2/3 of the material yield stress under worst loading conditions including emergency closure under turbine runaway conditions.

The designs shall include a corrosion allowance of not less than 1mm.

17.6.3 Surface Condition of Hydraulic Parts

The Contractor shall take care to ensure that the profile of wetted surfaces is continuous and that surface finish does not generate cavitation.

The surface finish shall be at least compatible with the roughness criteria specified in IEC 60193 Section 2.2.3, Table 1.

17.6.4 Resonance

The design shall avoid the potential for resonance to occur and analysis of turbine natural and forced frequencies shall be undertaken to identify and circumvent the potential for resonance to occur.

17.6.5 Particular Safety and Operating Conditions

Safety devices shall be designed to 'fail safe' such that turbine admission devices shall be automatically closed and held closed in the event of a power supply failure to the governor and control systems or a failure of the hydraulic pressure systems.

17.6.6 Turbine Housing Design

The turbine housing shall be of ample proportions and designed to carry water away from the runner with minimum loss of energy. The turbine housing shall be provided with all necessary fittings including lifting lugs, for drains and instrumentation.

A runner removal access hatch shall be provided in the side of the turbine pit to allow for the inspection purposes and removal/replacement of the runner without the need to dismantle the main turbine components. When in place the access hatch will be water tight. Provisions shall be made within the turbine pit for installing the demountable access and runner removal platform together with associated runner lowering/lifting equipment.

17.6.7 Turbine Shaft and Coupling

The turbine and generator shafts shall be of forged steel. In the design of the shafts all sudden variations in diameter shall be avoided. Shafts and couplings and shaft run out tolerances shall conform dimensionally with the metric equivalent of ANSI/IEEE 810. The shafts shall be free from visible defects or imperfections and no forging shall be used until it has been subjected to extensive non-destructive testing and examination.

Forged flanges forming an integral of each shaft shall be provided to couple the turbine and generator shafts and between the turbine runner and the turbine shaft. The respective manufacturers of the turbine and generator shall collaborate in the allowable tolerance applied to the drilling of bolt holes on the shaft coupling flanges. The shafts shall be suitably machined over their full length and shall be polished where the bearings are located and accessible points for purposes of checking shaft alignment. Shaft coupling guards shall be provided to meet safety requirements.

Turbine and generator shafts shall be matched and aligned in the manufacturers' works, unless other means are agreed, to ensure that the shafts can be aligned and assembled at Site in a satisfactory manner. The alignment check shall include the matching and alignment of all bores and reaming of the coupling bolt holes.

Each shaft shall be checked for run out in shop according to ANSI/IEEE 810. Alignment of the combined shaft system will be carried out at site according to NEMA

MG5.2. The maximum indicated run out shall be within 0.1 mm at any location on the combined shaft system.

A replaceable sleeve for the shaft seal shall be securely fitted to the turbine shaft. The sleeve shall be made of carefully machined and polished 13 percent chromium 4 percent nickel stainless steel. Where the design permits the sleeve shall be reversible so that two sealing surfaces are available; the faces shall be provided with adequate allowance to permit their renewal by re-machining.

17.6.8 Runner Design

The runner shall be designed and shaped and with surface finish, to minimize the potential for cavitation and erosion damage.

It shall be possible to install and remove the runner from the turbine unit for inspection and maintenance

The profile of the runner and runner buckets/cups shall be determined such that the maximum dynamic stress (peak to peak) is less than 60 MPa at any point on the runner, regardless of the machine operating condition.

The runner shall be made of cast or forged homogeneously welded stainless steel.

The material grade shall be GX4CrNi13-04 according to EN10283 or similar as a forged runner.

Residual stresses due to heat treatment, welding or machining operations shall not exceed 100 MPa.

If any defects outside tolerances are discovered during machining, they may be repaired by welding and followed by stress relief heat treatment.

On completion of machining the surface finish of the runner shall be meet the requirements of IEC 60193 Section 2.2.3, Table 1.

17.6.9 Bearings

17.6.9.1 Bearing brackets

The bearing bracket shall be designed for stiffness sufficient to fulfil the requirements for critical speed. The length and dimensioning of the anchoring bolts shall be sufficient for handling the forces during any foreseeable transient condition, including its pre-stressing.

17.6.9.2 Bearings

Bearings shall be of the hydrodynamic type. They shall allow for start up without priming, the oil volume shall be sufficient to cool the bearings under the most extreme conditions (full load rejection, no breaking and no cooling water flowing). The bearings shall be amply designed for normal operation and shall be able to function indefinitely under any emergency conditions which may occur, including runaway speed, at which the manufacturer's maximum permissible bearing or sleeve white metal temperatures shall not be exceeded.

The bearing shall be designed for the loading of the rotating parts of the turbine and transient hydraulic forces in any direction. The bearing metal shall be tin based babbit metal.

Each bearing shall be furnished with a lubrication oil pumps. Means shall be available for filling and draining the oil from the bearing housings.

Oil leaks, spills or vapour/mist will not be accepted, nor will condensation of oil drops on cold or other surfaces. All necessary oil and water piping, valves, fittings, connections, etc. shall be provided for the bearings. The isolating valves on the bearing drain pipes shall be provide with padlocks.

All precautions shall be taken with the construction of the Unit to limit the effect of harmful effect of shaft currents. Protection equipment shall be provided to give an alarm in the event of harmful shaft currents flowing.

Where fitted into the bearing pads, the thermometer bulbs and temperature detectors shall be as close to the white-metal surface as possible in the high temperature regions.

The range of the instrument will be 0^{o}C to 150^{o}C.

17.6.10 Governor

An essential requirement for the governor system is long term reliability and accuracy when the Unit is operated within the specified limits. A high level of circuit redundancy shall be incorporated such that availability of greater than 99.98 percent shall be readily achieved.

Turbine unit shall be provided with an electro hydraulic governor with an electronic regulator section, electrically operated pilot valve and hydraulic servomotors to provide speed control for the turbine generator and adjustment of speed droop, load limit and control for loading from the switchgear panel.

It shall have sufficient capacity to function without instability under all conditions so that ready adjustment can be obtained to ensure that the best possible speed control can be affected.

The governor shall be suitable for black starting and shall be provided with emergency shutdown facilities.

The speed droop shall be adjustable with a range of 0-8%. The governor oil pumping set shall be suitable for operation from a 400V 3ph 50Hz electrical supply and the Contractor shall supply a motor starter for the governor oil pump. Control of the pump shall be manual with automatic trip of the motor in the event of low oil level.

The design shall include for the maximum pressure and speed rise and governing stability on the basis of the penstock design and inertia from the combined turbine and generator. The servomotor opening and closing times shall be adjustable.

The governor shall be suitable for limiting frequency excursions to 48-52 Hz and parallel operation. It shall also have two principle control modes; head pond level control and/or to follow the electrical load demand.

17.6.10.1 Dead Band

The maximum allowable dead band shall be ±0.15 Hz for governing. That is, no response is required from the unit while the frequency is greater than 49.85 and less than 50.15 Hz.

17.6.11 Hydraulic High Pressure Oil Control Unit

A hydraulic high pressure oil control unit shall be supplied for turbine generator unit. This unit will be used for operating the nozzle and turbine inlet valves.

The equipment shall comprise of an oil reservoir on which the system components are mounted.

The oil reservoir shall have a removable inspection cover to facilitate replacement of the pump suction strainers.

The oil reservoir shall also include:

- Oil level sight gauge incorporating a thermometer
- Tank top filler breather
- Oil drain valve with outlet plugged for safety
- Lifting eyes at each corner
- Mounts for the hand pump handles

On the top of the tank the following components shall be installed:

- Two fixed pumps driven by AC motors providing oil at a maximum operating pressure. Oil grade should be ISO VG 46. A pressure relief valve will be provided to protect overload of motors.

- An indicating flow switch fitted downstream of the pump to be connected to the turbine shutdown line to shutdown the turbine on loss of oil flow.
- A differential un-loader valve in the line after the flow switches to maintain the system pressure at the design pressure but unloads the pump when the demand is low.
- An inline filter with clogging indicator to be fitted to protect the control valve from oil borne contaminants. Filter elements for initial flushing purposes to be included.
- Electro-hydraulic proportional valve for the operation of the nozzle mechanism.
- Electro-hydraulic solenoid valves for open/close operation of the inlet valve.
- Hand pumps and isolating valves to be provided to enable the turbine to be started when no electrical power is available.
- An oil level switch with alarm and abort reed switches to be connected to the shutdown line to protect the pump against running dry on loss of oil.

17.6.12 Indications and Alarms

The following turbine and associated equipment valve indications / alarms shall be provided at the turbine Unit Local Control Board for the unit, in addition to instruments necessary for maintenance and readings made by operations personnel (visual indicators, thermometers, manometers, etc.):

- All temperature probes shall be double wound and have four wires.

The different position contact shall be by the position loop of the speed governor and not by limit switches.

Turbine regulation:

- 8 oil level contacts in the air / oil accumulator ("too high" level – "intermittent high" level – normal level – sufficient level – insufficient level – "intermittent low" level – "too low" level – "minimum useable" level),
- 1 oil level contact, available,
- 1 "e air / oil accumulator isolating valve closed" limit switch contacts,
- 1 " air / oil accumulator isolating valve open" limit switch contacts,
- 1 level contacts in the regulation oil tank (low level),
- 2 resistance probes with electrical thermostat detecting too high temperature of the regulation oil,

- 1 pressure switch detecting normal pressure in the regulation oil circuit,
- 1 pressure switch detecting a pressure drop in the regulation oil circuit.

Safety device:

- 1 emergency stop ;
- 1 adjustable centrifugal type mechanical over-speed detector with manual reset;
- 1 control pressure sensor closing of guide vanes in the event of drop oil pressure loss.

17.7 Factory Acceptance Tests

Factory acceptance tests shall be carried out in accordance with IEC 60308. And shall include but not be limited to:

- Runner chamber hydraulic pressure tests;
- Static and dynamic balancing of rotating parts in assembled unit;
- Hydraulic power unit.
- Complete turbine system

17.8 Tests on Completion

17.8.1 General

The testing and commissioning of the turbine and its governor shall be carried out generally in accordance with BS EN 60041 (IEC 41) and the Employer's Requirements.

17.8.2 Pre-Commissioning Tests

The turbine and governor shall be subjected to pre-commissioning tests to prove readiness for energising control circuits and control devices. To this end tests shall include, but not necessarily be limited to:

- Hydrostatic pressure tests on all pressure systems
- Insulation and continuity tests on wiring including tests for correctness of connection
- Checking for correct operation of each control, protection and indication device which is mechanically, electrically, hydraulically or pneumatically operated

17.8.3 Commissioning Tests

The turbine and the governor shall be subjected to commissioning tests including, but not necessarily limited to:

- Tests for correct operation, control, indication and protection of all ancillary systems required to be in service for the operation of the turbine/generator unit including:
    - Inlet valve and associated operating systems.
    - Governor pumping set
    - Turbine regulating gear and governor
    - Bearing lubrication system
    - Dewatering and drainage systems
- Rotational tests of the turbine and generator including alignment checks, measurement of guide leakages, bearing temperature measurement, at over speed as well as rated speed, prior to loading.
- Loading and load rejection tests
- Speed and pressure regulating tests.
- Check of pressure and output fluctuations.
- Tests of correct functioning of automatic and manual controls, protection and indication equipment. These shall include a demonstration of correct repetition of each of the possible mode changes, conducted over the widest practicable range of head conditions available.
- Test of performance of governing and control systems in accordance with IEC 60308.
- Test at maximum runaway speed of 2 minutes duration.
- Turbine and Generator Output Guarantee test.
- Turbine and Generator Efficiency Guarantee test.
- Turbine Speed and Pressure Rise Guarantee test.
- Reliability Test.

17.9 Spare Parts

Spare parts for the turbine units and associated equipment shall be provided for 10 years operation and maintenance and shall include, but not be limited to, the following:

Turbine Spare Parts

- Turbine shaft seal assembly
- Turbine shaft seal renewable components
- Turbine bearings

Hydraulic High Pressure Control Unit System Spare Parts

- Pumps and motor assemblies
- Hydraulic oil filters for generating unit
- Oil Tank sight gauge
- Governor electro-hydraulic pilot valves, complete system
- Drainage pump

Other General Spare Parts

- Instrumentation
- Valves
- Pressure gauges
- Electrical relays, switches, solenoids and devices not listed
- Fuses
- Lamps, lamp covers
- Flexible hoses
- Nuts, bolts, fasteners etc.

Section 18: Technical Specifications– Cooling Water System

18.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the powerhouse cooling water system.

The cooling water system shall be provided to supply cooling water to the two turbine generator units and common station services including the following:

- Generator air coolers;
- Generator thrust and guide bearing oil coolers;
- Turbine bearing oil coolers;

18.2 Scope of Work

The cooling water system shall be complete in all respects and for turbine generator unit shall include, but not be limited to the following;

- Cooling water shall be drawn from the penstock
- Two 100% duty/standby hydro-cyclones and isolation valves.
- Stainless steel cooling water pipework.
- 1 set of valves and control devices for the system.
- 1 set of controls and indications for the system.
- Local control panel situated on the turbine floor.

18.3 Design Concept

Cooling water is to be provided for cooling of the turbine lubricating oil.

The system shall be an open circuit water system with cooling water drawn from the penstock. The hydro-cyclones shall be provided to remove particulate matter before distribution to the separate oil coolers, following which, the cooling water shall be discharged into the unit tailrace outfall downstream of the common cooling water sump.

The cooling water discharge temperature shall not be more than 5ºC greater than the inlet temperature.

18.4 Particular Requirements

18.4.1 Hydro-cyclones

The hydro-cyclone separators shall be capable of removing all particles larger than 250 microns. The separators shall be required to operate continuously while the unit is running. The separators shall be of robust construction. Eye-bolts shall be fitted to any large/heavy components that require lifting during routine maintenance/inspection activities.

The hydro-cyclones shall be lined with rubber bonded to the steel parts and the casing shall be manufactured from a number of easily replaceable sections. The vortex finder and inlet liner shall be readily interchangeable after wear. The hydro-cyclone slurry discharge line shall be connected directly to the corresponding unit turbine discharge/outfall.

18.4.2 Heat Exchangers

The heat exchangers shall be sized taking into consideration of the plant requirements and consideration of fouling factors on the exchangers. The heat exchangers shall then further be sized with 10% excess capacity.

18.4.3 Valves, Piping and Fittings

All components of the cooling water system shall be of stainless steel as far as possible. Where components are not of stainless steel and are connected to stainless steel, galvanic isolation shall be provided.

Sufficient valves shall be provided on the system to enable easy isolation of system components (heat exchangers and hydro-cyclones, without disturbance to the remainder of the system. Where 100% duty and standby facilities are provided the valves shall enable the remainder of the system to continue operating.

18.5 Tests on Completion

18.5.1 Pre-commissioning Tests

The cooling water system shall be subjected to pre-commissioning tests to prove readiness for energising control circuits and control devices. To this end tests shall include, but not necessarily be limited to (where applicable):

(i) Wiring checks of all control, indication and protection devices;

(ii) Functional checks of limit switches, actuators, pressure switches etc.;

18.5.2 Commissioning Tests

Upon completion of the pre-commissioning tests and once all generating plant is ready, the following commissioning tests shall be performed on the cooling water system to be co-ordinated with the tests of other plant:

(i) System functional checks;

(ii) Heat run/load tests; and

(iii) Reliability test.

18.6 Spare Parts

Spare parts for the cooling water system and associated equipment shall be provided for 10 years operation and maintenance, .and shall include one complete submersible cooling water pump unit including its waterproof power supply and control cables.

Section 19: Technical Specifications – Drainage Systems

19.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the powerhouse drainage system.

The drainage system shall be provided to pump out seepage water and any leakages in the power house through appropriately designed pipework. Pumps shall be installed in the power house drainage pit.

19.2 Scope of Work

The powerhouse drainage system shall be complete in all respects and shall include, but not be limited to the following;

- Appropriately sized pumps
- None return valves.
- Pump isolating gate valves.
- Discharge pipework.
- Drainage system control panel.
- Float switches

19.3 Design Concept

Drainage pumps shall be installed on lowest position of the Power house, this being the drainage pit.

The pumps shall be suitably sized to pump leakage and seepage water out of the power house. The pumps shall be of equal capacity. Each pump shall be sized to enable it cope with worst possible leakage scenario in the power house. At least one pump shall work at given time while the other one shall be a standby pump.

The pumps shall be able to start and stop automatically depending of the water level in the drainage pit. The pumps shall be activated and deactivated by drainage pit float switches.

19.4 Particular Requirements

19.4.1 Drainage Pumps

The pumps shall be located in the drainage pit. The 100% duty/standby pumps shall include automatic changeover in the event of a pump failure. Duty between the pumps will be changed periodically. Pumps shall be designed to pump water with abrasive materials (slug pumps) without wear or damage.

The design of the pump connections and associated handling equipment shall be installed to enable the pumps to be removed from the pit utilising a demountable stool and guide rails, without the need for personnel to enter the common cooling water sump.

19.4.2 Valves, Piping and Fittings

Sufficient valves shall be provided on the system to enable easy isolation of system components (pumps), without disturbance to the remainder of the system. Where 100% duty and standby facilities are provided the valves shall enable the remainder of the system to continue operating.

19.5 Tests on Completion

19.5.1 Pre-commissioning Tests

The drainage system shall be subjected to pre-commissioning tests to prove readiness for energising control circuits and control devices. To this end tests shall include, but not necessarily be limited to:

(i) Wiring checks of all control, indication and protection devices;

(ii) Functional checks of floating switches etc.;

19.5.2 Commissioning Tests

Upon completion of the pre-commissioning tests and once all generating plant is ready, the following commissioning tests shall be performed on the drainage and dewatering system to be co-ordinated with the tests of other plant:

(i) Rotation checks of pumps;

(ii) System functional checks;

(iii) Reliability test.

19.6 Spare Parts

Spare parts for the drainage water system and associated equipment shall be provided for 10 years operation and maintenance, .and shall include one complete submersible pump including power supply and control cables.

Section 20: Technical Specifications – Workshop and Maintenance Equipment

20.1 General Requirements

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of workshop, maintenance and stores facilities to support the maintenance of the Plant and Equipment.

The scope of supply for the workshop and maintenance equipment includes provision of all machine tools and maintenance equipment to fully equip the hydro power station with the necessary equipment for its effective maintenance.

Except for mobile and portable equipment all other equipment shall be installed functionally and permanently in the workshop.

All hand tools, where applicable, shall be of Chrome-Vanadium forged and polished.

20.2 Workshop & Maintenance Equipment

The Workshop and Warehouse shall be located in a dedicated building/s adjacent to the power house.

20.2.1 Scope

The scope of supply of the workshop and maintenance equipment shall include, but not be limited to, the following:

- Hacksaw/s
- Drilling Machine
- Bench Grinding Machine
- Hydraulic Press
- Mobile Electric Welding Equipment
- Oxy Acetylene Welding and Cutting Equipment
- Mobile Compressed Air Unit
- Hydraulic Jacks
- Hand Operated Chain Block
- Miscellaneous Workshop Equipment
- Electrical Test Equipment

20.3 Mechanical Equipment

20.3.1.1 Racks

Two racks of steel construction and with vertically adjustable shelves shall be supplied. Each shall have the following approximate measurements:

Height	2,000mm
Width	1,200mm
Depth	600mm

Each shall be complete with steel bottom plate, slotted angular supporting posts, metallic shelves (capacity: 200 kg each) and a cover sheet. Vertical adjustment of the shelves shall be in steps of approximately 70mm. Each rack shall be provided with seven shelves and the clamps and latches for joining the two racks, as well as all necessary screws shall be included in the supply.

20.3.1.2 Work Benches

Two work benches (3,000 x 800 x 850mm) complete with 3 drawers combination (560 x 670 x 370mm), and hard worktop.

One bench vices (150mm jaw width, 250mm jaw distance) with one pair each of lead and synthetic resin jaw chucks.

One bench vices (100mm jaw width, 110mm jaw distance) with one pair each of lead and synthetic resin jaw chucks.

20.3.1.3 Hand Tools

A range of hand tools shall be provided for use in the instrument workshop and shall include, but not limited to the following:

One (1) external micrometer (0-25mm) with friction thimble
One (1) external micrometer (25-50mm) with friction thimble
One (1) digital readout depth gauges (0 and 100mm)
One (1) dial gauges with magnetic base
One (1) height gauge (300mm) with digital readout
One (1) set of thread gauges
One (1) set of radius gauges
Two (2) Sliding digital readout callipers (1 x 150 and 1x 300mm)
Three (3) steel rules (one each 300, 500 & 1000mm long) with engraved graduations.
Two (2) combination squares (300 x 175mm) with engraved graduation and stop
Two.(2) precision squares (1 x 50mm,& 1x 100mm)
Three (3) sets of scriber points
Three (3) sets of centre punches
One (1) set number stamps 0 to 9, (3mm, 6mm)
One (1) set letter stamps A to Z, (3mm, 6mm)

Two (2) hand hack saws each with set spare blades (36 each fine, medium and coarse teeth)
Two (2) jewellers hack saws each with 24 spare blades
Two (2) sets 'ball pein' hammers (each set with one each 200g & 500g)
Two (2) nylon hammers
Two (2) sets of screw drivers (each set with blades 2 to 12mm in 2mm intervals)
Two (2) sets of Philips screw drivers (each set with sizes 2,3 &4)
Two (2) sets of 4 watch makers screw drivers in case.
Three (3) sets of files (each set 100mm and 150mm coarse cut, medium cut and fine cut of each of flat, round, half-round, triangular, and square with wooden handles)
Two (2) sets of warding files (12 in each set)
Two (2) small triangular scrapers
Two (2) sets of hexagonal nut spinners (1 through to 8mm)
Two (2) socket sets ½'' drive, sockets 1 through to 12 mm, complete with ratchet and fixed handles, extensions and steel case.
Two (2) sets open ended spanners sizes 1mm through to 12mm.
Two (2) sets ring spanners sizes 1mm through to 12mm
Two (2) pairs small tin snips
Two (2)) sets combination pliers
Two (2) flat nose pliers
Two (2) round nose pliers
Two (2) cutting pliers
Two (2) seeger ring pliers
Two (2) plumber's pliers
Two (2) locking pliers
Two (2) industrial portable percussion electric drilling machines with drill capacity up to 20mm diameter
Two (2) sets of thread taps and dies (M 4, 5, 6, 8, 10 and 12)
One (1) set of thread taps and dies (M 16, 20, 24, 30 and 36)
One (1) set of thread tap wrenches and die stock
Three (3) measuring tapes (3m)
One (1) measuring tape (20m)

20.4 Electrical Test Equipment

20.4.1 General

Test and portable equipment shall be complete with catalogues, operating manuals and accessories. Only instruments of the highest quality shall be provided. They shall be robust in design, suitable for the intended application under site conditions, capable of giving accurate results even in adverse site conditions, and shall be of reputed make, type tested, and shall be subjected to acceptance and routine test in accordance with the appropriate Standards.

20.4.1.1 Digital Insulation Resistance Tester

One Digital Insulation Resistance Tester shall be provided.

Specification shall match or exceed the following:

Rated voltage selection	1 to 5 kV in selectable steps(d.c. Volts)
Rated resistance	0 to 100,000 mega ohms (MΩ) multi-range type.
Ambient temperature	0 to 50°C
Power supply	Battery powered rechargeable from an a.c. or d.c. source
Carrying case	Complete with all accessories including 3m long test cable and range of clamps
Software	Communication software and lead supplied as standard for transfer of data to laptop computer.
Control	Programmable test functions including pre-set timer, PI calculation, LCD display

20.4.1.2 Primary Current Injection Set

One Primary Current Injection Set shall be provided.

Specification shall match or exceed the following:

Input	230V, single phase a.c., 50Hz
Output	Selectable 0-20V, 500A 0-10V, 1000A 0-5V, 2000A
Duty cycle	Continuous
Capacity	15 kVA
Accuracy	± 1%

Unit shall be supplied with all necessary cables including output test cables suitable for 2000 A and of 10m length. The cable should be provided with suitable clamps for testing of all switchgear, switchboards and control boards on the Station.

The unit shall include:

- Thermal and short circuit protection
- Pilot lamp to indicate mains ON and test ON
- Continuously variable voltage output
- Multi ratio current transformer for measuring current output

- Built-in digital ammeter with 0.5% accuracy
- Built-in digital timer with 1ms resolution
- Signal monitor with dry contact input and voltage input
- Communication software and lead supplied as standard for transfer of data to laptop computer.

20.4.1.3 Secondary Current Injection Set

One portable Secondary Current Injection and Relay Test Kit shall be provided.

The instrument shall be suitable for testing all types of electronic and electro-mechanical single and three phase protection relays based on impedance, voltage, current, frequency, harmonics, synchronization. The testing system shall be capable of flexibly simulating waveforms and transients. The system should be operable manually, semi-automatically and automatically and shall match or exceed the following:

The testing system shall generate at least four independent voltages and six independent currents with the facility to control their amplitudes and phase angles independently. The kit should have df/dt facility (i.e. frequency variation with respect to time).

Voltage and current outputs:

Four phase voltage output:	0-300V
Six phase current output:	0-30A

There shall be provision for increasing three phase current using an external current amplifier.

Output power for voltage :	4 x 85VA
Output power for current:	6 ×70VA

Power supply requirements:

Nominal input voltage	230V ± 15%V a.c., single phase
Frequency	50Hz ± 5%

Timer section:

There shall be at least 10 (binary) independent input contacts each with voltage rating at least 300V d.c. and a.c. Contacts shall be galvanically separated.

Measuring time	0-99,999sec.
Resolution	0.1ms

The unit shall also have at least 6 independent, galvanically isolated, output relay contacts with the following specification :

Voltage :	300 V AC/DC
Current:	1A continuous, 8A max

The relay testing kit shall incorporate auxiliary DC voltage with range 24V- 250V and output power minimum 70W.

Generator frequency range:

Continuous signals	d.c. – 10,000 Hz
Frequency accuracy	± 1 ppm
Frequency resolution	1 mHz

The relay testing kit shall be computer compatible, but capable of being operated either with or without a computer. A keyboard on the front panel and an on-board digital display shall be provided for manual operation and for variation of all parameters. A laptop computer pre-loaded with relay testing software should be provided for fully automatic operation of the relay testing set.

Software:

The software should be easy to use without the requirement for extensive training and should be possible to use in manual, semi-automatic and fully automatic modes. It should be possible to automatically create the IEC and IEEE standard waves and/or create other characteristics using standard circular lens and linear elements. The software should also contain an automatic test plan editor to create automatic test plans for new/unknown relays easily and without programming knowledge. The kit should have the capability to accept transient fault data recorded by disturbance recorder and the relay under test. It should be able to perform both static and dynamic testing such as fault and pre-fault generation, simultaneous ramping of quantities and editing waveforms etc.

Calibration:

Apart from self-calibration (software), the system shall also be provided with an independent calibration box as an independent external means of verifying the relevant parameters. It shall be possible to calibrate the calibration box and therefore the kit to relevant International standards.

Analogue inputs:

The kit shall have analogue inputs for measurement of a.c./d.c. current and voltages (both low and high) as follows:

D.C. current measuring inputs (Low)

Measuring range	± 20mA
Accuracy	0.01%

D.C. voltage measuring input (Low)

Measuring range	± 10V
Accuracy	0.01%

A.C./D.C. current measuring input (High)

Measuring range	± 10A d.c., 10A a.c. rms
Accuracy	d.c. < 0.1%, a.c. < 0. 3%

A.C./D.C. voltage measuring input (High)

Measuring range	± 220 V d.c., 150 V a.c. rms
Accuracy	d.c. < 0.05%, a.c. <0.2%

Phase Shifting Kit:

A phase shifting kit, with provision for digital display of phase angle, shall be included for testing relays in situations where current, voltage and phase angle must be varied independently.

Range	0-360° variable
Accuracy	1° or better
Resolution	0.1° or better

20.4.1.4 Laptop /Desktop Computer

Computers (Laptop/Desktop) shall be provided for field use by electrical maintenance personnel. Each computer shall be provided with a docking station giving access to network external hard drive backup facilities.

The computers shall be robust industrial models suitable for field use.

Specification of each computer shall match or exceed the following:

Processor:	2.4Ghz or faster Intel processor.
RAM:	1024 MB minimum
CD/DVD/CDRW drive:	1 x CD-RW drive
Hard disk:	120 GB minimum
Display:	Integral TFT screen, 15.6" (Laptop) or 21" (Desktop)
Ports:	1 x spare PC card (PCMCIA) type II slot 2-4 x USB port The laptop must be capable of simultaneous output to an external colour display
Expansion:	1 x spare RAM expansion slot

Pointing device:	1 x integrated pointing device (touch pad or other device) plus external mouse (or equivalent) with a suitable connection.
Keyboard:	Standard keyboard with full-size keys
Networking:	On-board 10/100 network interface
Power:	1 x Lithium Ion rechargeable battery, 1 x mains adapter. Battery to have minimum of 4-hour life under continuous use.
Carry Case:	Carrying case with handle, sufficiently large to carry the computer, mains adapter, disks and CDs
Operating System:	Microsoft Windows XP Pro
Software:	In addition to specialist software as required, the computers shall be provided with general Office software including Microsoft Excel

20.4.1.5 Digital Earth Tester

One Digital Earth Tester shall be provided.

Specification shall match or exceed the following:

The earth tester shall be of the four pole type for measuring earth electrode resistance and soil resistivity. It shall be of the battery operated digital type. Hand-crank type shall not be accepted. The equipment shall be of rugged construction, suitable for field use and complete with 4 ground probes, necessary length of test leads, terminal shorting bars and robust carrying case.

Earth Resistance Ranges	0.02 to 10 kOhm (Auto ranging)
Accuracy :	±1%
Display	L.C.D display
Voltage Withstand	240V a.c. between any two terminals
Working temperature range :	0°C to 50°C

20.4.2 Electrical Hand Tools

A range of hand tools shall be provided for use by the electrical maintenance personnel and shall include, but not limited to the following:

Vacuum cleaner	1
	1
Infrared digital thermometer	1
Stabilized power supply 0/240V and 2 x 0/120V, 10A	1
Double stabilized supply 2 x 60V 5A	1
Autotransformer variable	1

Current generator 0/20mA	1
Pressure Transducers	
Ammeter 0 to 10A alternating and direct cl 0.5	1
Wattmeter cl 0.5	1
Set CT reducers for class 0.5 meters	1
Shunts for class 0.5 meters	1
Bridge RLC	1
Optical tachometer (with magnetic base and fixing tools)	1
Hygrometer	1
Polarimeter	1
Microammeter	1
Calibrated pump for test of gas and oil surge relay	1
Ohmmeter box 0.1 ohm to 1 kilo ohm (kΩ)	1
Electric Soldering iron with thermostat control 200W 230V	1
Electric fine soldering iron with thermostat control 50W 230V	2
Desoldering set with thermostat control	1
Vice for electronic circuit	1
Hot air gun 1000W 230V	2
Logic circuit tester	1
Junction tester	1
Protocol analyser	1
Endoscope equipment	1
Vibration analyser	1
Digital multi meter (electrical)	3
With matching adaptors	
Adaptor for 50kV	1
Capacity meter adaptor	1
Current clamps	
3000/1 for cable ϕ 54mm	2
1000/1 for cable ϕ 30mm	2
1000/1 for thin cable	2
Digital multi meter (I & C)	3
With matching adaptors	
Current clamps	
1000/1 for cable ϕ 30mm	2
1000/1 for thin cable	2
Phase rotation indicator 50/600V	3

Together with:

Three (3) sets combination pliers
Three (3) flat nose pliers
Three (3) round nose pliers
Three (3) cutting pliers
Three (3) seeger ring pliers
Three (3) plumber's pliers
Three (3) locking pliers
Three (3) sets Swedish pattern pipe wrenches each set (one 150mm & 300mm)

20.5 Tests for Workshop and Maintenance Equipment

20.5.1 Workshop and Maintenance Equipment Factory Tests

All workshop and stores equipment shall be subjected to inspections and tests at the manufacturer's factory, or type test certificates provided, as required by the Contract and the relevant applicable standards.

The tests shall include functional tests of all machine tools, plant and equipment.

Machine tool and instrumentation accuracy shall be tested and run out recorded.

20.5.2 Workshop and Maintenance Equipment Tests on Completion

20.5.2.1 Workshop and Maintenance Equipment Pre-commissioning Tests

Machine tool levels and run-out shall be tested and recorded following installation. The run-out test result shall be equal to or better than the factory run-out test results.

20.5.2.2 Workshop and Maintenance Equipment Commissioning Tests

Tests on Completion of the workshop and maintenance equipment shall include functional tests on the installed machine tools, plant and equipment.

20.6 Spare Parts

Spare parts for the workshop and maintenance equipment, including fork lift truck, shall be provided for 10 years operation and maintenance.

Section 21: Technical Specifications – Fire Detection and Protection

21.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of fire detection and protection systems for the Powerhouse.

21.2 Scope

The fire detection and protection systems shall be provided including, but not limited to, the following

- Fire detection in the Powerhouse.
- Central fire alarm panels in the Powerhouse Control Room.
- Handheld fire protection equipment (Extinguishers) including foam, water, CO_2 and dry powder.
- Fire fighter's equipment.

21.3 Design

21.3.1 General

The fire detection and protection systems shall be complete in all respects including all components necessary for a complete functioning system under all service and maintenance conditions.

In addition to obtaining fire detection and protection design approval from the Employer, the Contractor shall be solely responsible for ensuring that the fire detection and protection systems are approved by the necessary relevant authorities of the Republic of Zambia

Instructions for the operation of all fire detection and protection equipment including extinguishers and fire equipment cabinets shall be clearly legible in the English language.

The Contractor shall be solely responsible for identifying all credible fire scenarios and shall carrying out a detailed Fire Risk Evaluation for all aspects of the works including establishing appropriate fire zone areas. However a preliminary Fire Risk Evaluation is included at the end of the section. On this basis the fire protection and detection facilities shall include, but shall not be limited to, those described in this section of the Technical Specification.

The design, specification, material selection, construction and operating practices of the fire detection and protection system shall provide for personnel safety and property preservation. The design shall include the following principles:

- Minimisation of all potential sources of fire, explosion, excessive heat, faults, fuel and combustible or flammable materials;
- Detection of incipient fire hazards and provision of appropriate signals for personnel and equipment responses;
- Separation and isolation of potential sources of fire, explosion or smoke from each other and surrounding equipment or spaces;
- Limitation of the spread of fire and smoke to other areas;
- Provision of appropriate responses of fire suppression and isolation systems to incipient fires, including safe heat and smoke removal;
- Provision of safe egress routes from all areas

21.3.2 Codes and Standards

Equipment shall be designed, manufactured and put into service in accordance with British and NFPA standards.

21.3.3 Fire Detection and Alarms

The fire detection and alarm system including all detectors, wiring, fire alarm panel together with local sirens and sounders shall be provided for all areas within the Powerhouse.

The fire alarm panel shall be mounted within the Powerhouse control room

Zone alarms and system status shall be relayed to the station Control and Monitoring System. The fire detection and alarm system shall operate either from the station a.c. auxiliary UPS supply or the Station D.C. auxiliary system.

The fire detection and alarm system shall be supplied by power from a secure power supply system.

21.3.4 Fire Protection System

21.3.4.1 Portable Extinguisher

Portable fire extinguishers shall be provided throughout the works in types, numbers and capacities provide effective first line fire protection in the zones and at the locations identified in the Hazard Risk Assessment and to comply with fire protection requirements of the Republic of Zambia.

The fire extinguishers shall be of and shall be of a make and type that is readily serviceable and refillable in the Republic of Zambia.

Portable fire extinguishers shall be provided including, but not limited to, the following:

Area/Room	CO_2	Dry Powder	Water	Foam	Notes
Power House					
Generator Floor	x2	x2	-	x2	
Generator Units	-	-	-	-	CO_2 – Generator CO_2 fire protection
Turbine Floor	x2	x2	-	x2	
Inlet Valve Floor	-	x2	-	x2	
Battery Room		x2	-	-	
Battery Charger Room	x2	x2	-	-	
Warehouse	-	x1	x1	-	
Management House	x2	x2	-	-	
Protection Room/panels	x1	x1	-	-	
Toilets	-	-	-	-	
Workshop	x2	x2	-	x2	

21.3.4.2 Generator Fire Protection Equipment

The protection of the generator units shall be by a dedicated CO_2 flooding system operating within each generator enclosure. The generator CO_2 system shall include, but not be limited to, the following:

- A CO_2 fire protection system shall be supplied, designed in accordance with NFPA 12.
- Each battery to consist of two banks of carbon dioxide cylinders, each arranged for initial discharge and delayed discharge. One bank shall be connected to the discharge manifolds with the second bank available in reserve.
- Over temperature sensing and alarm initiating devices, including at least 4 detectors, shall be installed in the hot air path at the back of each generator core.
- The equipment shall be complete with rechargeable cylinders, cylinder racks, safety interlocks, gas extraction fans, discharge nozzles, pipework and remote

initiation controls so that the protection can be initiated from the unit local control panel by push-button.

- Local manual and remote electrical initiation valves.
- One carbon dioxide concentration detection meter.

21.3.5 Fire Fighter's Equipment

Fire fighters equipment for fire fighters shall be provided including, but not limited to, the following:

- Fire suits, including boots and helmets - 2 sets
- Breathing apparatus - 4 sets
- Axes - 2 off
- Trolley mounted foam fire extinguisher - 2 off
- Dedicated storage cabinet for fire fighters equipment - 2 off

This equipment shall be stored in the fire fighters equipment dedicated storage cabinets to be located within the Powerhouse ground floor.

21.4 Factory Acceptance Tests

All fire detection and protection equipment shall be subjected to inspections and tests at the manufacturer's factory, or type test certificates provided, as required by the Contract and the relevant applicable standards.

The tests shall include functional tests of all plant and equipment.

21.5 Tests on Completion

21.5.1 Pre-Commissioning Tests

Pre-commissioning tests of the fire detection and protection systems shall include, but not be limited to, functional tests of system components including controls detectors and annunciators.

21.5.1.1 Commissioning Tests

There are no specific 'Functional Guarantees' directly associated with the fire detection and protection plant, however tests to be carried out during the commissioning period shall include, but not be limited to, the following:

- Tests shall be carried out to demonstrate that fire detection and protection systems meet the design and performance criteria.

- Demonstration of stability and sensitivity of the fire detection and alarm system.
- Inspection of the installed systems by the relevant fire authority of the Republic of Zambia and compliance with their reasonable requirements.
- Reliability Test.

21.6 Spare Parts

Spare parts for the fire detection and protection systems shall be provided for 10 years operation and maintenance.

Section 22: Technical Specifications – Generators, Excitation and Associated Equipment

22.1 General

This section of the Employer's Requirements covers requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of one synchronous generator and associated excitation equipment.

Each generator unit shall be directly coupled to the Turgo turbine as detailed in 'Technical Specification – Turbine & Governors'.

The rated terminal voltage shall be 0.4 kV.

22.2 Scope

The generator and associated equipment shall include, but not be limited to, the following:

- synchronous generator
- neutral earthing connections, including neutral earthing transformers, loading resistors and current transformer
- line terminal boxes, voltage transformers and current transformers
- all generator bearings, including lubricating oil tank and circulation system
- braking systems
- excitation systems and transformer
- control system

22.3 Main Generator Data

Rating	MVA	
Power factor		
Inertia (GD^2) (Combined turbine and generator)	tm^2	
Rated voltage (to be confirmed by the Design and Build Contractor)	V	400

Rated speed (provisional)	rpm	600
Frequency	Hz	50
Insulation class all windings	IEC 60034	F
Temperature rise all windings. (at altitude 1,000 m)	IEC 60034	C
Synchronous reactance	p.u.	
Cooling		
Excitation		

22.4 Performances and Guarantees

The generator and the excitation system shall be capable of running continuously at the maximum outputs under rated conditions and at generator voltage ±10 percent at full load without the temperature rise of any part exceeding those permitted for Class B insulation specified in IEC 60034-1.

The stator winding temperatures shall be measured by embedded temperature detectors. The rotor winding temperatures shall be measured by resistance whilst the generator is running on load.

For the commissioning tests, temperature detectors and the stator and rotor temperature indicators shall be used as well as any other equipment that may be necessary to determine the temperature rise.

The station output guarantee and combined turbine and generator output and efficiency guarantees shall be provided in the Contract Agreement. The separate losses and efficiencies of the generator shall be determined by the results of specified tests in accordance with IEC 60034-2.

The reactances and time constants of the generator, together with relevant tolerances, shall be determined from the results of specific tests in accordance with IEC 60034-4.

22.5 Particular Requirements

22.5.1 Rotor

22.5.1.1 Maximum Stresses

The stress in the different fixed and rotating parts of the equipment shall not exceed 2/3 of the yield stress of the metals used under worst conditions (runaway).

The rotor shall be designed to obviate any potential for fatigue failure.

22.5.1.2 Bolts

Bolts in structural elements shall be pre-stressed. Maximum bolt stress shall not exceed 80% of the elasticity limit. The bolt material shall be steel grade 8.8, unless other material can be justified.

22.5.1.3 Critical Speed

The Contractor shall provide critical speed calculations to the Employer for review. The calculation shall take into account the influence from turbine, the complete bearing support and the bearing structural stiffness. The first critical speed shall exceed 125% of the maximum speed of the unit.

22.5.1.4 Shaft

The shaft shall be of a single steel forging.

Shaft movement inductive sensors shall be provided to detect the movement of the shaft. The design of the neighbouring stationary parts shall allow access for the installation and subsequent maintenance of the sensors.

The maximum radial elastic deformation if 50% of the poles are excited at rated field current and the other 50% of poles are without field current, shall not be more than 75% of the air gap at 140% rated speed.

22.5.1.5 Fixing of Rotor Elements

The connections between shaft, spider and rotor ring shall be based on shrink fits sufficient for handling the torque at rated output at a power factor of 1.0. These shrink fits shall be 100% secured by sets of wedges. The maximum deviation from a true centred circle shall not exceed 0.1mm.

The connections between shaft, spider and rotor ring shall be capable of withstanding 1.4 times rated speed or 100% load rejection speed, which ever is the greater, without any loosening. Guiding elements shall be installed to bring the rotor ring back to its original position if the speed for some reason has exceeded that. The rotor shall be secured against any axial movements and shocks between the shaft, spider or rotor rim, such as may occur during load rejection or other transient conditions.

22.5.1.6 Poles and Damper Winding

The poles shall be made of steel laminations with sufficient electrical insulation. There shall be a complete damper winding of copper, covering not less than 40% of the pole surface. The damper winding shall be capable of handling not less than 30% negative sequence current continuously. A sudden 3-phase short circuit at rated voltage shall not create any damage or permanent deformation. The end sheets of the pole lamination may be of copper for the electrical connection of the damper winding from one pole to the next. Any jumpers from the damper winding of one pole to the next shall be designed to allow the movements of the poles without harmful deformations.

22.5.1.7 Field winding

All insulation details of the field winding shall fulfil the requirements of temperature class F or better. The minimum distance from uninsulated copper to other conducting material shall be more than 15mm.

The field winding shall be mechanically supported to withstand any permanent mechanical deformations due to centrifugal forces by maximum permissible speed. There shall be an allowance for close to free axial thermal expansion due to heating by maximum field current.

The design shall allow for splitting the electrical circuit between the shaft internal circuits and the pole end feeders for insulation resistance measurement.

22.5.1.8 Lifting and handling

The rotor shall be designed for easy and safe dismantling out of the stator. Special tools and lifting lugs shall be provided.

22.5.1.9 Rotor Fans

Necessary air pressure and flow shall be provided by integrated rotor fans. If double sided axial fans are supplied, the two parallel circuits at the rotor shall be physically separated by air guiding elements. The cooling shall provide even cooling over the length of the generator including the end windings.

22.5.2 Stator

22.5.2.1 Stator Frame and Core

The stator frame shall be rigid and capable of carrying the loads under all foreseeable conditions, transient as well as stationary without any harmful vibrations or deformation.

The frame and mounting shall be designed to minimize the transmission of vibration to the concrete foundation and to associated pipework and other equipment. The design shall allow radial movement of the stator assembly due to thermal expansion and contraction while retaining the capability of withstanding forces caused by short circuit conditions.

The stator core shall be built up of laminations to form a complete ring and shall not be sectionalised. The laminations shall have high permeability and low loss characteristics and be insulated using a system and materials of established design. The design of the core and clamping arrangements shall ensure a regular and uniformly tight core which can be so maintained throughout the service life of the generator.

22.5.2.2 Stator winding

The number of slots and the connection of the winding shall be arranged to avoid harmful interference with the fundamental magnetic flux from the rotor and sub harmonics from the stator winding.

The wedging and the filler materials of the winding shall be of Class F material or better in accordance with IEC 60085. Details of the winding and the insulation system shall be stated.

22.5.2.3 Insulation system

Stator winding insulation may be of either:

- epoxy rich or VPI impregnated and cured bars/coils inserted and wedged into the slots

or

- VPI impregnation of the stator winding and cured together with the stator core (compact).

22.5.2.4 Test records

The insulation process and the components used shall be under strict quality control. Test records shall be submitted not less than 10 working days after the impregnation and curing process is completed. It shall identify all insulation materials used. For each component production date, expiration date and a statement of proper storage (mainly temperature) shall be documented. It shall also identify main insulation and curing records like vacuum (if any), pressure, temperature and time

22.5.2.5 Wedging

The winding shall fit tight into the stator slots. There shall be a firm positive pressure between the winding and the wedges.

For impregnated coils inserted in the stator core: To avoid/ reduce dielectric slot discharge, an efficient semi-conductive layer shall be applied on the coils. This semi-conductive layer shall be in good electrical contact with some semi-conductive felt. This felt shall be in good electrical contact with the stator core. The surface of the slots shall be sandpapered and the electrical conductivity shall be measured prior to installation of the coils. Unless "round pack" is applied, this felt shall be installed on one side of the coils only.

22.5.2.6 Loss factor – tan δ

Each stator coil shall be tested for the loss factor tan δ in steps of 0.2 times rated voltage (Un) from 0.2 Un to 1.0 Un (For compact insulation; the complete winding). For voltages below 0.6 U_n the loss factor shall be about constant and less than 0.5%. –

The ignition level for partial discharge shall be above the maximum phase voltage. The difference of tan δ for each phase at the same test voltage shall not exceed 2%. The increment - delta tan δ – per measuring step shall not exceed 0.2%.

22.5.2.7 Earthing

The stator frame shall be connected to the main earthing system.

22.5.3 Cooling

22.5.3.1 Water cooling

The cooling air of the generator shall be cooled by air flow from the generator fan. The generator bearings shall be oil cooled from oil-water heat exchangers.

Wetted surfaces of the valves shall be corrosion protected by stainless steel/ non corrosive alloys.

A shut-off valve before the inlet and a control valve after the outlet valve shall be installed at each heat exchanger. The heat exchanger shall not be drained during a normal stop. Small valves for drainage and air ventilation shall be installed at each heat exchanger. Between the inlet and outlet valve of each heat exchanger and shut off valves, blanked off 25 mm tappings points shall be provided to facilitate chemical cleaning.

The heat exchanger and its arrangements shall also be designed to allow for mechanical cleaning by brushes.

22.5.3.2 Main and Neutral Connections

Main and Neutral terminal boxes or cubicles shall be provided with the Main terminals on the side closest to the switchyard and the neutral on the opposite side. The voltage and current transformers (PT and CT) shall be integrated in the generator's separate Main and Neutral cubicles.

A neutral earthing system shall be provided for the generator.

The neutral connections shall be designed for full phase to earth voltage and be capable of carrying maximum earth fault current in the event of a fault. The neutral shall be connected through a neutral transformer or resistor.

22.5.4 Bearings

22.5.4.1 Bearing pedestals

The bearing brackets shall be designed for stiffness sufficient to fulfil the requirements for critical speed. The length and dimensioning of the anchoring bolts shall be sufficient for handling the forces during any foreseeable transient condition, including its pre-stressing.

22.5.4.2 Bearings

Bearings shall be of the hydrodynamic type. The oil volumes shall be sufficient to cool the bearings under the most extreme conditions (full load rejection, no breaking and no cooling water flowing).

The bearings shall be designed for the weight of the rotating parts of the generator and flywheel normal and transient hydraulic forces in any direction. The bearing metal shall be tin based babbit metal.

The lubricating oil quality shall be the same as that used for the generator (ISO VG 46 or 68). The lubricating systems shall be designed such that in normal operation, oil changes are not required more than once every five years. When oil changes are required they will be on the basis of oil analysis and the Contractor shall provide details of lubrication oil analysis values in the O&M manuals.

Each bearing shall be furnished with tappings for oil tests samples. Oil leaks, spills or vapour/mist will not be accepted, nor will condensation of oil drops on cold or other surfaces.

22.5.5 Brakes

The generator unit shall be provided with a braking system.

22.5.6 Instrumentation

The following types of instrumentation shall be provided:

Location/ purpose	**Type**
Stator winding	Pt100
Stator core	Pt100
Cold air	Pt100
Warm air	Pt100
Guide bearing	Pt100
Thrust bearing	Pt100
Lube oil	Pt100
Cold water	Pt100
Warm cooling water	Pt100
Cooling water flow	Adjustable flow switch with dial
Oil level (visual type)	Contacts for 4 levels

Location/ purpose	Type
Oil level	Dipstick
Brake pressure	Contact manometer with dial
Warm and cold air & cooling water	Alcohol thermometer

22.5.7 Excitation System

A complete excitation system including a automatic voltage regulator (AVR) shall be supplied for the generator unit.

22.5.7.1 General Requirements

The Contractor shall demonstrate that the exciter and AVR system has had proven track record of reliable operation of not less than five years. It is a fundamental requirement that the automatic regulating equipment gives correct, safe and long term continuous operation of the generator.

Exciter voltage shall be suitable for the operation. The excitation system shall have a continuous capability of not less than 110% of the excitation required for the generator when the latter is delivering 100% rated kVA and at 105% rated voltage, 0.8 power factor, lagging and 0.95 leading at rated frequency. The system shall have a rate of response not less than 2.0 per unit per second as defined in IEC 60034-16. Provision shall be made for both manual and automatic control of the exciter voltage. Manual control shall be provided which shall be effective should the voltage regulator fail.

Means for adjusting the set point voltage for the automatic regulator shall be provided. Adjustment shall be possible locally at the equipment and from a remote point. The required set point range shall be 0 to 125%.

The equipment shall be of robust construction and so designed that it requires minimum maintenance. Easy access shall be provided to all parts requiring periodic attention or replacement. The main and standby automatic control circuits shall be electrically and physically segregated such that maintenance can be safely carried out on the faulty circuits whilst the machine remains in operation.

Control equipment shall comply with the general requirements for electronic control equipment in these Specifications.

22.5.7.2 Automatic Voltage Regulator

The AVR, of proven design, to be provided shall incorporate the following features:

The voltage regulating system shall be digital, microprocessor based.

A reference voltage of adequate stability shall be provided together with means for adjustment to give the generator terminal voltage range required.

As a measure of the accuracy of control, the equipment shall be capable of maintaining the generator terminal voltage within 0.5 per cent of the preset value for a gradual change of output within the specified load range of the machine.

The regulating equipment shall be free from voltage drift due to temperature error, ageing or similar causes. It shall be insensitive to frequency changes between 48 to 51 Hz.

When the generator is subjected to a sudden loss of full load at rated power factor, the automatic excitation control equipment shall be capable of limiting the momentary overvoltage of the generator to a value not exceeding 20% of the rated. It shall also restore the voltage to within 2 per cent of the nominal preset level within a period not exceeding 0.5 seconds.

1. Local/remote auto control and local manual control.

2. Local and remote voltage set-point controllers with both digital and analogue set point control.

3. Auto/manual and local/remote change-over switches.

4. Automatic change-over to manual on failure of the automatic channel.

5. Automatic follow-up such that in the event of a change-over from the automatic channel to the manual channel or vice versa, no significant change of excitation shall occur.

6. A manual control limiter to prevent the manual control follower from reducing the manual setting below safe limits.

7. An under-excitation or MVAr limiter to prevent the regulator reducing the excitation below safe limits. The setting shall be adjustable and dependent on the generator power (MW) output.

8. Over-excitation limiter to over-ride regulator action, limiting action either immediate or delayed.

9. Volts per Hertz limiter to operate in such a manner as to cause the regulated voltage to decrease in proportion with the frequency reduction, if the frequency falls below a predetermined value.

10. Power factor / reactive current regulation.

11. Current compounding to improve regulator operation under power system voltage dips.

12. Under manual control, ability to regulate the excitation between 0% and 110% of the excitation range for commissioning purposes.

13. Black start facility.

The main generator voltage control shall be accomplished basically by the continuous comparison of the average three phase voltage of the generator with a reliable and stable reference meeting the requirements of the manufacturer's regulating system. There shall be no appreciable dead band. Matching current and voltage transformers required for AVR operation shall be included in the supply.

The AVR shall continuously and instantaneously respond to correct any change in generator voltage and shall maintain the generator voltage under steady state load conditions, without hunting, within plus or minus 0.5% for any excitation within the operating range of the AVR. Under steady-state conditions with the generator open-circuited the AVR shall hold the terminal voltage of the generator to not more than 105% of its setting up to an overspeed of 50%.

Monitoring unit: Facilities shall be provided for checking the operation of the various circuits in the regulating equipment by station maintenance staff. These facilities may consist of permanently installed instruments and switches; of a portable diagnostic unit that can be plugged into the regulator, or of test sockets and the necessary portable instruments.

22.5.7.3 Field Suppression

A field suppression switch shall be supplied complete with the necessary discharge resistance to discharge the generator field under the most arduous asynchronous running conditions; also to protect the unit under fault or runaway conditions.

Field circuit breaker: The suppression equipment shall include a multi-pole circuit breaker suitable for connection between the generator field circuit and the direct current excitation supply.

The circuit breaker position inside the cubicle shall ensure that no damage results to the cubicle or to ancillary apparatus contained therein when the circuit breaker opens under the worst fault conditions.

The circuit breaker shall be arranged and interlocked with the suppression equipment to allow for safe manual and electrical closing and tripping. The trip coil shall-be suitable for energizing by the contacts of a tripping or shutdown relay. Close and trip coils shall be designed for operation on a direct current supply, and shall operate correctly over a supply range of 70% to 100% rated supply voltage.

The circuit breaker shall be arranged for remote and local trip-free operation. The circuit breaker shall be rated not less than the maximum continuous current of the circuit under any of the specified conditions of the generator and shall also be capable of interrupting the field circuit successfully under maximum possible short circuit conditions. The contacts shall be of a type which is readily accessible for inspection and replacement. A circuit breaker enclosed in a moulded case will not be acceptable.

22.5.7.4 Exciter Control Cubicles

Metal enclosed cubicles of approved appearance shall be furnished to house the excitation, voltage regulation and field suppression equipment. Each cubicle shall consist of rigid, self supporting enclosed panels with removable front access doors to provide easy access to the equipment. Louvres necessary for adequate ventilation shall be provided where required, and shall be so designed or screened as to prevent the entrance of vermin. All screens in front of air passages must be readily accessible for cleaning. Anti-condensation heaters shall be incorporated. Doors shall be provided with locks approved by the Employer. Floor sills (structural channels) and anchor bolts shall be furnished with the cubicles. Temporary lifting eyes shall be bolted to the top of the cubicles and shall be removed after installation.

Interior lighting shall be provided, with internally mounted switch. The wiring to all apparatus shall be brought out to readily accessible terminal boards with an adequate number of spare ways and gland plates fitted with compression type glands with armour clamps for multicore armoured cables.

All interconnecting cables between the generator and the exciter control cubicles and the unit local control board shall be supplied by the Contractor.

All controls and equipment necessary for the automatic and manual control of the generator excitation system shall be supplied and mounted on the exciter control cubicles in an approved manner to provide a fully functioning system.

Provision shall be made on the front of the exciter control cubicle for displaying general excitation alarms.

Indicators, instruments and auxiliary equipment

Indication shall be provided on the excitation control panel, either by lamp or semaphore, of the status of the field circuit breaker.

In addition there shall be a mechanical indication on the field circuit breaker to show open or closed.

Provisions shall be included for the remote indication of the status of the field circuit breaker on the Control Room equipment.

It shall be possible to trip the field circuit breaker, either manually or electrically, without opening the door of the circuit breaker cubicle.

The excitation circuit earth fault protection equipment shall be located inside the field circuit breaker cubicle.

The cubicle shall also contain the transducers necessary for the field ammeter and the field winding temperature indicating instrument.

22.5.7.5 Excitation system protection

General: Adequate protection shall be provided for the generator excitation system equipment. The protection equipment shall prevent damage to the generator or to the excitation equipment, due to faults in the excitation circuits, by initiating an appropriate trip.

The Contractor shall include protection for all prospective fault conditions.

Excitation system faults: The excitation system protection equipment shall detect at least the following conditions:

- Failure of automatic voltage regulator.
- Short circuit across the excitation system output.
- Failure of standby excitation current regulator.
- Insufficient rectifier capacity available.
- • Sustained excitation in excess of equipment continuous rating.
- Loss of field, or sustained low excitation.
- Excitation circuit earth fault.

The response of the protective devices shall not open the field circuit breaker if the generator circuit breaker is closed.

Generator field circuit earth fault protection: Generator field circuit earth fault protection shall be provided and shall respond if the insulation resistance of the circuit is below 5 kilohms. The output relay shall be of a type suitable for operating in conjunction with the main shutdown relay although initially the relay may be used for alarm circuits only. All necessary compensation to prevent incorrect relay response due to stray capacitive currents resulting from ripple components in the excitation rectifier output shall be provided.

22.5.7.6 Auxiliary equipment

Instrument transformers:

All instrument transformers connected to the generator shall comply with international standards.

Power supplies: Shall be provided.

Supply for starting: Means shall be provided to give initial excitation of the generator field during a normal "start-up" sequence.

The equipment shall include switching arrangements necessary for the start-up excitation supply.

The sensing and control equipment needed to detect the rise of generator terminal voltage, to initiate changeover to the main excitation equipment, and to disconnect the starting supply shall he provided. Failure to excite during the start-up sequence shall also be detected. Such a failure shall trip the starting supply and bring up an alarm.

Control switches: All switches necessary for local control of the excitation equipment shall be provided. These switches shall comply with the requirements of the international standards.

Generator field circuit connections: Connections between the generator fields shall be brushless.

Excitation circuit light current connections: All the cabling between items of excitation equipment and between this equipment and other apparatus shall comply with the requirements of these Specifications.

22.6 Factory Acceptance Tests

Factory tests shall be carried meeting the requirements of IEC 60034.

The factory tests of the generator unit shall include, but not be limited to, the following:

(a) Shaft run-out tests.

(b) Static core loss tests.

(c) Winding resistance tests.

(d) High voltage tests.

The insulation between turns of the stator coils shall be tested by impressing an alternating potential of suitable frequency across each coil so as to produce a voltage of not less than ten times normal operating voltage between adjacent turns.

All other electrical parts, such as regulator rheostats and similar devices, shall be tested individually in accordance with applicable IEC Standards, except that where the parts are in quantity production and routine tests are made, and such routine tests are in accordance with the IEC Standards, individual tests of such parts will not be required. However, in either event, certified test data covering each part shall be submitted.

The waiving of any test, or the witnessing thereof shall not constitute a release of the Contractor's responsibility to meet fully the requirements of the Specifications.

22.7 Tests on Completion

Tests on completion tests shall be carried meeting the requirements of IEC 60034.

22.7.1 Pre-commissioning Tests

The Generator shall be subjected to pre-commissioning tests to prove readiness for energising control circuits and control devices and the first mechanical run of the unit. To this end tests shall include, but not necessarily limited to:

(i) DC resistance of stator and field winding

(ii) Insulation resistance of stator and field winding

(iii) High voltage tests

22.7.2 Commissioning Tests

Upon completion of the pre-commissioning tests the following commissioning tests shall be performed on the generator, in co-ordination with the tests on other plant:

- First mechanical run – check of vibration
- Functional tests on bearing lubrication system
- Bearing heat run
- Short circuit tests, including tests on excitation
- Open circuit characteristics test including test on excitation
- Load tests
- Load rejection and overspeed tests
- Temperature rise test
    - Station Overall Output Guarantee test.
    - Turbine and Generator Output Guarantee test.
- Turbine and Generator Efficiency Guarantee test
- Reliability Test.

22.8 Spare Parts

Spare parts for the generator units and associated equipment shall be provided for 10 years operation and maintenance and shall include, but not be limited to, the following:

22.8.1 Generator

- Bearing pads for generating unit 1 set
- Journal bearing 1 Set
- Lubrication Oil Pump-motor 1 Set
- Oil Suction strainers 1 Set
- Spare parts for the excitation system, comprising:

  1 of each type of electronic card
  1 power supply (DC/DC converter)
  1 gate pulse transducer unit
  1 thyristors mounted on heat sinks
  1 set of all other types of fuses
  1 fan including motor for thyristor cooling
  1 set of closing and opening coils for field circuit breaker

22.8.2 General Spare Parts List

- Instrumentation 1 off each type or 1 complete unit set
- Valves 1 of each type
- Pressure gauges 1 of each type
- Electrical relays, switches, solenoids and devices not listed 2 of each type
- Fuses 1 of each type/size
- Lamps, lamp covers 1 of each type/colour

Section 23: Technical Specifications – Generator Power Connections

23.1 General

This section of the Employer's Requirements describes the minimum acceptable requirements for design, manufacture, assembly, testing at manufacturer's works before dispatch, packing, forwarding, erection, testing, commissioning and documentation relative to the Generator Switchgear, relays, measuring and indicating instruments included, between the generator terminals and the cable connection to the Generator Transformer.

23.2 Scope of Works

The main power connections for the generating unit shall comprise:

a) Connection between the generator terminals and the generator transformer terminals.

b) Surge diverters, current and voltage transformers and earthing switches.

c) Generator and Generator Transformer cable connection and voltage transformers.

d) Generator neutral connections:

- From the generator neutral terminals to the star point of the generator neutral;
- From the generator neutral star point to the neutral earthing transformer or neutral earthing resistor.

All connections shall be designed to withstand the corresponding full asymmetrical peak currents corresponding to the prospective maximum short circuit fault current conditions.

The neutral connections from the generators shall be designed for full phase to earth voltage.

The Contractor shall be responsible for amongst other things:

i. Storage, security and preservation at site till installation and commissioning. Storage shall be in specifically built weather-proof facilities, providing a dry and dust-protected environment.

ii. Complete erection, testing, both at the manufacturers' premises and at site, and commissioning at site.

iii. All other works incidental and connected with above services from delivery up to the handing over the equipment and the system after commissioning.

The scope of the supply also includes necessary special tools and plants required for erection and maintenance of the equipment. The Contractor shall also list out the details of tools & plants being covered under the scope of supply. The Contractor shall recommend any other in additional necessary spares to those specified hereunder required for normal operation and maintenance of the switchgear for a period of ten years.

23.1 Neutral Earthing Equipment

23.1.1 Neutral Transformers

A single-phase, 50 Hz, dry type, naturally cooled neutral earthing transformer to IEC 60076-11 or resistor earthing shall be provided for the generating unit.

The transformer and/or resistor shall be housed in a generator neutral terminal enclosure abutting the generator enclosure.

The neutral equipment shall be appropriately sized in relation to the generator setting.

Section 24: Technical Specifications – Power Transformer

24.1 General

This section of the Employer's Requirements covers the requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the power transformer complete with all ancillary equipment and spares.

24.2 Scope of Work

The following transformer and reactor shall be provided by the Contractor:

- Two 250 kVA 11/0.4 kV Generator Transformers, to be installed in the 11kV Substation.

The 0.4 kV generator transformer LV voltage is a provisional value and shall be finally selected once the generator voltage is confirmed by the Contractor. The generator voltage shall be selected by the Contractor according to his generator design, which shall be subject to the Employer's approval.

Each transformer shall be fully assembled and tested as appropriate in the manufacturer's works prior to delivery to site for installation.

24.3 System Conditions

LV: 0.4 kV, 3-phase, 50 Hz. Neutral is earthed through generator star point earthing transformer which will restrict the earth fault current to a low value.

HV: 11 kV, 3-phase, 50 Hz. Neutral solidly earthed.

24.4 Standards

The transformers shall be designed and manufactured in accordance with the following Standards:

IEC 60076-1 - Power transformers, General

IEC 60076-2 - Power transformers, Temperature rise

IEC 60076-3 - Power transformers, Insulation levels, dielectric tests and external clearances in
air

IEC 60076-5 - Power transformers, Ability to withstand short circuit

IEC 60076-10 - Power transformers, Determination of sound levels

IEC 60726 Dry Type power transformers

IEC 60085 Methods for determining the thermal classification of electrical insulation

IEC 60214 On-load tap changers for power transformers

IEC 60137 Insulating bushings for alternating voltages above 1 kV

IEC 60296 - Fluids for electro-technical applications. Unused mineral insulating oils for Transformers and switchgear

IEC 60354 - Loading guide for oil-immersed power transformers

IEC 60529 - Degrees of protection provided by enclosures

24.5 Particular Requirements

The Generator Transformers shall be installed outdoors in the 11 kV Substation.

The design of the transformers shall be based upon minimum maintenance criteria appropriate to the environmental conditions applicable to the Site and to suit the design life of the transformers. The Contractor shall provide condition-monitoring facilities. The design and manufacture of the transformers and auxiliary plant shall be such that the noise level is a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. The average surface noise level of each transformer shall not be greater than that specified in NEMA TR1. Measurements shall be in accordance with IEC 60076-10.

The transformers shall be capable of withstanding, without injury, a three-phase or line-to earth short circuit on any terminal for duration of 3 seconds. The transformer manufacturer shall supply sufficient information to the civil works contractor to ensure adequate design of the transformer mounting structure.

The transformers shall be designed with particular attention to the suppression of harmonic currents, especially-the third and fifth, so as to minimize interference with communications circuits. Transformers and associated equipment shall be designed in such a manner as to meet the requirements in this section, Technical Schedules and Drawings at ambient site conditions. Therefore the temperature-rise limits given in IEC 60076-2 and IEC 60354 (i.e. hotspot) shall be reduced accordingly to take into account correction reflective of high annual average temperature.

The transformers shall be capable of operating continuously at their maximum rated power at all tap positions within the specified temperature rise limit at 10 % over- or under excitation.

All oil pipe flanges shall be to DIN or international equivalent standards, as regards both dimensions and drilling.

The transformer losses at rated output and rated voltage shall be guaranteed.

24.6 Principal Parameters

24.6.1 Transformers

The type and principal parameters of the transformers shall be as follows:

	Generator Transformer	Auxiliary Transformer
Type of construction	Three-phase, two winding,	Three-phase, two winding
Rated frequency	50 Hz	50 Hz
Winding cooling medium	Oil immersed, mineral oil	Oil immersed, mineral oil
Type of cooling		
Continuous maximum rating at site conditions	250 kVA on all taps	
Voltage ratio		
System highest voltage		
Impedance Voltage at base MVA		To be determined by Contractor
Temperature rise	In accordance with IEC 60076 – corrected to site conditions	In accordance with IEC 60076 – corrected to site conditions
Vector Group	YNd1	Dyn11
Sound power level	$\leq$ 82 dB(A)	

24.7 Sound Power Level

The sound power level of the transformer, measured in accordance with IEC 60076-10. Cooling System

For the transformer coolers (radiators) connected directly to the tank.

Radiators and coolers shall be designed so that all painted surfaces can be readily cleaned and subsequently painted in position.

24.8 Core

The core of the transformer shall be constructed of non-ageing cold rolled grain oriented low carbon silicon steel lamination sheets.

The lamination sheets shall be deburred and coated with a high performance modem insulation coating providing a high degree of resistance to electrical, mechanical, temperature and environmental aging during the normal lifetime of the transformer. Sufficient core pressure shall be applied during the piling of the core to prevent settling of the core and to minimise core vibration and noise during the operation of the transformer. The core shall be of mitred construction and shall be of a rigid design sufficient to withstand the forces and stresses imposed on the transformer core during transportation and under the most severe short circuits that can be experienced during service. Designs shall be such that no adverse effects due to core or stray flux heating will be produced under any operating condition. The flux density in the core shall not exceed 1.7 Tesla at rated voltage and frequency.

24.9 Windings

24.9.1 Construction

The windings shall be designed to withstand all dielectric, electromagnetic and thermal stresses which might occur under the operating conditions including those produced by lightning surges, short circuits, faulty synchronising and vibration.

The conductors shall be free from scale, burrs and splinters and shall have suitably rounded edges to reduce electrostatic flux concentrations. Joints shall be welded or brazed.

The transformer windings shall be manufactured of high conductivity electrolytic copper.

The windings shall be adequately braced and shall allow for expansion and contraction due to temperature changes and also due to abnormal operating conditions. The windings shall also withstand mechanical shocks originating from handling during transport and seismic disturbances.

Adequate barriers shall be provided between high and low voltage windings and between winding and core.

24.9.2 Insulation

Winding insulation materials shall have high dielectric and mechanical strength and shall be resistant to thermal and environmental ageing due to the action of hot oil.

The high-voltage winding of the Power Transformer shall have graded insulation. The insulation level of the neutral end of the high-voltage winding shall not be less than that of the low-voltage winding. The low-voltage winding of the Power Transformer shall be uniformly insulated.

The windings and the neutral end of the high-voltage winding shall be designed to withstand the specified impulse and other tests.

24.9.3 Securing of core and windings within tank

All transformer nuts and bolts shall be locked with lock-nuts, tag washers or other approved locking means. Conductor bolted terminals shall have means of maintaining contact pressure.

24.10 Internal earthing arrangement

All metal parts of the transformers with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at earth potential.

The magnetic circuit shall be bonded to the clamping structure at one point only via a through-tank bushing and an external removable earthing link to permit disconnection for testing without draining oil from the tank.

The magnetic circuit shall be capable of withstanding a test voltage as specified by the contractor.

24.11 Tank

The tank shall be of welded steel construction and shall be designed to withstand all stresses which may occur in service, during transport and during oil treatment, including full vacuum with radiators fitted.

The transformer tank shall be of the upper flange type with bolted-on cover and shall be fully vacuum proof. Screwed joints shall not be used where oil tightness is required. The inside of the tank and cover shall present no obstructions to the passage of gas bubbles to the oil-surge and gas-operated relay.

Provision shall be made for adequate venting of all portions of the tank and tank attachments to prevent trapping of air during oil filling.

Transformers shall be designed to withstand the test pressures and vacuum specified in the standards. The tank cover shall be designed with sufficient slope to facilitate the run-off of water and to allow accumulated gas to collect at the highest point, without causing a safety hazard to personnel.

Transformer tanks shall be designed to allow the complete transformer, when arranged for transport, to be lifted by crane and transported without overstraining any joints and without causing subsequent leakage of oil. The tank shall be provided with a minimum of four jacking lugs, to enable the transformer, complete with all tank-mounted accessories and filled with oil, to be raised or lowered by jacks. The base of the tank shall be so designed that it will be possible to move the complete transformer in any direction without injury when using rollers, plates or rails. A design that necessitates either slide rails being placed in particular positions or detachable under bases shall not be used.

The plate thickness for the tank sides shall be a minimum of 6 mm.

Tank stiffeners shall be continuously welded to the tank. Mounting brackets are bolted to the tank.

Wherever possible, the transformer tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe.

The tank cover and subassemblies shall have lifting lugs. Eyes for lifting the core, coils, tank and/or tank cover shall be provided and handed over to the Owner at the completion of transformer installation. Tank covers shall not permanently distort when lifted. Inspection openings of ample size shall be provided to give easy access for checking, repair or removal of bushings current transformers and tap changer components, for changing ratio or winding connections, and for testing the earth connections. All joints at manhole, handhole and bushing openings shall be bolted and shall be provided with suitable gas and oil resistant gaskets. Gasket stops shall be provided where necessary, to prevent the gasket material from spreading and to prevent excessive compression.

The tank cover shall be fitted with a thermometer pocket, with captive screwed cap, located in the position of maximum oil temperature at continuous maximum rating.

A pressure relief device capable of functioning without electrical power shall be provided for the rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, but it shall be capable of maintaining the oil tightness of the transformer under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tanks and shall be designed to prevent further oil flow from the transformer following its operation.

The relief device shall be mounted on the main tank and if mounted on the cover it shall be fitted with a skirt projecting inside the tank to prevent an accumulation of gas within the device.

For larger transformers, a ladder attached to the side of the tank, equipped with an access barrier and locking device, shall be provided for gaining access to the top of the transformer.

A dismountable safety post and handrail system shall be provided for use during maintenance and repair operations.

Terminals shall be provided close to each comer at the base of the tank for earthing purposes.

The following plates shall be fixed to the transformer tank at an approximate height above the ground level.-

a. A rating plate bearing the data specified in lEC 60076.

b. A diagram plate on which the transformer tapping voltages in kilovolts shall also be indicated for each tap, together with the transformer impedances at minimum and maximum voltage ratios and for the nominal tapping.

c. A property plate.

d. A title plate.

e. A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices.

24.11.1 Gaskets and Joints

Gaskets shall be of approved material impervious to and having no deleterious effect on transformer oil. Gaskets made from nitrile rubber and utilising compression control stops are preferred.

All joints to be made oil-tight shall be so designed that no deterioration of the gaskets, which could give rise to oil leakage, will take place in service, and all such joints shall withstand without leakage the maximum vacuum which may be applied to the assembled transformer during commissioning or subsequent maintenance.

24.12 Conservator vessels, oil level gauges and breathers

The transformer shall be provided with a conservator for expansion of the oil which shall be sized with due regard to the full range of climatic and operating conditions. One end of each conservator shall be removable. The conservator shall be fitted with an air bag to prevent the transformer oil coming into direct contact with the outside air. The ends of the pipe connecting the transformer tank with the conservator shall be flush with the inside surface of the tank cover and protrude 25 mm into the conservator.

The main oil feed pipe from the conservator vessel to the transformer shall be connected to the highest point of the tank and shall be arranged at a rising angle towards the conservator of from 3 degrees to 7 degrees to the horizontal. A valve shall be provided at the conservator to cut off the oil to the transformer.

Where provision is made in this pipe for the installation of the oil-surge and gas-operated relay the slope of the pipe shall be not less than 3° from the horizontal and shall be upward towards the conservator, and the highest point of every pocket in the tank and attachments at which gas may accumulate shall be connected to this pipe on the transformer side of the relay.

Each conservator shall be provided with a prismatic or magnetic dial-type oil-level indicator with the dial markings visible from the ground. The indicated oil level range shall correspond to average oil temperatures from the minimum ambient to plus 90°C. The oil levels at 15°C and 35°C shall be marked on the gauge.

Taps or valves shall not be fitted to oil gauges.

Each conservator shall have a filling cap, an adequate sump, and be so designed that it can be completely drained by means of a drain valve. One end of the conservator shall have a removable end cover, complete with integral lugs for lifting purposes and secured by nut and bolt fixings, to permit internal cleaning of the conservator.

Whether or not the oil is in direct contact with air or gas the air outlet from each conservator vessel shall be connected to a dehumidifying breather, suitably sized for the high humidity conditions, which shall be mounted at approximately 1.4m above ground level. It shall be designed to achieve a minimum value of humidity and shall maintain the humidity at a level which will tend to extract the moisture generated within the conservator air bag.

24.13 Valves

Valves shall be of the full sealing full-way type and shall be opened by turning counter clockwise when facing the handwheel. They shall be suitable for working between the minimum ambient and the maximum oil temperatures.

Padlocks shall be provided for locking all valves other than individual radiator valves in the "open" and "closed" positions. Valves other than filter and drain valves shall be provided with an indicator, readily visible from ground level, to show clearly the position of the valve.

All valves opening to atmosphere shall be fitted with blanking plates.

The transformer tank shall be fitted with the following:

a. One valve at the top and one valve at the bottom of the tank, mounted diagonally opposite each other, for connection to oil circulating and oil filtering equipment. The lower valve shall also function as a drain valve.

b. An oil-sampling device at the top and bottom of the main tank. Screwed caps with chains shall be fitted to sampling valves.

c. All parts containing oil, and liable to trap air during filling, shall be fitted with a flanged type air release plug at their highest points.

In addition to valves supplied for normal operation of the transformer, pipework and valves shall be provided in convenient positions to permit the following operations:

(i) removal of coolers without draining the transformer;

(ii) Isolation of oil surge and gas relay (Buchholz relay).

24.13.1 Other fittings

The transformer shall be provided with the following fittings.

(i) Seismic restraints.

(ii) A valve for checking nitrogen pressure during shipment, protected against damage during transport.

24.14 Cooling plant

The generator transformers shall be of the ONAN type.

Radiators and coolers shall be designed so that all painted surfaces can be readily cleaned and subsequently painted in position.

MARSHALLING BOX:

1. A weather and vermin proof steel enclosure having degree of protection IP55 shall be provided for the transformer ancillary apparatus. The box shall have sloping roofs and the interior and exterior painted. The marshalling box shall be suitably mounted and the mounting arrangements drawing shall be supplied for approval during the design stage.

2. The marshalling box shall accommodate the following equipment:

   i. Temperature indicators

   ii. Terminal Boards and gland plates for incoming and outgoing cables

   iii. Illumination lamp and 5 Amp, 230V, 3 pin BS Standard socket and switch.

3. All the above equipment except (ii) shall be mounted and panels and back of panel wiring shall be used for interconnection.

4. The temperature indicators shall be mounted such that the dials are not more than 1600 mm from ground level and the door(s) are of adequate size.

5. To prevent internal condensation an approved type of metal clad heater shall be provided controlled by suitable thermostat.

6. All incoming cables shall enter the kiosk from the bottom and the gland plate shall not be less than 450 mm from the base of the box. The gland plate and associated compartment shall be sealed in suitable manner to prevent the ingress of moisture and vermin.

7. Undrilled gland plate shall be provided for accommodating glands for incoming and outgoing cables.

24.15 Temperature indicating devices and alarms

Oil temperature indicating devices shall be adjustable over the range 60°C to 110°C. The device shall have a dial type indicator and, in addition, a pointer to register the highest temperature reached. Three separate sets of contacts shall be fitted, one of which shall be used to give an alarm, and the second to trip the associated circuit breakers and to shut down the generator. For transformers having or being suitable for mixed or forced cooled ratings, the third set of normally open switch contacts shall be provided to automatically control the forced cooling plant.

Each temperature indicating device shall be supplied in a hermetically sealed case and shall be mounted on the transformer at a convenient height above ground level. It shall be designed so that it is possible to move the pointers by hand to check the operation of the contacts and associated equipment. Accuracy shall be better than ±2°C.

The winding temperature indicator shall be a thermal image device utilising an auxiliary current transformer and a heated thermowell.

Winding temperature indicating devices shall indicate the temperature of the hottest spot of the winding and shall have a load-temperature characteristic approximating to that of the main winding. Two sets of contacts shall be provided for initiating of alarm and trip relays. The winding temperature indicating devices shall be so designed that it shall be possible to move the pointers by hand for the purpose of checking the operating of the contacts and associated equipment. The working parts of the instruments shall be made visible by the provision of cut-away dials and glass fronted covers.

24.16 Bushings and Terminals

Bushings shall be in accordance with IEC 60137 (Insulating Bushings) and the associated barrel porcelains shall comply with IEC 60233 together with the requirements of this Specification. The bushings shall be designed for the insulation levels and other tests as specified and shall withstand mechanical and thermal stresses imposed by transformer short-circuit currents or seismic disturbances.

Bushing terminal contact surfaces shall be silver-plated. Oil filled bushings shall be sealed to prevent breathing, with no connection with the oil in the transformer and an oil gauge shall be provided. A facility shall be provided to view the oil level over the complete range of oil temperature of the transformers.

Synthetic resin bonded paper bushings will not be accepted.

Connections from the main windings to bushings shall be flexible and shall be such that undue mechanical stresses are not imposed on them during assembly on site. Terminal clamps shall be supplied with each bushing for flexible or rigid busbars as may be required.

Both the high-voltage and low-voltage bushings shall be designed for permanent installation during the vacuuming of the transformer. They shall form a pressure tight barrier and be capable of withstanding a full vacuum being applied to the transformer.

11 kV terminals shall comprise outdoor condenser type bushings fitted with arcing horns. The HV neutral terminal shall comprise an appropriately sized outdoor bushing.

The LV winding shall be brought out to a cable box suitable for termination of three-core stranded copper conductor cable, XLPE and steel wire armoured.

24.16.1 Cable boxes

At voltage ratings up to and including 12kV, air-filled cable boxes are preferred. LV cable boxes shall be suitable for the termination of the required number of single core cables, XLPE insulated with semi-conducting screen and aluminium wire armour.

Cable boxes shall be designed to accommodate all cable fittings required for terminating the cables, including stress-cones or other necessary means for grading the voltage stress on the terminal or the cables.

Cable boxes shall be designed to withstand the thermal and mechanical loads for which the transformer is rated; under the specified normal, overload and fault withstand conditions.

Unless specified otherwise, all cable entries shall be from below.

In the absence of IEC dimensional standards, all clearances shall be in accordance with an internationally recognised IEC-coordinated national standard, e.g. CENELEC/BS/DIN.

Cable boxes shall be sized to ensure that there are adequate connectors and glands to accommodate the agreed cable configurations of the project.

24.16.1.1 Cable Connection – Compound-Filled Cable Box (CCF)

The term 'compound-filled' includes bituminous, oil-based and oil-resin filling mediums. Cable boxes shall include filling, expansion and breather provisions. In addition, a drain valve shall be provided for filling mediums that remain liquid at normal ambient temperatures.

Where compound-filled boxes are specified, an oil-filled disconnecting chamber with removable links shall be provided for testing purposes. A barrier shall be provided on both sides of the disconnecting chamber to prevent ingress of the oil used for filling the chamber into the cable box or the transformer tank.

The oil level in the disconnecting chamber shall be maintained from the main conservator tank.

Provision shall be made in the cable box to allow for the expansion of the compound-filling medium.

24.16.1.2 Cable Connection – Air-Filled Cable Box (CAF) [Preferred]

Where air-filled cable boxes are specified XLPE cables shall be terminated with either heat-shrink or separable polymeric 'elbow' terminations.

It is a requirement that sufficient clearances and supports are available within the box to allow site testing of the transformer and cables. All terminations shall be of proven reliability and in accordance with a recognised national or international standard.

Phase segregation shall be employed when terminations do not feature fully shrouded connections. In all cases the termination will be made fully in accordance with the manufacturer's instructions.

Means shall be provided to resist ingress of dust into the cable box, whilst allowing moisture accumulations from condensation to drain. The minimum Protection Class shall be IP65.

An earthing terminal shall be provided to which the connections from the transformer winding can be earthed during cable testing.

Provision shall be made to allow low voltage cables and wiring to be terminated.

24.16.2 Neutral Connections

The preferred arrangement for neutral connections is via outdoor air bushings on the transformer cover. Earthing connection shall be by copper conductors of adequate size secured by insulators to pads on the tank wall, with bolted connections descending to the ground grid. Bare conductors will have protective covers to prevent contact by personnel. Where Neutral CTs are specified, preferred location is in the neutral bushing turrets.

24.17 Surge Arrestors

Surge arresters shall be of the metal-oxide, gapless type.

The design of equipment shall be in accordance with the requirements of lEC 60099-4, lEC: 60037(C0)38 and any additional requirements of this Specification. Each pressure vessel shall comply with the requirements of the appropriate CENELEC document and European standard. The testing of the equipment shall be in accordance with the requirements of lEC 60060 and 60270.

The surge arresters shall be designed to incorporate a pressure relief device to prevent shattering of the blocks/or housing, following prolonged current flow or internal flashover.

24.17.1 Surge Counters

Surge counters shall be provided and shall be operated by the discharge current passed by the surge arrester. Surge counters shall be of the electro-mechanical type and designed for continuous service.

Surge counters shall have weatherproof housings to IP 55 designed to allow the recording device to be read without exposing the internal parts to the atmosphere.

The surge counter shall be connected in the main earth lead from the diverter in such a manner that the direction of the earth lead is not changed or its surge impedance materially altered. A bolted link shall be provided so that the surge counter may be short circuited and removed without taking the arrester out of service.

24.18 Control cabinet

A control and marshalling cabinet shall be provided which shall house the transformer control gear as well as trip and alarm circuits. The cabinet shall be of ample size to allow easy access to terminal blocks and equipment for inspection and maintenance. The cabinet shall be made of rigid sheet steel and shall be manufactured to protection class IP55. Access to the control equipment shall be via lockable doors, which shall be restrained in the open position. Sunshades shall be provided to protect the cabinet against direct solar radiation. An accessible rigid pocket for storing diagrams shall be provided, preferably on the inside of the door.

The control cabinets shall be provided with an internal fluorescent lamp, a single phase 13 amp socket and a three phase socket. A humidistat controlled heating element shall also be provided. A removable gland plate, of sufficient size, shall be fitted in the bottom of the cabinet. Sufficient space shall be allowed above, the gland plate for the terminating and connection of cables and their cores. A copper earth bar shall be provided inside the cabinet to which all earthed equipment shall be connected. Provisions shall be provided for connecting the cabinet earth bar to the station earthing system.

All wiring shall preferably be enclosed in covered trunking and shall be installed in a neat and tidy manner. All wiring connections shall be crimped and shall be identified by slipover ferrules which shall adhere tightly to the wiring. Control circuits shall be protected by miniature circuit breakers with alarm contacts, fuses will not be accepted. The enclosure will house the control equipment for the cooling fans, and the transformer alarm and protection circuits. All alarm and trip signals shall be connected to the outgoing terminal blocks for subsequent connection to the substation control room and station SCADA system.

24.19 Oil

The transformer shall be supplied complete with the first filling of oil. Oil shall comply with IEC 60296 and shall be compatible with oil which is readily available commercially in Zambia.

The transformer oil shall be uninhibited mineral oil and shall be free from additives and foreign materials and shall not form a deposit under normal operating conditions.

Transformers that are shipped without oil shall be filled with dry nitrogen. The Contractor shall be responsible for ensuring that the nitrogen pressure is maintained during transportation and prior to filling according to the instructions of the manufacturer.

Oil shall be delivered in drums sufficient to fill the transformers and to replenish losses during processing at site.

The oil shall be treated at site to achieve the highest practicable dielectric strength.

The Contractor shall be responsible for supplying the necessary temporary oil drums, tanks or oil tankers and mobile oil filtration plant for the initial filling, drying and polishing of the oil.

24.19.1 Oil handling equipment

A complete, dedicated oil processing plant for removing solid matter, dissolved gases and moisture from transformer oil shall be provided.

The oil treatment plant should be able to achieve a standard of oil purity similar to that specified by the transformer manufacturer for the first filling, and the rate of flow shall be suitable for filling the Generator transformer within 4 hours.

The flow rate shall be variable, but when adjusted it should be steady, continuous and automatic in operation. The degasifier and the filter shall be able to operate together or independently.

The pumps shall be rated suitably for the treatment of the required quantities of oil at ground level, and to deliver oil into the highest part of the oil system of the transformers specified herein. The equipment shall be designed to operate from a 400 V, 3-phase, 50 Hz supply.

The oil processing plant shall be mounted on a weatherproof trailer suitable for movement about the Site on its own wheels.

The plant will be used:

a. For routine oil processing of transformer oil in tap changers and small low voltage transformers.

b. To process oil in the high voltage transformers specified in this document, or other similar transformers.

c. To create, under special conditions, a high vacuum in the tank of the high voltage transformers, or similar transformers. It is not expected that the vacuum pumps will have the capacity necessary for a complete transformer dry-out, but rather that they should be able to de-gas the empty tank, or the space above the lowered oil level in the tank, and then to maintain a higher vacuum whilst oil is pumped into the space.

Mobile oil storage tanks shall be supplied. Oil shall not be transferred directly from barrels into the transformers, but passed into the storage tank(s) where it shall be circulated and treated within the storage system until the oil attains the required level of purity before being transferred into the transformers.

24.19.2 Topping up with oil and drying out on Site

If oil is to be added to a transformer at Site prior to commissioning, the oil in the transformer shall first be tested for dielectric strength and water content, and each container of makeup oil shall be similarly tested.

Should it be found necessary to resort to oil treatment before a transformer is commissioned, the Contractor shall submit to the Owner, in writing, a full description of the process to be adopted, the equipment to be used and a statement of the precautions being taken to prevent fire or explosion.

Should a transformer arrive on Site without positive pressure of gas in the tank, it shall be dried out on Site.

Clear instructions shall be included in the maintenance instructions regarding any special precautionary measures which must be taken before vacuum treatment can be carried out.

Any special equipment necessary to enable the transformer to withstand vacuum treatment shall be provided with each transformer. The maximum vacuum which the complete transformer, filled with oil, can safely withstand without any special precautionary measures being taken, shall be stated in the Maintenance Instructions.

24.20 Monitoring and Protection

The transformer shall be equipped with instrumentation and protection as follows:

24.20.1 Oil surge and gas operated relay

Oil surge and gas operated relay shall be of the two element type having alarm contacts which close on the collection of gas or low oil level and tripping contacts which close on oil surge. Each relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas relay and brought down to a point approximately 1400 mm above ground level, where it shall be terminated by a lockable cock.

The design of the relay mounting arrangements, the associated pipework and the cooling plant shall be such that maloperation of the relays will not take place under normal service conditions under all operating temperatures.

The pipework shall be so arranged that all gas arising from the transformer will pass into the gas operated relay. The oil circuit through the relay shall not form a delivery path in parallel with any circulating oil pipe, nor is it to be teed into or connected through the pressure relief vent. Sharp bends in the pipework shall be avoided.

24.20.2 Temperature monitoring

Both high-voltage and low-voltage winding temperature indicators and a top oil temperature indicator shall be provided for the transformer, giving local indication of temperature and adjustable alarm and trip contacts.

In addition to local indication, continuous remote indication of winding and top oil temperature shall be provided.

24.20.3 Protection Alarms and Trips

The following alarms and trips, including the related sensors, shall be provided:

- Buchholz (gas) alarm
- Buchholz (surge) trip
- Top oil temperature alarm
- Top oil temperature trip
- Winding temperature alarm
- Winding temperature trip
- Oil level alarm
- Oil level trip
- Overpressure trip (if necessary)
- Numeric earth fault and overcurrent relay

All alarms and trips shall be monitored by the control system and shall be displayed in the control room.

24.20.4 Current Transformers

The following current transformers (CTs) shall be provided with the generator transformer, installed on the HV terminals;

Overcurrent and earth fault CT	Ratio	As required
	Class	As required
HV neutral CT	Ratio	As required
	Class	As required

The CTs shall have atleast a protection core and a measurement core.

24.21 Voltage Transformers

The following voltage transformers (VTs) shall be provided with the generator transformer, installed on the HV phase terminals;

Overvoltage/measurements	Ratio	As required

VT

Class As required

24.22 Corrosion Protection and Painting

Before painting all metal surfaces shall be thoroughly cleaned of rust, scale, grease and dirt and other foreign matter and all imperfections removed by shot blasting. The equipment must be so designed that any features that may encourage the formation of rust, are avoided.

The following painting treatment shall be applied:

Coat	No. coats and thickness	Binder	Pigment
Primer	2 x 35µm	Epoxy resin, hardened with polyamide	Titanium dioxide, zinc oxide, zinc phosphate, tinting additives
Intermediate	1 x 35µm	As above	Titanium dioxide, micaceous iron oxide, tinting additives
Top	2 x 150µm	Polyurethane hardened with isocyanate	As above

The total dry film coating thickness shall be not less than 400 µm.

Conservator vessel, radiators, fan grills, pipe-work, control boxes or cubicles, marshalling cubicles shall be hot-dip galvanized and painted. Where conservator vessels are impractically large for galvanising, the bidder may offer an identical finish to that used on the transformer tank but this must be clearly indicated in the bid documents.

External surfaces shall be treated with anticorrosive and water-resistant paint and internal surfaces with oil-resistant anti condensation paint.

24.23 Transportation

The transformer shall be transported with the core and winding sealed with a blanket of dry air, or in an inert gas under a positive pressure, after the oil has been partially or fully drained. Means shall be provided for maintaining the pressure during transport if a minor leak shall occur.

Adequate and approved means shall be provided for checking the conditions inside the sealed transformer during transit and to ascertain whether site drying out is necessary.

24.24 Tests of insulation while in storage at site

The Contractor shall measure, at not more than weekly intervals, the insulation resistance as specified, using a D.C. voltage of 2 kV.

The Contractor shall investigate and take corrective action for any significant drop in resistance compared to the values recorded at the factory or during storage.

24.25 Factory Acceptance Tests

The transformer and ancillaries shall be subjected to tests at the manufacturer's works as specified in Part 2 Section 1 and in particular the following:

24.25.1 Transformer Material Tests

The following material tests shall be carried out on all important stressed steel components.

1. Dimensional checks of all components and assemblies;
2. Non-destructive testing of welds;
3. Sample tests of core lamination material for magnetic characteristics and losses.

24.25.2 Transformer Hydrostatic Tests

The generator transformer complete with coolers and fittings and filled with oil shall be tested with an incremental pressure of 35 kPa for 24 hours and shall be completely free of leakage.

24.25.3 Transformer Bushing Tests

Type tests, sample tests and routine tests shall be conducted in accordance with IEC 60137.

24.25.4 Current Transformer Tests

Type and routine tests in accordance with IEC 60044.

24.25.5 Voltage Transformer Test

Type and routine tests in accordance with IEC 60044.

24.25.6 Transformer, Protection and Alarm Devices Tests

The proper functioning of all thermometers and other devices shall be tested.

24.25.7 Transformer Core Tests

An Insulation tester shall be applied between each core bolt and the core laminations after final tightening of bolts.

24.25.8 Complete Transformer Tests

The transformer shall be subjected to the complete series of type and routine tests in accordance with IEC 60076, including:

(a) Temperature rise test (one transformer of each type only)

(b) Dielectric type tests

(c) Measurement of winding resistance

(d) Measurement of voltage ratio and phase displacement

(e) Measurement of short circuit impedance and load loss

(f) Measurement of no-load loss and current

(g) Dielectric routine tests

(h) Tests of on-load tap-changer

(i) Partial discharge tests applied as a routine test for the Generator Transformer

(j) Full wave impulse-voltage withstand tests applied as a routine test to the Generator Transformer.

During the tests of the Generator transformer, core loss, excitation voltage and excitation current shall be measured at 10 minute intervals over a period of 6 hours with the transformer excited at rated frequency and 110 percent voltage. This test shall be made after the high-voltage withstand tests.

24.26 Generator Transformer Special Tests

Special tests in accordance with IEC 60076 shall be carried out including loss tests and measurement of sound power level.

Generator Transformer loss tests shall be carried out to demonstrate compliance with Appendix 8 of the Contract Agreement.

24.27 Tests on Completion

24.27.1 Transformer Pre-commissioning Tests at Site

The pre-commissioning tests including tests on transformer auxiliary equipment shall include the following:

(a) Check impact recorders (where applicable) on installation, and if significant impact is recorded carry out a comprehensive check for external and internal damage.

(b) Tests of transformer oil for moisture and drying out if necessary.

(c) High-voltage tests at the site test voltages specified in the relevant IEC Standards. Where site test voltages are not specified in the standards the test levels shall be 75 per cent of the factory test values.

(d) Measurement of winding resistance of transformer.

(e) Insulation resistance measurements at the specified voltages appropriate to the circuits and equipment.

(f) Ratio and polarity check of current transformers and test of magnetising curve.

(g) Proof of phasing or polarity of power cables.

(h) Proof of control connection and continuity of wiring for all control, protection, auxiliary and alarm equipment in accordance with the overall diagrams as provided by the Design and Build Contractor.

(i) Operation of all control equipment at 80 percent, 100 percent and 110 percent of rated voltage.

(j) Demonstration of sensitivity of gas and oil surge relays.

(k) Tests of all temperature and level indications, displayed quantities and analogue outputs to show such items are within the accuracy limits specified.

24.27.2 Transformer Commissioning Tests

The Commissioning Tests shall include the following:

(a) Demonstration of performance in service of all auxiliary equipment including tap changer.

(b) Demonstration that all controls, alarms and indications, including displays, operate correctly.

(c) During the above tests the whole of the equipment shall perform without adjustment.

(d) Tests to verify that the performance of transformers is in accordance with the Contract, including monitoring of winding and oil temperature during sustained loading.

(e) The Reliability Test Period.

24.27.3 Completion – Power Transformers

Upon successful completion of the Tests on Completion the equipment shall be cleaned, checked for oil leaks and all paint blemishes made good. Breathers shall be recharged with fresh silica gel before the issue of the Operational Acceptance Certificate.

24.28 Special Equipment and Tools

Works to be done under this section include the delivery of special equipment and tools for erection, installation, maintenance, setting to work and other purposes. Requirements for special equipment and tools shall be detailed by the equipment manufacturer.

These shall include among other tools but not limited to;

- Insulation resistance tester,
- Earthing resistance tester,
- Phase rotation tester,
- Multimeter,
- Contact resistance tester,
- Ductor (milliohms),
- Basic secondary injection set,
- Infrared thermometer,

Section 25: Technical Specifications – HV Substation Equipment

25.1 General

This section specifies the detailed requirements for the design, manufacture, supply, installation and commissioning of HV Substation plant and equipment.

25.2 Scope of Work

The scope of work includes the following HV Substation plant and equipment:

(i) One 11 kV Vacuum outdoor circuit breaker.

(ii) One 11 kV outdoor line disconnecting and earth switch (line isolators).

(iii) One set of 11 kV outdoor current transformers (each 3 x single phase CTs) for protection and metering, plus One single phase neutral CTs for protection.

(iv) One set of 11 kV outdoor voltage transformers (each 3 x single phase VTs) for protection and metering.

(v) Two sets of 11 kV outdoor surge arresters (each 3 x single phase surge arresters) complete with surge counters.

(vi) One set of 11 kV outdoor overhead connectors between circuit breaker, disconnectors, transformer, surge arresters, current transformers and voltage transformers, complete with all necessary insulator strings, clamps and connectors.

(vii) One outdoor galvanised steel earth wire and lightning protection system covering the entire Substation.

(viii) All supporting structures as necessary.

(ix) All necessary fittings and fixtures.

(x) One complete earth system comprising buried copper earth mesh and earthing pits with earth rods, bonding connections to all steelwork and copper tape risers to all equipment earth connections and guard wire connections, including test wells.

25.3 Particular Requirements

The switchgear shall be suitable for an outdoor location and shall be capable of continuous operation under the climatic conditions existing at site. It shall be designed to comply with the relevant IEC and British Standards where applicable, and in particular BS 7354 (Code of Practice for Design of High Voltage Open Terminal Stations).

In all cases the ancillary plant necessary to complete the installation of the switchgear and equipment shall be included in the Contract.

The disposition of plant within the Substation shall be such that the operation of any item of plant under the specified service conditions shall in no way create a condition that could adversely affect the performance of adjacent circuit breakers or any associated equipment.

The Contractor shall ensure that the complete Substation installation shall satisfy the requirements of this Specification and the appropriate Standards in respect of insulation, fault levels, mechanical stresses etc., and any additional equipment found to be necessary to obtain these conditions shall be deemed to have been included in the Contract Price.

The layout and design of plant and equipment in the 11 kV Substation shall provide for ready access for operation, maintenance and extension whilst the remaining sections of equipment are alive. Working clearances provided between isolated equipment and nearest live metalwork shall not be less than the British Standard section clearances and those stated in this Section.

Insulation creepage distances shall be suitable to meet the per kV rated voltage between phases.

Circuit breakers shall be electrically controlled locally, remotely and by supervisory telecontrol.

Position indication of these devices shall be provided directly from auxiliary switches on their operating mechanisms. The Contractor shall include the supply of all necessary auxiliary switches.

All equipment necessary at the substation for the effective control of these devices, locally, remotely and by supervisory telecontrol shall be included in this Contract.

25.4 Switchgear Ratings

The switchgear shall be designed for the following system ratings:

Nominal voltage of system	kV	
Highest voltage for equipment	kV	
Rated frequency	Hz	50
Standard switching impulse withstand voltage phase to earth	kV peak	TBA
Standard lightning impulse withstand voltage	kV peak	TBA

Rated short-circuit breaking current of circuit breakers	kA	TBA
Neutral earthing		Solid

25.5 The Circuit Breaker

25.5.1 General

The Circuit breaker shall be of the three pole Vacuum type suitable for outdoor operation and shall be operated by motor charged spring operating mechanisms. Each pole shall include an "open" and "closed" position indicator clearly visible from ground level and each operating mechanism shall be equipped with an operation counter. Insulators shall be of the porcelain type. Trip coils shall be duplicated.

The Circuit breaker shall be provided with supporting structures and all necessary equipment and materials for a complete installation. The operating mechanisms shall be housed in weatherproof enclosures to IP55 class in accordance with IEC 60529. Enclosures shall be provided with a heater and thermostat, single phase power socket and a door operated interior light. The doors of such enclosures shall be fitted with door restrainers and shall be lockable. Facilities shall be provided for the local and remote display of all indications and alarms.

The Circuit breaker shall be rated for their intended duties and shall be capable of switching magnetising currents associated with transformers, out-of phase switching and short-line faults that may occur in service. The circuit breaker for switching the capacitor bank shall be rated for switching capacitive currents.

The Circuit breaker shall comply in all respects with the requirements of IEC 62271-100 and related standards.

25.5.2 Technical Requirements

The circuit breakers shall be designed for the following minimum specific conditions and requirements:

Nominal voltage of system	kV	33
Number of poles		3
Rated voltage	kV	36.3
Rated short-duration power-frequency withstand voltage	kV	TBA
Rated switching impulse withstand voltage	kV peak	TBA
Rated lightning impulse withstand voltage	kV	TBA
Rated frequency	Hz	50

Rated normal current	A	TBA
Rated short-circuit breaking current	kA	TBA
First pole to clear factor		1.3
Rated operating sequence		O–0.3s–CO–3min–CO
Operating mechanism		Spring charged
Rated supply voltage of closing and opening devices and auxiliary and control circuits	V	110 (d.c.) (Subject to confirmation by the contractor)

(a) Separate arcing contacts shall be provided on the circuit breaker to protect the main contacts from burning during operation and shall be arranged to ensure arcing after commutation of the main current always occurs in the arcing zone between the arcing contacts.

(b) Design shall permit rapid removal of complete interrupting chambers of Vacuum circuit breakers.

(c) Static and moving seals shall be designed to prevent any leakage of gas or ingress of moisture whilst in service and without deterioration.

(d) Circuit breakers of the Vacuum type shall not comprise materials liable to deterioration or create undesirable chemical action when in operation. Precautions to minimise the presence of moisture and other by-products of arcing in Vacuum design shall be incorporated.

(e) Where the circuit breaker comprises three independent units it shall be possible to make independent adjustments to each unit. For three-phase operation the three units shall make and break circuits simultaneously. In the event of any phase failing to complete a closing operation, provision shall be made for automatic tripping of all three phases of the circuit breaker.

(f) An approved schematic diagram of the part of the control system local to the circuit breaker, identifying the various components within the cubicle on the circuit breaker and referring to the appropriate drawings and maintenance instructions, shall be affixed to the inside of the cubicle access door. The diagram shall be marked on durable non-fading material suitable for the specified site conditions.

25.5.3 Control Circuits

Control circuits shall be designed with consideration of the following:

(a) Duplicate trip coils shall be supplied from separate dc supplies from the dc distribution board.

(b) The spring charging motor dc supply shall be separate from the control dc supply.

(c) Excessive spring charging time shall be alarmed to the control room.

(d) "Close-Trip" push buttons shall be provided in the central control panel and in each pole mechanism.

(e) A "Local/Remote" selector switch shall be provided in the central control cabinet.

(f) For three phase circuit breakers with single pole mechanisms a time delayed adjustable alarm contact for phase discrepancy shall be provided.

25.6 Current Transformers

Current transformers shall comply with the requirements of IEC 60044-1.

Current transformers shall be suitable for their intended application. The Contractor shall be responsible for determining the correct rating and characteristics for each current transformer and shall submit his calculations for the Employer's approval. Magnetisation and core loss curves and secondary resistance details shall also be submitted for each type and rating of current transformer.

The VA rating of the current transformers shall be chosen to match the requirements of protection relays, instrumentation and metering equipment. The secondary windings of the current transformers shall be rated for 1 ampere. The accuracy class of the current transformers shall be according to the following table:

Protection	5P20
Instrumentation	Class 1.0
SCADA transducers	Class 0.5
Tariff metering	Class 0.2

Current transformer secondary windings shall be connected to earth in the related relay, instrumentation or metering cubicle. Only one earthing point for each current transformer circuit shall be permitted. The connection to earth shall be on the side of the S2 terminal.

The protection class of secondary terminal boxes shall be IP55 according to IEC 60529.

Neutral current transformers shall be of the outdoor totally enclosed, porcelain bushing type.

The supply shall include the provision of suitable mounting steelwork for the current transformers together with foundation anchor bolts.

25.7 Voltage Transformers

Voltage transformers shall be of the capacitive type and shall comply with IEC 60044-5.

Where voltage transformers are provided for revenue metering, separate secondary cores shall be provided for main and check metering.

Voltage transformers shall be provided complete with galvanised steel supporting structures.

25.8 Surge Arresters

Surge arresters shall be station class and shall comply with the requirements of IEC 60099-4.

They shall be of the metal-oxide type without gaps and shall be supplied with porcelain housings. The arresters shall be provided complete with insulated bases, surge counters (one per phase); grading rings as applicable, supporting steelwork and foundation bolts. The arrester terminals shall be compatible with the conductors to be connected.

Surge arresters shall be fitted with pressure relief devices to prevent the porcelain housing shattering in the event of an arrester failure.

25.9 Insulators

Porcelain and toughened glass cap and pin insulators shall meet the requirements of IEC 60305 and BS EN 60383. The associated fittings shall comply with IEC 60383. Post insulators shall comply with IEC 60273 and BS EN 60168.

The minimum creepage distance for insulators shall be 25 mm/kV.

Porcelain insulators shall be free from defects, thoroughly vitrified and provided with a uniform smooth hard glaze, brown in colour. Direct jointing of hollow or solid insulators shall not be permitted.

Direct contact between metal parts and the porcelain or glass insulation materials shall be avoided. Flexible oil and water resistant materials shall be fitted between both parts where necessary. Where cement is used for bonding, the cement thickness shall be kept to a minimum and the insulation and metal parts shall be carefully located and centred.

Insulators shall be marked in an approved manner with the manufacturer's name, year of manufacture and electro-mechanical strength.

Where a batch of insulators is rejected during works tests, the insulators shall be permanently marked or destroyed to ensure that there is no possibility of the rejected insulators being supplied for the project.

25.10 Conductors

The conductors and connections shall preferably be of aluminium. Consideration will however be given to the provision of copper conductors, if proposed by the Contractor. Conductor sizes shall be determined by the Contractor in accordance with international practice and shall be submitted for the Employer's approval.

The current rating and material analysis of aluminium conductors shall be in accordance with BS 215, BS EN 755 and BS EN 1592.

Copper busbars shall be in accordance with BS 125 and BS EN 13600.

Where stranded aluminium wire conductors are used they shall normally be of pure aluminium to BS 215. Tubular conductors shall be of aluminium alloy E91E to BS 2898.

The conductor sizes shall be chosen according to the rated current of the circuits.

Where tubular conductors are used the spacing of the supports shall be chosen so as to avoid resonance of the tube due to wind effects.

Where dissimilar metals are in contact, appropriate measures shall be taken to prevent galvanic corrosion.

25.11 Substation Steelwork Structures

The Contractor shall provide all structures required for supporting circuit breakers, disconnectors, current transformers, voltage transformers, surge arresters, post insulators, etc. including busbar support structures (towers and girders) and line bay terminal gantries. The structures shall be of the lattice steel or pedestal type, suitable for mounting on concrete foundations.

All steelwork shall be hot dip galvanised. All drilling, punching, cutting banding and welding shall be completed before the galvanising process is applied. Galvanising and testing shall be in accordance with BS EN ISO 1461.

Calculations shall be submitted showing the conductor stress and guard wire stress on each girder.

25.12 Installation

During installation the following requirements shall be observed:

(a) Conductors shall be installed in continuous lengths; joints will not be permitted.

(b) Conductors shall not be stressed to more than 40% of their elastic limit.

(c) Overhead conductors shall be installed such that the Substation structures are not subject to loads of more than 40% of their design strength.

(d) Connections between conductors, and between conductors and equipment, shall be by bolted connections.

(e) Suspension and tension conductor clamps shall be of an approved type. Those for aluminium conductor shall preferably be of the compression type complying with BS 3288.

(f) Clamps and bolts shall be of galvanised steel or other corrosion resistant material.

(g) Clearances between live conductors and earthed metalwork and between live conductors and ground shall be not less than the specified distance.

25.13 Testing and Inspection

25.13.1 Factory Inspections

Circuit breakers, disconnectors, current transformers, voltage transformers, surge arresters, insulators, conductors, fittings and structures shall be tested in accordance with the requirements of the relevant BS and IEC standards.

Type test certificates will be accepted in lieu of type tests; however where type test certificates are unavailable the type tests shall be performed.

All equipment will be subject to routine tests in accordance with the relevant IEC standard.

25.13.2 Tests on Completion

After installation every item of equipment shall be tested to ensure no damage has occurred during transport or installation, and the equipment has been correctly installed.

Routine tests in accordance with the relevant IEC Standard, as well as insulation resistance tests and high voltage tests shall be carried out. All tension joints shall be inspected and torque settings confirmed and recorded. Each torqued bolt shall be indelibly marked.

Functional tests shall be conducted on all circuit breakers and disconnectors, including operation of any interlocks.

All control wiring and connections shall be checked and insulation resistance tested.

As a minimum, the following site pre-commissioning tests shall be performed:

Circuit breakers:

(a) Visual inspection

(b) Insulation resistance test

(c) Functional tests

(d) Interlocking test

Current Transformers

(a) Visual inspection

(b) Insulation resistance test

(c) Polarity test

(d) Primary injection test

(e) Ratio check at actual burden

(f) Measurement of burden

(g) Verification of excitation curve

Voltage Transformers

(a) Visual inspection

(b) Insulation resistance test

(c) Polarity check

(d) Turns ratio test

Surge Arresters

(a) Visual inspection

(b) Surge counter operation test

25.14 Spare Parts

11 kV Circuit Breakers

(a)	Interrupter (one phase)	1 Set
(b)	Closing coils for circuit-breaker	1 Nos.
(c)	Tripping coils for circuit-breaker	1 Nos.
(d)	Circuit-breaker operating mechanism motor	1 No.

Section 26: Technical Specifications – Control and Monitoring System (CMS)

26.1 General

The Contractor shall provide a Control and Monitoring System for the turbine and generator (and auxiliary plants), and this shall include monitoring and control of the 11 kV Substation, LV auxiliary supplies distribution and other essential components of the installation.

The turbine/generator control system shall be arranged to allow initiation of fully automatic starting and stopping from the Control Room.

Control systems shall comply with the provisions of IEC 60870

The control of the turbine/generator and auxiliaries shall be through programmable logic controllers (PLCs). The PLCs shall be high reliability dual redundant devices. However in the event of a complete PLC failure it shall be possible to start, stop and load the unit using manual controls but with only the essential hardwired protection operative and limited plant information available.

The PLCs shall have the facility to communicate with the overall Control and Monitoring System, and shall have colour alphanumeric display units. The displays shall be consistent throughout the plant.

The PLCs shall implement the turbine/generator automatic start up and shut down sequences, and their associated pre-start checks.

26.2 Scope of Work

The scope of work shall include the design, manufacture, supply, erection, factory acceptance testing and commissioning of the control equipment required for operation of Kasanjiku hydroelectric power generating station.

The scope of work shall include the supply of the following equipment:

a) Local level PLCs, each with HMI, as follows:

- Power house PLC controlling generating Unit and auxiliaries
- 11 kV Substation PLC controlling plant and equipment within the 11 kV Substation

b) Unit Local Control Boards with the following features:

- High capacity PLC (Dual CPU hot standby solution) as above

- Automatic equipment required for the auto-start, auto-stop and tripping of the turbine/generator
- Hardwired manual controls
- Stand-alone alarm system

c) 11 kV Substation Local Control Board with the following features:

- High capacity PLC (Dual CPU hot standby solution) as above
- Hardwired manual controls
- Stand-alone alarm system

d) At the station level in the Control Room, one (01) Server for supervisory control and status monitoring shall be provided. The operating system for the server shall be Windows.

e) One (01) Operator workstation, One (01) printer and one (01) desk

f) One (01) Engineering Laptop. The Laptop will be required both during commissioning and subsequently for operations and maintenance. All the necessary engineering software shall be provided.

g) All additional items required for the safe and efficient operation of the plant.

The supply shall include primary measuring equipment, initiating contacts and transducers. The Contractor shall provide, under the contract, sufficient controls and indications for the turbine/generator set, outdoor Substation, and any further items required to ensure the safe and reliable operation of the generating station. Interfacing of equipment supplied under this section of the specifications with equipment and sub-systems supplied under other sections of the specifications, as appropriate, shall also be included.

The control and instrumentation system shall include:

- PLC (programmable logic control) system
- Drive control modules
- Interfaces with proprietary equipment (i.e. turbine, generator etc.)
- Field sensors and local instruments provided by the package plant suppliers. The instrumentation shall be smart instruments with standard communication protocols.
- PLC driven alarm displays and information systems

- Interfaces with the PLC, protection equipment and switchgear
- One (01) operator workstation in the Powerhouse Central Control Room
- All necessary data links and communication facilities between elements of the CMS

26.3 Unit Control

26.3.1 Control Philosophy

The unit shall normally be operated from the Control Room. However, facilities shall be provided for local operation of the turbine/generator unit at the Unit Local Control Board, located on the generator floor. The extent of control shall be as follows:

26.3.1.1 Local Operation

Unit Local Control Boards for the Unit shall be provided at the machine hall floor level, for the local control of the generating unit. Local control shall normally only be used for testing, commissioning, maintenance and in the event of failure of the Control and Monitoring System (CMS).

Local automatic control shall be provided via a programmable logic controller (PLC), which shall be included as part of the Unit Local Control Boards. Facilities shall be provided by means of a local operator terminal for the automatic starting, loading and stopping of the unit. Black start start-up sequence shall also be included.

In addition to the automatic control system, an independent hardwired manual control system shall be provided. Local manual (hardwired) control shall be used during testing, commissioning, maintenance and to maintain the unit in operation in the event that the PLC is unavailable.

26.3.1.2 Control Room

The units shall be controlled via the CMS operator stations in the control room. The following operating modes shall be possible from the operator station:

– automatic start up
– automatic shut down
– on load control
– black start
– Voltage Control
– Generation Control including control of the units in Joint Mode.

Unit alarms and indications shall also be monitored at the operator station.

26.3.2 Unit Automatic Start/Stop Operation

26.3.2.1 Automatic Start

There shall be four types of automatic start for each unit as follows:

Electrical Start: fully automatic start and putting the unit on line, and loading to power set point or for headwater level control.

Mechanical Start: automatic start up to near synchronous speed, excited and unsynchronised.

Step-by-Step Start: after completion of a step, the control system shall wait until the operator initiates the next step.

Black start: with black start override key selected, the unit will start automatically and close the generator circuit breaker without synchronisation function with dead bus check ascertained.

The programmable logic controller shall be programmed to carryout the following control functions:

(i) Verify that the unit is in a condition to start, i.e. no alarms up, generator brakes off, electrical supplies established, governor and excitation systems healthy etc. When all start-up conditions are satisfied the PLC shall give the output message "UNIT READY TO START".

(ii) Start turbine, generator and transformer auxiliaries such as cooling water, governor pumps, thrust bearing pumps, etc.

(iii) Conduct all turbine, generator, transformer and switchgear pre-start checks to ensure that auxiliaries have started and supplies are established.

(iv) Instruct the digital governor to run up the unit.

(v) Stop the thrust bearing oil pumps at a pre-set speed.

(vi) Start the excitation system at a pre-set speed.

(vii) Accept a ready to synchronise and voltage matched signal from the digital governor and AVR respectively.

(viii) For an "Electrical Start", proceed to close the transformer circuit-breaker and load the unit.

(ix) Check for excess starting time to on-line operation, and alarm and shut down if excessive. In the case of a "Mechanical" start up, the check shall be done in two stages, i.e. to speed no load and to on-line operation.

26.3.2.2 Automatic Stop

There shall be three shutdown modes of the unit as follows:

Normal Stop: unloading the unit, automatic trip of the transfofrmer circuit breaker and stop of the unit and auxiliaries.

Partial Shutdown: unloading the unit, automatic trip of the transformer circuit breaker, unit excited at synchronous speed.

Emergency Shutdown: on-load trip of the transformer circuit breaker, stop of the unit and auxiliaries.

26.3.3 Control and Monitoring of 33 kV Transformer Circuit Breaker

The 11 kV transformer circuit breaker shall be hardwired to the Unit Local Control Board.

The transformer circuit breaker will be controlled either from the operator station in the Control Room (Supervisory control) or via the Unit Local Control Board (Manual control). For maintenance purposes local control shall be available at the 11 kV transformer circuit breaker.

During normal operation, the circuit breaker will be controlled automatically by the PLC. In the event of failure of the PLC, local manual control shall be available from the PLC hardwired controls.

The 11 kV transformer circuit breaker shall be equipped with a local/remote selector switch on the relay/control panel. The "remote" selection of the selector switch shall transfer the 11 kV transformer circuit breaker controls to the Unit Local Control Board. With the "local" selection, the control of the 11 kV transformer circuit breaker shall only be possible from the generator circuit breaker local control panel.

26.4 Unit Local Control Board (ULCB)

26.4.1 General Requirements

A Unit Local Control Board shall be provided at generator floor level for each turbine/generator unit.

The Unit Local Control Board shall consist of a suite of panels housing the programmable logic controller (PLC) and the manual (hardwired) control equipment. The ULCB shall consist of:

- Hydraulic/mechanical control panel

- Electrical control panel, including mimic
- Local alarm panel
- PLC panel

The automatic controls shall allow the automatic starting, loading and stopping of the unit. Preset Load Setting, Governor speed/load control and Excitation and AVR controls shall be included.

An independent hardwired manual control system shall be provided, as a back-up, in case of fault or unavailability of the PLC. Local manual (hardwired) control shall include all necessary controls, interlocks, protection functions and indications to ensure safe and reliable operation of the unit. This shall include the control and monitoring of the plant auxiliaries. Automatic and manual stepped start via push-button operation shall be provided. It shall be possible for a single operator to start up the unit using the local manual controls.

All unit and auxiliary plant alarms shall be displayed at the ULCB. The same shall be repeated at the Control Room.

Alarm and trip modules shall be mounted in different racks from those used for sequence control.

The following controls, indications and alarms shall be provided on the Unit Local Control Board:

(a) Sufficient indications of all critical variables necessary for safe operation of the unit.

(b) Local controls for all plant regulators.

(c) Annunciation of all alarms on the plant.

(d) Control of all unit auxiliaries.

(e) Remote/Local and Automatic/Manual control selection switch.

26.4.2 Construction

The Unit Local Control Board shall be a freestanding suite of panels of fabricated steel construction, with cable entry from below. The thickness of the sheet steel shall not be less than 2 mm. The panels shall be suitable for a tropical environment and shall have ingress protection classification IP54, as defined in IEC 60529. The height of the panels shall not exceed 2250 mm and indicating instruments shall not be mounted below 1500 mm, unless otherwise approved by the Employer. External mounted equipment shall be flush mounted and shall be suitably labelled with permanent labels, black lettering on a white background, to the approval of the Employer.

The panels shall be provided with both front and rear lockable doors providing easy access to internal equipment. The doors shall be provided with suitable ventilation grills fitted with removable filters to prevent the ingress of insects and dust. Door operated internal lights shall be fitted and a power socket shall be provided inside each panel. Copper earth bars shall be provided in the bottom of the panels. The metal cases of all devices and equipment shall be connected to the earth bars with green/yellow insulated copper conductors of minimum 2.5 mm^2 cross-sectional area.

The external colour of the panels shall be grey, the shade being subject to the approval of the Employer. The internal colour of the panels shall be matt white.

In selecting the temperature rating of electrical and electronic components due allowance shall be made for the temperature rise due to the heat generated from internal equipment at the specified ambient temperature.

Relays, electronic cards and devices shall be identified with labels in English permanently attached to the panel.

Printed circuit boards shall be of the rack mounted, plug-in type and shall be clearly marked with serial number, identity and function. The rack position of each printed circuit board shall be clearly marked.

The internal wiring shall be arranged in a neat and consistent manner and shall be adequately supported. Exposed wiring shall be run in vertical or horizontal formation with tight bends. Where several cables run along the same route they shall be grouped and bound together. The wiring shall be sized for the prospective short circuit current. Where wires terminate at devices or terminal blocks, they shall be fitted with suitable white, heat imprinted, tubular wire markers, securely fixed to the wires (including all spare cores). A consistent wire numbering system shall be used. All connections shall be made at connection blocks: joints, splicing or paralleling of wires will not be accepted.

Terminal blocks shall be located to facilitate the connection of incoming cables. A minimum of 15 percent spare terminals shall be provided in each terminal block. Terminal blocks shall be rated for 600 V and shall be fitted with covers.

26.4.3 Hardwired controls and indications

26.4.3.1 Hydraulic/Mechanical Panel

All necessary controls and indications shall be provided for complete operation of the plant. An indication of the controls, indications and alarms required is given below. The Contractor shall be responsible for detailing the final controls and indications, which will be subject to the approval of the Employer.

Typical controls and indications shall include, but necessarily limited to:

Indications/instruments:

- Speed
- Cooling water pressure
- Governor oil pressure
- HP lubrication oil pressure
- Thrust bearing pad temperature
- Generator guide bearing pad temperature
- Turbine guide bearing pad temperature
- Thrust and guide bearing oil temperature
- Turbine bearing oil temperature
- Inlet valve open / closed indication

Controls:

- Start/Stop – Governor oil pump (in stepped start mode)
- Start/Stop – Cooling water system (in stepped start mode)
- Start/Stop – Thrust bearing oil pumps (in stepped start mode)
- Apply/Release Brakes
- Open/Close Governor oil valve
- Power set point control or headwater level control

Push-button (protected with key release)

- Fire protection initiation (with emergency shutdown)
- Penstock emergency closure valve trip (with emergency shutdown)

26.4.3.2 Electrical Control Panel

Indications/instruments

- Generator MW
- Generator MVAr
- Generator Current (3 line currents with selector switch)

- Generator Voltage (phase to phase)
- Excitation Current
- Excitation Voltage
- Frequency

Selector Switches

- Local hardwired control/Local PLC control/Remote control
- Automatic start/stepped start
- Auto/Manual - Voltage control

Push-button

- Normal start
- Black start
- Normal stop
- Quick stop
- Emergency stop
- Excitation raise
- Excitation lower
- Raise transformer tap
- Lower transformer tap

Status Indications

The Contractor shall provide sufficient status indications to verify the status of all plant and auxiliaries associated with the control of the Unit.

26.4.3.3 Alarm Panel

An approved alarm annunciator with alarm acknowledge, accept and reset pushbuttons shall be provided. The annunciator colours shall be red for trip alarms, amber for non-trip alarms and white for check start conditions.

All local alarms from the generator and turbine shall be displayed at the alarm panel, as well as grouped alarms from generator transformer and circuit breaker.

Transient alarms shall be suppressed.

26.5 Control and Monitoring of 11 kV Switchgear

The 11 kV Substation shall be controlled at the Local Level PLC. Only supervisory control functionality and co-ordination shall be performed at the "Remote" and "Supervisory" Level control equipment. All plant shall remain fully functional and under the control of the appropriate Local Level PLC in the event of failure of the Remote or Supervisory controllers or of the communication loop.

Local Level PLCs shall be equipped with Panel view type HMIs to provide control, both automatic and manual, and status monitoring for the plant and equipment.

The equipment of the 11 kV substation shall be operated from either:

- Powerhouse Control Room
- Locally from the Substation local control panels
- Locally from the control cabinets in the Substation (operation under maintenance only)

The Contractor shall install a Substation local control panel (SLCP) for the control of complete 11 kV switchgear including, meters, selector switches etc, a Substation common panel for power supplies, alarm annunciations, and a Substation interface panel which shall provide interface points for the 11 kV Substation CMS. In the event of failure of the 11 kV Substation CMS, local manual control of the switchgear shall be available from the SLCP.

Primary protection systems shall be hardwired and remain fully functional and effective in the event of failure of Local Level PLCs.

Manual controls local to plant and equipment shall be provided and it shall be possible to safely operate the plant and equipment in the event of failure of Local Level PLC.

11 kV switchgear local control cubicles installed in the Substation control room shall be equipped with necessary mimic diagram.

Controls, alarms and indications for interfacing with the CMS from the individual plant items shall be hard wired to the Substation interface panel.

All trip circuits shall be hard wired to allow safe shut down with only monitoring by the Substation CMS.

The Substation Interface Panel shall house all terminals/signals through which the Control and Monitoring System shall communicate with the 11 kV Substation outdoor equipment.

26.6 Programmable Logic Controller (PLC)

26.6.1 General

The programmable logic controller (PLC) shall be from a manufacturer of international repute and shall have a proven record of control and monitoring of hydropower generating stations. The preferred PLC manufacturers of international repute shall include any of the following; GE, ABB and SIEMENS. If the contractor proposes any other brands, proof shall be provided that they are of the same performance record traced. The equipment shall support upgrades and enhancements without the need for modification or replacement. The Contractor shall provide evidence of the manufacturer's compliance with this requirement and shall also provide evidence that the equipment will be supported by the manufacturer for a period of at least fifteen years from the date of tender submission. The support shall include the ability to provide spares for the equipment supplied and to provide engineering support and software services for the original system and any extensions and expansions required.

The PLC shall be of a modular kind, by cards that shall be mounted over a rack or back panel. Susceptible equipment shall be protected from the effects of electrostatic discharge, radiated electromagnetic fields and conducted or induced fast transients or bursts of noise. In case the software required for the system functionality demands hardware with higher performance features, the Contractor shall supply it.

The programmable logic controllers for the Turbine/Generator Unit will have the following characteristics:

(a) High capacity controller for I/O signals.

(b) CPU redundancy for backup control and memory. Hot standby: automatic reaction-free switching to the standby unit in the event of a fault.

(c) High memory capacity with capability for expansion.

(d) Digital input cards.

(e) Digital output cards.

(f) Analogue input cards.

(g) Analogue output cards.

(h) Redundant power supply unit.

(i) Ethernet connection cards.

(j) Galvanic isolation for the signals.

(k) Outputs through relay voltage free contacts.

(l) Empty slots for future expansion.

26.6.2 Functional Requirements

The PLC shall provide the following functions:

(a) Control and co-ordinate the plant during normal operation, including steady state and transient load conditions.

(b) Protect the plant from damage due to out-of-course events, as evidenced by excursions in certain key measured parameters, by automatically starting standby auxiliary plant if available, or to initiate orderly unit shutdown.

(c) Enable controlled start-up and stopping of the plant either by automatic sequence or by manual control from the operator station subject to permissive action of safety interlocks.

(d) Process alarms and application of logic to decide when to initiate a trip.

(e) Monitor field contacts, either changeover, NO or NC type.

(f) Collect and condition both analogue measurements and binary signals from the plant and distribute them for use by the control and monitoring equipment.

(g) Perform data processing and calculations including water levels and flows and active and reactive energy.

(h) Provide an interface with the turbine governor, generator AVR, and other equipment controls to enable remote monitoring and control.

(i) Enable measured variables and status signals to be tagged and displayed, stored or recalled as required.

(j) Allow plant operators full plant control both locally from the Operating Floor, and remotely from the Powerhouse Control Room.

(k) Data storage for a minimum of 7 days, with each data item measured half hourly.

(l) Display stored data in trended format as required.

26.6.3 CPU Power supply

The PLC shall include dual supply source deriving all working voltages internally.

The supply shall comply with the following characteristics:

- Input voltage: 230 V a.c. from a secure supply (battery-backed UPS).

- Easily accessible adjustment and test points.
- Low heat dissipation.
- Galvanic isolation between input and output voltage.
- All outputs shall be protected against overload, short circuit and surge.
- The system shall have the possibility to generate an alarm in case of failure.
- Preferably rack-mounted, for ease of maintenance.
- For input and output cards (I/O), visual operation indication of each output voltage.

26.6.4 Central Processing Unit (CPU)

The main processing unit and memory shall be suitably sized for the application and shall have the following characteristics:

(a) It shall be based on microprocessors with a suitable calculation capacity for the number of signals and for the process to be controlled in such a way that the program cycle does not exceed 100 ms.

(b) It shall be able to manage 32 bit registers in floating point and make basic mathematical calculations with them.

(c) It shall have voltage supervision and monitoring circuits of the program cycle and watchdog with accessible external contacts.

(d) It shall have sufficient RAM memory and EPROM memory.

(e) Possibility of loading the user program in EPROM (preferably an EEPROM).

(f) The CPU shall have status indication LEDs (operation, failure, etc.).

(g) In the event of supply loss or manual disconnection, the data necessary to restart the system (programs and variables) shall be permanently safeguarded.

The Contractor shall also provide details of the capability of the equipment to cater for future expansion.

The CPU shall be capable of I/O forcing and simulation, for test, commissioning and maintenance purposes. These functions shall be facilitated through a locally connected programmer. The I/O forcing shall only be possible by use of security passwords or key switching.

The processor shall allow sequence of event recording so as to facilitate troubleshooting during automatic sequence failure.

The PLC shall be programmed by a high level programming language that is user-friendly and based on the IEC 61131 international standard. Windows pull down menus and mouse control interface software shall be provided. In the case of power supply failure to the PLC any volatile memory shall be maintained by backup battery for a minimum of 300 hours under normal service conditions. A warning shall be given when the battery volts are low. No loss or corruption of memory shall occur when the batteries are changed.

26.6.5 Input and Output Cards

Generally, all the interfaces shall have the following characteristics:

(a) All the signals may be isolated at the terminal block using links, without having to disconnect the wiring.

(b) The inputs and outputs shall be individually protected against short circuits. A short circuit in a signal shall not affect to the entire card.

(c) They shall have galvanic isolation between the field signals and the PLC circuits and preferably also between both.

(d) Signal connection shall be by means of connectable terminal plug and mechanical safety attachment (screws, etc.) to withstand the weight of the connection plug.

(e) Each input/output shall be electrically isolated and immune to transient interference.

26.6.6 Digital Input Cards

Digital inputs from the plant to the PLC shall be achieved by means of volt-free contacts.

Some input channels shall also be used for event recording. Some digital Input cards with 1ms SOE time stamping capability shall also be provided for critical signals for advanced analysis.

The digital input interface modules shall be designed to work with voltage-free contacts. The cards shall have state indication LEDs for each input.

An anti-rebound filter shall be performed, preferably individual for each signal, by firmware programming and recording of the moment of change of each signal with a precision better than 10 ms.

26.6.7 Digital Output Cards

Digital outputs from the PLC shall be provided via suitable output modules. The output channels and the supply shall be isolated from the processor circuitry.

These shall have galvanic isolation to external circuits by means of relays (relays included in the card itself). All the contacts shall be voltage-free and the use of voltage commons is not permitted.

Besides the general characteristics already described, they shall have the following:

(a) Signalling of their status by means of LEDs.

(b) All the outputs shall remain idle in the event of shutdown or any PLC anomaly.

(c) Their status shall be readable from the automatic program in order to verify execution of field outputs.

Each output shall be electrically isolated and immune to transient interference, and shall be provided with a state indicator.

Suitable interposing relays shall be incorporated in order to drive the plant equipment relays, solenoids, contactors, alarms etc. as required by the design. The output contact rating shall be sufficient to handle the required function.

26.6.8 Analogue Inputs

The analogue input cards shall be capable of handling the following signals from the field sensors:

- Input current of 4-20 mA.
- PT100 sensors and thermocouples.
- Input voltage.

Apart from the general characteristics already described, they shall have:

- Resolution of at least 16 bits + sign.
- Underpass analogue filter in all the inputs.
- Surge protection.
- Short circuit protection for active inputs.
- Out-of-range monitor.

26.6.9 Communication Cards

In order to access the data obtained by the Unit PLCs and to perform local operations, each PLC shall include communication cards for connection to the local operator panel PC.

26.6.10 Field Bus Communication Card

The PLC shall have ports for connection to field buses. They shall be RS232C or RS485 (configurable).

If smart instruments are supplied and installed, the PLC shall also have capability to connect to the smart instruments using international standards including HART protocol.

The ports shall be able to be configured and may handle speeds from 2400 to 114,000 bps, all types of parity and 7 or 8 data bits.

Additionally, the PLC shall be configured to work with the following protocols:

- Modbus RTU
- Profibus DP

26.6.11 Self Testing and Self Diagnostics

Comprehensive self-testing and self-diagnostic facilities are required to be included in the PLC equipment.

The Contractor shall provide details of the following facilities offered:

(a) Correct application program scanning check.

(b) Memory integrity checks.

(c) Validity of data exchange between memories, processing units and I/O modules.

(d) Power supply checks.

(e) Main processor unit status check.

(f) I/O channel integrity check.

(g) Error message display.

(h) Integral supervision functions.

(i) Powerful aid for testing.

(j) Other self test and diagnostic execution details.

The Contractor shall also provide details of the facility proposed for reporting the self test and diagnostic message. An output contact shall be provided for fault indication.

26.6.12 Other Requirements

In the event of a fault, the PLC shall respond so as to ensure no damage to the plant. In the event of loss of power supplies, the PLC shall shut down the plant in a controlled manner, ensuring that the plant is left in a safe condition. When power is restored, the system shall resume operation in a controlled manner with manual intervention.

26.6.13 Power Supplies

Power for the CMS, including all peripherals such as operator workstations, display units and printers, shall be drawn from the 230 V a.c. 50 Hz UPS supplies.

The Contractor shall establish the requirements for secure power supply to the system.

26.6.14 Local Operator Panel (OP)

The local operator panel (OP) PC shall be a rugged industrial PC for acquiring and processing machine and process data, for operating and visualizing machine processes and for control tasks.

The OP shall have at least the following features:

(a) Easy configuration of user solution.

(b) Graphics library supplied for rapid picture configuration.

(c) Plant control graphic display.

(d) User-definable configuration documentation.

(e) Alarm logging and management system. All Unit alarms and messages shall be indicated chronologically with time and date stamping. Acknowledge, accept and reset functions shall be provided.

(f) Message logging and management system.

(g) Start/stop sequence visualization.

(h) Actual measurands indication screen.

(i) Electrical diagrams showing the status of various switches.

(j) Curves display.

(k) Data capture window to store analogue signals prior to and after a trip operation, with sufficient memory and resolution.

(l) Reports from long time archive.

(m) Tools to operate the system (local controls).

(n) Online reports.

The OP shall have the following minimum requirements:

(a) Latest high speed processor.

(b) Minimum Hard disk size of 500 GB.

(c) 2 GB RAM.

(d) Two (02) 19" High resolution flat screen extended displays.

(e) High performance graphic display card.

(f) Free PCI slots.

(g) Serial Interface to PLC, LTP1.

(h) Operating system software - Windows based.

(i) Control and monitoring software.

(j) Powered by 230 V a.c. from a secure supply (battery-backed UPS).

The Unit OP shall display as a minimum, the following screens (where applicable, a separate display screen for each Unit):

(a) Overview

(b) Electrical scheme

(c) Hydraulic scheme

(d) Cooling system

(e) Governor system

(f) High pressure pump

(g) Start-up conditions

(h) Start/Stop sequences

(i) Electrical and mechanical parameters

(j) Electrical and mechanical measurement curves

(k) Temperatures

(l) Temperature curves

(m) Bearing system – oil level and temperatures

(n) Brakes

(o) Trending curves for all analogues measured.

The Unit OP display screens shall display as a minimum, the following:

(a) Unit active and reactive power, voltage, current, frequency and power factor.

(b) Unit active and reactive energy (KWh and KVArh) received through the field bus. The system shall record and store records every half hour over a 24 hour period.

(c) Unit excitation current and voltage.

(d) Unit speed, machine discharge flow rate, total flow.

(e) Temperatures, pressures, oil levels, loading and tailrace levels, etc.

(f) Unit circuit breakers and disconnectors status.

(g) Status indications of mechanical systems; e.g. inlet valve, governor system, etc. as applicable.

26.6.15 Software

The operator PC shall have the necessary operating software licences and shall be configured for all functions. The Contractor shall provide the relevant software licences and establish all required configurations for operation of the unit.

26.6.16 Programming

All hardware, cable connections, software and software licences (PLC, HMI and Plant Information) required for programming (based on the IEC 61131 international standard), debugging, maintenance, fault finding, purging and diagnosing the PLC and communication ports shall be included in the supply. The programming device (laptop or similar device) shall operate from a 230 V 50 Hz supply.

The application software shall be the latest Windows compliant version. Modifications to an existing programme shall be password or key switch security protected.

A copy of the operating software shall be provided in DVD format. Documentation shall include a hard copy of the program together with setting parameters and range.

26.7 Operator Workstations, SCADA Server and Furnishings

Operator workstation shall be provided at the following locations:

- Powerhouse Control Room

The operator station at the powerhouse shall be fully functional.

One Hot standby SCADA server shall be supplied to serve as the main repository of all SCADA functions and applications and historical information. The server shall be rack mounted.

Local workstations shall be supplied with keyboard, visual graphic display unit, mouse or trackball and printer.

A control desk shall be provided for the workstation together with 2 operator adjustable and movable arm chairs. Suitable furniture shall be provided for the printers.

The operator workstations shall display pages containing mimic views, list of data, tables, etc. All the data available at the station control level shall be displayed on the mimic views.

Control of equipment by the operator shall be possible from the mimic view and all necessary information for the safe operation shall be displayed.

The entire internal fitting of the Central Control Room is included in this Contract, including the provision of a false floor assembly.

The CCR shall comply with high environmental standards. Noise levels shall not exceed 55 dB at any position within the control room.

The Contractor shall gain written approval from the Employer, before placing an order for manufacturing, for all the colour schemes pertaining to control room wall panelling, control desk, wall friezes, control panels etc.

26.8 Marshalling Cubicles

The Contractor shall provide cable marshalling cubicles in the quantities and locations found necessary for the optimization of cabling design. In particular, marshalling cubicles are required for the termination of all cables leaving or entering the Powerhouse or Substation Control Building.

All terminals and wiring shall be spaced sufficiently within the cubicles to prevent flashovers between cables to different locations. All pilot cable pairs shall be able to be isolated by withdrawing links on each end of the pair. These removable links shall be located in the pilot isolation cubicle or lockable cabinet. The electrostatic screen on the cables shall be earthed at the end of the cable where the earth potential rise is lowest. The cable armour shall be earthed at the same end as the electrostatic shield.

26.9 Communications

26.9.1 Networks

The peer to peer PLC controller network within the Power Station shall be implemented in a fibre-optic based Ethernet ring configuration. Any such failure shall be alarmed at the Control Room.

26.9.2 Communication between Auxiliary Equipment or Sub-systems

Auxiliary equipment and sub-system interfaces shall be designed so that each sub-system can be tested, commissioned and maintained without the need to have any additional systems connected.

RS485 Modbus on paired copper cable is the preferred protocol for communication from the PLCs to auxiliary equipment including power monitors, transformer management system, protection relays, building management system, governors and excitation systems etc.

Communications between equipment or sub-systems shall be designed so that communications is fault tolerant and so that failure of a communications channel is detected and alarmed and the processor function is not comprised by the loss of communications.

26.9.3 Multiplexers and Optic Fibre

Data links shall be via fibre optic equipment. All necessary adapters and converters for connection to the optic fibre equipment shall be included in the supply of the CMS, as well as multi-channel PCM multiplexers , and adapters for use of data channels for SCADA links. These shall be used as alternative backup channels in case of failure of the main channels on the Optic Fibre Network.

Two (02) Ethernet data channels for SCADA links shall be configured in the optic fibre system for communication to NCC. The IEC 60870-104 telecontrol protocol shall be used.

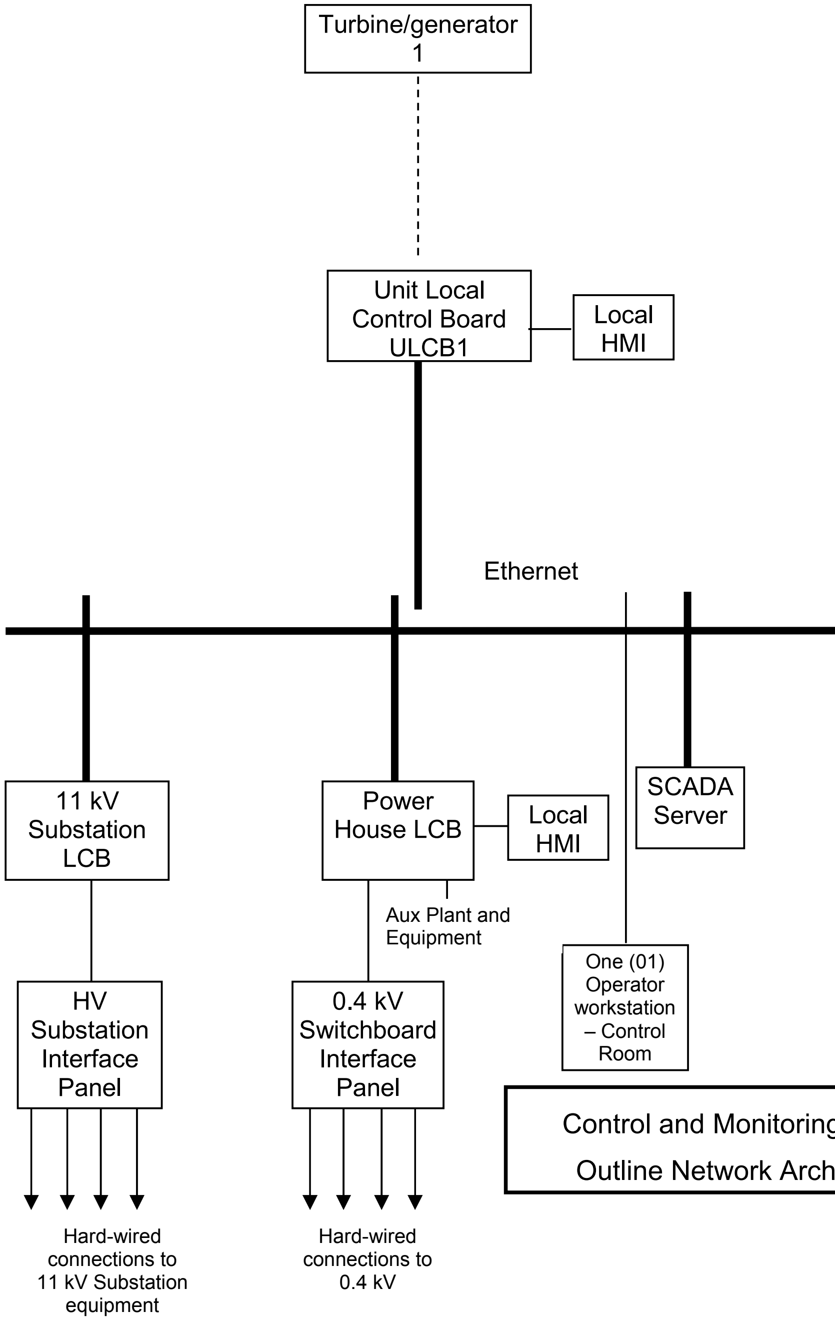
26.10 Signal List

A signal list or points list shall be prepared by the Contractor detailing every input and output of the CMS.

In general, all major parameters of the turbine/generator units and ancillaries shall be included, such as all alarms and trips; measurements of temperatures, pressures, flows, vibration etc.; and electrical measurands such as voltage, frequency, current, real and reactive power and energy, and power factor.

Status indications of the 11 kV circuit breaker shall be included, plus all alarms and indications from the Substation including battery and charger alarms.

26.11 Outline Network Architecture Diagram



Control and Monitoring System
Outline Network Architecture

26.12 Tests on Completion

26.12.1 General

The Contractor's test schedules shall include comprehensive check lists for testing of the control, protection, alarm and indication facilities.

26.12.2 Factory Acceptance Tests

All components and assemblies of the CMS and the communications systems shall be tested in accordance with the relevant IEC Standards to verify compliance with the requirements of the Standards and Specification.

The Control and Monitoring System shall have functional tests carried out at the factory before dispatch to prove that all components operate together as a system and that all operating sequences and device responses are satisfactory. It shall be the responsibility of the Contractor to provide test boxes and other test equipment for sufficiently comprehensive tests.

All cubicles shall be subject to inspection during manufacture and on completion to verify compliance with all the requirements of the Employer's Requirements, including surface finish and insulation resistance.

The Employer shall witness the factory tests.

26.12.3 Pre-Commissioning Tests

The pre-commissioning tests shall include the following:

(a) Insulation resistance measurements at the specified voltages appropriate to the circuits and equipment.

(b) Signal Test: Proof of correct connection and continuity of wiring for all control, protection, auxiliary and alarm equipment in accordance with the overall diagrams as provided by the Contractor.

(c) Functional tests to prove that all components operate together as a system and that all operating sequences and device responses are satisfactory. It shall be the responsibility of the Contractor to provide test programmes, test boxes and other test equipment for sufficiently comprehensive tests.

(d) Tests of all indications, displayed quantities and analogue outputs to show such items are within the accuracy limits specified.

26.12.4 Commissioning Tests

Commissioning tests shall include the following:

(a) Demonstration that all controls, alarms and indications, including all sequences, displays and reports operate correctly.

(b) The Reliability Test Period.

26.12.5 Completion

The Control and Monitoring System shall be completed in phases, integrated with the completion of generating unit. The Unit Local Control Boards shall have completed all functional tests and sequences and shall be completed as an integral part of the Turbine/Generator Unit before issue of the Operational Acceptance Certificate.

The common control aspects of the Control and Monitoring System, including the interface to the HV Substation and the Control Room operator interface, shall be taken over on successful completion of a total system functional test, including a test to prove resilience under various failure modes of central processors, communications links and power supplies.

The telephone and voice communications system shall undergo a comprehensive functional test to prove satisfactory voice communication with all parts of the Employer's system before issue of the Operational Acceptance Certificate.

26.13 Spare Parts

The supply of spares for the PLC shall be guaranteed for a minimum of 10 years.

Spare parts shall be provided for the Control and Monitoring System for 10 year operation and maintenance, including, but not limited to the following:

(i) 1 printed circuit boards of each type

(ii) 1 power supply of each type

(iii) spares for the Workstation and Server

(iv) spares for Local Operator Panel

(v) One process instrument of each type

(vi) Consumable items (such as printer paper and cartridges).

The range of replacement parts supplied shall be such that damage which may possibly occur and which can be fixed outside the manufacturer's workshop can be rectified on Site in the shortest possible time.

Section 27: Technical Specifications – Protection and Metering

27.1 General

Under this section of the Employer's Requirements, protection relays shall be provided for the protection of generator, power transformer and 11 kV switchgear. Metering equipment is also included in this section of the Employer's Requirements.

Protective relays and systems shall be provided to detect all credible faults on each item of plant and equipment and their primary interconnections. In the event of unacceptable electrical system disturbances occurring, the protection shall operate, as rapidly as possible, consistent with maintaining adequate discrimination, to minimize damage to the plant and equipment and disturbance to the system as a whole. It shall be designed to preclude, as far as possible, all possibility of inadvertent operation. However, a failure shall not prevent fault clearance.

27.2 Scope

The supply and services to be performed by the Contractor shall comprise the design, manufacture, shop testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of the Employer's personnel and warranty of the works.

The Contractor is bound to provide complete works, even if the equipment or services to be provided are not specifically mentioned in the specification. The Contractor shall be responsible for ensuring that all protection/control schemes, such as tripping, interlocking, alarms, protection setting etc. are in line with existing practices, the Zambian Grid Code and relevant Employer's standards.

The scope of works under this section shall include, but not limited to, the following:

- Turbine generator unit protection panels;
- Power transformer protection panels;
- 11 kV transmission system protection panels;
- Energy metering panels;

27.3 Protection Equipment and Auxiliary Relays

27.3.1 General Requirements

This section contains the general requirements applicable to all protection relays.

In order to maximise the cost-benefit of the protection in all groups and to reduce lifetime costs, all protection relays shall be of numerical design wherever practical. The main numerical relays should offer instrumentation, disturbance recording and event logging functions in addition to providing protection. Routine test requirements shall be limited to basic function testing only, through the provision of comprehensive, continuous self-monitoring with alarm and diagnostic functions.

Numerical relays and schemes provided shall all be possible to interrogate all numerical relays and schemes to monitor and extract recorded data (including settings, measurement parameters and disturbance records).

Numerical relays shall also be provided with a local communications port to allow direct interfacing to a laptop PC, to facilitate local interrogation, setting-up and recorded data extraction. The protection unit shall be provided with an integral user interface to facilitate setting changes and observation of indications without the use of remote communications.

Protection relays shall be from approved suppliers and they shall be type-tested according to relevant sections of the current IEC 60255 standards and copies of type test certificates should be provided.

Relays shall be CE - marked in accordance with European Union requirements related to Electromagnetic Compatibility and Low Voltage Equipment safety. Equipment complying with other national standards may be accepted at the Employer's discretion and where the vendor provides copies of the relevant standards.

Protection relays shall have a minimum of two year's satisfactory service history in similar applications with at least 5 utilities. The history is to be supported by reference lists.

Relays must be offered on the basis of a minimum service life of 15 years. Statements must be obtained from the relay manufacturers) to this effect with confirmation that a spares and repairs service will be available for the stated minimum service life.

Redundant auxiliary supplies shall be used and there shall be redundant tripping systems.

The failure of any equipment or the loss of power supply to that equipment shall raise an alarm. The equipment shall be designed to fail to a reliable state on either power supply or equipment failure. Latched devices shall be used wherever the resetting of a continuously energized device (e.g. through the failure of a solenoid coil) could result in an unsafe condition.

Each trip relay or tripping circuit shall be separately protected by a miniature circuit-breaker. Each supply circuit shall be allocated to protection functions only. Each tripping circuit and/or trip coil shall be separately monitored.

The Contractor shall ensure that each electrical protection relay is independent of others and can be individually isolated to allow each alone to be taken out of service for testing or operational purposes.

All shutdown initiating devices require a flag or LED operation indicator on the protection panel. Electrical and mechanical protective devices may require an interposing relay with sufficient contacts to perform the alarm functions plus one spare normally-open contact. A minimum of two initiating contacts are required; one for tripping and the other for operating the interposing relay.

All current operated relays and voltage operated relays shall have provision for testing by secondary current and/or voltage injection while the primary equipment is in service.

The Contractor shall be responsible for the determination of the protection settings for the protection relays; and shall submit the settings together with their calculations for the Employer's review.

27.3.2 Protection Types

Relay and protection systems shall comply with the requirements of the appropriate parts of IEC 60255.

All relays performing measuring and/or protection function shall be microprocessor based multi-function units. Auxiliary relays, repeat relays, trip relays and any other simple auxiliary or contact multiplication function may be based on standard attracted armature or other electromechanical techniques. All relevant software and documentation shall be provided. Similarly all test equipment required for fully testing and adjusting the relay systems shall be furnished.

It shall be demonstrated that all relay equipment offered has a good level of in-service experience. The following conditions also apply:

- It shall be demonstrated that a minimum of 10 relays of each type offered have been in full service without relay failures occurring for a minimum of three years in two different countries, one of which may be the country of manufacture. Experience involving trial installations is not accepted.

- A statement shall be given of the number of years of guaranteed manufacturing and parts support that will be provided for the relays offered.

27.3.3 Constructional requirements

27.3.3.1 General

Protection systems shall preferably be accommodated in 19-inch rack or hinged rack cubicles and be of modular construction with factory assembled and tested wiring. The construction method shall offer benefits of minimum site construction times and circuit outage requirements.

It shall not be possible to remove any module without first short-circuiting all associated current transformer circuits. All other main protection relays shall be accommodated within withdrawable cases. Means shall be provided to ensure that current transformer connections are short-circuited prior to being disconnected when the relay is withdrawn from its case.

Relays shall be mounted on a lockable hinged door frame equipped with separate lockable Plexiglas door for cover.

All relay cases shall be earthed except where insulated cases are provided for special requirements.

27.3.3.2 Identification

Each protection relay shall have a unique identifier, which is clearly visible. If the protection system is software operated the software reference and issue level shall be identified. The marking of all relays shall comply with Clause 12 of IEC 60255-6.

Each protection relay shall be provided with a card holder and card or other similar facilities with reference number to the plant documentation on which shall be shown:

a. The current transformer ratio (if applicable), including all ratios of multi-ratio transformers and the ratio selected.

b. Voltage transformer ratio (if applicable).

27.3.3.3 Settings

Each protection relay shall provide a means by which the user can easily apply the required settings, which is also secure from inadvertent operation. A display of the selected settings shall be provided on the protection relay.

A protection setting study shall be performed as part of the contract and a list of the settings to be applied to all protection equipment, together with all associated calculations and relay co-ordination curves on log paper, shall be provided for review and approval not less than 3 months prior to the first programme date for commissioning. Any limitations imposed on the power system operation as a result of the settings proposed shall be explicitly stated. In the absence of system data required for calculation purposes, assumptions may be made, providing these are clearly identified as such in the relevant calculations.

27.3.3.4 Indications

The protection scheme shall be provided with an adequate number of indications to ensure that the appropriate faulted phase, zone, etc. can be easily identified after a fault condition. Each indicator shall be visible and capable of being reset without removing the relay cover. It shall not be possible to operate the relay when resetting the indication. Indications shall only be given by the protection(s) causing the fault to be cleared.

For relays based upon digital or numerical techniques, indication shall be provided for failures detected in the protection relay or communications equipment. The indications provided shall be designed to allow the defective item to be quickly identified. The status of the D.C. power supplies shall be permanently indicated.

27.3.3.5 Output contacts

All protection relays shall be provided with an adequate number of contacts of suitable rating to carry out the required tripping functions, alarm indications, fault recorder functions and such supplementary signalling functions as may be necessary for initiation of automatic switching control, inter-tripping etc. In all cases contacts intended for tripping duty shall be designed such that:

a. They cannot inadvertently interrupt trip coil current.

b. They initiate the circuit breaker trip coil directly without the interposition of auxiliary relays or reinforcing contacts.

27.3.3.6 Test and isolation facilities

Each functional protection relay shall be so arranged that operational and calibration checks can be carried out with the associated primary circuit(s) in service.

Adequate test facilities shall be provided within the protection relay to enable the protection and auto-reclosing equipment to be tested from the front of the protection equipment panel with the primary circuit(s) in service. The test points shall be clearly identified and labelled.

Relays based on digital and numerical design techniques shall include supervision facilities which provide a periodic self-check of the key elements within the relay and also provide continuous self-monitoring of all internal power supplies and microprocessor operation. A defect in any of the self-supervision facilities shall not cause mal-operation of the protection relay internal self-test facilities and shall give an alarm should an internal fault occur.

Adequate facilities shall be provided, preferably at the front of each protection equipment panel, to isolate all d.c. and a.c. incoming and outgoing circuits so that work may be carried out on the equipment with complete safety for personnel and without loss of security in the operation of the switching station. The isolation points shall be clearly identified and labelled. The labels on the isolation points shall either describe the function or be uniquely numbered.

27.3.3.7 Environmental requirements

All relays shall be type tested according to relevant IEC standards.

27.3.3.7.1 Atmospheric environment

Temperature

The protection system shall operate satisfactorily when tested to the following requirements:

i. IEC 60255-6 with severity class -10°C, 96 hours.

ii. lEC 60255-6 with severity class 55°C, 96 hours.

The protection system shall be able to withstand the temperature requirements for storage and transportation and shall be tested to the following requirements:

i. lEC 60068-2-1 with severity class -25°C, 96 hours.

ii. lEC 60068-2-2 with severity class 70°C, 96 hours.

Relative humidity

The protection system shall operate correctly with a relative humidity of 93 per cent and shall be tested to lEC 60068-3-4 with severity class 56 days.

Where the protection system is housed in a controlled environment products tested to lEC 60068-2 with severity class 4 days are acceptable.

Enclosure

The protection relay shall meet the requirements of the tests detailed in lEC 60529 with classification IP 50 (dust protected). If the individual enclosure of the relay is to a class less than IP50 then the bidder shall provide a cubicle to classification IP 50 to accommodate the relay.

27.3.3.7.2 Mechanical environment

Vibration

The protection system shall meet the requirements of the tests detailed in lEC 60255-21-1 with severity class 1.

Shock and bump

The protection system shall meet the requirements of the tests detailed in lEC 60255-21-2 with severity class 1.

Seismic

The protection system shall meet the requirements of the tests detailed in IEC 60255-21-3 with severity class 1.

27.3.3.7.3 Electrical environment

DC auxiliary energizing quantity

The protection systems shall be capable of being energized from a d.c. auxiliary energizing voltage of 110 V (nominal).

The protection system or its associated power supply for use in a 110 V (nominal) D.C. supply system shall operate correctly over a voltage range of 88 V to 137.5 V and shall withstand a maximum voltage of 143 V.

Where digital and numerical protection systems are used they shall meet the requirements of lEC 60255-11 with interruptions to the D.C. auxiliary energizing quantity of 50 ms.

Frequency

The standard rated frequency shall be 50 Hz. The nominal range of frequency shall be -5 per cent to +5 per cent.

Thermal rating of equipment

Relay equipment intended to perform a current measurement function shall be capable of continuous operation at a current of not less than 2.4 times the nominal rating or 2 times the setting value, whichever is the more onerous.

Relay equipment intended for use in a normally quiescent mode and having a short time rating shall be rated in accordance with the intended function and taking account of such inherent protective devices as may be incorporated in the design,

The short time rating for all protection relaying schemes shall be 100 times the nominal relay rating for a duration of 1 s.

Voltage sensitive equipment intended for use on effectively earthed networks shall have a continuous withstand of not less than 1.2 times nominal voltage and a short duration withstand of not less than 1.5 times nominal phase-to-earth voltage for 30 s.

Insulation

- Rated Insulation Voltage:

  The rated insulation voltage of circuits connected to current transformers of high impedance relays shall be 1000 V. All other circuits shall have an insulation voltage of 250 V.

  All open contacts of the protection system shall withstand a voltage of 1000 V.

- Dielectric Tests:

  The protection system shall comply with the dielectric test requirements of IEC 60255-5. The test voltage shall be selected according to the rated insulation voltage of the circuits being tested from Series C of Table I of IEC 60255-5.

- Impulse Voltage:

  The protection system shall comply with the impulse test requirements of IEC 60255-5 with test voltage of 2 kV.

27.3.3.8 Mechanical requirements

All relay cases shall prevent the ingress of dust and shall meet the requirements of IEC 60529 Classification IP 50, Category 2. For certain special applications, a more stringent classification, IP 54, may be called for in the Specification.

Wherever practicable the design of the relay schemes shall be based on the "fail-safe" principle. For example, care shall be taken to ensure that loss of D.C. supply or an open circuit does not cause incorrect opening or closing of a circuit breaker. Circuit breaker repeat relays shall be of the latching type, and a discrepancy alarm shall be provided to check the correct operation of the relays following circuit breaker operation.

27.3.3.9 Power supplies

Auxiliary supplies for the protection relays shall be derived from the 110V d.c. system.

The auxiliary supply to each relay unit shall be continuously monitored and an alarm shall be given whenever the voltage exceeds or falls below the limits set for reliable protection operation.

27.3.3.10 Multi-contact tripping relays

All multi-contact tripping relays shall be suitable for panel mounting. The design of the operating coil shall be such as to permit operation in conjunction with series trip flag relays should these be specified. When provided on the relays, economy contacts used to reduce the level of energization of the operating coil after operation shall be delayed in operation sufficiently long enough to ensure that series flag relays operate correctly.

All contacts shall operate within the prescribed time for the particular category which shall not, in any case, exceed 10 ms from the time at which the operating coil is first energized to the time of complete contact closure.

Where lockout relays are specified, these must be of the mechanically latched type and shall be hand or electrically reset as specified.

27.3.3.11 Commissioning and routine testing facilities

Each functional relay scheme shall be so arranged that operational and calibration checks can be carried out when the associated primary circuit(s) is/are in service and form part of the operational network.

Adequate test facilities shall be provided at the front of the relay panel to enable the protection equipment to be tested whilst the primary circuit is on load, without having to disturb any wiring.

Adequate facilities shall be provided to isolate all a.c. and d.c. incoming and outgoing circuits so that work may be carried out on the equipment with complete safety to personnel and without loss of security in the operation of the switching station.

27.4 Particular Requirements

27.4.1 Power Transformer Protection Panels

The power transformer protection panels shall be located in the Powerhouse protection relay room, adjacent to the associated generator protection panels, and shall incorporate all the functions listed in the table below.

The relays and associated equipment shall be accommodated in floor standing, rear entry cubicle type relay panels with cable entry from the bottom.

The scheme shall be such that a trip from transformer protection stops the turbine and opens the field breaker as an inter-trip.

The protection scheme shall include:

- Overcurrent
- Earth fault
- Neutral earth fault
- Mechanical protections (buchholz, oil/winding temperature), and
- Generator Guard Relays

27.4.2 Generator Protection Panels

The following Generator protection guard relays shall be provided to issue an inter-trip to the transformer circuit breaker, field breaker and turbine;

- Loss of excititation,
- Rotor earth fault,
- Stator earth fault,
- Generator over and under frequency,
- Governor fault,
- Overspeed
- Loss of auxiliary power
- Inlet valve closing

27.4.3 11 kV Transmission System Protection Panels

The11 kV transmission line shall be protected by appropriately sized drop out fuses.

27.4.4 Metering

Metering panels incorporating Main and Check kWh and kVArh, and import and export revenue meters for the transmission line and generator circuits shall be supplied as required.

27.5 Unit Electrical Protection

The protection scheme applied to each turbine generator unit including generator, generator transformer, excitation system and generator connections and switchgear shall be based on numerical relays. The scheme shall be designed to ensure that faults are cleared within the clearance times required to ensure stability and minimise damage, with any one component of the protection scheme out of service. This shall include the removal from service, intentionally or otherwise, of any relay including multi-function relay, battery, communication path, CT core, VT core, CB trip coil or wire. The integrity of the relays and tripping circuits shall be continually monitored.

The operation of protection devices shall result in shutdown of plant in a defined sequence, details of which are to be submitted by the Contractor.

It is operationally important that some advance warning of impending trip action is given. This shall be by the initiation of a first stage alarm, set to operate before the trip condition is reached. In the case of high-speed trip devices no first stage alarm is required.

Protection devices shall operate emergency shutdown/stop latched trip relays. Operation of shutdown relays shall prevent any attempt to restart the Unit. Failure of any stop sequence shall cause a unit emergency shutdown. It will be necessary for the operator to manually reset trip relays, usually following an investigation into the cause of operation. However, alarms shall be grouped together to allow limited electrical reset from remote where machine harm is not of concern. Different levels of trip action shall ensure that the Unit is not suddenly tripped off line, with consequent disturbances to the system, unless it is imperative for the safety of the machine to do so.

Emergency shutdown due to electrical or mechanical protection operation shall be carried out independently of the Unit control system. The correct functioning of the protection system shall not rely in any way on the correct functioning of the control system.

27.5.1 Miscellaneous Protection relays

Other protection relays and ancillary equipment to be provided:

Circuit breaker fail relay

A relay shall be provided to monitor all trip signals sent to the transformer circuit breaker, and shall send an inter-trip signal to the high voltage if current continues to flow after a preset time. The time delay setting range shall be sufficient to allow for the maximum fault clearance time of the transformer circuit breaker.

Tripping and shutdown relays

All tripping relays shall be of the heavy duty type with robust operating coils of sufficiently high burden to be operated in conjunction with series trip flags. "Cut-throat" contacts in series with operating coils shall be delayed to ensure series trip relays operate correctly. Relay operating time shall not exceed 10 ms from energisation of the trip relay operating coil.

Relays shall be electrically reset with hand reset flags, or self-reset as appropriate.

Lockout tripping relays shall be of the latching type with flag indicators. Resetting of the relay shall not require opening of the relay case.

27.6 Unit & Associated Plant Mechanical Protection and Alarms

The Contractor shall provide protection and alarm devices as he considers necessary for the safe operation of the mechanical elements of the turbine generator unit and all associated plant and equipment including hydro mechanical plant and equipment. The minimum provision shall be as detailed in the table overleaf.

The Contractor shall provide all necessary mechanical protection devices, together with all necessary piping, valves, fittings and electrical connections.

The Contractor shall provide hand-reset emergency stop and shutdown relays for the turbine generator units including:

- Unit emergency shutdown;
- Unit quick (mechanical) shutdown;
- Unit hydraulic shutdown; and
- Unit normal stop.

27.7 Energy Metering

Revenue metering shall be provided on the outgoing transmission lines and shall be installed at the 11 kV switchyard control building.

Revenue class energy meters shall be provided as follows:

(a) A revenue meter and a check meter shall be provided, the meter and check meter utilising separate CT and VT secondary windings.

(b) Metering systems shall meter kWh and kVArh, import and export, on half hour intervals.

(c) Revenue meters shall be equipped, interfaced and made functional for download of recorded data via the SCADA system.

(d) Meters shall be class 0.2 electronic digital meters.

(e) Electrical power transducers shall be capable of making power measurement.

(f) Meters shall be capable of displaying primary values.

VTs and CTs used for revenue metering shall be class 0.2.

27.8 Factory Acceptance Tests

Protection panels (including relays) and metering equipment shall be subjected to routine and type tests at the manufacturer's works in accordance with the relevant International Electrotechnical Commission (IEC) Standards or equivalent.

All protection relays and associated equipment shall be tested in accordance with the requirements of IEC 60255.

Type test reports shall be accepted in lieu of type testing; provided that the Contractor submits in advance certified type test reports for tests on similar equipment carried out by an independent accredited testing authority.

27.8.1 Type Tests

A type test certificate shall be provided for each relay type, which should confirm compliance of the protection relay with the requirements of the relevant sections of IEC 60255 as detailed in this specification. Any areas of non-compliance shall specifically be identified. It shall be stated whether the protection relay has been approved by any independent approval bodies or users.

Should the certificates be invalid or unacceptable to the Employer, the type tests shall be performed by a recognised and Employer approved independent laboratory.

27.8.2 Routine Tests

A routine testing programme shall be determined between the Engineer and the Contractor before the tests are undertaken at the premises of the equipment supplier. Notwithstanding, the routine testing shall comprise, as a minimum, of the following tests performed on one tenth of each relay type:-

a. Functional tests.

b. Dielectric Test (a.c. power frequency high voltage test) with 2 kV, 50Hz for 1min as per IEC-60255-5.

c. Electrical disturbance test (for static relays only) to IEC 60255-22.

The tests shall be conducted in the presence of the Owner or their representative.

The Contractor shall submit a report to the Engineer detailing the routine tests and the test results.

Inspection and taking over in the factory do not relieve the Contractor from his obligations as per the contract documents and guarantee of performance.

27.9 Tests on Completion

All test sets and test equipment required for testing the protection relays and metering equipment shall be provided by the Contractor.

All protection relays and associated equipment shall be tested in accordance with the requirements of IEC 60255.

The Contractor shall perform the following site tests on the protective relays:-

a. Relay auxiliary D.C. supply checks

b. CTs and associated secondary wiring tests

c. VTs and associated secondary wiring tests

d. Application of relay settings as determined in the Protection Setting Report

e. Secondary injection testing to determine relay settings and operation within manufacturers stated parameters.

f. Checks of all alarm circuits

g. Primary injection tests where appropriate

h. Functional testing of all relays. This includes testing protection relays, aided by secondary as necessary, a scheme operation of relevant CBs

The Contractor shall submit for approval a Commissioning Programme prior to the tests being performed. The Commissioning Programme shall include, as a minimum, the following:-

a. List of the site test for all protection systems/relays and associated power equipment (CTs/VTs etc.)

b. Procedures and methods for each commissioning test including those to be performed on-load.

c. Testing equipment and instruments necessary for performing of each test

d. Format of site test reports for each test.

e. Installation, operation and maintenance manuals

Each site test shall be witnessed and signed off by an Employer's Engineer or their representative.

One month before the site tests and commissioning start the Contractor shall submit to the Employer the Protection Setting Report.

Commissioning will be deemed complete when all relevant equipment is energised, loaded and all necessary on-load tests, measurements and checks are complete and signed for by the Engineer.

27.9.1 Pre-Commissioning Tests

The pre-commissioning tests on the protection equipment shall include, but not be limited to, the following:

(a) Visual inspection

(b) Insulation resistance test

(c) Wiring checks and loop resistance

(d) CT polarity and magnetisation curves

(e) Secondary injection tests on protection relays

(f) Primary injection tests of relays and circuit wiring

(g) Alarm and trip testing

(h) On-load tests with simulation of faults

(i) Operation and accuracy of all meters shall be verified

27.9.2 Commissioning Tests

Commissioning tests on the protection equipment shall include, but not be limited to, the following:

(a) Alarm and trip testing.

(b) On-load tests with simulation of faults.

(c) Operation and accuracy of all meters shall be verified.

(d) Reliability Test.

Following commissioning tests the relays shall be sealed to prevent unauthorised alteration of settings or logic programming and a table of relay settings at the time of taking over shall be provided.

27.10 Service life and Service Support

The protection systems shall be designed for a service life of at least 15 years, allowing for only routine testing that is limited to basic functional testing in accordance with manufacturers recommendations.

The service life of the protection system equipment in relation to that of the main HV plant and apparatus shall be stated so that the cost of any replacement during the life of the substation can be assessed.

The period for which lifetime support will be provided for the protection system equipment shall be stated. Recommendations for the provision of spare parts are required.

Circuit diagrams for each protection system and the associated tripping system(s) shall be supplied. The diagrams shall provide sufficient information to enable fault finding and maintenance to be carried out and shall not consist solely of information used for equipment manufacture.

A service to enable any faulty item of protection equipment to be rectified or replaced within a stated period of the fault being reported shall be provided. The repair/replacement period shall be defined.

Training for the Employer's personnel in the operation and maintenance of the protection equipment shall be offered.

Section 28: Technical Specifications – AC Auxiliary Power System

28.1 General

This section of the Employer's Requirements covers the requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the A.C. auxiliary power system comprising 0.4kV switchboard together with all auxiliary equipment and spares.

28.2 Scope of Work

The scope of work includes the following equipment:

- 400V switchboard

  Lighting sub-distribution boards are specified under the Employer's Requirements for "Lighting and Small Power".

28.3 400 V Switchboard

28.3.1 General

The Contractor shall be responsible for determining the arrangement of the 400V switchboard and sub-distribution boards and the number and rating of incoming and outgoing circuits. The switchboards and sub-distribution boards shall be equipped with spare feeder compartments or outgoing circuits of typical ratings. The spare compartments or outgoing feeders shall be fully equipped.

The switchboards shall be fully assembled and tested as appropriate in the manufacturer's works prior to delivery to site for installation.

28.3.2 Principal Parameters

Operating voltage and frequency	400 V 50 Hz
Insulation voltage (phase-neutral/phase-phase)	600/1000 V
Neutral earthing	Solid
Impulse withstand voltage	12 kV
Rated short-time withstand rms current for 1 s	TBA
Auxiliary supply voltage (tripping/control)	110 V d.c.

Busbar rated current	1000 A
Cable entry	Top and Bottom
Ingress protection (IEC 60529)	IP41
Form of separation	Form 3b Type 1
Access	Front and rear
Extension capability	Both ends

28.3.3 Particular Requirements

The 400 V switchboard shall be of the metal clad modular type, complying with IEC 60439-1 and -2, and shall be equipped with a single set of three-phase and neutral and earth busbars incorporating air circuit breakers, contactors, moulded case circuit breakers, fuse switch units and distribution fuse boards as necessary. The switchboard shall be suitable for use on a 400 V 50 Hz three phase and neutral system with the neutral solidly earthed, and otherwise as stated in the principal parameters table above.

The switchboard shall be designed to supply rated power continuously to the connected loads within the limits of voltage and frequency variations allowed and shall be capable of withstanding the thermal effects and the electromagnetic forces that may occur during a through fault.

Incoming and outgoing circuits on the 400 V switchboard shall be protected against short circuits by moulded case circuit breakers as appropriate to the duty and the available fault current. The Design and Build Contractor shall determine the circuit breaker ratings following the finalisation of unit auxiliary loads.

The construction of the 400 V switchboard shall comply with IEC 60439. Both demountable and withdrawable types of compartment are acceptable.

All control devices associated with load circuit functions, including starters, contactors, change-over switches, pushbuttons, etc. shall be grouped together on the control panel to facilitate operation of an auxiliary (and its standby).

The Contractor shall provide a handling truck for 400 V circuitbreaker handling, such that it shall be possible for one man to remove a circuit breaker from its compartment and transport it from the switchboard.

The switchboards shall be suitable for mounting on a concrete floor or plinth. All necessary foundation fixing bolts and rails shall be provided.

All indication lamps shall be of the high-intensity multi-element LED type.

28.3.4 Circuit Breakers

The circuit breakers shall be four pole, air break, motor wound, spring operated, horizontal draw-out type and have inherent fault making and breaking capacity required by the system.

Each circuit breaker shall be mounted on a wheeled carriage to give ease of withdrawal onto the circuit breaker truck.

Each circuit breaker shall be provided with three positions - service, test and fully withdrawn. The test position shall allow the circuit breaker to be tested for operation without energising the power circuits.

A loose earthing device shall be provided to allow either the busbar or load circuits to be earthed through the circuit breaker.

Where a circuit breaker supplies a switchboard containing latched contactors then the circuit breaker shall be equipped with an under voltage relay.

Each circuit breaker shall be equipped with the following equipment:

(a) trip/close control switch

(b) emergency trip pushbutton (stayput)

(c) local/remote selector switch, lockable

(d) ammeter with selector switch

(e) voltmeter with selector switch

(f) overload relays

28.3.5 Contactors

Normal control of the turbine and generator auxiliary motors and heaters will be remote from the Unit Local Control Board through the automatic start-up sequencing equipment.

Contactor circuits shall be provided with the following facilities, as appropriate:

(a) Start/Stop pushbuttons

(b) Local manual/Auto/Maintenance selector switch

(c) Duty/Standby selector switch in the case of duplicate drives

(d) Remote indication of motor running / motor stopped

28.3.6 Fuse Switches

Fuse switches shall comply with the requirements of IEC 60947-3. The operating mechanism shall be of the spring-loaded type, such that the operator cannot control the speed of operation. Full opening and closing of the switch shall be achieved independent of the operator's actions.

Mechanical interlocking shall be provided so that the door cannot be opened whilst the switch is in the closed position. Facilities shall be provided for locking the switch in the open position.

An insulating barrier shall be fitted to separate the fuse switch from the busbar connections so that maintenance may be carried out in safety.

28.3.7 Local Pushbutton Stations

Local start/stop pushbutton stations complete with ammeters shall be provided adjacent to each motor, for maintenance purposes.

28.3.8 Protection

The incoming circuit breaker shall be fitted with overcurrent and earth fault relays. A three-phase voltage transformer shall be provided in the incoming circuits from the station auxiliary transformers for control and metering.

The MCCBs and MCBs for the outgoing circuits shall be fitted with thermal overload and instantaneous magnetic trips for short-circuit protection.

Contactors used for motor starting shall be equipped with phase failure relays.

For circuits controlling motors over 30 kW, transformer operated overload, phase failure and instantaneous earth fault relays shall be provided. Phase failure protection shall operate with out-of-balance currents not exceeding 85% full load motor current.

Where latched-type contactors are being supplied, the switchboard shall be supplied with an under voltage relay and a timer controlled master tripping relay. The under voltage relay and timer shall have adjustable settings. The switchboard shall be so connected that, on operation of its master tripping relay, all contactors on that switchboard shall trip.

28.3.9 Interface with Control System

The Contractor shall provide the necessary hardware for interfacing the 400 V switchboards with the Controland Monitoring System (CMS). The CMS shall monitor switchboard alarms, circuit breaker status and voltage/current/power measurements.

28.3.10 MCB Distribution Boards

MCB distribution boards shall be supplied to provide single phase 230 V a.c. supplies as required. These supplies will be for the following:

- Powerhouse lighting distribution
- Powerhouse small power distribution
- Powerhouse auxiliary supplies
- Substation lighting and small power distribution
- Building lighting and small power distribution
- Intake lighting and small power distribution

28.3.11 Tests on Completion

The following site pre-commissioning tests shall be performed including, but not limited to, the following:

a) Visual inspection

b) Insulation resistance tests

c) Continuity tests

d) Routine high voltage tests

e) Protection relay primary and secondary injection tests

Commissioning tests shall be performed including, but not limited to, the following:

a) Function tests to verify tripping, closing, interlocking, alarms and indications, etc.

Section 29: Technical Specifications – DC Systems and Uninterruptible Power Supplies

29.1 General

This section of the Employer's Requirements covers the requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the DC Systems & Uninterruptible Power Supplies.

29.2 Scope of Work

The DC Systems & Uninterruptible Power Supplies shall include, but not be limited to the following:

Powerhouse and Substation

- Two 110 V battery sets consisting of valve-regulated lead-acid cells of suitable ampere hour (Ah) capacity, for essential supplies to switchgear, protection and control systems.
- Two 110 V d.c. battery chargers, each comprising a 100% rated battery boost/float charger, with automatic change-over on the DC side, suitable for operation from a 400 V, 50 Hz, 3-phase and neutral a.c. supply, complete with incoming isolators and all necessary fuses, indications and selector switches etc.
- One common 110 V d.c. distribution board.
- One 48 V battery set consisting of valve-regulated lead-acid cells of suitable Ah capacity (minimum 80 Ah) for supplies to the telephone and communications system.
- One 48 V battery charger comprising a 100% rated battery boost/float charger, with automatic change-over on the DC side, suitable for operation from a 400 V, 50 Hz, 3-phase and neutral a.c. supply, complete with incoming isolators and all necessary fuses, indications and selector switches etc.
- One common 48 V d.c. distribution board, with a minimum of eight outgoing ways.
- One uninterruptible power supply (UPS) system.
- One 230 V a.c. distribution board for UPS supply distribution.

Provision for the monitoring of alarms, status and parameters by the Control and Monitoring system shall be included.

The batteries shall be housed in a ventilated battery room, specifically constructed for the purpose. The battery chargers, inverters and associated distribution switchboards shall be housed in rooms separate from the batteries.

29.3 Principal Parameters

Cell type	Valve-regulated lead-acid (sealed recombination type)
Cell capacity (10-hour rate)	To be sized by the Contractor according to functional requirements
Number of cells per battery	To be selected by the Contractor according to functional requirements
Charger type	Constant voltage
Nominal battery/charger voltage	110 V or 48 V
Charger supply voltage	230 V a.c. 50 Hz single phase or 400 V a.c. 3-phase
UPS output rating	To be selected by the Contractor according to functional requirements

29.4 Batteries

Batteries shall consist of lead/acid cells of the valve-regulated sealed recombination type, with a minimum 5 year guaranteed life. Minimum capacity at the 10-hour discharge rate shall be selected by the Contractor, based on the following duty:

The powerhouse/Substation battery shall be capable of maintaining all essential loads including turbine/generator lubricating oil pumps for 1 hour, and of maintaining the turbine/generator control system and ancillaries for a total of 8 hours. It shall also be capable of carrying the standing load of the 11 kV switchboard and for a minimum of 8 hours and of closing and tripping each circuit breaker at least twice. The control system supply may be either directly from the battery or via the UPS unit. The UPS unit shall also supply the fibre optic equipment and Control and Monitoring System operator interface equipment.

The communications battery shall be capable of maintaining the telephone exchange and all peripheral communications equipment for a minimum of 8 hours.

Batteries shall be supplied complete with stands and all necessary connecting links.

Batteries shall be completely maintenance free, and it shall not be possible to open the cells, which must be leak-proof and spill-proof.

The 110 V battery shall be completely isolated from earth, with both positive and negative legs floating. The 48 V battery shall have the positive leg solidly earthed through a test link.

29.5 Chargers and Voltage Control

29.5.1 General

Each installation shall comprise duplicate 100% chargers. Each charger shall be capable of carrying the total d.c. load and full battery float charge requirements.

The battery chargers shall be of the automatic, constant voltage, thyristor-controlled type; equipped with full wave silicon controlled rectifiers, current-limiting facilities and plug in modules.

The continuous current rating of the battery chargers shall be determined such that the battery may be fully recharged in 12 hours after 90% discharge.

The battery charger circuitry shall include current limiting, short circuit protection, and reverse polarity protection.

The battery chargers shall include:

(a) Control and indication facilities mounted on the front panel of the charger;

(b) Electronic protection to prevent the battery discharging through the charger should the latter become defective;

(c) Alarm devices and indication lamps;

(d) A totally enclosed load-breaking isolator to control the incoming a.c. supply;

(e) Thermal overload relay and contactor on the a.c. input side arranged to open on a.c. supply failure of any phase;

(f) Fuses for the protection of semi-conducting rectifiers or thyristors;

(g) A lockout relay to open the a.c. supply contactor in the event that the charger d.c. output voltage exceeds 2.5 V/cell when on auto control.

The chargers shall have a constant voltage characteristic and shall be designed to carry the load current while the battery floats and to replenish the battery after intermittent discharges. The d.c. voltage shall be maintained within ± 0.5 percent of the set voltage for all loads from zero to rated output for any variation of between ± 10 percent of the nominal a.c. input voltage or between 48-55 Hz in frequency.

With the battery connected and at any load between zero and rated load (non-reactive) the peak value of the ripple voltage (unweighted) measured across the output terminals shall not exceed the following:

Charger nominal d.c. voltage	110 V or 48 V
Ripple voltage limit peak to peak (as % of nominal d.c. voltage)	3%

29.5.2 Control and Indication Facilities

Ammeters and voltmeters shall be provided to indicate the a.c. and d.c. voltage and current of the charger. All indicating instruments shall be at least 96 mm square.

29.5.3 Alarm Facilities

The alarm equipment shall include multi-segment high intensity LED lamps to indicate the individual alarm conditions shown below, together with a common relay with a time delay adjustable from 0-10 seconds with hand reset flag and contacts for remote indication of the alarm group:

(a) Charger output volts high

(b) Charger output volts low

(c) Charger a.c. supply failed

(d) Charger fault

(e) Battery earth fault

(f) Charger on boost

(g) common alarm volt-free contacts, audible alarm and reset

The 'charger volts low' alarm shall be prevented from operating when the a.c. supply falls. The 'charger a.c. supply failed' alarm shall operate in the event of the failure of any one phase or when the charger is switched off.

The battery earth fault device shall distinguish between positive and negative earth faults.

29.5.4 Construction Details

The charger cubicles shall offer a degree of protection of not less than IP31 to IEC 60529, except for the top of the cubicles which shall be IP51. If practicable, ventilating screens or louvres shall be positioned only at the rear.

29.6 D.C. Distribution Boards

29.6.1 General

The continuous current rating of the distribution boards shall be determined by the Contractor. The boards shall be supplied complete with disconnecting switches, moulded case circuit breakers, control, indication and alarm devices as necessary.

The d.c. distribution boards should preferably be arranged together with the D.C chargers to form a common suite of panels. They shall consist of floor-mounted cubicles with front and rear doors. The boards shall offer a degree of protection of not less than IP51 to IEC 60529. A label shall be provided for each circuit, giving breaker type and size and a description of the circuit supplied.

Double pole circuit-breakers with thermally operated overload trips and instantaneous magnetic trips for short-circuit protection shall be provided for each outgoing circuit and for the incoming d.c. supply from the charger. The MCBs and MCCBs shall be fitted with auxiliary contacts for alarm purposes.

The boards shall be designed so that all disconnecting switches, indicating and control devices are mounted on the front of each board, while all the relays and circuit-breakers are mounted on an internal fixed panel behind the front door. The wiring terminal blocks and cable terminations shall be located in the area behind the internal fixed panel and shall be accessible from the board's rear doors. No wiring to equipment mounted on the internal fixed panel shall be visible from the front of this panel.

29.7 UPS

29.7.1 General

A suitably sized uninterruptible power supply unit shall be provided, fed by the powerhouse 110 V battery detailed above.

Input supply shall be 110 V D.C. and output shall be 230 V a.c. (50 Hz).

The UPS unit shall have an integral static bypass switch for maintenance or repair purposes.

The rating of the UPS shall allow for the following loads, with a suitable safety margin of overcapacity: all Control and Monitoring System load, including generator local control and protection panels and control room operator workstations, all telephone system loads including telephone exchange and tie-lines, all fibre optic communications links loads including multiplexers, and any other critical or essential loads supplied at 230 V a.c.

29.8 A.C. Distribution Board

29.8.1 General

The AC distribution board shall be a single phase 230 V a.c. 50 Hz board with suitable main switch and adequate outgoing ways for the required duty. The AC distribution board shall be sized to accommodate the incoming and outgoing cables required for essential supplies to the Control and Monitoring System, such as PLC cabinet, communications cubicles, outstations and operator workstations. Further outgoing ways are required for telephone equipment, control room equipment and optic fibre/multiplexer loads.

29.9 Factory Acceptance Tests

The batteries, battery chargers, D.C. distribution boards and their components shall be tested in accordance with the applicable IEC Standards or equivalent.

The works tests shall include, but not be limited to:

(a) Temperature rise;

(b) Insulation resistance;

(c) Operational tests;

(d) Radio interference tests;

(e) Ripple measurement of the charger output without battery connected.

29.10 Tests on Completion

29.10.1 Pre-Commissioning Tests

The pre-commissioning tests on the DC Systems & Uninterruptible Power Supplies and associated equipment shall include, but not be limited to, the following:

(a) Visual inspection;

(b) Insulation resistance;

(c) Tests to confirm the charger rating;

29.10.2 Commissioning Tests

Commissioning tests on the DC Systems & Uninterruptible Power Supplies and associated equipment shall include, but not be limited to, the following:

(a) Functional tests;

(b) Setting and functional tests of protective devices

(c) Ripple measurement of the charger output with battery connected.

(d) Reliability Test

29.11 Spare Parts

Spare parts for the DC Systems and Uninterruptible Power Supplies and associated equipment shall be provided for 5 years' operation and maintenance including but not limited to the following:

(a)	10% of each type of printed circuit board, plug-in module and similar assemblies, (minimum one).	1set
(b)	25% of each type of thyristor power diode and similar components (minimum one).	1set
(c)	Each type of transducer used	1 each

Section 30: Technical Specifications – Cabling

30.1 General

The Contractor is responsible for all aspects of the cabling and associated equipment including the design, supply, delivery, erection and commissioning. The associated equipment includes, but is not limited to, cable racks, ladders and trays, cleats, steelwork and supports necessary for securing all cables.

Where cable concentration in marshalling boxes is advantageous and agreed with the Employer, the Contractor shall supply such boxes and associated terminal drawings.

30.2 Scope of Work

The scope of work covers the complete supply and installation of all cabling together with all associated containment, fittings and fixtures, and shall include but not be limited to the following:

(i) 400 V power cabling.

(ii) AC and DC auxiliary power and control cabling and all multicore screened and twisted pair cables.

(iii) All ladders, racks, trays, trunking, cleats, supports, ties, glands, terminations, markers, labels and jointing materials.

(iv) Marshalling boxes.

(v) Lighting and small power cabling associated with the equipment detailed in Employer's Requirements section – Lighting and Small Power.

30.3 Cables

Cables shall be of the following types:

(a) Cables for use on the 0.4 kV systems shall be stranded copper conductor, semi-conducting screen, cross-linked polyethylene (XLPE) insulated, copper tape shield, wire armoured (aluminium wire for single core cables, steel wire for multicore cables), LSF outer sheathed cables.

(b) Cables for use on the low voltage 400 V a.c., 110 V D.C. or 50 V D.C. systems shall be stranded copper conductor, cross-linked polyethylene or ethylene propylene rubber (EPR) insulated, wire armoured as appropriate, LSF outer sheathed cables.

(c) Cables for protection, control and indication shall be multi-core stranded copper conductor, cross-linked polyethylene or PVC insulated, wire armoured as appropriate, LSF outer sheathed cables.

(d) Cables for analogue indication signals shall be multi-pair twisted pair, individually screened, PVC sheath, screened, with a copper drain wire, steel wire armoured as appropriate, LSF outer sheathed cables to BS EN 50288. The conductor size shall be 1.5 mm^2 in 5-, 10- or 15-pair cables.

Conductors of cables shall consist of stranded annealed copper, as IEC 60228.

Cables shall be cross linked polyethylene (XLPE), ethylene propylene rubber (EPR) or polyvinylchloride (PVC) insulated cables complying with IEC 60502, and shall have a rated voltage appropriate to the service but not less than 1 kV.

All cables to outdoor areas and the main power cables to distribution boards shall be armoured, with the armour consisting of one layer of galvanised steel wires for multi-core cables or one layer of aluminium wires for single core cables, and complying with the requirements of BS EN 10257 or BS 2627.

Cables shall be provided with a black outer sheath which shall be embossed with the rated voltage, the name of the manufacturer and year of manufacture. The outer sheaths of all cables shall be of the low smoke and fume (LSF) and flame retardant types.

30.4 Cable Ratings

The Contractor shall select the type and size of cable for each circuit and shall take account of the circuit loading, circuit short circuit rating, the ambient conditions and the method of installation including adjacent circuits.

Conductors for power cables shall have a minimum cross sectional area of 2.5 mm^2. Conductors for control and protection cables shall have a minimum cross sectional area of 2.5 mm^2 except that cables for current transformer secondary circuits shall have a minimum cross sectional area of 4 mm^2. Conductors for instrumentation cables shall have a minimum cross sectional area of 1.5 mm^2.

Cables shall be sized to carry the maximum circuit load continuously without exceeding the continuous current carrying capacity calculated in accordance with IEC 60287, and taking account of adjacent current carrying cables.

Low voltage a.c. and d.c. cables shall be sized such as to give a voltage drop under maximum normal load conditions from the point of transformation from the high voltage source to the final load of not more than 2.5%. Cables supplying motors shall be sized such as to give a voltage drop from the point of transformation from the high voltage source to the motor terminals of not more than 12.5% on motor starting.

Cables shall be rated to withstand without permanent damage the thermal effects of the maximum short-circuit current available at the originating distribution board for a short circuit duration of 1 second.

30.5 Number of Cores

Cables shall have a number of cores appropriate to the service.

Cables for use on the 400 V a.c. auxiliary system shall have four equal cores for three phase circuits except for final supply to three-phase motors or distribution switchboards supplying only three-phase motors, in which case cables may have three cores or three cores with a reduced size neutral core as appropriate. The cross-sectional area of the reduced size neutral core shall be not less than half of the cross-sectional area of the phase cores.

Multi-core cables with more than 7 cores shall have approximately 20% spare cores for future use. Multi-core cables shall have no more than 37 cores, and cables shall be installed in parallel if the circuit requires more than 37 cores including spares.

30.6 Cable Trays

Cable trays shall be 200 mm wide with a distance between supports of not more than 2 m and designed to support a minimum load of 30 kg per metre length. Cable tray and supports shall be steel, hot-dipped galvanised. Tees and crosses in cable tray shall be made using prefabricated pieces. Edges shall be rolled to avoid sharp edges. Cable tray shall be cut by saw not by oxy-acetylene torch, and the cut edge shall be rolled and the finish made good.

30.7 Cable Joints

Joints in cables are to be avoided wherever possible, and may only be used where an un-jointed run is impossible, and only with the agreement of the Employer. Straight through joints, where approved, shall be made with factory prepared kits designed for the type and size of cable. Joints shall be epoxy resin type with compression type conductor joints and all components necessary to maintain electrical continuity of shields and armour. The joint shall give a degree of mechanical protection and a thermal current rating equal to that of the cable. Where joints are made in more than one cable running together the joints shall be staggered such that the joints do not lie together.

30.8 Terminations

Medium voltage cables shall be terminated with factory prepared kits designed for the type and size of cable to be terminated. Terminations shall be heat shrink polymeric type with all components necessary to reinstate the cable insulation and shielding. Voltage stress relief shall be provided.

At all terminations of wires and cables, the insulation shall be neatly stripped without buckling the strands of the conductors. Cable lugs for power cables shall be of adequate size and shall be of the compression type.

Cable glands or clamps shall be fitted in all cases to prevent any stress being taken by the conductors or the terminals. The sealing compound and sleeves used in terminations shall be selected to suit the service temperature conditions under which the cable is to operate.

Where cable terminations are likely to be disturbed for maintenance purposes, some slack cable, in a loop or other suitable form, shall be allowed at a convenient place in the run close to the termination.

30.9 Cable Glands

Cable glands shall be of the compression type with armour and bonding clamps designed to secure the armour and to provide electrical continuity between the armour and the cable box and to provide watertight seals between the cable outer sheath and the cable box. The glands shall project above the gland plate to avoid entry of moisture into the cable.

30.10 Cable and Core Ferrules

All cables and cores shall be identified in accordance with the associated cable schedules by means of discrete cable and wire numbers. Both ends of every cable shall be fitted with ferrules of white insulating material indelibly marked with black characters. Heat shrink marking sleeves may be used, but adhesive markers are not acceptable. Both ends of every core shall be identified with slip-on ferrules of white insulating material indelibly marked with black characters. Cores used for tripping shall additional be identified at both ends with slip-on ferrules of white insulating material indelibly marked with the letter T in red.

The cable and wire numbering system shall be agreed with the Employer at the start of the Contract.

30.11 Installation

Cable systems within the Powerhouse and other enclosed areas shall be installed on cable trays.

Cables shall be installed to provide segregation between the following classes of cables:

- Medium voltage cable circuits.
- Low voltage a.c. and D.C. power circuits.
- Control and protection circuits.
- Instrumentation.

Joints in cable circuits that run entirely within the Powerhouse will not be permitted.

30.12 Fire Risk

The complete cable installation shall be designed and installed so as to minimise the risk of fire and damage in the event of fire.

Wherever cables pass through floors, walls or other indoor partitions, the Contractor shall supply and install fire protection barriers, which shall be arranged to prevent the spread of fire. The fire protection barriers shall comprise seals or bushes of an approved type. Where the cables pass through the fire protection barriers, the penetration shall be sealed using fire-resisting materials.

30.13 Factory Acceptance Tests

Prior to shipment from the manufacturer's works all cables shall be tested.

Factory test certificates for all cables shall be provided.

LV cables shall be sourced from a reputable manufacturer with certified quality assurance procedures and traceable records for all supplied cables.

30.14 Tests on Completion

30.14.1 Pre-Commissioning Tests

The pre-commissioning tests on the cabling and associated equipment shall include, but not be limited to, the following:

- Visual inspection.
- Continuity tests.

30.14.2 Commissioning Tests

Commissioning tests on the tests on the cabling and associated equipment shall include, but not be limited to, the following:

- Insulation resistance tests (Megger tests).
- High voltage tests (pressure test).

Section 31: Technical Specifications – Lighting and Small Power

31.1 General

This section of the Employer's Requirements covers the requirements for the design, manufacture, workshop testing, protective coating, supply, delivery, erection, commissioning, testing and setting to work of the small power and lighting system.

31.2 Scope of Work

The scope of work shall include the design, supply, installation, testing and putting into operation of a complete small power and lighting system covering the following areas:

- Powerhouse
- Management House and Staff House
- 11 kV Substation
- Intake Area
- Tailrace area

31.3 Particular Requirements

Lighting distribution is, in general, to be arranged on a radial principle with each circuit being controlled by a suitably rated miniature circuit breaker. Switching of plant lights should be arranged from one or more central positions with two-way switching if necessary on a limited number of circuits to permit essential lights to be switched on when entering the building. In small buildings and rooms switching should be from the door or entrance.

In designing plant lighting distribution schemes the loading of individual circuits should not be more than approximately 10 A per circuit. To minimise the effect of a circuit failure, plant lighting circuits should be so arranged that the failure of one circuit will cause the loss of no more than half the lights in that particular area.

Small power distribution should be based on a radial principle using main and sub-main distribution boards suitably located. Circuit breakers in sub-main distribution boards and lighting distribution boards shall be suitably rated for the calculated fault level at the distribution board. If necessary 400/400 V auxiliary transformers shall be used for lighting or small power circuits to reduce the prospective short circuit current.

All lighting and small power equipment shall conform to IEC/BS or equivalent standards.

31.4 Illumination Levels

Lighting shall be designed to achieve the minimum light levels stated below, for both normal lighting and emergency lighting:

	Normal light level (lux)	Emergency light level (lux)
Powerhouse floors	300	20
Equipment rooms and galleries	150	20
Passages	150	20
Switchrooms	200	50
Relay rooms	350	20
Above control panels	350	20
Management/Staff House/Workshop	500	20
Exterior walkways and platforms	50	20
Exterior stairways and ladders	100	20
Roadways in plant area	10	-
General outside lighting	5	-
Substation (outdoor)	20	-
Environmental flow outlet area	100	20
Headrace tunnel intake area)	100	20
Scour tunnel and tunnel portal area	50	20
Penstock access walkways and stairways	50	20

31.5 Luminaires

31.5.1 Normal Lighting

Fluorescent lighting fixtures with one or two fluorescent lamp(s), starter(s) and ballast(s) shall be provided.

Unless otherwise approved, fluorescent lamp circuits shall be of the switch start type with shunt capacitors. Ballasts shall be low-loss or electronic.

Fluorescent lamps shall be tubular type to IEC 60081 with a rated life not less than 7500 hours.

31.5.2 Emergency Lighting

Self-contained emergency lighting luminaires shall be of the type incorporating an in-built battery supply capable of maintaining the output of the luminaire for not less than

2 hours after the failure of the mains supply. The luminaire battery shall be of the no-maintenance, long life (minimum 15 years) type and shall be automatically recharged on restoration of the mains supply.

The luminaires shall be of the type which is illuminated only when the mains supply fails.

31.6 Switches

Switches for the control of lighting shall be furnished and installed. All switches shall be heavy-duty toggle type rated at least 20 A at 250 V a.c. for tungsten filament or fluorescent lamp load.

31.7 Small Power and Associated Cabling

The supply and installation of cabling and associated equipment shall be in accordance with these Employer's requirements and the relevant Zambian and International codes.

Earthing and bonding shall comply with BS 7430 (Code of Practice for Earthing) and the whole of the Facility shall be solidly bonded into the station earthing system.

31.8 Powerhouse High Bay Lighting

31.8.1 General

The powerhouse high bay lighting system shall be controlled by a photoelectric cell. The high bay lighting shall be arranged in three circuits so that it shall be possible to switch-off one third or two-thirds of the light fittings during periods of low occupancy of the powerhouse.

31.8.1.1 Luminaires

For the powerhouse floor and maintenance bay areas, T5 high-intensity fluorescent luminaries complete with power factor correction capacitor and all necessary fittings and fixings shall be provided.

31.8.2 Photoelectric Control Unit

A photoelectric control unit shall be provided to control the powerhouse high bay lighting system.

The photoelectric control unit shall be designed to operate at an illumination level adjustment from 5 to 50 lux. It shall operate from a 230 V a.c. 50 Hz source, be furnished with an adjustable time delay, and shall be complete with manual-off-auto control switch, all necessary control relays, and photoelectric cell. The control unit shall be enclosed in an outdoor type enclosure.

31.9 Outdoor Lighting

31.9.1 Substation

General area lighting in the 11 kV outdoor Substation shall have a minimum illumination level of 20 lux throughout the fenced area. Lighting shall be by means of high mast installations or columns located around the perimeter fence and floodlight fittings located on the steel gantries or support steelwork.

31.10 Tests on Completion

31.10.1 Pre-Commissioning Tests

The pre-commissioning tests on the small power and lighting systems shall include, but not be limited to, the following:

- Visual inspection.
- Continuity tests.

31.10.2 Commissioning Tests

Commissioning tests on the tests on the small power and lighting systems shall include, but not be limited to, the following:

- Insulation resistance tests (Megger tests).
- Earth fault loop impedance tests.
- Illumination level tests.
- Reliability test.

Section 32: Technical Specifications – Earthing and Lightning Protection

32.1 General

The earthing system shall conform to the relevant sections of IEC 60364-5-54, IEEE 80 and IEEE 665.

The combined resistance of the earth electrode system shall, if possible, be less than 0.5 ohm and shall not exceed 2 ohms under any climatic conditions. The Contractor shall make tests of the soil resistivity on site and state the results together with his proposals for achieving an acceptable value of earth resistance.

Earth conductors installed directly into the ground shall normally be laid bare and the trench back filled with fine topsoil. Where the soil is of a hostile nature, precautions must be taken to protect the earth conductor. In addition marker tapes shall be installed above the earth conductors directly buried in the ground.

Copper to copper joints shall be exothermically welded to produce a permanent electrical connection. Bolted joints are only acceptable in disconnection link boxes and on the final connection to equipment. Joints shall have a resistance not exceeding that of an equivalent length of conductor and the Employer may require any joint to be tested to prove compliance with this requirement.

The earthing systems for the power plant house and Substation and the complex shall be interconnected.

The earthing and lightning protection installations shall comply with the requirements of BS 7430 and BS 6651 (and for the switchyard earth grid, with IEEE 80 or IEC 60479).

32.2 Scope of Work

The scope of work shall include the design, supply, installation, testing and putting into operation of all primary and secondary earthing systems and lightning protection systems for the Facilities.

The earthing and lightning protection installations shall include, but not be limited to, the following:

- An interconnected earthing system for the powerhouse.
- Earthing of plant and equipment in the powerhouse, including turbine and generator.
- Earthing of all exposed metalwork.

- Earthing of switchgear, structures and associated equipment in the 11 kV switchyard and control building, including a buried grid of earthing conductors in the switchyard, and earthing of the boundary fence and gates.
- Earthing of all cable trays and associated equipment.
- Earthing of all other steelwork including penstocks.
- Earthing of all plant and equipment for the environmental outlet and headrace tunnel intake.
- Lightning protection system for the powerhouse building and associated structures.
- Lightning protection system for the HV switchyard, covering all buildings, structures, busbars and conductors, including transmission line terminal gantries.
- Lightning protection systems for the environmental outlet and headrace tunnel intake.

32.3 Earthing Conductors

Main earthing conductors shall be soft-drawn copper tape to BS EN 13601 with a cross-sectional area not less than 150 mm^2 and a thickness not less than 3 mm and not more than 7 mm.

Main stranded earthing conductors shall be PVC insulated copper conductors with not less than seven strands and a cross-sectional area not less than 70 mm^2 to BS 6004.

Branch earthing conductors shall be soft-drawn copper tape to BS EN 13601 or PVC insulated copper conductors with not less than seven strands to BS 6004. Except where otherwise specified, branch earthing conductors shall have a cross-sectional area not less than 75 mm^2 with a thickness not less than 3 mm. The minimum cross-sectional area of the PVC insulated branch earthing conductors shall be not less than 2.5 mm^2.

Branch earthing conductors for plant operating at generator voltage, including portable earthing terminals, shall be of the same size and type as the main earthing conductors.

PVC insulated earthing conductors shall be coloured green-and-yellow.

Buried earthing conductors, such as the switchyard earthing grid, shall be either soft-drawn bare copper tape with minimum dimensions of 40x4 mm or bare stranded copper cable with a minimum cross-sectional area of 150 mm^2.

Overhead earthing conductors, such as switchyard guard wires or transmission line guard wires shall be galvanised steel wire, typically 19-strand 2.64 mm or 7-strand 4 mm, or similar.

32.4 Installation of Earthing Conductors

Earthing conductors shall be installed in a neat and workmanlike manner. Conductors shall be laid straight and level, running vertical and parallel to walls and floors. Earthing busbars shall be fixed with masonry anchors, spaced a minimum of 5 mm off the surface, using nylon spacers. Fixings shall be spaced not more than 100 times the thickness of the busbar.

Closed loops formed by the earthing system and plant adjacent to unshielded high current conductors shall be avoided. Should overheating of a part of the conductors be found, the loop shall be interrupted whilst retaining the earthing function.

Earthing switches and surge diverters shall be directly connected to the electrical conductor earthing terminals and shall not rely on earth paths through the support structure. The support structure shall be separately earthed.

Except where unavoidable, earthing conductors shall not be run on floors in areas which may be used as walkways. Where run on floors, conductors shall be suitably protected from mechanical damage.

Busbars installed in locations subject to becoming immersed in water shall be painted in epoxy paint.

The use of PVC insulated stranded branch earthing conductors shall be limited to earthing of separately mounted control devices and similar small items and for other items where the installation of copper tape is impractical.

Stranded branch earthing conductors shall be installed on perforated cable trays or enclosed in hot dipped galvanized steel conduit. The conduit serves as mechanical protection and support only. Conduits need only be installed on straight runs and may stop short of joints and terminations. The ends of all conduits shall be bushed.

32.5 Earthing Terminations and Joints

Connections to the embedded stub plates in the Powerhouse shall be by a flat steel extension bar brazed to the copper conductor and arc welded to the steel stub plates, or by copper conductor brazed to the copper alloy stub plates. Any variation in height of embedded stub plates shall be allowed for in the length of the extension bars to ensure the straightness of the copper busbar.

For steel stub plates the galvanized finish on the exposed surface of the stub plates shall be ground back before welding. After welding, the stub plate and extension bar shall be cleaned back to bright steel, degreased and painted with two coats of zinc rich primer.

At points of connection to plant and equipment the contact surface shall be cleaned, and the connection made tight with the nuts and washers provided on the plant item.

Before brazing the tinned coating, if applicable, of the busbars shall be removed from the joint area. As soon as practicable after joining, the joints shall be painted to avoid corrosion.

Stranded earthing conductors shall be terminated using approved crimped cable lugs. The joint between the main earthing busbars and the cable lugs shall be brazed. The PVC insulation shall be cut back and protected during brazing.

The Contractor shall bond miscellaneous pipes and other metal work as required.

Any underground joints between earth conductors, or conductor to earth rod shall be made by the thermoweld process (exothermic process).

32.6 Substation earthing systems

Substation earthing system shall comprise a mesh grid formed by copper strip or flexible conductor buried directly in the ground and arranged so as to utilise fully the available site area.

A continuous conductor shall be laid outside the periphery of the substation site at a distance of 1.5 m to 2.0 m from the boundary fence and at a depth of between 0.3 m and 0.4 m below the surface.

A mesh system shall be formed by interconnection at various points to the perimeter conductor. The spacing between conductors forming the mesh system shall be such as to limit the grid potential rise to a value that limits the touch voltage to a value not greater than the maximum tolerable touch potential assuming a fault clearance time equal to that of the back-up protective gear being provided.

The earth system shall be so designed as to include all overhead line terminal towers, which shall be earthed by extending the system so as to envelope all towers within the earth system. Each tower shall be bonded directly to the earth system from at least two (2) locations/points. The overhead line's earth wire shall be earthed through the steel structure of the towers.

Structures and masts for lightning and security surveillance equipment shall also be within the perimeter of the earth grid. No fixed low voltage equipment, with the exception of a warning or alarm button and intruder alarms, which shall be of the double insulation type, shall be erected outside the perimeter of the earth grid.

Earthing for high frequency coupling equipment and surge diverters shall be via a copper rod (or equivalent copper-clad steel rod) driven directly into the ground at a position immediately adjacent to the equipment being earthed in addition to the normal earth connection.

Earth bars installed directly into the ground should normally be laid bare and the trench back-filled with fine top soil. Where the soil is of a hostile nature, precautions must be taken to protect the earth bar.

All exposed joints shall be at a minimum height of 150 mm above floor or ground level.

Earth conductor joints that are required to be broken for testing or maintenance shall have mating surfaces tinned.

A facility shall be provided on the earth bar run between the equipment and the base of the structure, comprising a looped copper strip, so as to permit the attachment of portable earth connections for maintenance purposes.

32.7 System earthing

The 400 V and 11 kV systems shall be solidly earthed at the neutral points of the associated transformers.

32.8 Electrical equipment earthing

Metal parts of all equipment, other than those forming an electrical circuit, shall be directly connected to the main station earth system. In the case of main items of electrical equipment including switchboards, the frame shall be connected to the main station earth bar via at least two conductors from opposite ends of the frame.

These conductors shall each be capable of carrying safely the prospective earth current with any neutral earthing impedance short circuited for a period of 3 seconds without damage. The arrangement of the main earth system shall be such as to minimize the length of these connections.

32.9 Miscellaneous instrument earthing

The frame of draw out equipment shall be connected to the earth bar through a substantial plug type contact.

32.10 Current and voltage transformer earthing

Current and voltage transformer low voltage (secondary) circuits shall be earthed at one point only through links situated in an accessible position.

32.11 Motor earthing

All motors shall be connected via a separate earthing conductor to the general earthing system.

32.12 Structure earthing

Any reinforced steelwork of the control building structure shall be bonded together during construction and shall also be connected to the station main earth bar.

32.13 Perimeter fences

The perimeter fences shall be earthed by earth rods at points directly below overhead line entries and at appropriate intervals and at all gateways. Gate posts which form part of the fence shall be bonded together with below ground connections. The movable portion of each gate is to be earthed via a flexible copper connection to the gate stanchion or perimeter fence.

32.14 Lightning protection

The substation shall be adequately protected against direct lightning strikes, either by the use of spikes or earth wires located on the substation structures; the use of spikes is preferred. The height, location and number of spikes or earth wires shall be such as to protect all equipment installed within the substation, in accordance with DIN VDE 0141.

32.15 Surge protection

One surge arrester per phase mounted as close as possible to the protected element. Surge arresters shall be of the metal oxide type without gaps for a.c. systems in accordance with the requirements of IEC 60099-4.

Surge arrester application shall be designed as per recommendations of IEC 60099-5: Selection and Application of Surge Arresters.

32.16 Tests on Completion

32.16.1 Pre-Commissioning Tests

The pre-commissioning tests on the earthing and associated equipment shall include, but not be limited to, the following:

- Visual inspection.
- Continuity tests.

32.16.2 Commissioning Tests

Commissioning tests on the earthing and associated equipment shall include, but not be limited to, the following:

- Earth resistance tests using test electrodes.
- Reliability Test.

Total earth resistance shall be less than 0.5 Ω. If this figure cannot be achieved, additional buried conductor and/or driven earth rods shall be installed.

Section 33: Technical Specifications – Communication Equipment

33.1 General

This section specifies the detailed requirements for the design, manufacture, supply, installation and commissioning of telecommunication equipment to be used in conjunction with 11 kV overhead transmission lines.

The purpose of the telecommunication equipment is to provide communication links within Chipota Mini-hydro power station. The communication links will be used for data transfer (SCADA and remote control) and protection (accelerated inter-tripping of distance relays).

33.2 Communications

Voice and signaling links shall be via Mobile phones and radios and a suitable communication protocol as suggested by the Contractor.

33.3 Power Supply Requirements

In general, the communication equipment shall be designed to operate from a nominal 48 Vdc, positive earthed supply. However, the NMS application/communication server, operator workstations and printers that are to be installed in the SCC shall be designed to operate from the existing 240 Vac uninterruptible power supply (UPS) system.

A 48 Vdc power supply system shall be provided at Chipota Mini-hydro power station for communication equipment installed. The 48 Vdc power supply system shall consist of duplicated 100% float/boost chargers and one set of storage battery. In the case of the mains failure, the autonomy of the system shall be 10 hours. Power supply system operating in so called full float regime shall be used. Proposed batteries NiCd or lead acid type with chargers aimed at supplying of communication equipment shall have output psofometric voltage below 2 mV. The batteries and the chargers shall be sized to support the full load and 50 per cent spare capacity over and above the required loading requirements.

33.4 Electromagnetic Compatibility (EMC)

The communication equipment supplied must be able to co-exist and operate within the electromagnetic environment with adequate immunity to any electromagnetic disturbances in order that operations will be free of malfunction and safe.

Equipment and system designs proposed by the Contractor shall take into account the requirements outlined in the relevant internationally recognised Standards and Regulations to ensure electromagnetic compatibility.

The design shall take account of all aspects of EMC including, for example, circuit design; equipment and cable screening; filtering; grounding and bonding. The inclusion of EMC requirements in the equipment/system design shall not cause any degradation of quality, performance or loss of function.

The Tenderer shall include in his Tender the following:

a. A list of Standards which the proposed equipment will comply with the EMC requirements.

b. EMC type test certification, if any, for the proposed equipment.

33.5 Training

The Contractor shall be responsible for providing suitable technical training on the communication system for selected staff of the Employer. Details of the training considered appropriate shall be stated clearly in the Tender, based on the number of trainees specified.

The areas in which it is considered training should be provided, and duration of the training courses, are given in Section 1.23 of these Specifications. Alternative arrangements, where considered appropriate, should be suggested in the Tender.

33.6 Technical Requirements

33.7 Site Acceptance Tests

On arrival on site, all equipment including cabling shall be inspected and tested to insure that there shall be no delay in installation and commissioning due to supply of incorrect or damaged equipment.

After the equipment has been erected and connected up on site, the Contractor shall carry out to the satisfaction of the Employer and/or its representatives, such tests as may be required to prove compliance with the Specification, independently of any factory acceptance tests.

It must be emphasised that all site testing that requires an interface to operational equipment must only be carried out after prior agreement with the Employer and adequate advance notice shall be given to the Employer by the Contractor of his intent to conduct testing involving operational equipment.

The site acceptance tests (SATs) are subdivided into two stages:

a. Tests during and after installation, and

b. System commissioning tests.

During the pre-commissioning checks and acceptance tests, the Contractor shall demonstrate to the satisfaction of the Employer that:

a. All equipment, materials, spare parts and documentation are installed and/or provided and satisfy the requirements of this Specification and all further requirements to guarantee on completely working system.

b. All equipment meets the performance requirements under the local ambient conditions specified in this Specification.

The Employer shall have the right to witness all site tests, and the results must be available to him as the tests proceed. The Employer may add further tests if considered necessary to prove compliance with the Specification.

The Contractor shall submit for approval by the Employer a schedule of site acceptance tests to prove that the installed system meets the requirements of the Specification. These tests shall also prove whether the work has been executed with satisfactory workmanship and whether the equipment is in conformity with the prevailing standards and regulations as well as with the present state of modern techniques.

The SATs to be conducted by the Contractor shall include, as a minimum, the following:

a. Checks to ensure that the system is complete and configured according to the design.

b. Functionality testing of the communication system.

c. Communication end to end circuit testing.

d. The correct routing, and where appropriate, the correct automatic re-routing of all circuits.

e. System performance tests to demonstrate that the new communication system will give satisfactory service under normal working conditions.

f. System functional and performance tests under abnormal conditions such as disturbances.

g. System trial operation and availability test over a period of 1 month.

Once the system is put into trial operation and availability testing, the Contractor may not work or make changes to any part of the system without first obtaining permission from the Employer.

All construction drawings, manuals and factory acceptance test records shall be made available on site during all site acceptance tests.

When the communication system has been demonstrated to be working satisfactorily and the handover certificate has been issued to the Contactor the warranty period shall commence.

33.8 Test Apparatus

The test apparatus shall be supplied for operation, troubleshooting and maintenance of the new communication system. The Tenderer is welcome to suggest a list of test apparatus which he thinks is appropriate for his proposed communication system.

33.9 Documentation

Documentation and drawings shall relate solely to the actual equipment supplied. They should not include any irrelevant or superfluous information, e.g. information relating to variants not supplied under this Contract and options that are not potential future extensions to the supplied System.

All drawings, manuals, specifications, component lists, etc., shall have a unique document identification number that conforms to an approved numbering scheme, along with an issue or revision number and a record of modification.

System documentation shall comply with the relevant sections of ISO 6592 (or an equivalent national or international standard).

Additional specific communication system documentation required is as follows:

(a) Communication channel allocation and utilisation plan.

(b) System configuration and settings.

The Contractor shall also supply documentation electronically in CD-ROMs.

Section 34: Technical Specifications – Telephone Equipment

34.1 Not applicable for Chipota Falls Mini Hydropower Project

Section 35: Outline Design Drawings

35.1 Outline Design Drawings

The Outline Design Drawings included in this Section indicate the Employer's outline design and all dimensions and details are deemed to be indicative only. The Contractor shall design the Facilities in accordance with the other Sections of the Employer's Requirements, which will take precedence over any indicative dimensions or details shown on the drawings.

The Outline Design Drawings included in this Section are as follows;

Drawing Title	Drawing No	Rev
Construction Progress Chart-Construction Organization		
Design Diagram of Dam (Compared Plan)-Hydraulic		
Design Diagram of Dam (Recommended Plan)-Hydraulic		
Design Diagram of Diversion System (Compared Plan)-Hydraulic		
Design Diagram of Diversion System (Recommended Plan)-Hydraulic		
General Plane Layout of Plant Area (Compared Plan)-Hydraulic		
General Plane Layout of Plant Area (Recommended Plan)-Hydraulic		
Layout of Construction Diversion (Compared Plan)-Construction Organization		
Layout of Construction Diversion (Recommended Plan)-Construction Organization		
Layout of Dam Construction Area (Recommended Plan)-Construction Organization		
Layout of Dam Construction Area (Recommended Plan)-Construction Organization		
Layout of Penstock Construction Area (Recommended Plan)-Construction Organization		
Layout of Turbine-generator Units-Hydraulic		

Drawing Title	Drawing No	Rev
General Plane Layout of Plant Area (Recommended Plan)-Hydraulic		
Main Electrical Connection Diagram-Electric		
Plane and Section of Booster Station-Electric		
Plane Layout of Chipota Falls Station (Compared Plan)-Hydraulic		
Plane Layout of Chipota Falls Station (Recommended Plan)-Hydraulics		
Plane Layout of Dam (Compared Plan)-Hydraulic		
Plane Layout of Dam (Recommended Plan)-Hydraulic		
Plane Layout of Electromechanical Equipments-Electric		
Plane Layout of General Construction (Recommended Plan)-Construction Organization		
Plane Layout of Powerhouse-Hydraulic		
Vertical Section of Dam (Compared Plan)-Hydraulic		
Vertical Section of Dam (Recommended Plan)-Hydraulic		