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Municipal Services Delivery Program (MSDP)
P&D Department, Government of Sindh**

**A&E Services for Jacobabad Water, Wastewater, and Solid
Waste Infrastructure**

**CONTRACT PACKAGE EM-11
Procurement and Installation of E&M Works**

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VOLUME-II

TECHNICAL SPECIFICATIONS

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MUNICIPAL SERVICES PROGRAM (MSP)
A&E Services for Jacobabad Water, Wastewater & Solid Waste
Infrastructure
IQC 391 – I – 11 – 00003
AID – 391 – TO – 12 – 00007

SPECIFICATIONS

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1.0 THE PROJECT

1.1 Purpose and Location of the Works

The Municipal utility services of Jacobabad are in very poor condition due to neglected operation and maintenance facilities, rapid growth in population, non-availability of required resources for efficient operation and lack of professional management.

The Municipal Services Program is aimed to improve Municipal utility services, especially to rehabilitate and upgrade the water storage, filtration and treatment works, distribution network including improvement at intake Khirthar canal at Jacobabad city.

1.2 Description of the Works

The Works under the Contract comprises of rehabilitation and up-gradation of equipment and machinery installed at the sites specified.

1.3 Standard Specifications

Plant, materials and workmanship shall comply with the requirements of relevant American Standards and Codes of Practice current at the time of bid. Equivalent International Standards will be accepted by the ENGINEER provided their requirements are no less stringent.

The CONTRACTOR shall supply two copies of each IEEE, NEC and other approved national or international standards which are referred to in the Specification and of each such other standard which applies to materials which are being supplied to, or workmanship which is being executed on the Works. One copy of these standards shall be available to the ENGINEER, and the remaining copy shall be kept by the CONTRACTOR on the Site.

All materials and workmanship not covered by a IEEE or NEC or approved alternative shall be of such kind as is used in first class work and suitable for the climate in the area where the works are to be constructed, for which ENGINEER's decision is a binding.

1.4 Drawings

Drawings which form part of the Contract are attached in Volume III.

1.5 Record Drawings

Within twenty-eight days of the issue of Certificate of Completion, the CONTRACTOR shall provide 6 copies and one reproducible of all drawings amended to comply with the works as built. These drawings shall include:

- Electric cable route diagram along with its connection and equipments viz, from SEPCO mains to changeover to standby generator to incoming panels of electrical motors.
- Single phase line diagram for internal and external lighting purpose.

1.6 Materials and Suppliers of Materials

Before ordering materials of any description intended for the Permanent Works, the CONTRACTOR shall submit for the approval of the ENGINEER the names of the makers or suppliers proposed, a specification of the materials and details of their place of manufacture.

The CONTRACTOR may be required to supply to the ENGINEER for his retention, a copy of each order placed.

1.7 Climatic Data

The CONTRACTOR shall take account of the climatic conditions at the Site of the Works. The following information is provided as a guide to the climatic conditions likely to be encountered on the site to assist the CONTRACTOR, but this shall not relieve him of his responsibility under the Contract.

- (1) Monthly average temperatures:
 - a. Maximum 35 degree C
 - b. Minimum 18 degree C
- (2) Extreme Temperatures
 - a. 50 degree C in May, June, July and August
 - b. 1 degree C December and January
- (3) Annual Average Rainfall
192 mm per year, the majority falling in the monsoon months of July and August. On average there are 10 rainy days per year. Storm intensities can be high with storm totals reaching 440mm, with normal durations of 36 hours.

The climatic data given above are based on limited records and their accuracy cannot therefore be guaranteed.

1.8 Programme

Before commencing the Works the CONTRACTOR shall submit to the ENGINEER for his approval a programme showing the order in which he proposes to carry out the Works. The programme shall be in the form of a bar chart, or any other form as may be agreed by the ENGINEER, and shall clearly indicate the following:

- a. the sequence of each activity, the proposed start and completion dates of each activity, the rate of progress and the cumulative quantity or percentage of work expected to be achieved on each activity by the end of each month;
- b. the time allocated for work by others, including those of the EMPLOYER and by utility undertakings;

The programme shall also include details of the following:

- a. A statement giving the numbers and categories of supervisory and technical staff and skilled and unskilled workers to be employed on the Works.
- b. A list and type details of major Constructional Plan (including vehicles) which the CONTRACTOR proposes to employ on the Works.
- c. Details of the CONTRACTOR's methods of working for all operations.
- d. A statement giving the proposals for location or locations and sizes of base camps, accommodation, offices, workshops and stores.

- e. Details of the programme for the Works from the date of receipt of the ENGINEER's order to commence the Works including a complete resources allocation showing the number of units and allotted times for each unit of Constructional Plan, materials and labour allocated to each part of the works.

1.9 Notice of Operations

The CONTRACTOR shall give full and complete written notice of all important operations to the ENGINEER sufficiently in advance to enable the ENGINEER to make such arrangements as he may consider necessary for inspection or for any other purpose. The CONTRACTOR shall not commence any important operation without the written approval of the ENGINEER.

The ENGINEER's Site supervision staff shall be working 8 hours per day, Monday to Saturday. Expense incurred due to operations beyond above stated time frame which requires ENGINEER's staff supervision, shall be borne by the CONTRACTOR.

1.10 Temporary Works

Not less than fourteen days before commencing any portion of the Works, the CONTRACTOR shall, if ordered, submit to the ENGINEER for his approval complete drawings and calculations for all Temporary Works the CONTRACTOR may be proposing for the construction of that part of the Works.

Notwithstanding approval by the ENGINEER of any design for the Temporary Works, the CONTRACTOR shall be entirely responsible for their efficiency, security and maintenance and for all obligations and risks in regard to such Temporary Works specified or implied in the Contract.

1.11 Water and Electricity Supply

The CONTRACTOR shall at his own cost make arrangements for the supply of water and electricity for the purposes of the Works.

1.12 Disposal of Water

Water and wastewater derived from the construction, testing and completion of the Works shall be disposed of clear of the Site to the satisfaction of the ENGINEER so as to cause no damage or complaint.

1.13 Contractor's Facilities

The CONTRACTOR shall provide all site facilities including offices with telephone, workshops, stores, accommodation, washing, latrines etc. necessary for use by his own staff.

The CONTRACTOR shall be responsible for making all arrangements for drainage from his site facilities and shall be responsible for payment of all charges in connection therewith. Arrangements for the supply of electricity, water and gas shall be the responsibility of the CONTRACTOR.

Works Areas for the Contract in addition to those defined as Site of the Works shall be agreed with the ENGINEER.

1.14 Latrines

Throughout the period of construction of the Works the CONTRACTOR shall provide, maintain and cleanse suitable and sufficient latrines for use by his employees; he shall ensure that his employees do not foul the Site but make proper use of the latrines. Where practicable the latrines shall be connected to the nearest sewer, or if this is not practicable the CONTRACTOR shall provide an adequately sized septic tank and soak away.

1.15 Meetings and Reports

Representatives of the CONTRACTOR, approved by the ENGINEER, shall attend monthly progress meetings on Site or at the offices of the EMPLOYER/ENGINEER at any other place. In addition, approved representatives of the CONTRACTOR shall attend further meetings in cases of emergencies or for other reasons when called upon by the EMPLOYER/ENGINEER.

The CONTRACTOR shall submit to the ENGINEER each month a report on his progress on the performance of the Contract. The report shall include a copy of the approved programme with the current progress for each activity shown. No separate payment shall be made for this item.

1.16 Contract Signboard

The CONTRACTOR shall supply and erect one or more contract signboards at locations agreed by the ENGINEER. The signboards shall be of substantial construction to the approval of the ENGINEER and the lettering, in both English and Urdu shall be black on a yellow fluorescent background.

The layout and dimensions of the signboard shall be with the approval of the ENGINEER's Representative.

1.17 Level Datum

All levels stated shall be related to bench-marks located.

1.18 Contamination of Water Supplies

Before any person is engaged on work involving a risk to the purity of potable water supplies or deemed to involve such a risk by the ENGINEER, he shall be tested to indicate that he is not a carrier of typhoid or other waterborne disease and he shall be informed of the dangers of contamination. The CONTRACTOR shall notify the ENGINEER of any person who has been certified by a doctor as suffering from an illness associated with the looseness of the bowels, and no such person shall be employed on such work until the EMPLOYER's medical adviser is satisfied that it is safe for him to be so employed.

The CONTRACTOR shall comply with the provisions of National Environmental Quality Standards in the operation and management of his work.

1.19 Maintenance of Existing Access Track during the Works

On commencement of the Contract the CONTRACTOR shall be solely responsible for the maintenance of the existing access roads within the Site. This responsibility shall continue until the contract completion date, or until such earlier date as the ENGINEER may advise the CONTRACTOR in writing. In preparing his rate for maintenance of these access roads, the CONTRACTOR shall take into account that the access roads under his maintenance

control will also be used by the EMPLOYER's and his staffs vehicles and also those of other CONTRACTORS. Such maintenance work shall include general up keeping, and any necessary repairs to damaged road surfaces, pavement, drainage, associated slopes, etc (whether caused by the CONTRACTOR's activities or not) to a standard no worse than the original condition. During the carrying out of such maintenance work, the CONTRACTOR shall make arrangements to maintain through passage for the EMPLOYER's and his, staff's vehicles and also those of other CONTRACTORS over these access roads, which may comprise temporary diversions all to the approval and satisfaction of the ENGINEER.

The CONTRACTOR shall not run tracked or unsprung vehicles on surfaced roads without the express approval of the ENGINEER who may require that planking or some other protective material be used to protect the road surface.

1.20 Existing Installations

The CONTRACTOR shall execute the Works in such a manner as to avoid interruption and interference with the operation of the existing water and sewerage conveyance system, treatment works, pumping stations and distribution systems and to minimize disturbance to the existing staff quarters and mosque adjacent to the Site. Access to the existing facilities shall be maintained, to the satisfaction of the ENGINEER, at all times.

The CONTRACTOR shall apply in advance to the ENGINEER in writing at least 28 days before starting any work which involves interference with existing structures, equipment, etc or otherwise interfere with or interrupt the EMPLOYER's normal operation of the existing conveyance system, pumping and treatment works, and distribution system. The CONTRACTOR shall not execute such work until he has received permission to proceed, in writing from the ENGINEER.

The CONTRACTOR shall ensure that no earth, debris or rock is deposited on existing conduits, structures, public or private roads or rights of way as a result of the Works and all vehicles leaving the Site shall be cleaned accordingly.

The CONTRACTOR shall be responsible for the safety and security of existing services encountered during the course of execution of works and any damage to existing installation and services due to CONTRACTOR's operations shall be made good at his risk and cost. The CONTRACTOR shall gather the information of all services require protection and relocations, falls within the area of works, from SSGC, SEPCO, PTCL, TMA and any other agencies. The CONTRACTOR shall strictly comply with the safety and precautions requirements as deemed necessary by the owner of the services.

1.21 Units of Measurement

All designs, drainage, specifications and manuals shall use SI (kg m s) units and all measurements, dimensions and performance data shall be quoted in those units.

1.22 Languages

All drawings, instructions, signs, notices, name-plates etc. for use in the operation and maintenance of the completed works shall be in English.

Warning signs shall be in Urdu and English.

1.23 Advertising

The CONTRACTOR shall not use any part of the Site for any form of advertising without the prior written approval of the ENGINEER.

1.24 Site Investigation Records

The site investigation if deemed necessary by the ENGINEER, during the execution of the work shall be carried out by the CONTRACTOR at his own cost.

Before commencement of work at site the CONTRACTOR shall carry out the trial pits up to the required formation level to locate any existing underground services and utility lines.

1.25 Safety and Environmental Regulations on Site

The CONTRACTOR shall comply with all statutory and other regulations concerning the safety of his site staff, operatives, staff of the EMPLOYER and ENGINEER and members of the public and protection of Environment, as a result of his operations. He shall obtain copies of all the relevant regulations, and shall make them available for inspection by the ENGINEER.

The CONTRACTOR shall make adopt safety measures in accordance with Chapter 12 and 13 of BS-7671: 2008.

1.26 Other Works and Services

For all other works and services specified in the Specifications or shown on Drawings and for which there is no separate item in the Bill of Quantities, no payment shall be made directly and the cost thereof shall be deemed to be included in the unit rates of other items of BOQ.

1.27 Quality Assurance and Quality Control

There shall be no separate payment for arrangement of lab facilities for quality control at site. The cost for carrying out required tests for quality control and quality assurance is deemed to be included in the Contract Price.

1.28 Costs

The costs for complying with this section of specification shall not be paid separately and shall be included in the CONTRACTOR's rates and prices of the Bill of Quantities.

1.29 Nomenclature

The following nomenclature has been used throughout project documentation:

- LLPS – Low Lift Pumping Station
- HLPS – High Lift Pumping Station
- WFP – Water Filtration Plant

The overall project is referred as MSP Jacobabad (Municipal Services Program) and/ or the Project.

1.30 References

BS 7671: 2008: Requirements for Electrical Installations: IEE Wiring Regulations, Seventeenth Edition.

2.0 THE SITE

2.1 Site

The extent of the Site is defined in Specifications and the drawings. The CONTRACTOR shall not use the site for any purpose not required by the Contract.

The Sites located are:

- (i) Water Intake works near Khirthar canal (High Lift Pumping Station and Low Lift Pumping Station)
- (ii) Water Filter Plant near Jamali Waah, Garhi Khairo road
- (iii) Overhead reservoirs located in the six water supply Zones

2.2 Areas outside the Site

For the CONTRACTOR making use of any special or temporary way leave or additional accommodation acquired by him or any tip for the disposal of surplus materials he shall obtain the written consent of the owner, occupier or authority having charge of the land in which such way leave, accommodation or tip is situated and shall make a record agreed by the owner, occupier or authority as aforesaid of the condition of the surface of that land before entering thereon.

The CONTRACTOR shall permit the EMPLOYER and the ENGINEER and any person authorized by the EMPLOYER or the ENGINEER access for the purposes of the Contract to any such special or temporary way leave or additional accommodation.

In the event of the CONTRACTOR making use of any special or temporary wayleave or additional accommodation made available to him by the EMPLOYER for the purpose of the Contract, the land in which such way leave or accommodation is situated shall be deemed to be part of the Site as defined in Clause 2.1 hereof.

For the purposes of this Clause, 'accommodation' shall be deemed to include housing, offices, workshops, warehouses, storage areas and disposal areas.

2.3 Access to Site

The CONTRACTOR shall where necessary provide access to and through the site to adjacent properties as well as to other agencies/CONTRACTOR who might be executing any development work for TMA, PMU or for any other agencies and coordinate his work with these agencies / CONTRACTOR.

Before the commencement of any part of the Works, the CONTRACTOR shall make temporary access tracks including temporary diversions, approach roads, temporary roads in side river for movement of vehicles, transporting Pipe lines and other Construction material during execution of the work with approval of the ENGINEER. The CONTRACTOR shall maintain such access tracks in a condition suitable for the safe and easy passage of plant, vehicles and pedestrians required for the purpose of the Contract.

The CONTRACTOR shall make a record to be agreed by the ENGINEER of the condition of the surfaces of any private lands or of any public cultivated or maintained lands over which access to the Site lies before any work is commenced to make them suitable for access and he shall keep such surfaces in a reasonable state of cleanliness and repair during the execution of the Works. On the termination of the CONTRACTOR's use of such access he

shall restore the surfaces to a condition at least equal to that existing before his first entry on them.

2.4 Clearance and Reinstatement of Site

The CONTRACTOR shall clear the Site of all vegetation, trees, hutments, obstructions etc. to the extent required by the ENGINEER for checking the setting out. The CONTRACTOR shall also ensure that the parts of the Site to be occupied by the Permanent Works are clear and maintain the remainder of the Site as may be required for access and Temporary Works areas.

The CONTRACTOR shall remove the material arising from such clearance and dispose off it in a manner and at a location, away from the site and inhabitant areas, no obstruction shall be cause to the existing traffic and adjacent properties and no excavated material shall be dumped or stock pile at site but removed directly to disposal areas identified by the CONTRACTOR, to the approval of the ENGINEER.

No heavy equipment/ plant whether mobile or stationery shall be allowed to come nearer than 1.5 m of the existing sewage conveyance structures. For this purpose such structures and pipelines shall be protected by erecting warning fence or barricades.

The CONTRACTOR shall fill and make good with appropriate materials those cavities and losses of soil which result from clearing the parts of the Site not subsequently to be occupied by the Permanent Works.

The CONTRACTOR shall not clear the Site of any structure without the prior written permission of the ENGINEER.

2.5 Condition of Site

The CONTRACTOR shall maintain the Site in a neat, tidy and healthy condition for the whole of such time as he is responsible for the care of the Works.

2.6 Site Records

The CONTRACTOR shall make records of the position and extent in the excavations of every type of service, stratum and obstruction encountered during the construction of the Works.

2.7 Permits

The CONTRACTOR shall be fully responsible for obtaining necessary permits and permissions, except those normally obtained by the EMPLOYER or ENGINEER, prior to commencement of the Works.

2.8 Protection of Works against Flooding

The CONTRACTOR shall ensure the protection of all temporary and permanent works including plants, materials and equipments against flooding cause by sewage flow in river / nala as well as recurrent rains or any other reasons, during the course of execution of works. Before the commencement of works the CONTRACTOR will submit its detail work methodology, for ENGINEER's approval, showing manners to divert the existing flows in the river/nala away from the work area to be acquired in orderly state. The CONTRACTOR shall maintain such flow diversions in part or as a whole till the works have been completed or covered in accordance with drawing, specifications or as directed by the ENGINEER. The

cost of complying with this section is deemed to be included in other items of BOQ, unless expressly specified otherwise.

2.9 Costs

The costs for complying with this section of specification shall not be paid separately and shall be deemed to be included in the CONTRACTOR's rates and prices of the Bill of Quantities.

3.0 ELECTRICAL GENERAL REQUIREMENTS

3.1 General

3.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work to provide complete electrical systems as specified in other chapters of the specifications.

3.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

3.1.3 Codes and Standards

In general, the electrical systems should use standard manufactured materials and equipment normally used in industrial facilities. This project's electrical systems should be designed in general compliance with the applicable portions of the following codes and standards, or equivalent as related:

1. ANSI (American National Standards Institute)
2. NEMA (National Electrical Manufacturers Assoc.)
3. National Electrical Code (NEC) - NFPA 70
4. Electrical Standard for Industrial Machinery (JIC) - NFPA 79
5. ICEA-IPCEA (Insulated Cable Engineers)
6. IEEE (Institute of Electrical and Electronics Engineers)
7. IET (Institute of Engineering and Technology) *formerly known as IEE*
8. IES (Illumination Engineers Society)
9. ISA (Instrument Society of America)
10. UL-Underwriter s Laboratories
11. Electricity Act of Pakistan
12. Applicable Local Codes

Except where otherwise specified materials shall comply with the standards and codes mentioned above, however, equivalent National or International Standard Specifications may be substituted at the sole discretion of the ENGINEER or as may have been agreed in the Contract. All standards used will be the current version at the time of bidding.

The CONTRACTOR shall obtain at least one copy of each IEEE, NEC, ANSI, ASME (American Society of Mechanical Engineers), CE (Conformité Européenne) or other approved standard and reference work which is referred to in the Specification, and of each other standard which applies to materials which are being supplied to, or workmanship executed on, the Works. These standards and reference works shall be supplied to the ENGINEER within 60 days of the ENGINEER's order to commence the Works and will be available to the CONTRACTOR at all reasonable times.

All materials and workmanship not fully specified herein or covered by an approved standard shall be of such kind as is used in first class work and suitable to the climate in the project area, for which ENGINEER's decision is a binding.

3.1.4 Specifications

It is the intention of these specifications to fully cover all work and materials for a complete, first-class electric installation, and any devices such as pull boxes and disconnect switches, usually employed in the class of work, though not specifically mentioned in this specification, but which may be necessary for the satisfactory completion of the work, shall be furnished and installed by the CONTRACTOR as a part of his total work. Cooperate and coordinate with other CONTRACTORS to furnish complete workable systems.

In case of conflicting information on the drawings and/or in the specifications, the ENGINEER shall make the proper interpretation.

Carefully check space requirements to insure that equipment, pipes, conduits, etc. can be installed in the spaces allotted for them. Where interference occurs and work must be relocated, relocate without additional cost.

Changes and additions to scope of work under this contract shall be submitted to the ENGINEER and his written approval obtained before proceeding with the changed work.

During construction, the CONTRACTOR shall keep an accurate record of all deviations between the work as shown on the contract drawings and that which is actually installed. He shall secure a set of construction drawings for this purpose, and note changes thereon in red ink, in a neat and accurate manner, thus making a complete record of all changes and revisions in the original design, which exist in the completed work. The cost of furnishing above prints and preparing these record drawings shall be borne by the CONTRACTOR, and shall be included in the contract price. When all revisions have been shown on these prints to indicate the work as finally installed, the prints shall be delivered to the ENGINEER, before final payment.

3.1.5 Services, Inspection and Tests

CONTRACTOR shall show evidence that credible local service organization is in existence to service and furnish spare and replacement parts of all equipment.

The right is reserved to inspect and test any portion of the equipment during the progress of its installation. The CONTRACTOR shall test all wiring for continuity and ground before connecting any fixtures or devices. The CONTRACTOR shall test the entire system, when the work is finally completed, to insure that all portions are free from short circuits and grounds. All equipment necessary to conduct the above tests shall be furnished by the CONTRACTOR at its expense.

Secure and pay for all required permits and inspections. Inspection certificates from local authorities having jurisdiction shall be delivered to the EMPLOYER before final payment.

3.2 Products

3.2.1 Manufacturing Standards

Materials shall be new and approved and labeled by the UL or equivalent wherever standards have been established by that agency. Materials to be furnished under this specification shall be the standard products of manufacturers regularly engaged in the production of such equipment and shall be the manufacturer's latest standard design. All items of the same type and rating shall be identical. Defective equipment or equipment

damaged in the course of installation or testing shall be replaced or repaired in a manner meeting the approval of the ENGINEER.

3.2.2 Trade Names and Criteria and Substitutions

Manufacturers' names and catalog numbers indicated herein are not intended to be proprietary designations. They are used for convenience and indicate general type and quality of materials and equipment required. Equipment and materials by other manufacturers, which in the opinion of the ENGINEER are of equal quality and which will produce the same result with regard to both their ability to perform the required technical functions as well as to their appearance in the specific location on this project, will be considered.

Approval for equipment specified herein will not be given merely upon the submission of manufacturer's name. Notwithstanding, anything to be contrary in the specifications, approvals for equipment will be given only after the receipt of complete and satisfactory performance data in tabular and/or graphical form, as required by the ENGINEER. Complete and satisfactory information shall also be furnished relative to equipment dimensions, weight and other physical characteristics.

Wherever detailed operating features or a definite make and size of apparatus are specified, for which such quantities are readily determinable, the make and size of apparatus, which is proposed for use, must conform substantially to the equipment specified. The same shall apply to important dimensions of the apparatus in relation to the rest of the system to properly fit it into the available space proposed by the CONTRACTOR. Any additional costs whatsoever that result from any approved substitution shall be borne by the CONTRACTOR.

3.2.3 Color Code

All cables, wiring and busbars shall comply with the following color code, including single core wiring, sleeves of mineral insulated metal sheathed cable, identification tape on the cores of paper insulated and similar cables and on short lengths of single core cable used to interconnect electrical apparatus:

1. TP, TPN, DC 2 wire, DC 3 wire, in accordance with Tables 51A and 51B of the IEE regulations (16th edition).
2. SPN - Main or sub-main cables, single core interconnections on switchgear and the like, busbars and risers - Red or Yellow or Blue, Black.
3. SPN - Final sub-circuit wiring - Red, Black (irrespective of phase).
4. All outdoor cables shall be marked permanently.

3.3 Execution

3.3.1 Schedule of Work

The schedule of the electrical work shall be arranged to suit the progress of the overall work. Cutting and patching shall be done in an approved manner. Cutting shall not endanger structural integrity or function of the building. Patching shall exactly match contiguous work. Costs of such cutting and patching shall be borne by the CONTRACTOR. Cutting shall be carefully done and damage to the building, piping, wiring or equipment, as a result of cutting, shall be repaired by skilled mechanics of trade involved. Cutting of masonry block and brick shall be done with masonry saw.

3.3.2 Labeling of Equipment

All motor disconnect switches, motor controllers, motor control center, panel board, transformer, etc., shall be identified by designation plates permanently attached thereto. All component parts of each item of equipment or device shall bear the manufacturer's nameplate, giving name of manufacturer, description, size, type, serial and model number and electrical characteristics in order to facilitate maintenance or replacement. The nameplate of a CONTRACTOR, SUBCONTRACTOR or distributor will not be acceptable.

3.3.3 Clearance from Other Services

Electrical services shall be kept at least 150 mm clear of water, steam, condensate and other mechanical services.

3.3.4 Wall Fixings and Steelwork Supports

The CONTRACTOR shall be responsible for installing all rag bolts, expansion shields, and the like and for all additional steelwork required for supporting cables, fuse gear, isolators, starters, lighting fittings and the like.

3.3.5 Painting

Paint all exposed conduit as well as cabinets and related items, etc. not supplied with a factory finish. Touch up all factory finishes damaged during installation or by adjacent construction work.

3.3.6 Outlets, Equipment Connection and Standards

Disconnect switches and power wiring, up to and including motor connections for all equipment provided under other Chapters of this specification, shall be included in this Chapter unless specifically excluded.

No conduit, outlet box, conduit stub-up, controller, etc. shall be installed until exact location has been determined by the coordinated effort of all SUBCONTRACTORS concerned. Any relocating of outlet boxes, etc., or cutting or patching, which becomes necessary due to improper coordination between trades, shall be done at the CONTRACTOR'S expense.

Determine electrical requirements of other sections in order to fully understand wiring, and provide as required for the complete and satisfactory operation of the project. Make connections for other sections where indicated or required.

The CONTRACTOR will prepare the relevant Drawings and submit them to the ENGINEER for approval.

The CONTRACTOR will obtain approved shop drawings showing wiring diagrams, connection diagrams, rough-in and hook-up details, for all equipment from the ENGINEER and comply therewith.

3.3.7 Execution of related civil works

It shall be part of the Contract of the CONTRACTOR to execute all the relevant items for related civil/ builder's works items for the construction of foundations, making holes in the walls, making chases in walls/ floors and making them good etc. for the installation of E&M Equipment (like generators, pumps, motors and panels etc.). The CONTRACTOR shall undertake and execute all the relevant items for related civil/ builder's work complete in all

respect to the approval of the ENGINEER. In this regards, the CONTRACTOR will coordinate with the civil works contractor before commencing any related civil/ builder's work.

3.3.8 Replacement of inoperable lamps

All inoperable lamps shall be replaced with new lamps during the course of construction, up to and including the date of final acceptance of the building by the ENGINEER/EMPLOYER.

4.0 BASIC ELECTRICAL MATERIALS AND METHODS

4.1 General

4.1.1 Summary

This chapter applies to all chapters related to all the “Electrical” work of this project’s specifications; including relevant materials & procedures; unless specified otherwise in the individual chapters.

Reference to any specific equipment or material does not necessarily imply that such material or equipment is to be included in the Works.

4.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

4.1.3 Definitions

The technical chapters referred to herein are those specification chapters that describe products, installation procedures, and equipment operations and that refer to this chapter for detailed description of submittal types.

4.1.4 General Requirements

Electrical materials and equipment should be specified to withstand the environmental conditions associated with raw/ clear water pumping stations with a normal life expectancy of 20 years.

All electrical connections, receptacles, etc. that have the potential to be negatively affected by moisture, dust, and extreme temperatures shall be protected as necessary.

The electrical systems should be designed to be cost and energy efficient, maintainable and operable.

4.1.5 Suppliers of Equipment

Before ordering material of any description intended for the Permanent Works, the CONTRACTOR shall submit for the approval of the ENGINEER the names of the maker or supplier proposed, a specification of the material and details of the place of origin or manufacture. If it is found necessary test regarding its compatibility with specifications be carried out at external facility. If requested by the ENGINEER the CONTRACTOR shall supply to the ENGINEER for his retention, a copy of any such order placed.

All materials used in the Permanent Works must be new, unless the use of old or refurbished material is expressly permitted by the Specification or the ENGINEER.

Materials used in the Works which are, or can be, in contact with the untreated or treated water shall not contain any matter which could impair taste, odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed. Approval by bodies mentioned in Clause 3.1.3 will generally be regarded as satisfactory evidence of suitability.

4.1.6 Manufacturer's Catalog Data

Submittals for each manufactured item shall be current manufacturer's descriptive literature of cataloged products, equipment drawings, diagrams, performance and characteristic curves, and catalog cuts. Handwritten and typed modifications and other notations not part of the manufacturer's pre-printed data will result in the rejection of the submittal. Should manufacturer's data require supplemental information for clarification, the supplemental information shall be submitted as specified for certificates of compliance.

4.1.6.1 Drawings

Submit Drawings including wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices.

4.1.6.2 Instructions

Where installation procedures or part of the installation procedures are required to be in accordance with manufacturer's instructions, submit printed copies of those instructions prior to installation. Installation of the item shall not proceed until manufacturer's instructions are received. Failure to submit manufacturer's instructions shall be cause for rejection of the equipment or material.

4.1.6.3 Certificates

Submit manufacturer's certifications as required for products, materials, finishes, and equipment as specified in the technical chapters. Certificates from material suppliers are not acceptable. Preprinted certifications and copies of previously submitted documents will not be acceptable. The manufacturer's certifications shall name the appropriate products, equipment, or materials and the publication specified as controlling the quality of that item. Certification shall not contain statements to imply that the item does not meet requirements specified, such as "as good as"; "achieve the same end use and results as materials formulated in accordance with the referenced publications"; or "equal or exceed the service and performance of the specified material." Certifications shall simply state that the item conforms to the requirements specified. Certificates shall be printed on the manufacturer's letterhead and shall be signed by the manufacturer's official authorized to sign certificates of compliance.

4.1.6.4 Testing Certificate

Submit a certificate that shall state that the item has been tested in accordance with the specified organization's test methods and that the item complies with the specified organization's reference standard.

4.1.6.5 Operating Instructions

Submit text of operating instruction manuals for each system and principal item of equipment.

4.1.7 Quality Assurance

4.1.7.1 Material and Equipment Qualifications

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products, which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in the technical chapter.

4.1.7.2 Service Support

The equipment items shall be supported by service organizations, which are reasonably convenient to the equipment installation, in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

4.1.7.3 Manufacturer's Nameplate

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number.

4.1.8 Posted Operating Instructions

Provide for each system and principal item of equipment as specified in the technical chapters for use by operation and maintenance personnel. The operating instructions shall include the following:

1. Wiring diagrams, control diagrams, and control sequence for each principal system and item of equipment.
2. Start up, proper adjustment, operating, lubrication, and shutdown procedures.
3. Safety Precautions
4. The procedure in the event of equipment failure.
5. Other items of instruction as recommended by the manufacturer of each system or item of equipment.

Print or engrave operating instructions and frame under glass or in approved laminated plastic. Post instructions where directed. For operating instructions exposed to the weather, provide weather-resistant materials or weatherproof enclosures. Operating instructions shall not fade when exposed to sunlight and shall be secured to prevent easy removal or peeling.

4.1.9 Labels, Notices & Nameplates

4.1.9.1 Nameplates

Provide nameplates for each panel board, switchboards, control panels, distribution fuse-boards, equipment, enclosure, relay, switch, and device; as specified in the technical chapters or as indicated on the drawings.

Characters shall be black on white where the function is to convey information and yellow on black where the function is to convey warning, as indicated elsewhere in this Specification.

4.1.9.2 Fixing

Fixing shall be by means of a minimum of two brass or chrome plated screws and nuts or self-tapping screws. Labels must be removable and fixings by means of rivets, adhesives, and the like will not be acceptable.

4.1.9.3 Labels

Labels shall be provided to indicate the following:

1. Reference number of each and every separate switch, fuse-switch, distribution fuse-board and the like.
2. Rating for switches, fuse-switches, and the like.
 - a. Current or kW for contactors and the like.
 - b. Number of fuse-ways and current rating for distribution fuse-boards.
3. Service – e.g. feeder or distribution system or equipment controlled for switches, fuse switches and the like.
 - a. Equipment controlled for contactors and starters.
 - b. Area served and the service (i.e. lighting, power and the like) for distribution fuse-boards.
4. Reference number of controlling switch, fuse switches and the like – this will apply generally to contactors and distribution fuse-boards.
5. Any other information called for elsewhere in this Specification.

4.1.9.4 Labels and Notices

Labels and notices shall be provided for:

1. Connections to an earth electrode or bonding conductor.
2. The intake point or metering position of each installation regarding periodic inspection.
3. The access point or points for apparatus installed at voltages exceeding low voltage.
4. Cables installed at voltages exceeding low voltage in any duct having access for personnel, inside any building, on any wall or structure, or suspended on any support. Notices shall be fixed where such cables emerge from the ground or from a duct, and on each side of any wall or partition through which the cable may pass and at intervals not exceeding 5m.
5. The access door or doors of every switch-room, switchgear cupboard or enclosure, generator house or similar electrical plant room.
6. Every item of apparatus, or enclosure, within which a voltage exceeding 250 volts exists and where the presence of such a voltage would not normally be expected.
7. Every item of apparatus, the operation of which requires special consideration, or may involve some risk to the operation or to others or which is interlocked with and/or operated in conjunction with other apparatus, or whose function is to act as a shutdown under given conditions. Such labels and notices shall give clear and unambiguous instructions as to the procedures to be followed, dangers involved and the like.
8. Every sub-station, walk-in switch-room, generator house or electrical plant room, giving instructions for the treatment of persons suffering from electrical shock. Detail of the notices shall be agreed with the ENGINEER.
9. Entry points of cables into buildings.

4.1.10 Polythene Cable Tags

Provide polythene cable tags where required.

4.1.11 Electrical Requirements

Provide electrical components of mechanical equipment, such as motors, motor starters, control or push-button stations, float or pressure switches, solenoid valves, and other devices functioning to control mechanical equipment, including control wiring and conduit for circuits rated 400 volts, to conform to the requirements of the chapter covering the mechanical equipment. The interconnecting power wiring and conduit, control wiring rated 400 volts and conduit, the motor control equipment forming a part of motor control centers, and the electrical power circuits shall be provided.

Provide internal wiring for components of packaged equipment as an integral part of the equipment. Provide power wiring and conduit for lighting, receptacles, field-installed equipment, motor control equipment, motor control center assemblies, etc. Control wiring and conduit shall be provided under, and conform to the requirements of the chapter specifying the associated equipment.

Where existing mechanical systems and motor-operated equipment require modifications, provide electrical components as shown or specified.

4.1.12 Instruction to EMPLOYER'S Maintenance Personnel

Where specified in the technical chapters, furnish the services of competent instructors to give full instruction to the EMPLOYER'S designated personnel in the adjustment, operation, and maintenance of the specified systems and equipment, including pertinent safety requirements as required. Instructors shall be thoroughly familiar with all parts of the installation and shall be trained in operating theory as well as practical operation and maintenance work. Instruction shall be given during the first regular work week after the equipment or system has been accepted and turned over to the EMPLOYER for regular operation.

4.2 Execution

4.2.1 Painting of Equipment

4.2.1.1 Factory Applied

Electrical equipment shall have factory-applied painting systems which shall, as a minimum, meet the requirements of NEMA ICS 6 corrosion-resistance test (or equivalent) and the additional requirements specified in the technical specification chapters.

4.2.1.2 Field Applied

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria.

4.2.2 Spark Protection

All such metal items shall be configured, covered, protected, or made so as to present non-sparking surfaces. The supplier shall provide evidence of this protection to the ENGINEER and receive approval of their product before installation.

4.2.3 Safe Temperatures

All apparatus and conductors shall be of such construction as to operate at a safe temperature having regard to the conditions in which they shall be used and be so installed as to ensure that such temperature is not exceeded.

4.2.4 Electrical Grounding (Earthing) Requirements

Particular attention shall be paid to earthing. Earthing on power systems shall be in accordance with Electricity Act of Pakistan, or equivalent, and sensitive earth fault protection shall be employed at all sub-circuit or final sub-circuit boards or final sub-circuits where discrimination is necessary.

Earthing shall be made separately from main Earthing bar to all individual equipments.

4.2.5 Installation in Dangerous & Explosive Areas

Where installations are carried out in areas designated dangerous or hazardous, they shall be installed according to that Code of Practice as appropriate to the hazard classification and as directed by the Specification or the ENGINEER.

In all areas metalwork shall be galvanized. All equipment installed in hazardous areas shall be certified as complying with recognized safety standards. Installations shall be carried out in screwed heavy gauge solid drawn galvanized steel conduit. Alternatively thermoplastic or elastomer insulated, screen or armoured cable, with PVC, PCP or similar sheath overall may be used in conjunction with glands suitable for the area designation.

Accidental contact between flameproof apparatus, conduit or cables and pipe work shall be avoided.

4.2.6 Corrosion Protection

All exposed metal items, such as nuts, bolts, cables, supports, etc., must be made of an approved stainless steel for raw water applications. Internal piping must be an approved stainless steel for raw water applications or ductile iron Class 50. All ductile iron Class 50 components must be cleaned in accordance with the coating manufacturer's recommendations and painted with an epoxy coating approved for raw water use.

4.2.7 Humidity Protection

All electrical equipment, cabinets, switchboards and control boards shall be adequately protected from the effects of humidity. The CONTRACTOR shall fit anti-condensation heaters and/or forced ventilation to all items of equipment installed in locations subject to the effects of high humidity and condensation.

4.2.8 Access to Dangerous Voltage

All voltages in excess of 60 volts DC and 55 volts RMS AC between any two conductors of an un-earthed system or, where a system is earthed, between any conductor and earth, shall be considered dangerous to life and shall be treated accordingly.

All main switches specified herein shall be arranged with lock and key such that they can be locked in the 'OFF' position. All such necessary locks and keys shall be included in this Contract.

Any terminals that must normally remain live, such as the incoming terminals of main switches, shall be shrouded such that accidental contact at any time is not possible.

All removable covers to switchboards, terminal boxes, and the like shall be bolted on so that they cannot be opened by hand.

All such covers shall be labeled in block capitals with red lettering on white background in English and Urdu:

‘DANGER VOLTS’

Whether individually specified herein or not, all circuits shall be provided with isolating facilities such that each section and or part of the circuit can be disconnected and worked on safely at all times.

Fuses or other approved protective devices having a rated capacity based on the maximum current taken by the apparatus during normal operation shall be inserted in phase leads to each unit in a circuit. All fuses shall be readily replaceable without danger and any overload devices other than fuses shall be resettable without requiring entry into safety interlocked enclosure.

Notwithstanding the above, interlocking facilities shall be provided wherever safety requires that the contents of a cabinet or cubicle shall not be live when the enclosure doors are opened.

4.2.9 Interference Suppression

All electrical apparatus shall be suppressed to the satisfaction of the ENGINEER to minimize interference by power apparatus and circuits. Particular attention shall be given to items such as AC and DC machines. Suppression shall be effective at all radio frequencies.

Earth leakage current due to suppression equipment shall be restricted to 3.5 mA.

4.2.10 Spare Fuses and Miniature Circuit Breakers

Spare fuses and miniature circuit breakers shall be provided for each size and rating installed. The number of spares shall be agreed upon between the ENGINEER and the CONTRACTOR.

4.2.11 Wall Panels for Special Tools

All special tools for each item of plant shall be mounted on a suitable wall panel fixed as near as possible to that particular item of plant. None of these tools are to be used by the CONTRACTOR, but shall be handed over complete in a new condition.

4.2.12 Solid State Equipment

Where solid state equipment is used it shall be adequately protected from atmospheric pollution and adequately cooled to a standard as required by the manufacturer of the equipment and to the approval of the Engineer.

All solid state equipment and its inter-connecting circuitry shall be screened to prevent electrical interference from other equipment, cabling or wiring.

Thyristor drives, if used, shall be protected from line voltage variations. Each thyristor unit shall be fitted with an individual semi-conductor protection fuse and trip indicator.

5.0 POWER CONNECTION FROM SEPCO

5.1 Obtaining Power Connection from SEPCO

For satisfactory operation of the proposed and existing electrical equipment at all sites, following additional loads have to be obtained from SEPCO:

1. At High Lift Pump House, 450 KW (over and above 243 KW existing Load)
2. At Water Filter Plant (Water distribution) 450 KW (Over and above 451 KW existing Load)
3. At Zone 1 overhead reservoir, 2 KW
4. At Zone 2 overhead reservoir, 2 KW
5. At Zone 3 overhead reservoir, 2 KW
6. At Zone 4 overhead reservoir, 2 KW
7. At Zone 5 overhead reservoir, 2 KW
8. At Zone 6 overhead reservoir, 2 KW

5.2 Execution

The Contractor will be responsible for:

1. Submission of applications, affidavits and agreements duly signed by bill payee authority in Jacobabad to SEPCO Office in Jacobabad.
2. Carrying out joint survey with SEPCO contractor, TMA official and representative of Engineer for verification of applied load.
3. Installation of step-down transformer 11 KV/ 400 V at all the above places viz. 750 KVA at High Lift Pumping Station and 640 KVA at Water Filtration Plant and connections with appropriate size cable HT/LT, with end termination and safety arrangements as per relevant IEEE / NEC standards and earthing / grounding facilities.
4. Connection / end termination of these transformers to Water supply Stations with appropriate size of cable, through incoming / outgoing panels with over / under voltage relays, PTs, CTs and all other safety arrangements / earthing System under relevant IEEE / NEC standard.
5. Connections of this newly obtained load to incoming panels of Low Lift Pumping Station, High Lift Pumping Station and Water Filtration Plant through main switches and with safety arrangements, grounding / earthing to stand-by Generator changeover switches.

All these connections/ equipments should be compatible to IEEE / NEC standards.

6.0 LOW VOLTAGE DISTRIBUTION

6.1 General

6.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for low voltage distribution.

6.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

The CONTRACTOR shall submit with his design layout, drawings and dimensions of all items of switchgear offered, for approval by the ENGINEER.

6.2 Products

6.2.1 Low Voltage Switchboards

All switchboards shall be metal-clad, totally enclosed, extendable, unit or cubicle type and equipped as indicated in the specifications or approved on the Drawings.

Switchboards shall be ASTA certified (or equivalent) at the fault rating indicated elsewhere in this Specification. Where the fault rating is not specified or indicated, switchboards and panels energized through a circuit breaker shall be capable of carrying the through fault current equivalent to a fault level of 31 MVA with a peak making current of 2.55 times the symmetrical fault current at a power factor of 0.15 for a period of 3 seconds.

Switchboards and panels energized through HRC fuses, shall be capable of carrying for 0.2 seconds the above fault current with a peak making current of 2 times the symmetrical fault current at a power factor of 0.3.

Switchboards shall have a solidly continuous neutral and be equipped with HRC fuses, unless indicated elsewhere in this Specification.

The switchboards shall be floor standing or wall mounting as indicated elsewhere in this Specification, be rigidly constructed, with smooth external surfaces and have a minimum degree of protection classification IP 54 unless stated otherwise.

The switchboards shall be so designed and constructed as to permit the connection of additional cables and/or wiring to outgoing circuits in complete safety without de-energizing the whole switchboard or panel.

Switchboards shall provide effective segregation between incoming circuits/ busbars/ outgoing circuits/ control circuits and equipment. Where equipment is fitted above busbar chambers it shall not be possible for objects to fall into the chamber.

The segregation provided shall prevent the passage of ionized gas, resulting from the making or breaking or any circuit under normal or fault conditions, to any busbar, or adjacent switch.

Switchboards shall have vermin-proof drainage and ventilation holes as necessary, not exceed 2300 mm in height, unless stated otherwise and have operating handles and control

devices located within the limit of 450 mm and 1950 mm above floor level. All cable entrances shall be from bottom, with proper cable gland.

6.2.1.1 Busbars

Busbars shall be of air insulated copper of constant cross section throughout with solid copper connections to outgoing switches and the like. The connections shall be as short and direct as possible and shall be air insulated except where insulated cable connections are a necessary design feature.

The busbars shall be rigidly clamped and secured to prevent undue movement under fault conditions or displacement as a result of the installation of cabling and be provided where necessary, with insulated phase or circuit barriers. Clamping and supporting bolts, screws and nuts, shall be of plated brass or steel.

6.2.1.2 Cable Glands and Terminations

Where the size and type of cables are indicated elsewhere in this Specification, then all necessary glands, spreader boxes and the like, shall be provided as part of the switchboard or panel by the manufacturer.

Where details of cables are not indicated removable plates shall be provided. For cubicle type switchboards and panels, sufficient gland plates shall be provided to cater for all future additions to the switchboard or panel, up to the maximum design capacity. The gland plates shall be so sized and arranged as to facilitate their removal for drilling for future additional cables.

Glands and terminals shall be so designed and constructed as to minimize the bending of cable cores.

Mains shall be provided as part of the switchboard or panel for securing these cores by means of clamps, trunking and the like. Cores shall not be run with busbars.

Where current transformers are called for, means shall be provided for properly securing these to the switchboard or panel proper. It will not be acceptable for current transformers to be fitted and secured to cable cores.

Terminations shall be made by sweated lugs, clamp connections or compression lugs.

Unless indicated elsewhere in this Specification, glands for paper-insulated cables shall be vertical, downward pointing, using where necessary, reverse entry boxes or adapters.

Auxiliary cables shall not be terminated in the same chamber as the main cables.

6.2.1.3 Earthing/ Grounding

Switchboards and panels shall have an earth bar to which all items of equipment shall be effectively bonded. This bar shall be of copper and shall be of the following minimum size:

Equipment with 3 second rating: 40 mm x 6.3 mm
Other equipment: 25 mm x 3 mm.

The earth bar shall be bolted to the main frame and located so as to facilitate the connection or protective conductors.

The metal sheaths and/ or armoring of all cables connected to the switchboard or panel shall be bonded to the earth bar by means of a separate protective conductor.

This conductor shall be a minimum size of 4 mm. All joints shall be tinned and bolted or clamped.

The frames of draw-out circuit breakers shall be earthed by means of a plug type contact sufficiently long to allow the shutters to close before contact is broken.

The star point of each group of current transformer secondary connections shall have a separate earthing link in an accessible position.

Neutral busbars shall be insulated from earth and, where necessary, shall have a cable gland and connection for an insulated single-core earthing conductor.

6.2.1.4 Current Transformers

Current transformers shall be fitted to the fixed portion of the equipment and suitable for the characteristics of the apparatus with which they are associated.

The transformers shall withstand safely and without damage the mechanical and thermal stresses set up by a short circuit equal to the full short circuit rating of the switchboard or panel and the effects of an open circuit in the secondary circuit with full load in the primary for a period of one minute.

Current transformers shall be secured in position using a method which does not exert undue pressure on the winding and shall have all secondary connections brought out to a terminal board by means of separate insulated leads. The leads shall be so arranged as to avoid the possibility of contact with any mains connection.

Labels shall show the polarity of primary and secondary windings and the duty or function of each transformer.

6.2.1.5 Indicating Instruments

Indicating Instruments shall be 'Industrial' grade, of robust construction, enclosed in dust-tight, flush mounting cases, will have 240° movement and maximum possible length of scale. Motor current ammeters shall have compressed or non-linear scales and a red line at normal full load current.

Ammeter scales shall be such that the normal full load current gives approximately 3/4 full scale deflection.

Meters shall have white faces with black markings, be moving-iron for ac circuits and moving coil for dc circuits, current transformers operated for ratings above 40 amps and where remote from the switchboard or panel.

Ammeters shall be capable of carrying full load current continuously, be suitable for operation with direct-on-line starting of motors where relevant and shall withstand without damage the passage of fault currents until operation of the main current protective device. Facilities shall be provided for zero adjustment without dismantling.

6.2.1.6 Locking Facilities

Locking facilities shall be provided in accordance with the following:

1. To enable all shutters to be locked in the closed position.
2. To enable each fuse switch, isolator and the like to be locked in the OFF position.
3. To enable each changeover switch to be locked in all positions.

Padlocks shall be non-ferrous and not smaller than 25 mm overall.

A minimum of 2 keys shall be provided with each lock or padlock.

Access doors to cubicle switchboards and panels shall have a lockable handle or padlock facilities.

Details of locks, keys, numbering and the like shall be confirmed with the ENGINEER before ordering.

6.2.1.7 Interlocks

Interlocks shall be provided to ensure that:

1. the cover of any fuse switch, isolator and the like cannot be opened with the switch closed;
2. any fuse switch, isolator and the like cannot be operated with the cover opened;
3. cubicle doors cannot be opened with the main isolator closed; and
4. The main isolator for any cubicle cannot be operated with the door open.

Note: Where it is impractical to comply with 3. and/ or 4., the equipment shall be fitted with a suitably worded warning notice.

The notice shall give instructions regarding the isolation of the equipment. Any equipment that is 'live' with the cubicle doors open shall be fully shrouded and fitted with a warning notice.

6.2.1.8 Small Wiring

Small wiring shall:

1. be not less than 1.0 mm, multi-stranded, black PVC as specified for Control Cables;
2. be grouped, as far as is practicable, according to the circuits involved;
3. be run in insulated cleats, plastic or steel conduit or trunking;
4. be terminated with clamp washers or crimped terminals;
5. have a numbered ferrule or sleeve at each end of each wire – the numbering shall
6. be in accordance with the wiring diagram;
7. be run between terminal points – joints will not be permitted;
8. be provided with fuses and links to enable all circuits to be isolated from any bus wires;
9. be so designed and installed as to permit maintenance and test work to be carried out without de-energizing the whole switchboard or panel;
10. Incorporate terminal boards having stud or clamp type connections – pinch screws will not be accepted;
11. be connected at the front of terminal boards;
12. be clearly identified and marked where it may be alive when the main circuit isolator is open;
13. be segregated, where relevant; and
14. Have a terminal for all spare wires and spare cores of multi-core cables.

6.2.1.9 Painting & Protection

Anti-corrosion treatment and painting shall be in accordance with the following:

1. Sheet steel shall be zinc-coated, rust-proofed.

2. Before dispatch from the manufacturer's works all equipment shall be painted with rustproof primer, filled and flattened, painted with 2 undercoats and a minimum of 2 finish coats of semi-gloss finishing paint to an approved color. Where a manufacturer proposes an alternative paint system, the approval of the ENGINEER must be obtained in writing before any work is put in hand.
3. Switchboards and Panels shall comply with this Specification for: Fuses; Miniature Circuit Breakers; Moulded Case Circuit Breakers; Distribution Fuse-boards; Fuse switches, Switch fuses and Isolators; Labeling; Contactors; Transformers; Motor Starters and Controllers.

6.2.2 Low Voltage Distribution Boards

All low voltage distribution boards shall be of fabricated sheet metal construction, fully rust-proofed, painted to an approved finish and protected against ingress of solid foreign bodies and liquid. All boards shall be rated as required.

They shall be arranged for conduit and/or cable entry as required and all boards shall be supplied complete with HRC cartridge fuses or miniature circuit breakers.

All low voltage distribution boards shall have banks of fuses or miniature circuit breakers that are easily removable and readily accessible for easy wiring. All boards shall have 25% spare ways fitted within the case.

Any boards that have feeders looped in or out at the busbars shall have double terminal blocks on each busbar.

All boards shall have insulating barriers installed between phases and between each phase and earth.

Where boards are fixed on steelwork or concrete columns, reinforced concrete or brick walls, they shall be mounted on the surface with conduits and/or trunking rising vertically from them.

Where boards are fixed on plaster finished walls, they shall be surface mounted on the finished face of the plaster with an adaptable galvanised metal box (minimum size 150 x 150 x 75 mm), recessed into the wall at the back of each board. Suitable holes or slots shall be cut in the back of the board to accommodate all incoming and outgoing cabling, these holes and slots being suitably bushed by sleeving. The adaptable box and fuse-board shall be separately fixed on the wall but electrically and mechanically linked together and the boards independently fixed on the wall by bolts and expansion shields.

Boards shall be mounted in positions finally agreed with the ENGINEER on site.

Distribution boards shall be fitted with a permanent label giving details of fuses or miniature circuit breakers when the use of equipment of other makes or types would adversely affect the protection or discrimination provided.

6.2.3 Miniature and Moulded Case Circuit Breakers

Miniature circuit breakers shall be of the suitable ratings.

The effect of ambient temperatures, operating duty and application shall be fully considered in applying de-rating factors for application at site.

Miniature and Moulded case circuit breakers shall have means for preventing any one pole of a multi-pole circuit breaker being operated or tripping independently of the other poles.

Miniature and Moulded case circuit breakers shall have locking facilities and be supplied with all keys, or shall be enclosed in cases with locking facilities which shall be provided with keys.

Miniature and Moulded case circuit breakers shall be of the same type throughout the Contract.

6.2.4 Residual Current Circuit Breakers

Residual current operated devices are to be either 3 phase and neutral or 1 phase and neutral.

Both types will be of the circuit current rating and rated tripping current as stated elsewhere in this Specification. Either type must isolate all poles and neutral and be complete with a test button marked 'PUSH TO TEST'. The unit must be of robust construction and be mounted in an enclosure of pressed steel.

Where residual current circuit breakers are used they shall be of the AC/ DC current-operated type when incorporated in fixed socket outlets, except that they shall be suitable for the service conditions as defined at site.

6.3 Execution

6.3.1 General Requirements

All low voltage fuse switchgear shall be metal clad, fully dust-proofed, painted to an approved finish and protected against ingress of solid foreign bodies and liquid. Where switchgear is exposed to weather, it must be completely watertight. All units are to be suitable for cable or conduit entry as required.

All isolators and fuse switch units shall be complete with "ON/OFF" padlocking facilities, including padlocks and keys. Where complete safety can be assured only by making dead a system inside a cubicle or cabinet, the doors of the cabinet or cubicle shall have interlocking facilities so that the act of opening a door removes power from the contents of the cabinet or cubicle.

All live metal parts shall be fully surrounded between phases and from each phase to earth by Moulded shrouds.

All low voltage fuse switches shall be load breaking, 'fault making' and each shall have a proved rupturing capacity of not less than 31 MVA at 415 volts. All switchboards shall be of the heavy duty industrial type, metal clad, floor standing or wall mounting as required, and as approved by the ENGINEER, fully rust-proofed and waterproofed where exposed to weather, with isolators and fuse switchgear units mounted thereon and complete with all necessary interconnections. All fuse switchgear shall carry short-circuit rating test certification.

All low voltage fuse switches and isolators shall have ratings adequate for the duty as detailed in this Specification and shall be suitable for conduit entry or fitted with cable boxes and/or glands as required.

7.0 CONDUCTORS & CABLES

7.1 General

7.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work to provide a complete system of conductors as indicated or necessary to accomplish the required connections. All conductors shall be installed in a neat and workmanlike manner, with care being taken that conductors are not kinked, scarred, or damaged during installation.

7.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

7.2 Products

7.2.1 Conductors and Insulation

Wire and cable shall be soft drawn, annealed copper with 600-volt insulation. Aluminum wire will not be accepted.

Conductor insulation shall be type THWN, THHN or XHHW.

The voltage drop at the end of any circuit shall not exceed 3% of the normal line voltage under full load.

7.2.2 Cables Run above ground

Cables run above ground shall be secured to walls, structures or cable trays by means of plastic or aluminum alloy cleats. The cleats shall be of one or two bolt type and correctly sized for the overall diameter of the cable. They shall be of the type that can be built up into multi-cable assemblies.

Cables shall be secured in accordance with the following:

1. Single multi-core cable; single cleat cable up to 25 mm diameter, fixed with brass woodscrews to brickwork and the like.
2. Single multi-core cable; single cleat cable above 25 mm diameter. Fixed using expansion bolts and sheradized or galvanized studs and nuts.
3. Multi-cable runs of multi-core cables; fixed to brickwork via galvanized proprietary back-strap or via galvanized channel with cleats fixed by means of galvanized or sheradized studs and nuts. The back-strap or channel shall be sized to permit the addition of at least 25% additional cables.
4. Multi-core cables; fixed to galvanized cable tray via sheradized bolts and nuts.
5. Single core cables; as agreed with the ENGINEER.

Multi-cable assemblies shall be arranged so that a minimum space of 20 mm is maintained between any cable and any other cable or any wall, cable tray or other surface.

Where cables enter through walls and floors cables shall be sealed with approved fire-resisting cable transits. Where cables pass through a floor at a position where they may be subject to mechanical damage they shall be protected to a height of 1800 mm by means of steel pipe work or galvanized sheet steel or such other method as may be approved by the ENGINEER.

7.2.3 Cables laid in the ground

7.2.3.1 General

Cable trenches shall be prepared such that the cable minimum bending radii are not reduced during cable installation.

Cables shall be segregated into the following categories:

1. power (greater than 1000 V)
2. power (less than 1000 V)
3. instrumentation/telemetry
4. control
5. telecommunications

Cables shall be laid in a manner such that any electrical interference between cables shall not have a detrimental effect on the life and operation of equipment installed within the installation. As a general rule there shall be a minimum separation of 600 mm between HV power and all other cables and 300 mm between LV power and all other cables. Instrumentation, control and telecommunications cables shall be laid together in PVC-U duct of minimum diameter 100 mm.

These separations are minimum and special circumstances such as the presence of high current flows, or harmonic content may necessitate larger separation distances. Buried cable up to 1000 V shall have a minimum cover of 500 mm measured to the top of the highest cable. On crossing roadways the cable shall be run through a PVC-U duct of minimum diameter 100 mm with a minimum of 1000 mm cover and encased on all sides by 150 mm of Class 20/20 concrete.

Higher voltage cables shall be buried with a minimum cover of 1000 mm.

Where, for any reason, the minimum specified cover cannot be provided the cables shall be run in cable ducts encased on all sides by 150 mm of Class 20/20 concrete.

7.2.3.2 Cables Installed Direct in Ground

Installation of cables direct in the ground shall be in accordance with the Standard Details. The bottom of the trench shall be free of sharp stones and the like.

Protective covers shall be interlocking clay or concrete cable tiles not less than 100 mm wide and clearly and indelibly marked 'DANGER ELECTRICITY'.

Warning tape shall be run in one or more continuous strips and laid so as to provide adequate cover to the cables. It shall be red and shall be clearly and indelibly marked 'DANGER ELECTRIC CABLES'.

The graded backfill above the sand shall be free from boulders and other sharp, deleterious material.

7.2.3.3 Cables Installed in Ducts

1. Underground ducts shall be of 100 mm diameter (minimum) impact resistant PVC-U.
2. They shall be laid with a minimum cover of 500 mm and surrounded by at least 75 mm of sieved sand.

3. At all road crossings, where the minimum cover shall be 1000 mm, and elsewhere where the specified minimum cover to buried cables cannot be provided, 100 mm diameter (minimum) PVC-U ducts shall be installed and encased on all sides by 150 mm of Class 20/20 concrete.
4. Cable draw pits shall be provided at a maximum spacing of 25 m and at all changes of direction. Nylon drawstrings of sufficient size shall be provided in all ducts to allow additional cables to be installed as required.
5. All ducts, whether containing a cable or not, shall be sealed at each end. Conduits into buildings shall be sand filled and sealed at each end by hot poured bitumen compound.
6. For situations subject to high water table or high water pressure, or in tanked buildings, multi-cable transits shall be installed. Ducts under roadways and the like shall be sealed by weak mortar.
7. Cables shall be identified at each end using permanent plastic labels secured using two bindings per label. The identification shall show a reference number, conductor size, number of cores and material, if not copper.

7.2.4 Cable Markers

Cable markers shall be installed to indicate the position of underground cable(s). Cable markers shall be installed in accordance with the following:

1. at each side of each road crossing;
2. at every change of direction;
3. at each point where cable(s) enter or pass under a building or structure, at 300 mm above ground level;
4. at each joint authorized by the ENGINEER;
5. at intervals not exceeding 45 m on straight runs.

7.2.5 Wiring to Lighting and General Power Circuits

Wiring to lighting circuits shall (unless indicated otherwise):

1. Be of one of the following sizes: 1.5 mm single core PVC except for circuits loaded above 1 kW where 2.5 mm shall be used, but 1.5 mm and 2.5 mm cables shall not be used in combination on the same circuits; 1.0 mm light duty multi-core mineral insulated, metal sheathed.
2. Where carried out in single core cables in conduit, be installed on the 'loop-in' principle, no joints or junction boxes being permitted. Line conductors shall be looped at switches. Neutral conductors shall be looped at lighting points.
3. Cables shall be drawn into a conduit simultaneously without twists. Cables bunched into circular groups shall have the appropriate de-rating factor applied.
4. Where carried out in multi-core cable, have the line and neutral conductors looped at the lighting point.
5. Not be looped at terminal blocks internal to lighting luminaries. For fluorescent or similar luminaries having internal terminal blocks, the fixed wiring shall terminate at the conduit box with tails taken into the fitting. The arrangement shall be such that the fittings and tails may be removed without causing the other lighting luminaries on the circuit to be disconnected.
6. Wiring to 13 A socket outlet circuits shall be ring wired throughout. Spur circuits shall be used only where specified.

7.2.6 PVC Insulated PVC Sheathed Cables

PVC insulated PVC sheathed cables shall be 1000 volt grade with copper conductors and incorporate an earth continuity conductor.

Where run in timber floors or roof voids, they shall be run either along the timber joists or at right angles to them.

When run in intermediate floors and at right angles to the joists, they shall be threaded through maximum 25 mm diameter holes, drilled at half joist depth.

When run in roof voids or underground floors, and at right angles to the joists, but not threaded through holes, i.e. clipped across the top of roof joists or clipped to the underside of floor joists, they shall be protected as necessary.

All drops to switches, socket outlets, and the like, shall be truly vertical, and when concealed by plaster, they shall be protected by galvanized channel. All cables shall be well fixed by cable clips, and for surface work these shall not be more than 225 mm apart.

On PVC insulated and PVC sheathed cable systems all lighting luminaries shall be mounted on conduit boxes securely fixed to timber battens, the battens being supplied and installed by others in positions indicated by the CONTRACTOR.

Cables to all tungsten lighting fittings shall terminate via heat resisting flexibles of high temperature glass, PTFE or other approved insulation.

Cables to all fluorescent lighting fittings shall terminate via high temperature PVC singles or other approved insulation.

In all cases the connection to the PVC insulated PVC sheathed main wiring system shall be by two screws, porcelain insulated brass connectors within the conduit box.

7.2.7 PVC Insulated Cables

1. Where wiring is in conduit and/or trunking it shall be installed using single core PVC insulated 1000 volt grade cables, and shall consist of high conductivity stranded copper conductors. On single phase circuits phase conductors shall be red, neutral conductors shall be black.
2. On three phase circuits the colors shall be red, yellow and blue, with black for neutral.
3. A separate circuit protective conductor shall be installed for each circuit with insulation colored green and yellow.
4. Cable shall be delivered to site on reels with seals and labels intact, and shall be of one manufacturer throughout the installation. Minimum conductor size shall be 1.5 mm.
5. As far as is practicable all cables shall be threaded rather than drawn into the conduit, the CONTRACTOR shall provide himself with suitable reels to prevent contact of the cables with floor and to prevent chafing or other accidental damage.
6. In the event of any protective insulation being damaged whilst cables are being threaded into conduit the whole of the particular length concerned must be replaced and re-fixed by the CONTRACTOR at his own expense.
7. The wiring of lighting and socket outlet systems shall be carried out on the 'loop in' system, all cables shall be continuous between definite terminal points, and joints in cables will not be permitted.
8. All connections shall be made in the terminals of ceiling roses, switches, switch sockets, or other termination boxes using approved pattern porcelain insulated brass connectors within the conduit boxes. PVC terminal block type connectors with grub screws shall not be used.

9. For butyl cables, the tape and braid shall be stripped back 10 mm from the connection.
10. Extra low voltage and communication cables shall not be run in the same trunking or conduit as low voltage cables. PVC cables shall not pass through or terminate in lighting luminaries.
11. All cables, except where otherwise stated, in this Specification, shall be threaded into the conduit, after erection, without undue tension. The CONTRACTOR may be required to withdraw cables contained in certain conduits at sundry selected points to demonstrate that these requirements have been complied with.
12. Cables shall be drawn into a conduit simultaneously without twists. Cables bunched into circular groups shall have the appropriate de-rating factor.
13. Cables shall not be drawn into trunking but laid in, necessitating, the removal of all trunking lids. This is to apply when new cables are being installed and/or existing cables are being renewed.

7.2.8 Flexible Cords

All flexible cords to be used in conjunction with lighting luminaries shall be white 3 core circular 300/500 volt grade PVC insulated and sheathed manufactured to BS 6500.

Conductors smaller than 0.75 mm shall not be used unless previously approved by the ENGINEER.

7.2.9 Voltage Drop

In addition to observing the above minima the CONTRACTOR shall ensure that all sub-circuit cable sizes are so selected that the total voltage drop does not exceed the limits stated in IEEE Regulations.

In considering the volt drop requirements of motor circuits due allowance shall be made for the effect of starting current on the motor terminal voltage and starting torque.

7.2.10 Control Cables and Cabling

Control cabling shall be carried out in 600 volt grade, circular multi-core cable, PVC insulated, single wire armoured and PVC sheathed overall, having a minimum conductor cross-sectional area of 1.5 mm. Cable terminations shall be made in approved type compression glands with armour clamps, PVC shrouds and earthing tags.

Each control cable shall have 25% spare cores to allow for any later additional requirements. Conductors shall be of stranded copper complying with BS 6360.

Marshalling boxes shall be provided as required for control cable connections. They shall be of sufficient size to accommodate all spare cores entering the box. Terminals shall be provided within the boxes sufficient to ensure that no more than one core is terminated at any terminal. Boxes shall allow a minimum clearance of 150 mm between terminal rails and the box sides and 100 mm between adjacent terminal rails. Each terminal in the marshalling box shall be identified in accordance with the relevant schematic or wiring diagram. Boxes shall be protected to IP 65.

7.2.11 Tests on Cables

Manufacturers' tests shall be carried out including conductor resistance and ac voltage tests.

Manufacturers' test certificates for all cables shall be submitted to the ENGINEER for approval.

7.2.12 Joints and Terminations

Leave at least 6 inches of free conductor in each outlet or junction-box for making up joints and making connections to fixtures, devices or equipment.

7.3 Execution

7.3.1 Conductor Installation

1. Conductors shall be continuous from outlet to outlet, and no splices shall be made except within outlet or junction boxes. Junction boxes shall be provided where required. Home runs may be combined in one conduit, provided all connections are in accordance with NEC requirements and the maximum unbalanced current in the neutral does not exceed the capacity of the conductor. All parallel feeder runs shall be laid out and cut to exact same lengths before pulling into conduits to insure load balance. No additional trimming of parallel conductors will be accepted. Conductors shall be pulled by hand and without aid of block and tackle or other mechanical device. Only approved pulling compounds, which will in no way damage the insulation on the conductors or hasten its aging, may be used to facilitate pulling of wire into conduit. Circuiting shown shall be followed unless specific changes are approved by the ENGINEER.
2. Balance circuits across phase wires of the branch and distribution panels.
3. Switches shall not be connected to the neutral conductor.
4. Where several feeders pass through a common pull box or junction box, the feeders shall be tagged to indicate clearly their electrical characteristics, circuit number, and panel designation. Paint this same information on the cover of the box.
5. Wherever cable minimum sizes and/or ratings are stated in the Specification, it is the CONTRACTOR'S responsibility to increase the rated size of any cable above the figures given should he, for any reason, consider such increase essential, whether to provide voltage drops within those stipulated in the IEEE Regulations, to comply with short circuit ratings, fault levels, or for any other reason.
6. The CONTRACTOR shall also be responsible for any cable capacity de-rating necessary because of the climatic conditions on site. The CONTRACTOR shall assess the actual length of any route and make all necessary allowances for bends, rises and falls, connections, and the like and apply any other de-rating factors necessary to prevent over-heating.
7. The CONTRACTOR shall provide and install any ancillary supporting steelwork, cable trays, or brackets, necessary to support, in accordance with the best current practice, all cables, conduits, trunking and lighting luminaries. This applies to all systems.
8. Where cables pass through floors or rise vertically up walls or structural steelwork, and the like, they shall be protected by passage through mild steel pipes to at least 1 m above floor level or to the underside of the dividing box, whichever is less. Cable slots or holes made in floors shall be provided either with a mild steel pipe or a concrete surround rising 75 mm above finished floor level.
9. The exits of all such pipes shall be properly sealed against water entry.
10. As far as possible, cables shall be routed along common multi-cable runs. If trays are provided they shall be supported by brackets. Purpose-made bends, tees and angled tray material shall be used where necessary.
11. Wherever cable trays are used, they shall be secured to the walls of the building structures by means of angle brackets spaced at intervals of not more than 1200 mm

or by angle suspenders from the ceilings at the same intervals. The fixing bolts which secure the brackets to the walls or underside of floor shall be of not less than 10 mm diameter.

12. The CONTRACTOR shall provide, fix and connect all cable saddles, cleats and brackets. All supporting steelwork shall be painted as specified.
13. All cables should be securely fixed to the tray. Where cables do not run in multi-cable runs they shall be fixed to walls by suitable cable cleats. The maximum spacing of cable cleats, saddles, and the like shall not exceed 610 mm in horizontal, or 810 mm in the vertical plane.
14. All manufactured supporting and fixing materials shall be hot dipped galvanized and all purpose-made and site fabricated steelwork shall be painted as specified. Fabricated brackets shall, wherever possible, be welded in preference to the use of bolts.
15. The CONTRACTOR shall be responsible for all off-loading and handling of cables on site and shall ensure that cables are delivered to site on drums properly protected against mechanical damage.

8.0 ELECTRICAL GROUND SYSTEM

8.1 General

8.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for electrical ground systems (or earthing) systems.

8.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

8.2 Products

8.2.1 Ground Conductors

Wire between Ground Grid and other points of the system shall be un-insulated copper with conductor properties, as required by the National Electrical Code and the Electricity Act of Pakistan.

8.2.2 Earth Bar

1. Each sub-station shall have a main earth bar consisting of a hard drawn high conductivity copper bar of at least 50 x 6 mm, mounted on stand-off insulators. Connections to this bar shall be by brass bolts, flat washers, nuts and lock-nuts.
2. The system neutral, where applicable, earth bars of all switchboards and all earthing terminals of all transformers shall be securely bonded to the main earth bar. For bonding purposes a copper earthing strip may be used, at least 25 x 3 mm in cross-section.
3. Metal sheaths and armouring of all incoming, outgoing and interconnecting sub-station cables shall be securely bonded to the main earth bar. The sizes of bonding conductors shall be in accordance with IEE Regulations Section 543. Bonding conductors may be connected to the earth bar of the switchboard or other apparatus served.
4. All cables and conduits used throughout the installation shall be securely bonded to the associated equipment and earthing straps shall be fitted. To facilitate such bonding, all cable glands shall be supplied with substantial armour clamps, having additional earthing lugs.
5. Compression glands shall be fitted with earth tags and brass set screws.
6. Earthing terminals of every distribution boards, isolator or switchgear item or other apparatus shall be securely conductor or 25 x 3mm copper strip or by connecting the bonding conductors to the earth bar of the apparatus.
7. All electric motors and other items of electrical equipment within the Contract shall be bonded to earth by flexible copper tables, braids or conductors of not less than 6mm² equivalent size connected to the armouring of armoured cables.
8. All bonding of motors shall be to the stator frame of the motor. Bonding to end-shields, terminal boxes and the like is not acceptable.
9. Incoming gas, water, piped services and ducting shall be bonded in accordance with the requirements of IEE Regulation 413-2. The minimum size of the bonding conductor shall be 6mm². Copper strip of green and yellow PVC insulated single core copper cables shall be used.
10. Earth clamps shall comply with BS 951. In dry areas tinned brass clamps shall be installed. In areas where dampness is to be expected phosphor bronze clamps shall be used.

11. Where electrical components are mounted on custom built frames, each of the above earth bonds shall include the metalwork of the support structure.
12. Conduit or trunking shall not be used as the sole circuit protective conductor.

8.2.3 Exothermic Weld

All cable to ground rod connections and all connections elsewhere shall be accomplished by the exothermic welding process.

Furnish all materials and molds necessary to properly perform all required exothermic welds.

8.3 Execution

8.3.1 General

Conduits, panels, metal boxes, cabinets, fixtures, outlets and other metal enclosures surrounding or containing electrical equipment, motors or apparatus with metal frames shall be grounded in accordance with the Electricity Act of Pakistan.

The network shall comply with the Electricity Act of Pakistan. The CONTRACTOR shall be responsible for satisfying the Government Inspector that the earthing installation complies with this Act.

8.3.2 Installation

The electrical continuity of all metal raceways shall be insured by means of properly installing locknuts, bonding straps or other approved means. Provide a separate conductor in all circuits installed in flexible conduit and bond the conductor to the cabinet, outlet box, etc., at each end of the run. Ground connections shall be made by means of welded or bolted ground clamps or grounding-type bushings.

Equipment grounding conductors shall be provided with green colored insulation in all raceway.

9.0 WIRING DEVICES

9.1 General

9.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for installation of wiring devices complete with wall plates.

9.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

9.2 Products

9.2.1 Wiring Devices

1. All wiring devices provided on this project shall be by the same manufacturer and shall be specified grade.
2. Local switches shall be single pole and three way of required ratings.
3. Duplex convenience receptacles shall be for 220 volt, 2- pole, 3-wire, NEMA or equivalent standard, grounded type.
4. Ground fault circuit interrupting receptacles shall conform to NEC, or equivalent, and shall have a visible indication of a tripped condition.

9.3 Execution

9.3.1 Installation

Devices shall be installed in a rigid manner in outlet boxes. Device plates shall be installed with all four edges in continuous contact with finished wall surfaces without the use of mats or similar devices. Plaster fillings will not be permitted. Plates shall be installed vertically and with an alignment tolerance of 1/16-inch.

10.0 MOTORS AND ITS CONTROLLERS/ CONTROL PANELS

10.1 General

10.1.1 Summary

This chapter addresses the work related to furnishing and installing the electric motors that drive the pumps at the sites specified in chapter 2, including all supervision, labor, materials and equipment in the work for component materials and functionality of the equipment that starts and stops the motors.

10.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

10.1.3 System Description

1. The motor & motor housing should be designed for usage in raw/ clear water.
2. Noise level and vibrations of the motors after repair and service shall be according to relevant standards. CONTRACTOR will demonstrate that the parameters (horsepower and efficiency) of the motors after repair and servicing have been restored.
3. Motor Control Cabinets shall be custom-engineered enclosures suitable for mounting as indicated on the approved drawings and contain the system components indicated on the approved drawings and specified herein. Unless specified, all controls, meters, and devices shall be placed within the interior of the cabinet.
4. The CONTRACTOR has to perform installation, testing and commissioning of all the systems described below including pumps and motor assembly and all related equipment including Motor Control Centres (MCCs), flow meters and Automation System to the satisfaction of the ENGINEER.

10.1.3.1 Low Lift Pumping Station (LLPS)

There are six 25 hp motors already installed at LLPS, which have to be repaired in accordance with the BOQ, serviced, reinstalled and made operational.

10.1.3.2 High Lift Pumping Station (HLPS)

1. There are seven 80 hp motors already installed at HLPS, which have to be repaired in accordance with the BOQ serviced, reinstalled and made operational.
2. Six (6) brand new pumps coupled with electric motors shall be procured according to the specifications given below and in the BOQ.

Table 10-1: Specification of new pumping sets for new pump room at High Lift.

Pump Type	Deep Well Vertical Turbine Pump
Flow Rate	245.5 m ³ /hr (900 IGPM)
Head	75 m (246 ft.)
Motor	400 V, 3 phase, 50 Hz, 100 HP

10.1.3.3 Water Distribution pump room

1. There are six 80 HP motors already installed at Water Distribution pump room, which have to be repaired in accordance with the BOQ serviced, reinstalled and made operational.
2. Six (6) brand new pumps coupled with electric motors shall be procured according to the specifications given below and in the BOQ.
3. It should be noted that the extension of this part has to be carried out without disrupting the main supply to the city. Hence, this component may have to be carried out in two or more phases. The timeline for repair of existing pumping sets and installation of new pumping sets will be approved by the Engineer prior to commencement of these works.

Table 10-2: Specification of new pumping sets for Water Distribution pump room.

Pump Type	Deep Well Vertical Turbine Pump
Flow Rate	245.5 m ³ /hr (900 IGPM)
Head	64 m (210 ft.)
Motor	400 V, 3 phase, 50 Hz, 80 HP

10.1.3.4 Operations and Maintenance Manual:

Provide complete manual for each pump room including all submittal data, wiring diagrams, testing reports, etc. Manual shall include names, addresses, location, phone number, e-mail address, fax phone number, of supplier, installer and factory. Additionally, provide a complete schedule of maintenance. Provide six copies of each manual in a 3-ring binder with a printed cover.

10.2 Products

10.2.1 Motors & Controllers

Motors and Controllers shall conform to the latest applicable standards of the NEMA and ANSI for type and class as specifically applied.

10.2.1.1 Type of motors:

1. The motors shall be 3-phase AC induction motors operating at 400V AC and 50 Hz.
2. High-efficiency motors should be used.

10.2.1.2 Thermal Overheat Protection

1. The motors should be capable for continuous operation for at least 24 hours without exceeding the temperature rise limits for the motor insulation system.
2. The motors should shut down on the detection of excessive temperature.
3. The motors shall be provided with RTDs to monitor temperature of bearing and winding.

10.2.1.3 Motor power supply

The motors must be designed to operate with voltage levels 10 percent above or 5 percent below the nameplate rating of 400V AC.

10.2.1.4 Approved Manufacturers

Approved manufacturers for electric motors include:

- Siemens
- ABB
- Approved equal

10.2.2 Motor Control Panels

Before placing the order, the contractor must submit shop drawings showing layout plan and electrical arrangement of the control panels for approval of the Engineer.

10.2.2.1 Components

The control panel shall include circuit breakers, dry running protection, relays, timers, control buttons and switches, meters, indicating lights and terminal boards as specified and required. The control panel shall be generally arranged as described herein. Should the physical size of any component vary from that shown on the Plans; the control panel shall be modified, as required, maintaining the same basic order of components.

10.2.2.2 Enclosure

The enclosure may be constructed as one piece or in sections, shall be NEMA 12 in design, wall mounted or of free standing style suitable for pad mounting.

The enclosure shall be provided with mechanical interlocks arranged in a manner that will completely prevent the opening of any and all enclosure doors; unless the flange mounted circuit breaker serving the respective section is in the de-energized position.

10.2.2.3 Panel Components

1. Wires shall be identified at both ends by adhesive wire labels and all wire numbers shall appear on shop drawings. No two wires shall have the same number. All motor wiring and line wiring in the control panel shall be copper type THHN or THWN. All wiring shall conform to NEMA, JIC, NMTBA Standards, or equivalent, and be completely connected, requiring only connection for service.
2. All equipment in the control panel shall be identified by nameplates. Devices such as indicating lights, selector switches, etc., should also be provided with standard nameplates.
3. Control relays shall be 10 ampere multi-pole machine tool type. Each contact shall be housed in a clear plastic enclosure to permit visual contact inspection. Contacts shall be easily convertible from normally open to normally closed and vice versa. The relays shall hold up to eight convertible contacts and four fixed contacts for a total of 12 pole capability. Relay magnets shall be of CI design and have a double-wound, molded epoxy magnet coil. Relays shall have a concealed but accessible operator for manual operation with provisions for holding the relay in the energized position for circuitry testing. Provide relays as required for system operation.
4. Pushbuttons, selector switches and pilot lights on the face of the control panel shall be 30mm diameter, NEMA 12. Lights shall have long life LED lamps.

10.2.2.4 Arrangement

All components shall be wired to terminal strips for wiring and quick-disconnect bulkhead fittings for tubing.

The control panel shall house the following:

1. A water intake level sensing system as specified to sense liquid level and transmit it to the PLC
2. A motor-winding-overheat system for each pump motor, which shall consist of temperature sensors imbedded in the motor windings, and necessary relays, timers, and indicators in the control panel. If sensors indicate a high winding temperature, relays in the control panel shall stop the respective motor. The sensors in the winding shall reset, automatically, when temperatures return to normal.
3. A voltage monitor shall continuously monitor supply side voltage to the control panel. The voltage monitor shall provide protection from under voltage, power loss in any phase and voltage unbalance. The monitor shall have separately adjustable pickup and dropout ranges and maximum 6 second time delay of drop out. Activation of the voltage monitor shall disconnect power to the pumps. The voltage monitor shall automatically reset upon restoration of proper voltage. The monitor shall have one set of normally open contacts with a minimum 3 ampere continuous current rating for remote alarm function.
4. A failure-to-pump alarm and shut down system for each pump, which shall consist of a lever arm type limit switch mounted on the discharge check valve at the pump, and necessary relays, timers, pilot lights and control switches in the control panel. When a pump is called upon to run, a time delay shall be energized to allow enough time for the pump to establish flow. If, after this set time elapses, the check valve limit switch has not detected flow, then the respective failure-to-pump light on the control panel shall be illuminated. A failure-to-pump condition shall not lock out the pump. The failure-to-pump light shall remain illuminated until the system is reset manually.
5. Interposing relays, as required, between PLC outputs and other system components.
6. The following components shall be mounted in the door or doors of the control panel with components directly associated with a pump in the door of the section containing control components for that pump and components common to the system and to both the pumps in the door of the system control section or sections:
 - i. 1 – White “control on” pilot light
 - ii. Manual transfer switch to switch between the PLC and wet well level gage.
 - iii. Hand-off-auto switches, one for each pump motor. Provide extra set of contacts in switch to provide means for detection of pumps in “off” or “hand” position. Handle shall be illuminated when switch is in the auto position by long life LED lamp, or separate pilot lights may be provided to indicate this condition.
 - iv. 1 – Selector switch for pump alternating (sequencing) system.
 - v. Pilot lights, one for each pump, to indicate a failure-to-pump condition.
 - vi. Reset pushbuttons, one for each pump, for reset of the failure-to-pump condition.
 - vii. Pilot lights, one for each pump, to indicate a motor overload trip condition.

10.2.3 Motor Starters

Suitable Automatic Star Delta (ASD) Starter system shall be installed for starting of all electric motors. ASD Starter system shall be subjected to prior approval of its design from the ENGINEER.

Each starter shall be provided with an interlocking mechanism that disconnects all external sources of power from the terminal blocks within the starter.

The starter systems should at least contain the following:

1. One properly sized main circuit breaker
2. A step-down transformer for station voltage of over 400 Volts.
3. A circuit breaker and starter for the starting of each pump motor properly sized for motor running current and short circuit protection on all three phases of the motor.
4. An adjustable three phase voltage sensor to protect motors and motors starters from single phasing & under voltage.

10.3 Execution

10.3.1 Work Included

1. The motors should be provided complete with holding down bolts, base-plates, slide rails, standard shaft extensions and couplings or drive pulleys as necessary.
2. Special ventilation/cooling arrangements should also be made for the motors if required.
3. The CONTRACTOR shall furnish all supervision, labor, materials, equipment and incidentals required to provide, install, test and place into operation the controllers as required for energizing & de-energizing the pump motors. CONTRACTOR shall also provide and install all related equipment and accessories as shown and specified.

10.3.2 Mounting

Mount Motor Controllers/ Panels securely to floor or wall with stainless steel anchors specifically designed for such installation. Manufacturer shall provide the diameter of fasteners. Fasteners shall be provided complete with washers, nuts, and miscellaneous hardware.

10.3.3 Installation

Provide a complete motor control panel, including equipment and systems as specified herein, all in accordance with NEMA Standards.

Supply voltage shall be as indicated on plans.

Installation procedures shall be in accordance with the recommendations of the manufacturers of the control panel and its components.

10.3.4 Testing

The complete control panel shall be subjected to a factory test for proper operation.

10.3.5 Field Test

The equipment shall be tested in operation in the presence of the EMPLOYER and ENGINEER to demonstrate compliance with specification requirements.

10.3.6 Startup Assistance

The CONTRACTOR shall furnish the services of a fully trained competent representative to assist in startup, programming, calibration and adjustment of the equipment. Such services shall be for a period of not less than eight (8) hours, on-site.

10.3.7 Maintenance and Operating Instructions

The control panel shall be connected, inspected and tested under the supervision of a representative of the manufacturer. The representative shall also instruct EMPLOYER personnel regarding proper operation and maintenance of the equipment. In addition, the manufacturer shall furnish three (3) copies of a bound manual covering complete operating instructions and maintenance requirements for all components of the control panel. The manual shall include a numbered parts list and complete wiring, interconnection and schematic diagrams.

11.0 INSTRUMENTATION

11.1 Instrumentation for Reservoirs

11.1.1 Reservoir Information

There are total 6-No. reservoirs at different locations in Jacobabad, as shown in GIS Satellite image below, with incoming water supply from a 16-inch diameter HDPE pipe. As the construction of the overhead reservoirs is currently in progress, contractor must confirm the actual locations of the overhead reservoirs at the time of execution.

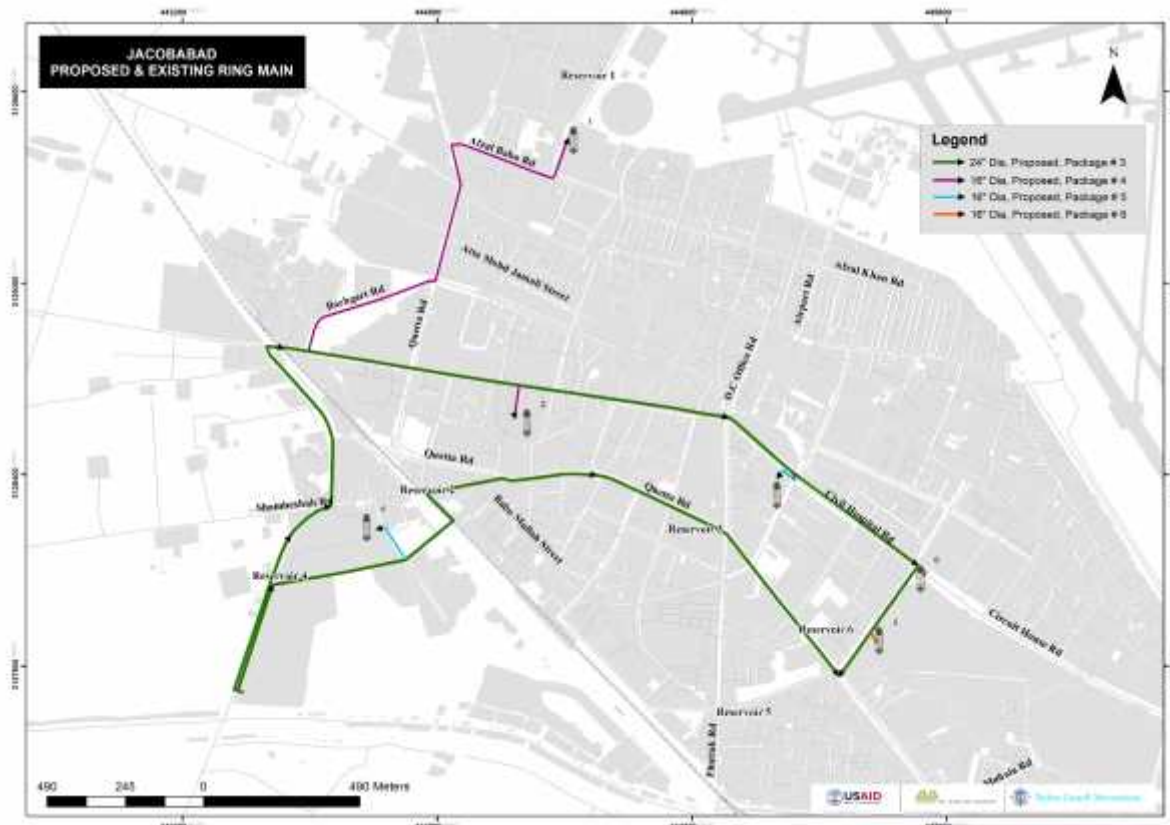


Figure 11-1: Location Map of six overhead reservoirs.

According to design all Tanks elevation and volume are given in Table 11-1. However, at the time of execution the contractor should consult the Engineer for verification any data given in this chapter of specifications.

11.1.2 General

Each reservoir's instrumentation shall be an individual Closed Loop Control System working independently on its own.

Instrumentation for each reservoir shall include 2-No. Ultrasonic level sensors working in parallel installed at the top of the Reservoir and connected with a Level Controller/Transmitter. One additional Ultrasonic level sensor is used as a fail-safe measure to make the Control system redundant to any failure, so may if one level sensor stop working the other can take over.

Table 11-1: Elevation and capacities of overhead reservoirs.

Tanks	Max elevation (m)	Min elevation (m)	Top elevation (m)	Bottom elevation (m)	Height (m)	Area (sq.m)	Volume		Imp. M. Gal
							cu.m	Imp. Gal	
Tank 1	29.05	24.6	28.55	24.9	3.65	347.42	1366.633	300607.3	0.300607
Tank 2	23.075	19	22.575	19.3	3.275	210.25	688.5688	151459	0.151459
Tank 3	28.8	24.6	28.3	24.9	3.4	497.56	1691.704	372110.6	0.372111
Tank 4	23.3	19	22.8	19.3	3.5	163.84	573.44	126135	0.126135
Tank 5	23.075	19	22.575	19.3	3.275	226.5	741.7875	163165.1	0.163165
Tank 6	28.975	24.6	28.475	24.9	3.575	318.62	1139.067	250551.3	0.250551

The Level Controller should be programmable and possess at least 4-No. relayed Outputs. The output of Level Controller shall be used to actuate the Electric based Control Valve based upon the Water level status transmitted by Ultrasonic level sensors.

A mechanical turbine water flow-meter (flange type) shall be connected to the incoming water supply HDPE 16-inch diameter pipe which will indicate flow rate of incoming water.

The above system shall be repeated for rest of the reservoirs.

11.1.3 List of instruments (for each overhead reservoir)

- | | |
|--|-------|
| a) Ultrasonic level sensor | 2-No. |
| b) Mechanical Turbine Water Flow meter | 1-No. |
| c) Electric based control valve | 1-No. |
| d) Level Controller/Transmitter | 1-No. |
| e) UPS Backup | 1-No. |

11.1.4 Instrument details

11.1.4.1 Ultrasonic level sensor

Ultrasonic level sensors will be used to monitor real time reservoir water level status and provide alarms for low and high reservoir level to level controller.

11.1.4.2 Mechanical Turbine Water Flow meter

Mechanical Turbine Flow meters are used to measure the incoming flow and total volume of water coming into each reservoir via 16-inch HDPE pipe. Specifications of flow meter are given in Table 10-2 below.

11.1.4.2.1 General

Flow meters for overhead reservoir instrumentation shall be turbine type, with double flanged for cold water up to 50°C with nominal pressure of 16 bars.

11.1.4.2.2 Standards

The Mechanical Turbine Flow meters supplied must be in accordance to ISO Standard 4064/1 and meet the following requirements:

- The prescription of the regulation No 49 of the OIML.
- The hermetically sealed register shall be (IP68)
- The Rotor shall be hydro dynamically balanced.
- Register may be rotated through 360°.
- It shall be capable of high over load.
- All flow meters have removable measuring elements capability.
- All flow meters shall not be effected by external magnetic field.
- All flow meters shall have powder epoxy coating for maximum corrosion protection.
- All flow meters shall have AMR capability.

They shall be approved as Class B, the supplier shall produce with its bid a copy of the said approval.

11.1.4.2.3 Performance

The maximum flow rate (Q_{max}) is the highest flow rate at which the meter can function over limited periods without damage, and without exceeding the maximum permissible errors (+/- 2%) and the maximum permissible value for loss of pressure 0.9 bars for an Q_n 1.5 and Q_n 2.5 and 1 bar for Q_n 3.5, Q_n 6 and Q_n 10.

The nominal flow rate (Q_n) equal to half the maximum flow rate, Q_{max} . It is expressed in cubic meters per hour and is used to designate the meter.

At the nominal flow rate, Q_n the meter should be able to function in nominal use, i.e. in continuous and intermittent operating conditions, without exceeding the maximum permissible errors (+/-2%).

The minimal flow rate (Q_{min}) is the flow rate above which the meter must not exceed the maximum permissible errors (+/-5%) and is fixed as a function of Q_n .

The transitional flow rate (Q_t) is the flow rate which divided the upper and lower regions of the flow range and the rate of the maximum permissible errors +/-2%.

The flow rate values are the following :

Table 11-2: Flow rate values.

Nominal Dia Meters	mm	50	80	100	150	200	250	300	400
Nominal Flow rate Q_n ($\pm 2\%$)	m ³ /h	15	40	60	150	250	400	600	1000
Maximal Flow rate Q_{max} ($\pm 2\%$)	m ³ /h	90	200	300	600	1200	1600	2000	3000
Manimal Flow rate Q_{max} ($\pm 5\%$)	m ³ /h	0.30	0.50	0.80	1.8	4.00	6.00	12.00	25

Transitional Flow rate Qt	m ³ /h	0.7	0.8	1.8	4.00	6.00	11.00	15.00	50
Head loss	Bar	1	1	1	1	1	1	1	1

11.1.4.2.4 Sizes

The length of water meters shall be as follows:

Table 11-3: Recommended length of mechanical turbine flow meters.

Nominal Dia Meters	mm	50	80	100	150	200	250	300	400
Length without connector	mm	200	225	250	300	350	450	600	1000

11.1.4.2.5 Tightness and Pressure Resistance

The water meter shall permanently sustain without leakage, mis-function of permanent deformation, a working pressure of 16 bars and test pressure of 24 bars.

11.1.4.2.6 Head Loss

The head loss through the meter shall not exceed 1 bar at Qmax.

11.1.4.2.7 Materials

- The water meter shall be made with material appropriate to each specific use.
- The body and head shall be made of high quality Cast Iron / Ductile Iron.
- The rotor shall be made of high quality plastic.
- The measuring element shall be of high grade polymer/ plastic.
- The separation between the dry and wet side shall be with water tight seal.

11.1.4.2.8 Totalizer

It shall include:

- a drum register with:
 - 6 drums register denoting m³
 - 3 drums denoting fractions of m³

Table 11-4: Totalizer Drum Register.

Diameter Nominal (DN)	Smallest Reading (m ³)	Maximum Reading (m ³)
50-----10	0.0005	1,000,000
150-----300	0.0005	10,000,000
400	0.05	100,000,000

- A magnifying glass shall be over the drum for easy reading of the index.
- An anti-fraud device shall protect from tampering.
- The totalizer shall be hermetically sealed in a water tight box with an hydroscopic capsule against moisture.

11.1.4.2.9 Protection

A Strainer shall protect the measuring mechanism.

11.1.4.2.10 Marking

On the body an arrow on both sides shall show the direction of flow.

On the dial the following marking shall be made:

- Type of meter
- Nominal flow rate
- Metrological class
- Symbol of manufacturer
- Pattern approval number
- Manufacturing year and meter number

11.1.4.2.11 Totalizer

Meters shall have a protection device in order to prevent any tempering.

11.1.4.2.12 Packing

Packing shall be made strong wooden crates, for see the transport , and inside such crate, each meter shall be packed in its carton box.

11.1.4.3 Electric based control valve

Electric based control valve will OPEN/CLOSE based on the output generated by Level Controller when reservoir is EMPTY/FULL. Specifications of electric based control valve are given below.

Table 11-5: Specifications of Control Valve.

Size	16-inch (400 mm)
Class #	150
Operation	220VAC Operated ON/OFF
Working Principle	Motor operated
Manual Override	YES
Ambient Temperature	-30°C to +70°C
Power Supply Tolerance	Nominal voltage: $\pm 10\%$ Frequency (for AC supply): $\pm 2\%$

This control valve can also be operated manually as a manual override using a mechanical lever in case of emergency or unforeseen circumstances, so both electrical and mechanical methods are available for operation. An example of control valve operation:

Table 11-6: Operation of Electric control valve.

Reservoir Level	Electric based Control Valve
>90%	CLOSE
<50%	OPEN

11.1.4.4 Level Controller/Transmitter

Level controller will take decision based on the signal of Ultrasonic Level sensors and generate OUTPUT to control electric based control valve. Specifications of level controller are given below.

Table 11-7: Technical specifications of Ultrasonic Level Controller.

ULTRASONIC LEVEL CONTROLLER	
Measuring Principle	Ultrasonic
Power Supply	90-253VAC
Level Input	2x Ultrasonic sensor (with automatic sensor recognition)
Switch Output	6x relay, SPDT
Output	2x 0/4-20mA HART
Accuracy	+/- 2mm + 0.17% of measured distance
Ambient Temperature	-40°C to +60°C
Degree of Protection	IP66 / NEMA 4x
Alarm	2-Channel
Display	Illuminated display with keypad for on-site configuration
Manufacturer Origin	EUROPE / USA / Equivalent

Table 11-8: Technical specifications of Ultrasonic Level Sensor.

ULTRASONIC LEVEL SENSOR	
Measuring Principle	Ultrasonic
Characteristic	Separated version with field housing or top hat rail housing up to 300m from the transmitter
Communication	4-wire (HART)
Output	4-20 mA HART
Accuracy	+/- 2mm + 0.17% of measured distance
Ambient temperature	-40°C to +80°C
Process pressure	0.7 bar to 4 bar abs (10 psi to 58 psi)
Degree of Protection	IP68 / NEMA6P (Weather Resistant / Flood proof)
Process Connection	Thread ANSI NPT1, PVDF
Cable Length	Up to 25 m (82 ft.)
Blocking Distance	0.3 m (1 ft.)
Max. measurement distance	10 m (33 ft.)
Manufacturer Origin	EUROPE / USA / Equivalent

11.1.4.5 Uninterruptable Power Supply (UPS)

Each reservoir site will be backed up by an Uninterruptable Power Supply system in case of Power failure so that Flow meter data and other control actions shall remain in action. The

power backup should at least be of minimum 4 hours. Specifications of UPS are given below.

Table 11-9: Technical specifications of UPS.

Rating	01 KVA
Output Power Factor	> 0.9
Topology	True Online Double Conversion Pure Sine wave
Backup time	4 to 5 Hours (at 600 watts load)
Battery	12V x 100AH x 03 PCs (NP Gel Batteries)
Manufacturer Origin	EUROPE / USA / Equivalent

11.1.5 Working

Automation of each reservoir (Total 6-No.) shall be based on Ultrasonic level sensors and level controller. There will be two ultrasonic level sensors installed in each Reservoir, one additional sensor is installed as a fail-safe measure and to make the system more redundant. These ultrasonic level sensors will be connected to a Level Controller. The level controller should possess at-least 4 relayed outputs to control the electric based control valve and generate alarm in case electric based control valve does not work.

As a general rule, actuators (control valve) shall be furnished with a manual override to open or close the valve in the event of loss of electric power. For safety reasons, manual declutch mechanism must be included. Engaging the de-clutch mechanism changes the operation from motor to manual (hand-wheel) operation. The de-clutch mechanism may be provided with a locking device to prevent unauthorized manual operation. Energizing the motor shall return the actuator to motor operation. In most applications, the hand-wheel should not turn while in motorized operation as a safety precaution. It should be noted that some compact electric actuator designs do not offer a declutch mechanism and may have hand-wheels which turn while in electric operation. The manufacturer is responsible to ensure that operation of either type can be accomplished safely, and the user should exercise extreme caution when operating an electric actuator which permits the hand-wheel to turn while operating electrically.

This instrumentation at reservoir shall be backed up by an Un-interruptible Power Supply (UPS) in case of power failure at each site (Total 6-No.). The backup time should be at-least 4 hours or more.

11.1.6 Total quantity of instruments for 6-no. reservoirs

Table 11-10: Total no. of instruments required for reservoir automation.

No.	Description	No. of Instruments for each Reservoir	Total No. of Instruments required
a)	Ultrasonic level sensor	2	12
b)	Electromagnetic Flow meter	1	6
c)	Electric based Control Valve	1	6
d)	Level Controller/Transmitter	1	6
e)	Uninterruptable Power Supply (UPS)	1	6

11.2 Instrumentation for Pumping sets

11.2.1 General

A Digitized electronic pressure transmitter on the 36-inch MS pipe discharge header / manifold will be required for measurement of pressure. An Ultrasonic level sensor shall be installed at the intake of pump station to indicate the water level in the intake tank and aid the operator to avoid dry running of pumps.

The pressure of each pump shall be monitored using Glycerin filled pressure gauges (12-No.) for monitoring of water pressure of each pump.

11.2.2 List of instruments

- | | |
|-----------------------------------|--------|
| a) Pressure gauge | 12-No. |
| b) Digitized pressure transmitter | 1-No. |
| c) Ultrasonic level sensor | 1-No. |
| d) Electromagnetic flow meter | 2-No. |

11.2.3 Instrument details

11.2.3.1 Pressure Gauge

A pressure gauge shall be installed with each pump (Total 9-No.) supplying water to main 36-inch manifold / header for main transmission. Specifications of pressure gauge are shown below.

Table 11-11: Technical specification of Pressure gauge.

Pressure Gauge Type	Liquid filled (Glycerin)
Range	20 barg
Dial Size	6"
Process connection	½" or ¾"

11.2.3.2 Digitized Pressure Transmitter

An electronic pressure transmitter shall be installed at the 36-inch MS pipe discharge header / manifold for continuous pressure measurement. Specifications of this pressure transmitter are given below.

Table 11-12: Technical specifications of Digitized electronic pressure transmitter.

Sensor Range	40 bar/ 4 MPa/ 600 psi gauge / 400 m H ₂ O / 1334 ft H ₂ O / 16000 in H ₂ O
Overload	160 bar / 16 MPa / 2400 psi
Output	4-20mA HART
Display	LCD
Operation	Push button on display/electronics
Housing	F31 Alu, glass window
Electrical connection	Gland M20
Degree of Protection	IP66/68, NEMA4X/6P

Process connection	Thread ANSI MNPT1, 316L, flush mount
Membrane Material	316L
Fill Fluid	Silicone oil
Ambient Temperature	-40°C to 85°C
Accuracy	±0.15%
Manufacturer Origin	EUROPE / USA / Equivalent

11.2.3.3 Ultrasonic Level sensor with Level Controller

An ultrasonic level sensor will be installed in the clear water tank which is of height 5.5 meter below ground level. This level sensor will be connected with an indicator to show Water level height in the clear water tank. Specifications of this Ultrasonic level sensor are given in Table 10-8.

11.2.3.4 Electromagnetic Flow Meter

An electromagnetic flow meter will be installed on the 24-inch MS pipe transmission loop. 24-inch MS pipe transmission loop will commence from the main 36-inch MS pipe discharge header dividing it into 2-No. 24-inch MS pipe. This flow meter will measure flow of the transmission loop. In ideal circumstances following equation should be fulfilled for flow:

$$F_L + F_R = F_1 + F_2 + F_3 + F_4 + F_5 + F_6$$

Water Flow in transmission loop = Water Flow in all 6-No. reservoirs

Where;

F_L is the water flow from transmission loop no. 1

F_R is the water flow from transmission loop no. 2

F_1 is the water flow going to Reservoir 1

F_2 is the water flow going to Reservoir 2

F_3 is the water flow going to Reservoir 3

F_4 is the water flow going to Reservoir 4

F_5 is the water flow going to Reservoir 5

F_6 is the water flow going to Reservoir 6

Transmission loop GIS Satellite image is also shown in Figure 11-1.

Specifications of this Flow meter are given in Table 11-13.

Table 11-13: Technical specifications of Flow meter for Loop network.

Measuring Principle	Electromagnetic
Nominal diameter	DN600 (24-inch)
Liner	Hard rubber
Power Supply	100-240VAC/24VAC/DC
Output	4-20mA HART, Pulse/frequency/switch output
Digital communication	HART/PROFIBUS/Ethernet/IP
Electrical Connection	Gland M20
Process Connection	Cl.150, carbon steel, Flange ASME B16.5
Electrodes	1.4435/316L

Degree of protection	Sensor: IP66/67, Type 4X enclosure Transmitter: IP66/67, Type 4X enclosure
Temperature range	0 to +80°C (+32 to +176°F)
Calibration Flow	0.5%
Measured variables	Volume flow, conductivity, mass flow
Max. measured error	Volume flow: $\pm 0.5\%$ OR ± 1 mm/s (0.04 in/s)
Measuring range	9 dm ³ /min to 110 000 m ³ /h (2.5 gal/min to 700 Mgal/d)
Max. process pressure	PN 40, Class 300, 20K
Data logger	Integrated
Display/Operation	Backlit display with touch control (operation from outside) Configuration via local display & web browser
Sensor features	Secure, reliable long-term operation, robust and completely welded sensor. Energy-saving flow measurement, no pressure loss due to cross-section constriction. Maintenance-free, no moving parts. International drinking water approvals.
Transmitter features	Safe Operation: Touch control, background lighting Housing: Compact, Polycarbonate
Manufacturer Origin	EUROPE / USA / Equivalent

11.2.4 Working

The ultrasonic level sensor installed at the clean water tank help the operator to decide whether water pumping is possible or not to avoid dry running of pumps. If the water level inside the clean water tank is above 2 feet (as per design report) then operator can turn on the pumping machinery.

The pressure of 12-No. pumps shall be monitored using pressure gauges installed with each pump.

Electromagnetic flow meters shall be installed at the 24-inch MS pipe transmission loop to measure outgoing water flow in the loop system.

11.3 Flow Meter

11.3.1 Existing Condition

The flow meter installed at 24-inch diameter supply rising main to city is out of order.

Table 11-14: Existing condition of Flow meter.

Make	+GF +Signet
Model	Part No. 3-2-2540-4, Sr. No. 35339
Operational Status	NO

11.3.2 Requirement

It is required to install flow meters on main pipe lines from manifold to measure the total flow entering in the transmission loop. Further, the flow meters will be installed on feeder lines for

each overhead reservoir. Hence, 8 flow meters will be provided which will facilitate the monitoring of water consumption in various zones. Any unauthorized waster connection from transmission loop or any major leakage in the loop system can also be identified by comparing the inflows in the loop and total outflows from the loops.

Pump station water shall be metered for several reasons:

- To calculate distribution system losses by subtracting the total of meter readings from total supply.
- To monitor pump efficiency.
- To determine gross billings for water supplied.

11.3.3 Recommendation

As discussed above, replacement of flow meter as per BS/AWWA standards is proposed. Water flow meter (Electromagnetic) must be provided for clean water flow monitoring. IP67/68 Protection will be provided to the flow meters.

The following flow meters are proposed:

- a) One flow meter each on the two 24-inch diameter MS pipe rising main supplying clean water to the city from the Water Filtration Plant (WFP). **[Total: 2-No.]**
- b) One flow meter each at the 16-inch diameter HDPE distribution line of all six overhead reservoirs. **[Total: 6-No.]**

Maximum and minimum flow data of 6-No. reservoirs and Transmission loop as per design is given below. However, the contractor will verify this data from the Engineer at the time of execution.

Table 11-15: Minimum and Maximum Flow data of all pipes.

PIPE	Diameter	Flow (IGPM)		
	<i>Inch</i>	<i>Max</i>	<i>Min</i>	<i>Design</i>
P ₁	16	5752	1100	2583
P ₂	16	5891	1100	1139
P ₃	16	4984	1100	1833
P ₄	16	4782	1100	993
P ₅	16	5057	1100	1395
P ₆	16	5523	1100	2125
P _L (Transmission Loop Pipe 1)	24	8439	1100	5555
P _R (Transmission Loop Pipe 2)	24	8027	1100	4513

Locations of flow meters are shown in GIS Satellite image below.

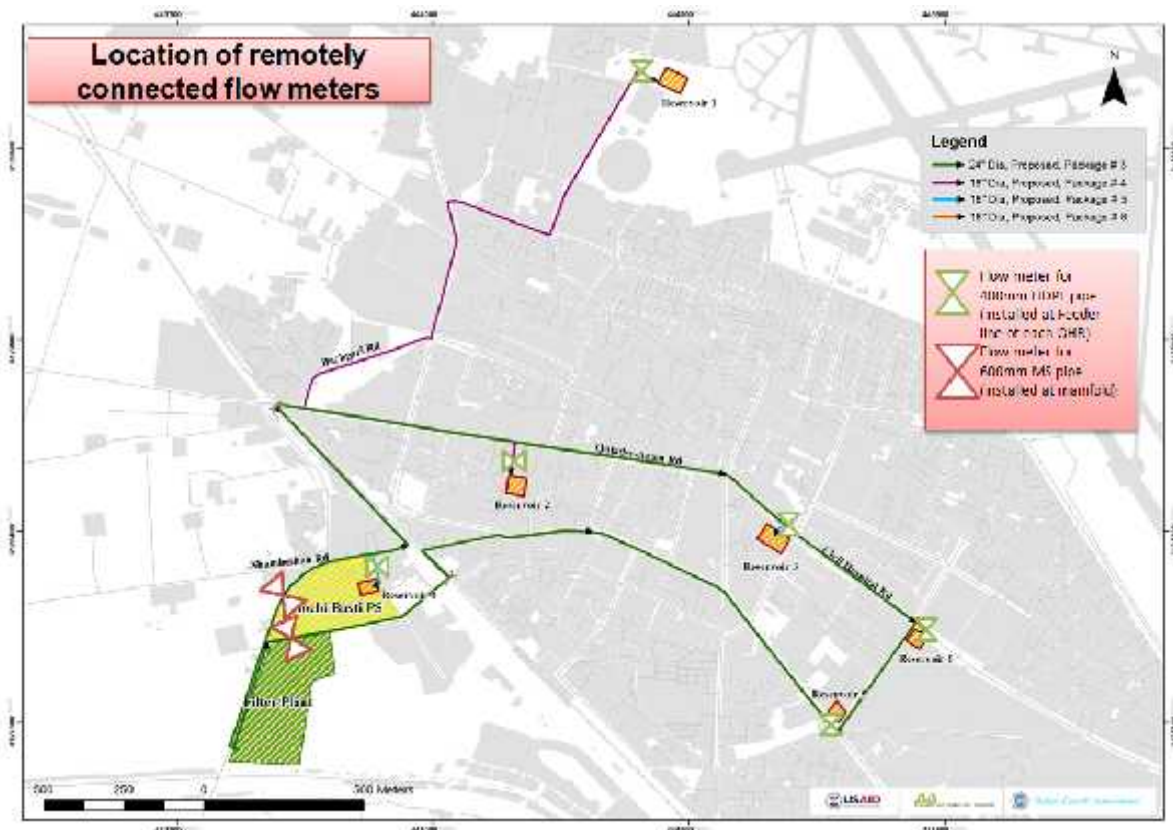


Figure 11-2: Location of Flow meters.

11.4 Flow Control

The CONTRACTOR shall submit flow control and bypassing arrangement plans to the ENGINEER for review and approval at least 14 days prior to commencing work on each portion of the system. Flow control includes, but is not limited to, plugging, bypass pumping or hauling as appropriate for the work to be performed. The plans must be specific and complete, and shall include, but not be limited to, the following details:

1. Capacities of equipment.
2. Number and types of pump
3. Protection against pipe breaks.
4. Size, length, material, and method of installation for suction and discharge piping.
5. Method of noise control for each pump and/or generator.
6. List of emergency CONTRACTOR contact phone numbers.

12.0 BACK-UP POWER SYSTEM (DIESEL FUELED)

12.1 General

12.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for component materials and functionality of the equipment that provides back-up electrical power to operate the pumping station when service from the power grid fails.

12.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter.

In addition to full descriptive data, dimensional drawings, and wiring diagrams, the following information must be furnished for evaluation of all equipment proposed:

1. Name and location of engine-generator supplier's parts and service facilities.
2. Manufacturer's Published Warranty.
3. Manufacturer and Model of Engine.
 - i. Bore, stroke, and number of pistons.
 - ii. Engine displacement.
 - iii. Piston speed.
 - iv. Engine rating at 1800 RPM.
 - v. BMEP.
 - vi. Exhaust emissions data.
4. Manufacturer of generator, make and type of generator, and generator electrical rating.
5. Manufacturer and type of voltage regulator.
6. Manufacturer and model of batteries and battery charger.
7. Manufacturer and type of governor.
8. Manufacturer and model of weather protective enclosure.

12.1.2.1 Operations and Maintenance Manual:

Provide complete manual including all submittal data; testing reports, etc. Manual shall include names, addresses, location, phone number, e-mail address, fax phone number, of supplier, installer and factory. Additionally, provide a complete schedule of maintenance. Provide six copies of each manual in a 3-ring binder with a printed cover.

The manual shall also include a list of O&M procedures and their detailed description for the generator for up to 5 years of operation; in addition to Maintenance and Management System (MMS) routines for weekly, monthly and quarterly frequencies.

12.1.3 Electrical General Provisions

It is the intent of these specifications to secure an engine driven, diesel fuel fueled, generator set of the latest commercial type and design as specified herein, complete with digital electronic controls. All material and equipment shall be new and undamaged. All equipment supplied shall meet the requirements of NFPA-110 standards. Generator set shall be UL 2200 listed or equivalent.

12.1.4 Work Included

Provide a standby power rated emergency generator set with accessories and attachments in strict accordance with these specifications. Services shall include installation supervision, initial start-up and checkout, and acceptance testing as detailed herein.

12.1.5 System Description

Provide a new, packaged generator set within a weatherproof sound attenuating enclosure for supply of electrical power in event of failure of normal electrical power supply, consisting of liquid-cooled, diesel fuel fueled engine directly coupled to AC generator, complete with frame mounted fuel tank, control panel, auxiliaries, meters, and safety devices necessary for a complete operating system.

The unit shall be capable of delivering the KW required at installed location after consideration of applicable de-rating factors.

12.1.6 Experience

The engine-generator set shall be the product of a firm regularly engaged in the manufacture of engines and generator sets and shall meet the requirements set forth herein. The equipment must be a standard model in regular production at the manufacturer's place of business. The generator set supplier shall also be the manufacturer of either the engine, the generator, or both major components. All components shall be covered under the warrantee of the supplier.

The engine-generator supplier shall be factory-authorized sales and service dealership for the equipment to be supplied. The supplier shall maintain a parts and service facility within 50 miles of the project site, with an inventory of maintenance and repair parts for the equipment to be provided, as well as a staff of trained service technicians. The supplier shall furnish all installation and testing supervision necessary for final approval and acceptance of the equipment by the ENGINEER.

12.1.7 Codes and Standards

The latest effective publications (listed below or equivalent) of following standards, codes, etc., as they apply, form part of these specifications as if written fully herein and constitute minimum requirements. Minimum requirements shall not relieve the CONTRACTOR of the responsibility for furnishing and installing higher-grade materials and workmanship than therein specified. These will be referred to throughout the abbreviated forms.

1. EPA SI NSPS – Environmental Protection Agency Spark-Ignition New Source Performance Standards.

12.2 Products

12.2.1 Emergency Generator Unit

All materials, equipment and parts comprising the units specified herein shall be new and unused, of current manufacturer and of highest grade, free from all defects or imperfections affecting performance. Workmanship shall be of the highest grade in accordance with modern practice.

The units shall meet the specifications listed in Table 11-1 below. Any variation in the specifications of the procured units should be approved from the ENGINEER prior to placing the order.

Table 12-1: Specifications of the backup generating sets.

General Specifications	
Power Rating	i) 100 KVA (1 set) at Low Lift Pumping Station ii) 800 KVA (1 set) at High Lift Pumping Station
Frequency	50 Hz
Rated Speed	1500 RPM
Power factor	0.8 lagging
Approved Manufacturers	<ul style="list-style-type: none"> • <u>Engine</u>: Caterpillar, Cummins, Perkins, FG Wilson, Volvo, or equivalent • <u>Alternator</u>: Caterpillar, Stamford, Siemens, or equivalent

12.2.1.1 Design and Construction

The design and construction of the emergency generator unit shall be neat and clean in appearance. Normal adjustments and maintenance must be accessible without the use of special tools. The engine, generator and all major items of auxiliary equipment shall be products of manufacturers regularly engaged in the production of such equipment, and shall be assembled, tested and shipped to the job site by the engine/generator manufacturer or his authorized distributor.

12.2.1.2 Power Rating

The unit shall have a minimum power rating as indicated in the BOQ at a 0.8 power factor and a frequency of 50 Hz. It shall operate at rated RPM. Rating shall be substantiated by the manufacturer's standard published curves and related data. Special ratings for a particular application will not be accepted. Rating shall reflect the net power available after deducting all engine-driven accessories. Maximum voltage dip shall be up to 30%.

12.2.1.3 Output voltage

The generator output voltage shall be as indicated in the BOQ. The regulator shall be of the three-phase sensing type. Voltage regulation shall be plus or minus 1.0 percent from no load to full load. An adjusting rheostat shall provide a plus or minus 5 percent voltage adjustment. Steady state frequency regulation shall be plus or minus 0.25 percent. The generator unit control system shall provide for instantaneous field over current trip to protect the voltage regulator in the event of output short circuit or improper connections.

12.2.1.4 Generator Size

The generator shall be sized to provide the specified output under job site conditions and shall be built to NEMA, IEEE and ANSI standards. It shall be a three- phase, 4-wire, 50 Hz, 0.8 power factor, single bearing, rotating field synchronous type. Readily accessible voltage level and voltage drop controls shall be provided.

12.2.1.5 Generator Engine

The engine shall be a full compression ignition diesel, four stroke cycle, single acting, solid injection, water cooled, in-line or "V" type. The engine shall be turbo-charged and after-cooled in accordance with the manufacturer's standards as required to perform the specified duty. The engine shall be equipped with an electronic governor for 1% regulation. The engine shall be capable of full load duty when operating on a commercial grade of fuel.

Engines requiring a premium grade of fuel will not be acceptable. The engine shall be equipped with reliable fuel, lube oil, and air intake filters, lube oil cooler, fuel transfer pump, fuel priming pump, and any other attachments required for continued, dependable, and low maintenance cost operation. Filter arrangements designed for light duty standby service will not be accepted.

Furnish an engine mounted radiator of sufficient capacity to maintain a safe engine operating temperature at the specified standby power load when the ambient temperature is 105 degrees F as specified and installed in the generator radiator as specified herein and on the drawings. The radiator shall be equipped with a blower-type fan with fan guard. The fan belts shall have a tension adjustment. The engine shall be equipped with an engine mounted jacket water pump and thermostat to properly control engine temperature. A suitable rust inhibitor shall be included in the coolant solution.

12.2.1.6 Changeover Switch

A manual changeover switch, to operate the pumping station using the backup generator when the electric supply by the Power Company is absent, is also to be provided.

12.2.1.7 Base

The emergency generator unit shall be mounted on a structural steel base, suitable for mounting to a sub-base fuel tank. The unit shall be equipped with linear type vibration isolators or a quantity and type recommended by the manufacturer.

12.2.1.8 Exhaust silencer

Provide a critical grade exhaust silencer, properly sized by the manufacturer for the specific engine installed. A stainless steel flexible exhaust fitting shall be provided between the engine and exhaust silencer. The exhaust system shall be sized to ensure against loss of power due to excessive back pressure. The exhaust silencer shall be installed within the enclosure. Silencer shall be constructed of stainless steel. Silencer discharge shall be directed vertically upward. Silencer shall be provided with a rain cap. Rain cap shall be provided with a rubber grommet to prevent the rain cap from directly contacting the silencer.

12.2.1.9 Batteries and charger

Furnish and install a 12 or 24 volt DC electric starting system. The starting system shall include two lead-acid batteries complete with cables. The ampere-hour capacity of the system shall be a minimum of 135 ampere-hour. Batteries shall be mounted inside the enclosure, adjacent to the engine.

Furnish and install a two-rate 12 or 24 volt DC battery charger suitable for use with lead-acid batteries. The charger shall be furnished with an automatic equalizing charge timer for fast recharge, and a low DC voltage alarm contact. It shall be suitable for operation on single phase, 220 volts, 50 Hz, AC. Battery charger output shall be 10 amperes. Mount charger on the generator set with a corrosion resistant enclosure.

12.2.1.10 Control Panel

A digital engine starting and control system shall be furnished by the engine manufacturer and included in a NEMA-1 generator control panel that shall be factory installed, with vibration isolators, on the generator set. The control panel shall meet UL508A. The starting controls shall be manually actuated. The engine starting controls shall be solid state and shall include, as a minimum, the following functions and equipment:

1. Instruments, including ammeter, voltmeter, frequency meter, tachometer, and hour meter.
2. Start-stop control module with adjustable cycle cranking and engine cool-down timer.
3. Ammeter - Voltmeter phase selector switch.
4. Engine control switches for auto, start/run, off/reset, and stop.
5. Oil pressure and water temperature gauges.
6. Safety shutoffs with individual alarm lights for low oil pressure, high water temperature, over-speed, and over-crank.
7. Emergency stop push-button.
8. Voltage adjust rheostat.
9. System diagnostic codes, digital readout.
10. DC panel illumination lights with switch.
11. Signal to alarm transmitter for generator failure (Common fail - all generator failure leads shall be connected together.)
12. Signal to alarm transmitter for fault (Common fault - all fault leads shall be connected together.) Dry contacts shall be rated to handle the voltage and current derived from the alarm transmitter.
13. Signal to alarm transmitter for generator running status. Dry contacts shall be rated to handle the voltage and current derived from the alarm transmitter.
14. Signal to alarm transmitter for fuel level.

In addition to the functions and equipment listed above, the generator control panel shall incorporate an automatic pre-alarm module in accordance with NFPA-110 with individual alarm lights and common alarm horn for:

1. Approach low oil pressure.
2. Approach high water temperature.
3. Low water temperature.
4. Low battery voltage (from battery charger contact).
5. System not-in-automatic.
6. Low fuel level.

All generator functions shall be fully programmable from the generator control panel. Generators requiring external devices or software for programming functions will not be accepted.

12.2.1.11 Molded Case Circuit Breaker

A molded case circuit breaker, rated as indicated on the drawings, shall be provided and mounted at the generator to provide overload protection and disconnect means. The breaker shall be installed in a NEMA-1 enclosure within the generator set enclosure and shall be equipped with copper output bus bars to accommodate the quantity and size of conductors per phase as shown on the drawings, plus the neutral and ground conductors as indicated. Neutral leads shall be brought out and terminated to an isolated bus bar mounted within the circuit breaker enclosure.

12.2.1.12 Enclosure

The generator set shall be enclosed in a factory installed UL2200 listed 14 gauge steel weather protective enclosure with polyester powder finish. Finish shall be factory painted. The enclosure shall have an internally mounted silencer and a minimum of four lockable, gasketed personnel doors for maintenance access, along with fixed air intake and radiator discharge louvers. The enclosure shall have the best (quietest) sound attenuating package offered by the manufacturer to achieve a maximum sound level under full load of 78 dBA at 25 feet from unit.

12.2.1.13 Fuel Tank

The generator set shall be installed on top of a UL 142 listed double wall base mounted fuel tank. The tank shall be constructed of primed/painted structural steel and be provided with all required accessories such as: venting, manual fill provisions, fuel level gauge, low level and tank rupture alarm contacts. Tank color shall match the generator enclosure. Tank shall be sized to provide a minimum of 24 hours of continuous operation at full rated load. A primary fuel filter/strainer shall be provided and mounted between the tank supply fitting and the engine fuel inlet. Flexible fuel lines shall be provided between all components. The tank base shall be equipped with four-point lifting provisions designed to allow safe unloading and setting of the complete generator set and tank/enclosure assembly.

Provide a fuel tank monitoring system to monitor actual fuel level within the tank. The system shall provide a 4-20 mA output.

12.2.1.14 Spare parts

One year's supply of spare parts/ maintenance kit will be provided by the contractor for operation and maintenance of each generator set. The contractor will also submit list of recommended spares and list of consumables for next 5 years along with price list.

12.3 Execution

12.3.1 Coordination

Coordinate with all trades and vendors to provide an efficient and well coordinated system.

12.3.2 Installation

Install generator set as indicated on the drawings and in accordance with the manufacturer's instructions and recommendations. Installation shall be in accordance with all applicable local, state, and federal codes and regulations.

Generator set shall be mounted on a concrete pad that is independent of all other concrete slabs or structures.

12.3.3 Wiring and Connections

Provide conduit, wiring, and connections within the enclosure packages. Provide field wiring consisting of power and control wiring between the emergency generator unit and the manual transfer switch.

Provide field wiring from the emergency generator unit to the alarm transmitter for the following alarm points.

1. Generator Running
2. Common Generator Failure
3. Common Generator Fault
4. Fuel Level

12.3.4 Testing

The emergency generator unit shall receive the manufacturer's standard testing at the factory. The factory testing shall be at 0.8 power factor. Certified copies of the factory test shall be supplied to the ENGINEER. Prior to acceptance of the installation, the equipment

shall be field tested to show it will start manually, complete a full load test, shut down and reset as required by these specifications.

Prior to acceptance, any defect which becomes evident shall be corrected. The test shall be performed in accordance with the following minimum requirements and shall include any other tests that may be recommended by the manufacturer or ENGINEER for the purpose of evaluation. A portable resistive (1.0pf) load bank shall be utilized for the field test. The generator shall be started and operated at 50% of rated load for a period not less than ½ hour, after which the load shall be increased to 75% of rated load and operated for the second ½ hour. The load will be then increased to 100% and held continuously for a period of not less than two hours, then operated at no load for a period of 15 minutes prior to shutting down the generator set. A full written report indicating KW output, voltage, current, frequency, oil pressure, water temperature, and ambient temperature variations taken at 15 minute intervals during the test shall be provided to the ENGINEER for evaluation and disposition. All tests shall be performed in the presence of the ENGINEER'S authorized representatives and the manufacturer's representative who shall validate the report. Fuel for testing shall be furnished by the CONTRACTOR.

Upon completion of the field testing, operating instructions and maintenance procedures shall be thoroughly explained to the operating personnel. Four sets of operating and maintenance manuals shall be supplied for the emergency generator unit and related auxiliary equipment.

Upon final acceptance, CONTRACTOR shall fill the generator's fuel tank to capacity for final delivery to ENGINEER.

12.3.5 Screening

Provide visual screening for the generator set as indicated on the drawings. Screening shall consist of a shadow box style fence with minimum 6" wide slats, minimum 50% overlap and maximum 50% gap. Minimum fence height shall match the height of the emergency generator unit enclosure.

12.3.6 Power Factor Improvement (PFI) plant

The CONTRACTOR shall provide/ install PFI capable to maintain power factor at 0.95 to 1, in case of less power factor from power utility company. It should be approved by the ENGINEER before installation.

12.4 Rehabilitation of Generator set

One 300 KVA standby Diesel Generator Set (Cummins and Siemens) is present at site with two 12 V, 200 amp batteries missing. Further technical specifications of this generator are given below:

Table 12-2: Existing Generator set specifications.

Generator Specifications	
Model No.	DG 300
Serial No.	DG H-0022
Year of Manufacturing	2001
Engine S. No.	12005926
Rating	300 KVA
Work Order No.	1/44110
Alternator Model No.	1FC6-354-4

LPK No.	09060249
Alternator Specifications	
Phase	3 phase alternator
Rating	300 KVA
Design	IP 23
Voltage	415 volts
Current	417 amp
Frequency	50 cycles/sec
PF	0.8
RPM	1500
Ambient Temperature	40 degree C
Temperature Rise	100 degree C
Year of Manufacture	2001
Insulation Class	F

The generator set was put out of order during floods of 2010-12. The engine has been repaired by local authorities, but the alternator still seems to be out of order.

The contractor is required to inspect both the generator and alternator; and submit a report to the Engineer about its condition. The generator set can only be sent for repair once the scope of repair work is approved by the Engineer.

12.4.1 Procedure for repair of 300 KVA generator

The procedure for repair of the 300 KVA standby generator at HLPS is given below:

- ✓ *Dismantling and shifting to the repair workshop for complete checking, inspection and report to Engineer.*
- ✓ *Engineer gives approval for the proposed scope of repair works.*
- ✓ *After complete repair (overhauling engine, re-varnishing of alternator etc), the generator set will be tested on no-load position at the repair workshop for at least six hours. After testing it will be shifted to site, for re-installation and connection under supervision of repair company. It will be commissioned by the repair company Engineers first on no-load and again on full load initially for at least 03 Hours and then during load shedding hours, twice or thrice a day.*
- ✓ *The repair company will be responsible for at least 4000 operational hours or two years, whichever comes earlier, for any technical fault either in the Engine or in Alternator.*

12.4.2 Costs

All charges for rehabilitation of the generator set to make it operational, including but not limited the following, should be incorporated in contractor's rate and no additional payment will be made to the contractor in this case:

1. All service charges like dismantling, assembling, machining, injector calibration, self-starter service, turbo-kit fitting, water pump kit fitting, fuel pump calibration, dynamo service and transportation charges, etc.
2. Replacement and/ or repair of rotor winding and stator winding is also included in the cost of this item.

3. Cost of spare parts including valve intake, valve exhaust, valve insert, valve seals, kit liner, piston ring set, con rod bearing, engine gasket, thermo state, etc.
4. Cost of consumables required during repair and testing, including engine oil, water filter, coolant DCA 4, air filter, oil filter, fuel filter, etc.
5. One year's supply of spare parts/ maintenance kit be provided for operation and maintenance of generator.
6. List of O&M procedures for the generator for up to 5 years of operation.

13.0 GENERAL MECHANICAL SPECIFICATION

13.1 General

13.1.1 Summary

The following Clauses shall apply to all relevant materials and procedures throughout the Mechanical Specification, unless other instructions are given in specific clauses of other Chapters of this Specification.

The following clauses of this Chapter of the Specification set out the minimum standards for Plant and workmanship to be used by the CONTRACTOR for the mechanical services Works. All component parts of the Works shall, unless otherwise specified, comply with the provisions of this section.

Reference to any specific equipment or material does not necessarily imply that such material or equipment is to be included in the Works.

13.1.2 Submittals

Submit all relevant shop drawings and manufacturers data.

Shop Drawings including detailed layout drawings shall be submitted to the ENGINEER for approval; and shall include dimensioning, methods, and locations of supports, and all other pertinent technical specifications for all works to be furnished.

13.2 Products

13.2.1 Pipe Work and Ancillaries

13.2.1.1 General

All materials used shall be suitable for the use for which they are intended, including being tested.

Materials shall comply with all relevant Standards and Codes of Practice.

13.2.1.2 Non-return Valves

Non-return (or check) valves shall be bronze swing pattern with screwed bonnet, metal to metal seat, pressure rating PN 25 and comply with BS 5154 Series 'B'.

13.2.1.3 Strainers

Strainers up to 50 mm nominal bore shall be bronze 'Y' pattern of pressure rating 32 bar at –10 to 120°C with perforated copper sheet screens having 0.84 mm diameter x 54 holes per cm².

Strainers of 50 mm nominal bore and above shall be cast iron 'Y' pattern of pressure rating 17 bar at 100°C with bolted cap and perforated stainless steel screen having 0.75 mm diameter x 61 holes per cm².

13.2.1.4 Pressure Gauges

Pressure gauges shall be mounted such that they can be read easily from ground or access platform level. Gauges shall be fitted using a female screwed outlet on the pipe.

13.2.1.5 Pipeline Installation

All exposed pipe runs shall be arranged to present a neat appearance, generally following the building structure.

Vertical pipes shall be plumb and all pipes shall be installed to facilitate natural draining and venting.

13.2.1.6 Other works

13.2.1.6.1 Joint Location

Joints shall not be made within the thickness of walls, floors or ceilings.

13.2.1.6.2 Tools

The correct tools shall be used for the assembly of pipe work, and any protective coatings marked shall be made good.

13.2.1.6.3 Cleanliness

Pipe work and fittings shall be inspected and foreign matter removed before installation.

As the installation of pipe work proceeds, all open ends shall be sealed with plugs, caps or blank flanges to avoid ingress of foreign matter. Under no circumstances shall paper or wood be used for this purpose.

At the completion of all or sections of the Works the pipe work or sections of pipe work shall be flushed out until all loose material has been completely removed. This flushing shall be in addition to any subsequent cleansing requirement.

13.2.1.6.4 Pipe Cutting

Pipes shall be cut clean and square with the axis, and all burrs removed.

13.2.1.6.5 Anti-vibration Couplings

Suitable anti-vibration couplings shall be provided to all moving machinery, and shall be installed such that they do not transmit any transverse stresses to or from the plant.

The couplings shall be installed without twisting, misalignment, stretching or compression.

Stool pieces shall be fitted during any testing that produces conditions outside those recommended for the couplings.

13.2.1.6.6 Vibration Isolation

All dynamic machinery shall be isolated from the building structure by vibration isolators or material designed and selected to suit the machinery.

Isolation components shall be installed in accordance with the manufacturer's instructions.

13.2.2 Pumps & Pumping Plant

13.2.2.1 Electric Motors

1. All motors shall comply with the appropriate standards mentioned in Chapter 9 and shall be of such a size and type to adequately drive the Plant under all normal conditions of service without overloading. Motors of 1 kW and greater shall be 3 phase.
2. All fan, pump, stoker and burner motors shall be continuously rated. The insulation shall comply with Class F.
3. Motor enclosures shall comply with BS 5490. Fan, pump, and similar motors larger than 1 kW shall be screen protected and drip-proof except in solid fuel fired boiler houses. Motors of less than 1 kW and all motors in solid fuel fired boiler houses shall be totally enclosed. Motors positioned remotely from their starters shall be provided with load-breaking isolating switches fitted adjacent to them.
4. Motors arranged for automatic restart shall have a label of durable material fixed permanently to them in a prominent position and having, in clearly inscribed characters, the legend:
DANGER: THIS MOTOR IS AUTOMATICALLY CONTROLLED AND MAY START WITHOUT WARNING. ISOLATE BEFORE INSPECTION.
5. Direction of rotation shall be clearly indicated.

13.2.3 Controls & Instrumentation

13.2.3.1 Extent of Work

The extent of controls and instrumentation shall include all electrical, electronic or pneumatic actuators and sensing devices, motor starting equipment, control panels and control wiring and tubing serving items of Plant.

The installation of the controls shall be carried out by a control specialist, who shall also commission the system, provide record drawings and manuals, and guarantee the system.

13.2.3.2 General Requirements

The following requirements shall be met:

1. Basic adjustments for original setting, such as slope of characteristic, sensitivity, etc shall be concealed within a lockable panel. Remaining controls shall be accessible but tamper-proof.
2. All time switches shall have easy to operate over-ride facility, and shall have self winding spring reserve of not less than 30 hours.
3. All instructions and other writing shall be in English.
4. All control valves, dampers and the like shall have position indicators clearly marked 'open' and 'shut'.
5. All hot water systems shall include high temperature protection to prevent water temperatures rising above pre-set limits.
6. All tempered air supply systems shall have low limit protection to prevent freezing of heater batteries or discharge of cold air.
7. All control valves and dampers shall be fail-safe.
8. The frequency of starts for all items of Plant shall be automatically limited to that recommended by the Plant supplier.
9. The sequence of start-up of items of plant shall be automatically controlled to avoid excessive electrical load at any time.

13.2.3.3 Control Panels

1. As far as is practicable all controls, indicator lamps and instruments elsewhere described shall be grouped and mounted together in a floor or wall-mounted panel. Oil burner and boiler automatic control units may be mounted upon or near the Plant to be controlled where this is the manufacturer's standard practice. The panel itself and all items on the outside face shall be identified by means of attached white laminated plastic labels engraved with black cyphers.
2. A drawing of the layout of the control panel shall be submitted for approval before manufacture. A neat and orderly arrangement is required. Plant shall not be fixed to panels removable for maintenance and not, as far as is practicable, to opening doors.
3. The control panel shall, as far as practicable, be manufactured, equipped, wired and tested before delivery to Site.
4. The manufacturer of the control panel shall commission the completed controls installation on Site.
5. Panels shall be totally enclosed and internally wired with no live terminals or components exposed. Complete access to the interior of panels shall be provided by means of lockable hinged doors or covers at the front and/or back as necessary. A front or side-mounted integral and interlocking isolating switch shall be provided, with ON/OFF indication, amperage rating shown, and an internal earth connection. Panels of above 60 A capacity shall contain a fully insulated DP busbar with copper cable or solid copper and clamp connections. Where a panel contains both pneumatic and electric Plant they shall be contained in separate sections with doors to each section.
6. Control panels shall be constructed in accordance with the following:

- i. **Construction**

Panels shall be constructed of folded mild steel sheet of minimum thickness 2.5 mm, or of mild steel angle frame which supports sheets of mild steel of minimum thickness 1.25 mm, or of an approved proprietary system of construction. No sharp edges or corners will be allowed, and all exposed screws, bolts or other fixings shall have rounded heads with protective and decorative plating. Panels shall be adequately stiffened and reinforced as necessary to ensure rigidity. A metal plinth shall be provided with provision for bolting down the cubicle. Lifting eyes shall be provided for convenience of handling.

Doors shall have gaskets for dust protection and be fitted with matt chrome plated lockable handle and catch. Hinges and front of panel screws shall be rustproofed and plated.

Ventilation openings shall be covered with galvanised mesh and vermin proof. Panels shall be finished externally with a semi-gloss stoved or cellulose enamel finish of an approved BS color. All surfaces shall be properly prepared before final finishing and the external appearance shall be of a high standard.

- ii. **Internal Wiring, and the like**

All indicating lamps, instruments and controls shall be, as far as is practicable, of the same manufacturer and style to provide uniformity of appearance and to facilitate maintenance. Externally visible equipment shall be flush mounted, with minimum projection and fixed securely to the front panels or other members. Internal equipment shall be secured to purpose-made rails or mounting bars. All fixings shall incorporate shake-proof washers or other vibration resistant fastenings.

Circuit protection shall be by means of SP circuit breakers where circuit protection does not exceed 60 A. Where a circuit exceeds 60 A protection shall be with HRC fuses.

Indicator lamps shall be 8 V, 2.4 W MES clear and shall be supplied from a 6 V output transformer complying with BS 3535. Glasses of not less than 25 mm diameter shall be fitted. Where indicator lamps are not immediately adjacent to their associated switches they shall be clearly labeled.

Internal wiring shall be coded and in general shall be neatly bunched and run on trays or in purpose-made slotted non-combustible cable trunking. Positive fixing of cable ends shall be ensured by purpose-made clamps, or pinch-type terminals, or by the use of crimped cable tags or other approved termination devices. All cable ends shall be permanently identified.

Wiring shall be not less than 240 V insulated and shall be rated in accordance with the IEE Regulations but with a minimum of 10 A.

Grouped terminal blocks of adequate capacity with pressure bar contacts and permanent labels shall be provided for all wires leading to equipment outside the panel. Removable covers or other facility shall be provided for the entry of incoming cables, conduits, trunking, and the like, with means for effective earthing to the panel chassis.

If main power terminals are incorporated within the control panel, soldered socket type terminals shall be provided.

Fuses shall be grouped and mounted so as to be readily accessible without danger. Fuses, terminal blocks and all items of equipment shall be readily identified by means of clearly visible labels secured to them by screws or by other approved methods.

iii. Cable Entry

Removable plates shall be provided at the top or elsewhere as specified for entry of cables or pneumatic tubes. Non-ferrous plates shall be used for copper tubing or MICC cables.

All cable entries shall be sealed to prevent ingress of dirt or moisture.

13.2.3.4 Instrumentation

All instruments, gauges and devices that have indicating scales shall be mounted such that they are accessible and can be easily read without the need for portable or temporary means of access.

Scale ranges shall be appropriate within the extremes that will be indicated when the plant is running and at rest. The design maximum operating condition shall be indicated at not less than 75% of the total scale length. Pressure gauges and dial thermometers shall be accurate to 1% of total scale reading.

13.2.3.5 Pressure Gauges

Pressure gauges shall have dials not less than 100 mm diameter and the cases shall be of polished brass or chromium plated mild steel or of approved enameled metal or of plastic. Pressure gauges shall be fitted with lever handle cocks and, where appropriate, siphon pipes.

The gauges shall be graduated in kPa and the scale ranges shall not exceed 1.5 times the maximum design working pressure.

Where gauges are provided in association with pumps, an adjustable red pointer shall mark the static head with the system normally full and the pumps at rest.

13.2.4 Testing and Commissioning

13.2.4.1 General

1. All systems shall be fully commissioned and tested in accordance with the requirements of this specification.
2. Works test certificates, where required, shall be provided in duplicate for approval.
3. A full record of all site tests shall be provided, in duplicate, for approval and further copies subsequently included in the O & M Manuals. The installation shall be demonstrated to confirm the installation is properly commissioned, operates in the correct manner and is capable of functioning satisfactorily to accomplish the design intention.
4. All certified instruments, equipment, labor and materials, electric power, fuel and water for all testing and commissioning shall be provided.
5. Notice, in writing, shall be given 48 hours prior to any portion of the Works being pressure tested.
6. In the event of any item of Plant or any section, or sections, of the Works not satisfying the prescribed tests, all faults shall be remedied and re-testing carried out until such items or sections are satisfactory and approved at no additional cost.
7. Details of all hydraulic tests and all tests on Plant or automatic controls made on site shall be recorded. No paint, insulation or non-conducting composition shall be applied to pipe work or items of Plant until all testing and witnessing of tests has taken place.
8. All test details shall include the following particulars:
 - i. Apparatus or pipe work section under test.
 - ii. Makers Nr (where appropriate).
 - iii. Nature, duration and condition of tests.
 - iv. Result of tests.
 - v. Date.
9. Where climatic conditions preclude the proper final adjustment of systems at the time, such adjustments shall be carried out during appropriate conditions within the Period of Maintenance. All testing and commissioning shall be carried out in accordance with the with British Chartered Institute of Building Services Engineers (CIBSE) Codes.

13.2.4.2 Cleanliness

1. All necessary precautions shall be taken to protect the system during the period of the Contract.
2. The entire system shall be flushed through (or gas services blown through) on completion of appropriate sections.
3. After flushing, heating and cooling water systems shall be chemically cleaned to prevent corrosion and scale formation.
4. After flushing hot, drinking and cold water services they shall be sterilized to the Local Water Authority requirements.
5. After sterilizing, samples from draw-off selected points shall be taken and tested for bacterial contamination by an independent laboratory. Test certificates shall then be provided.

13.2.4.3 Pipe Work Tests

1. Upon completion of each length of pipe work the section of pipe work shall be subjected to a pressure test and demonstrated and witnessed to ensure the section is sound and tight.

2. The whole of the testing gear required including all plugs, caps, tees and drain fittings shall be provided.
3. The tests shall be applied by filling the sections to be tested with air or water as appropriate and raising their pressure to a figure equal to twice the working head or 3.5 bars (gauge), whichever is the greater, after making safe all items of equipment that may be damaged by such tests.
4. The section shall then be left without further pressurization and all joints must remain tight for a period of at least two hours.
5. All necessary precautions against freezing shall be taken and the pipe work sections emptied down after testing except those for which a Certificate of partial Completion in respect of the Works has been issued and for which responsibility has been accepted by the EMPLOYER.
6. Any pipe work or plant damaged by frost or damage caused to the building structure by flooding during the contract period shall be reinstated as new.
7. All drainage pipe work shall be blanked off at the point at which it discharges into the main drains and shall be filled with water and hydraulically raised to not less than 345 mbar and checked for leaks over a two hour period.
8. Soil pipes and vents shall be plugged and tested to an air pressure of 5 mbar. This pressure shall be maintained and witnessed for a 15 minute period.
9. All gas service pipelines shall be tested to an air pressure of 30 mbar or in the case of high pressure gases to twice the working pressure maintained for a period of 24 hours.

13.2.4.4 Vibration Testing

All plant and equipment provided shall be free from excessive vibration. Any minor vibration that may occur shall not be transmitted from the plant or equipment into or through the supporting or enclosing structure.

13.2.4.5 Performance Tests

1. It shall be demonstrated that the Works is adjusted and regulated correctly to fulfill the functions for which it has been designed, e.g., room temperatures to be maintained, air change, water temperature and outflow of water from taps, and the like. Adjustments shall be made to balance and regulate the systems as necessary until the required conditions are attained.
2. Room temperatures shall be measured by mercury-in-glass thermometers located 1.5 m above floor level at points away from the influence of draughts, adjacent heaters or direct radiation from hot or cold surfaces.
3. No demonstration of room temperatures shall be carried out when the weather conditions are abnormal as to wind or rain or at times when the external air temperature is changing at a rate exceeding 2°C per hour.
4. The CONTRACTOR shall provide all instruments, equipment and labor required for the conduct of these demonstrations together with up-to-date calibration certificates for the instruments used in the tests.
5. Not less than 7 days notice shall be given prior to the performance tests being carried out.

13.2.4.6 Automatic Controls and Instrument Testing

All automatic controls and instruments shall be tested and commissioned by the manufacturer's representative in order to demonstrate that they are capable of meeting the demands specified and they shall be adjusted to suit the characteristics of the building and the system.

All valves, switches, controls and the like shall be regulated and capable of proper adjustment to conform to the design conditions.

A signed certificate from the control or instrument manufacturer's representative confirming that the systems for control of the Plant are operating to their satisfaction shall be provided.

13.2.4.7 Plant Operation

The plant shall be operated for a period of one week using any skilled personnel necessary to ensure its safe and satisfactory operation for this period.

During this period of plant operation, instruction shall be provided to all members of the EMPLOYER's staff, who will be responsible for the future day to day operation of the plant, equipment and automatic controls.

13.2.4.8 Post-Commissioning Checks

Upon completion of the testing and commissioning, the system shall be checked to ensure that all valves, dampers and automatic controls and the like are correctly set for normal operation.

14.0 VERTICAL DEEP WELL TURBINE (DWT) PUMPING EQUIPMENT

14.1 General

14.1.1 Summary

This chapter addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for Vertical Deep Well Turbine (DWT) pumps including motors, bearings and shafting, associated testing.

14.1.2 Submittals

Submit all relevant shop drawings and manufacturers data for this chapter, including the following:

1. Certified performance curves in accordance with Hydraulic Institute Standards sign and sealed by the manufacturer's licensed professional ENGINEER.
2. Certified copies of results of hydrostatic test report.
3. Setting plans which shall include:
 - i. Anchor bolt layout and bolt dimensions.
 - ii. Outline dimensions and weights of pumps, and control enclosures.
4. Pumps: Submittal Data and drawings shall include:
 - i. Manufacturer, type, and model number.
 - ii. Assembly drawing, nomenclature and material list, O&M manual, and parts list.
 - iii. Impeller type, diameter, sphere size passing, number of vanes and identification number.
 - iv. Complete motor performance data including: rating; voltage/phase/frequency.
 - v. Complete performance curve(s) showing full range (shutoff to run-out) head vs. capacity, NPSHR, hydraulic efficiency, motor active (KW) input power, and shaft power (BH).
5. Location and description of Service Centers and spare parts stock.
6. The manufacturer shall indicate, by arrows to points on the flow versus head in feet of water curves, the limits recommended for stable operation, between which the pumps are to be operated to prevent surging, cavitation, and vibration. The stable operating range shall meet the hydraulic performance requirements of the proposed system.
7. Torsional analysis of intermediate shafting.
8. Bearing life projection and warranty at the specified operating condition.
9. Total head of the system must be verified by the Contractor at the time of supplying pumps.

14.1.3 Quality Assurance

The pumps shall be suitable for pumping raw/potable water and shall be designed and fully guaranteed for this use. The fluid temperature range shall be from 40 degrees to 104 degrees F.

14.1.3.1 Reference Standards:

The pump shall follow the following standards or equivalent:

1. HI B Hydraulic Institute Standards for Centrifugal, Rotary, and Reciprocating Pumps.
2. ASTM B American Society for Testing and Materials.
3. AISI B American Iron and Steel Institute

4. ANSI B American National Standards Institute

14.2 Products

14.2.1 Pumps

Pumps shall be vertical, Deep Well Turbine (DWT) centrifugal raw/ clear water pumps.

Only continuous duty pumps designed and manufactured for use in conveying raw/ clear water shall be acceptable after approval from the ENGINEER.

System head shall be verified by the contractors before finalizing the pumps and shall be acceptable after approval from the Engineer. Pumps shall be selected of steeper curves to accommodate system head variation as per site requirement. Install a larger suction line than the pump inlet if required to reduce velocity and inlet head losses, in order to provide the required Net Positive Suction Head (NPSH) according to the Hydraulic Institute and prevent cavitation.

Pump seals shall be cool without an external coolant source.

Suction and discharge piping shall be installed with pressure gauges to monitor the suction and discharge pressure of the pump.

14.2.1.1 Impellers

Impellers shall be raw/ clear water type, manufactured of close-grained bronze (GCuSn10). Impellers shall be of one piece, single suction, enclosed radial flow design with well-rounded leading vane edges and a thick hydrofoil shape with large openings to prevent the accumulation of solids and stringy material. Impellers shall be statically and dynamically balanced and secured to a straight or tapered fit on the pump shaft by means of a bolt, washer and key. The arrangement shall be such that the impeller cannot be loosened by operating torque in either forward or reverse rotation.

14.2.1.2 Bases

Rugged heavy duty fabricated steel bases shall be provided, with openings large enough to permit access to the suction elbow and cleanout, bolted directly to the volute. Bases shall be designed to support the assembled weight of the pump and driver shafting. A cast iron suction elbow with ¼-inch gauge connection and 2-inch gauge, contoured handhold cleanout, and a 125 lb. raised or flat faced flange conforming to ANSI drilling shall be furnished.

14.2.1.3 Pump drive motors

Motors shall comply with IEEE and NEC and be non-overloading at any point on the pump curve. Motors shall be independently mounted and supported by high ring base support stands with adequately sized openings providing easy access to the coupling flange. More details about motors can be found in the specifications Chapter 10, Motors and its Controllers/Control Panels.

14.2.1.4 Shafts and bearings

The connecting shafts shall have universal couplings and solid pillow block intermediate bearings located at the shaft steady beams. The shafts shall run in ball bearings and shall be designed to withstand all radial and thrust loads applied throughout the normal pump

operating range. The intermediate pillow block bearings shall be designed in accordance with AFBMA standards for a minimum L-10 life of 50,000 hours. The bearings shall be sealed and contained in dust-proof moisture-proof housing. The deflection of both joints for intermediate shafts shall be equal to one another within plus or minus one degree. Maximum joint operating angle shall not exceed $\frac{1}{2}$ to one degree maximum offset, unless otherwise recommended by the pump manufacturer. Shaft deflection at the pump shall not exceed 0.002-inch at the stuffing box at plus/minus 40% of the best efficiency point of the impeller curve furnished. Bearings shall be grease lubricated through fittings provided at accessible points on the bearing housing and metal tubing and fittings shall be provided to allow bearing lubrication from floor level. Tubing shall be securely fastened to steady beams and wall. Shaft guards shall be provided.

14.2.1.5 Shop tests

Pumps shall be shop tested and six (6) certified copies of curves derived from such tests shall be furnished to the EMPLOYER for approval prior to shipment. Cases shall be proved tight by hydrostatic testing to 150 psi.

14.2.2 Shaft Assemblies

Pump shafts shall be high-strength alloy steel with a minimum 100,000 psi tensile strength and 75,000 psi yield strength, shafts shall be of sufficient diameter to carry the maximum loads imposed and to prevent vibration and fatigue. Shafts shall be accurately machined along their entire length and precision ground at bearing locations. Keyways shall be provided at both ends. A renewable shaft sleeve with positive o-ring sealed to prevent leakage between the shaft and the sleeve shall protect the shaft through the sealing box area. The shaft sleeve shall be stainless steel with a Brinell hardness of 425-475 (on mechanical seal pumps, shaft sleeves may be corrosion-resistant bronze). Radial bearings shall be grease-lubricated ball bearings designed to carry the hydraulic radial loads encountered in the service conditions. Thrust (outboard) bearings shall be designed to carry the pump hydraulic axial and dead load thrust. Bearing shall be designed for an L-10 life of 100,000 hours per AFBMA at the primary duty point and an L-10 life of 40,000 hours at the most extreme operating points on the pump performance curve.

14.2.3 High Ring Bases

Motors for sewage pumps shall be mounted on cast iron barrel type high ring bases of sufficient strength to support the full weight of the motor and of adequate height to permit access to the shaft coupling. The bases shall be furnished with a shaft guard.

14.2.4 Spare Parts

One (1) spare impeller, one (1) shaft sleeve, and One (1) impeller fastening hardware; and one (1) spare set of packing shall be provided with each pump furnished.

14.2.5 Approved manufacturers

- Goulds
- KSB
- LLOWARA
- Grundfos
- Approved equal

14.3 Execution

14.3.1 Installation

Pumping equipment shall be installed in accordance with recommendations of the manufacturer, and the details shown on the contract drawings. A copy of the installation instructions shall be made available to the ENGINEER and the EMPLOYER'S Construction Inspector prior to equipment installation.

The CONTRACTOR shall dynamically balance and align the shaft assembly, in the field, to within the pump manufacturer's required tolerance.

14.3.2 Pump Testing

After installation, the pumping system shall be field tested using potable water. Water will be furnished by the EMPLOYER at no cost to the CONTRACTOR. The CONTRACTOR shall be responsible for conveying the water to the site and providing required meter and back-flow prevention check valve assembly. Each pump shall be cycled through the sequence of operation "pump on" as the level rises in the wet well and then "pump off" during draw down.

Each pump shall operate over its intended operating range without undue noise, vibration, or cavitations. The CONTRACTOR shall monitor and record vibration at three symmetrically located points on each pump at maximum and minimum speed and supply data to the EMPLOYER. Each pump shall operate within the tolerances established in the Hydraulics Institute (HI) standards and within an acceptable range on the certified pump curve provided by the manufacturer.

Upon completion of the installation, on-site testing, and before acceptance by the EMPLOYER, the Pump Manufacturer or the authorized Pump Manufacturer's Representative shall submit a written statement that the pump installation has been completed in accordance with the manufacturer's recommendations.

14.3.3 Manufacturer's Representative

The CONTRACTOR shall provide the services of a factory trained representative of the sewage pump manufacturer to assist in installation, startup and testing of the pumps. Provision shall be made for a minimum of three visits of not less than four hours each, on site. The first visit shall be to assist the CONTRACTOR in proper installation. The second shall be to assist in startup of the pumping equipment. The third shall be to check the installation, after startup, at the invitation of the EMPLOYER.

After the pumps have been completely installed and wired, the CONTRACTOR shall have the manufacturer do the following:

1. Check megger stator and power cables.
2. Check proper rotation.
3. Check power supply voltage.
4. Measure motor operating load and no load current.
5. Check level control operation and sequence.

During this initial inspection, the manufacturer's service representative shall review recommended operation and maintenance procedures with the EMPLOYER'S personnel. Pump manufacturer shall submit a written report that the pump(s) are satisfactorily installed in accordance with the manufacturer's recommendations.

14.3.4 Operating Manuals

The pumps shall be supplied with six (6) copies of an Operating Manual with detailed pump assembly drawings, warranty, and component lists.

15.0 INTERIOR PIPE, FITTINGS, AND VALVES

15.1 General

15.1.1 Summary

This section addresses the work related to furnishing and installing all supervision, labor, materials and equipment in the work for pipe, fittings, and valves.

15.1.2 Submittals

Submit shop drawings and manufacturers data in accordance with the provisions of the section, General Provisions.

All iron pipe, fittings and valves to be installed under this Contract shall be inspected and tested at the foundry as required by the standard specifications to which the material is manufactured. Furnish in duplicate to the EMPLOYER sworn certificates of such tests and their results. In addition, all ductile iron pipe and fittings to be furnished under this Contract may be inspected at the foundry for compliance with these Specifications by an independent testing laboratory selected by the EMPLOYER. The manufacturer's cooperation shall be required in these inspections. The cost of foundry inspection of all pipe approved for this Contract, plus the cost of inspection of a reasonable amount of the disapproved pipe, shall be borne by the VENDOR.

Shop Drawings including detailed layout drawings shall be submitted to the EMPLOYER for approval; and shall include dimensioning, methods, and locations of supports, and all other pertinent technical specifications for all piping to be furnished.

The CONTRACTOR shall transmit from the Vendor to the ENGINEER, the pipe manufacturer's certification of compliance with the applicable sections of the Specifications.

The CONTRACTOR shall coordinate all submittals with the related VENDOR in a manner not to impede construction on individual projects.

15.2 Products

15.2.1 Materials

Pipe shall be supplied in lengths not in excess of 20 feet. Pipe shall be designed to be installed in accordance with the drawings. Working pressure of the pipe shall be 150 psi with 100 psi for surge allowance. Minimum test pressure shall be 500 psi. Flanged pipe that leaks will be rejected.

Unrestrained fittings shall meet the requirements of AWWA C110. Gaskets shall be SBR (Strene-Butadiene Rubber) reinforced with lightweight nylon cloth, or approved equal. Gaskets shall meet the requirements of ASTM D2000.

All pipe and fittings shall be double thickness cement-lined in accordance with ANSI/AWWA C104/A21.4. All pipe and fittings shall be seal coated on the interior in accordance with ANSI/AWWA C15/A21.51. Fittings shall have a pressure rating of 250 psi, and conform to ANSI/AWWA C110/A21.10.

Exterior surfaces of pipe, fittings and valves identified to receive final painting shall be in accordance with the relevant Section.

15.2.1.1 Resilient Seated Gate Valves – 200 mm (8-inch) and larger

1. Gate valves with 200 mm (8-inch) and larger diameters shall be resilient seated, manufactured to meet or exceed the requirements of AWWA C509, BS 5163 or BSEN1171 or its latest revision, and in accordance with the following specifications. Valves shall have an unobstructed waterway equal to or greater than the full nominal diameter of the valve. Working pressure up to 16 bars and test pressure shall be 24 bars.
2. Gate valves at discharge pipes installed for pumps in pump room shall be provided with hand wheel operated with gear box. Hand wheels shall be turned counter-clockwise to open the valve. An arrangement shall be provided to operate these valves from the ground floor of pumping station.
3. Gate valves shall be of renowned brand and with country of origin USA/EU (imported).
4. The valves are to be non-rising stem with the stem made of cast, forged, or rolled bronze shown in AWWA C509, BS 5163 or BS EN 1171. Two stem seals shall be provided and shall be of the O-ring type, one above and one below the thrust collar.
5. The sealing mechanism shall consist of a cast iron gate having a vulcanized synthetic rubber coating, or natural rubber seat ring. The resilient sealing mechanism shall provide zero leakage at the water working pressure when installed with the line flow in either direction.
6. The valve body, bonnet, and bonnet cover shall be cast iron ASTM A126, Class B. All ferrous surfaces, inside and outside, shall have a fusion-bonded epoxy coating. A hand-wheel or wrench nut shall be provided for operating the valve. All valves are to be tested in strict accordance with AWWA C509, BS 5163 or BS EN 1171.
7. Where indicated on the Drawings or necessary due to location, size, or inaccessibility, chain wheel operators shall be furnished with the valves. Such operators shall be designed with adequate strength and leverage for the valves with which they are supplied, and to provide for easy operation of the valve. Chains for valve operators shall be galvanized.
8. Where required, gate valves shall be provided with a box cast into the concrete slab and a box cover. Length of box shall equal slab thickness. Box cover opening shall be for valve stem and nut. Valve wrenches and extension stems shall be provided by the manufacturer to actuate the valves.

15.2.1.2 Manufacturers or Equal

1. Val Matic
2. SISTAG
3. KITZ
4. COSMOS Engineering Co.
5. KSB
6. SIAM

15.2.1.3 Painting

The inside and outside of all valves, together with the working parts except bronze and machined surfaces shall be wet-epoxy coated 150 micron in accordance with AWWA standards or prescribed BS Code.

15.2.1.4 Marking

Marking shall be in accordance with AWWA C-508 or prescribed BS Code and shall include size, working pressure, and cast arrow to indicate direction of flow, name of manufacturer, and year of manufacture.

15.3 Execution

15.3.1 CONTRACTOR's responsibilities during installation

1. The CONTRACTOR shall furnish and install all supervision, labor, equipment, materials and appurtenances complete for the pipe and fittings, as specified herein and as shown on the project drawings.
2. Install within the project site all materials and incidentals including iron pipe and restrained joint ductile iron pipe and fittings for buried and exposed force mains, complete, as shown on the project drawings.
3. Install all materials and incidentals required to install push-on joint or restrained joint iron pipe, complete as shown on respective project drawings and as specified herein.
4. Install all materials and incidentals required to install flanged joint ductile iron pipe, valves and fittings, complete, as shown on the project drawings.
5. The CONTRACTOR shall coordinate all deliveries with the related VENDOR(S) in a manner not to impede construction.
6. Reduced pressure zone assembly (RPZ) shall be installed inside pump station building 12 to 36-inches above finished floor and a drain shall be provided to the building's exterior.

15.3.2 Handling Pipe, Valves, and Fittings

1. Handling Pipe, Valves, and Fittings must be provided as per AWWA C600 and C605/BS 5404 or its latest version.
2. Care shall be taken in loading, transporting, and unloading to prevent injury to the pipe or coatings. Pipe, valves and fittings shall not be dropped. All material shall be examined before installation, and no piece shall be installed that is found to be defective. Any damage to the coatings shall be repaired as directed by the ENGINEER.
3. All pipe and fittings shall be subjected to a careful inspection and hammer test just prior to being installed.
4. If any defective pipe is discovered, after it has been installed, it shall be removed and replaced with new pipe in a satisfactory manner at no additional expense to the EMPLOYER.
5. The CONTRACTOR shall install the pipe true and plumb and no "springing" of pipe during the installation shall be allowed.
6. No field welding of ductile iron pipe shall be allowed.

15.3.3 Testing

1. Hydrostatic pressure and leakage test shall conform to Section 4 of AWWA C906 Specification, with the exception that the CONTRACTOR shall furnish all gauges, meters, pressure pumps, and other equipment needed to test the line. Allowable leakage for flanged pipe shall be zero.
2. The pressure required for the field hydrostatic pressure test shall be 50% above the normal working pressure, but not less than 150 psi (10 bars). The CONTRACTOR shall provide temporary plugs and blocking necessary to maintain the required test pressure. Corporation cocks at least 20 mm (¾-inches) in diameter, pipe riser and angle globe valves shall be provided at each pipe dead-end in order to bleed air from

the line. Duration of pressure test shall be at least 24 hours. The cost of these items shall be included as a part of testing.

3. The leakage test shall be a separate test at the maximum operating pressure, following the pressure test; and shall be of not less than two hours duration. All leaks evident at the surface shall be repaired, and leakage eliminated regardless of total leakage as shown by test. Lines which fail to pass tests shall be repaired and retested as necessary until test requirements are complied with. Defective materials, pipes, valves and accessories shall be removed and replaced with new. The pipe lines shall be tested in such sections as may be directed by the ENGINEER by shutting valves or installing temporary plugs as required. The line shall be filled with water, and all air removed; and the test pressure shall be maintained in the pipe +/- 5 percent for the entire test period by means of a pump to be furnished by the CONTRACTOR. Accurate means shall be provided for measuring the water required to maintain this pressure. The amount of make-up water required is a measure of the leakage.
4. Reduced pressure zone assembly (RPZ) shall be tested in-place and certified by a qualified Backflow Prevention Tester. Certified test results shall be provided to the ENGINEER.

15.3.4 Surface Preparation and Painting

1. All piping, fittings and valves exposed to view shall be left unpainted from manufacturer and receive paint in accordance with the relevant Section.
2. It shall be part of the work of this Section for the CONTRACTOR to assist, as required, the ENGINEER in identifying pipe contents, direction of flow, and all else required for proper marking of pipes.

16.0 ENGINEER'S REQUIREMENTS

16.1 General

The CONTRACTOR shall supply and maintain for the use of the ENGINEER and his staff certain facilities including an office, furniture, fixtures and equipment, services, survey instruments and equipment, computers and all other items as described herein.

The CONTRACTOR shall maintain service and insure such facilities for the CONTRACT Period or for such additional time as the ENGINEER may direct. The CONTRACTOR shall replace any such facility that is not in good condition if so instructed by the ENGINEER.

The CONTRACTOR shall also supply consumable items as described herein, for the period stated.

If for any reason the CONTRACTOR fails to provide, or replace as required, any of the facilities described herein, the EMPLOYER may provide the facilities himself or by others at the CONTRACTOR's risk and cost. The costs properly incurred by the EMPLOYER in taking such action shall be deducted from the Contract Price.

On Completion of the Works, or at such a time specified by the ENGINEER, the ownership of all furniture, equipment, shall be transferred to the EMPLOYER, after carrying out any necessary repairs etc, if required, to restore all the items handed over to good working condition.

16.2 Location of the Buildings

The office building shall be provided at a position within the Contract Temporary Works Area specified by the EMPLOYER/ ENGINEER. All-weather access roads shall be provided to serve the buildings.

Surface water drainage facilities shall be provided to protect the building from surface run-off and to convey it away from the buildings.

16.3 Office Accommodation for the ENGINEER

The CONTRACTOR shall supply, construct and erect on the Site a temporary office and maintain, service and insure them for the period of use. The office shall be for the sole use of the ENGINEER's / EMPLOYER's staff.

The office building shall be durable for the period of the project with 12 months grace period. The building shall be designed by the CONTRACTOR who shall provide design drawings to the ENGINEER for his approval. The design shall be based on the typical office layout. The office shall have a minimum of 3 rooms with attached bathrooms. All fixtures and fittings for the building shall be of good quality and all to the ENGINEER's approval.

The minimum floor area of the office building shall be 50 m², excluding covered car parking.

The building shall have adequate air-conditioning; lockable doors, wooden windows fitted with fly-mesh and steel security grilles, and shall be divided up by block work partitions into private offices and meeting rooms as directed by the ENGINEER.

Each individual office shall have a toilet and washbasins in addition to a set of communal toilets to cater for the ENGINEER and his staff, and the office shall be provided with a kitchen.

The CONTRACTOR shall provide all services and infrastructure. He shall light, clean and maintain the building and shall provide and maintain both hot and cold water and sanitary systems. The CONTRACTOR shall provide and maintain an electricity supply of sufficient power for general use, including air conditioning. All plumbing and wiring shall be concealed within the walls, and wiring shall be ducted.

The CONTRACTOR shall provide one office assistant conversant with the operation of the photocopier and other office duties; one tea boy/peon; and watchmen for 24 hour duty for the security of the ENGINEER's office.

The office and all furniture, fixings, equipment, services etc, shall be provided complete within 30 days from the date of the ENGINEER's Notice to Commence. If he fails to provide the building within the above stated time the CONTRACTOR shall provide alternative appropriate accommodation to the satisfaction of the ENGINEER.

16.4 Maintenance of the ENGINEER's Offices

The CONTRACTOR shall maintain the office building and all furniture fixings, equipment, services and all other facilities in good condition and shall carry out repair as and when required. The electricity, water supply, gas and the sewage disposal system shall be maintained in good order throughout the period of the Contract and up to the end of the maintenance period, or as directed by the ENGINEER.

16.5 Standby Generator

A standby generator shall be provided for use during any power supply failures, and shall have a continuous rated output of 10 kVA, suitable for operation of office lighting including fans, and at least 2 air conditioners of 18,000 BTU. It shall provide power at 240 V and 50 Hz. The power unit shall be a four-stroke diesel engine. It shall be housed in a separate building constructed by the CONTRACTOR adjacent to the ENGINEER's office. It shall be connected with the main electricity supply system to the ENGINEER's office through a change over switch to ensure continuity of the power supply to the ENGINEER's office in case of a power breakdown.

In addition to maintenance of the generator, the CONTRACTOR shall provide fuel and lubricating oils, etc as required throughout the period of the Contract and up to the end of the maintenance period, or as directed by the ENGINEER.

16.6 Furniture, Fixtures, Equipment, etc

The CONTRACTOR shall supply the furniture, fixtures and equipment, and shall install them in the office as required by the ENGINEER. They shall be for the sole use of the ENGINEER and his staff. All furniture, fixtures and equipment shall be supplied new, following the ENGINEER's approval of a manufacturer's description or catalogue. The CONTRACTOR shall keep insured all furniture, fixtures and equipment to their full value (including duty where appropriate) and shall maintain them in good order until the end of the maintenance period. On completion of the Works, furniture, fixtures and equipment shall become the property of the EMPLOYER.

ENGINEER's office is to be furnished with following minimum furniture to the approval of the ENGINEER:

Table 16-1: Minimum furniture for ENGINEER's Office.

Executive glass desk with 6 drawers with locks, plan dimensions 6ft x 3ft approx.	01 No.
Desk with 3 drawers plan dimensions 4 ft x 3 ft approx.	04 Nos.
Chairs with cushion seat & back	10 Nos.
Executive Chair	01 No.
Revolving Chairs, upholstered	04 Nos.
Filing cabinets, steel with locks and 4 drawers with suspended filing system	04Nos.
Cub-board steel with locks and four shelves Overall dimension 3 ft wide x 5 ft high x 18 inch deep	02 Nos.
Shelves (four partitions) approx. 6 ft wide x 4 ft high x 18 inch deep	02 Nos.
Waste Paper Baskets	07 Nos.
Steel straight edge, 3 ft long	01 No.
3 sided Engineering Scale	03 Nos.
Adequate Air Conditioning for the entire office and fans	

The kitchens, toilets, wash rooms to be provided with suitable fittings and fixtures for their proper functioning and use with consumables.

Equipment

Following minimum equipment is to be provided for ENGINEER's offices:

Table 16-2: Equipment required for ENGINEER's Office.

Electronic calculators, battery operated with liquid crystal display and trigonometric functions complete with batteries	04 Nos.
Electronic calculators with 4 basic functions and memory and with integral print-out mechanism	02 Nos.
IBM compatible Core i5 with 250 GB Hard Disk, 2 GB Ram, CD/DVD Writer, Color 21 inch LCD Monitor with Stabilizer and UPS with MS Office, M.S Project and AutoCAD V-2008 software etc. along with computer/printer table and revolving chair.	01 No.
Refrigerator, capacity 8 cu.ft approx.	01 No.
Samsung SCX-4521 F Mono multifunction machine (Laser multifunction printer, copier, fax, colour scanner)	01 No.
USB Flash Drive 16 GB Capacity	04 Nos.
Fire extinguishers	03 Nos.
Sundry office items, comprising letter tray, punch paper, stapling machine, pencil sharpener and eraser	6 Sets.

On completion of the Contract or at such a time specified by the ENGINEER, the ownership of all equipment shall be transferred to the EMPLOYER.

Table 16-3: Other requirements for ENGINEER's Office.

Stove with Gas Cylinder	01 Set
Set of Utensils	02 Sets
Crockery set for 10 persons	02 Sets

16.7 Stationery and Office Supplies

The CONTRACTOR shall supply all stationery and office consumables required for the normal functioning of the ENGINEER's office, including but not limited to survey books, drawing office supplies, computer disks and diskettes, computer printout paper, replacement toner cartridges for printers and photocopiers, as and when required. The CONTRACTOR shall continue this supply while the ENGINEER's office is on the Site.

16.8 Deadlines and Penalties

The movable offices shall be furnished and ready for occupation within one month of the ENGINEER's notice to commence the work. The CONTRACTOR shall provide alternative accommodation to the satisfaction of the ENGINEER if he fails to complete, or provide as appropriate, the buildings within the above stated time.

16.9 Water, Gas and Electricity

The CONTRACTOR shall supply or make provision for permanent 24 hour water, gas and electricity supplies and sewage disposal to the ENGINEER's offices which shall remain provided on hand over of the offices to the EMPLOYER. The CONTRACTOR shall also supply clean potable/ bottled water for the ENGINEER and his staff. He shall arrange for refuse disposal while the ENGINEER's office is on the Site.

Gas, water and electricity facilities shall include the installation of the necessary meters and shall be permanent structures and installations.

16.10 Telephone, fax & Internet

The CONTRACTOR shall arrange for the installation and maintenance of two telephone lines including one telephone set and one fax machine, to serve the ENGINEER's office from the public exchange. The CONTRACTOR shall ensure that these lines have the facility only for local telephone calls and the sending and receiving of local fax messages. On completion of the Works the equipment becomes EMPLOYER's property and the telephone line rental agreement shall be transferred to the EMPLOYER's name.

The CONTRACTOR shall provide and maintain broadband wireless internet connection for all computers in the ENGINEER's site office of the type and service provider approved by the ENGINEER up to the end of maintenance period.

No direct payment shall be made for providing and maintaining these services as above but the cost shall be deemed to be included in the contract price.

On completion of the work, these items will be returned to the CONTRACTOR.

16.11 Surveying Instruments and Equipment

The CONTRACTOR shall supply, for the sole use of the ENGINEER, survey and other instruments and equipment. The instruments and equipment shall be new and shall be maintained in a good state of repair. In the event of loss or damage, they shall be replaced by items of a similar nature.

- Total Station (One second Accuracy) with stand
- Automatic Level with stand
- Level Staff
- Ranging Rods
- Tripod Stand for Prisms
- Prism
- Prism Holder
- Measuring Steel Tape 100 meter (3 No.)

The CONTRACTOR shall provide survey assistance to the ENGINEER and his staff. On completion of the work, the survey instruments will be returned to the CONTRACTOR.

The CONTRACTOR shall not be entitled to separate payment for the provision of the above equipment, services, survey staff and their transport but the cost of the same shall be included in the item of assistance to the ENGINEER under survey staff.

16.12 Meetings and Reports

Approved representatives of the CONTRACTOR shall attend meetings at the office of the ENGINEER's Representative on Site, when called upon, for the purposes of Contract administration. Such meetings, unless otherwise agreed, shall not be less frequent than twice per month.

The CONTRACTOR shall submit to the ENGINEER each month a report on his progress in the performance of the Contract.

16.13 Photographs

The CONTRACTOR shall supply colour prints of photographs, not less than 200 mm by 225 mm, of such portions of the Works in progress and completed, as may be directed by the ENGINEER and specified herein. The negatives and prints shall not be retouched. No prints of these photographs shall be supplied to anyone without the written permission of the ENGINEER.

The photographs shall be of two categories:

1. progress photographs;
2. record photographs.

Both categories of photographs shall be properly referenced to the approval of the ENGINEER and on the back of each print shall be recorded the date of the photograph, the direction in which the camera was facing, an identifying description of the subject, and the reference.

Photographs taken for record purposes as ordered by the ENGINEER shall be supplied with two prints, having on the reverse of one print the signatures of the CONTRACTOR and the

ENGINEER (or their authorized representatives) for the purpose of attestation. If required, the CONTRACTOR may at his own cost have an additional print.

The CONTRACTOR shall supply two prints of each progress photograph ordered by the ENGINEER. He shall supply sets of four additional prints of progress photographs selected by the ENGINEER for incorporation in albums. He shall supply albums, mount the prints, and title the prints and albums all to the approval of the ENGINEER.

16.14 Assistance to the ENGINEER

The CONTRACTOR shall supply such labour, either continuously or from time to time, as may be required by the ENGINEER, to assist in the checking of materials on Site, the setting out of the Works and in measuring the Works.

- | | |
|---------------------|---|
| • Office Assistants | 1 |
| • Tea Boys | 1 |
| • Watchmen | 1 |

In case the performance of any of such staff is considered by the ENGINEER as unsatisfactory, the CONTRACTOR shall replace the same forthwith with acceptable personnel.

17.0 TESTS ON COMPLETION

17.1 General

This chapter describes specifications for Tests on Completion of the Project.

17.2 CONTRACTOR's Obligations

Surface water drainage facilities shall be provided to protect the buildings from surface run-off and to convey it away from the buildings.

The CONTRACTOR shall carry out the Tests on Completion.

The CONTRACTOR shall give to the EMPLOYER not less than 21 days' notice of the date after which the CONTRACTOR will be ready to carry out each of the Tests on Completion. Unless otherwise agreed, Tests on Completion shall be carried out within 14 days after this date, on such day or days as the EMPLOYER shall instruct.

Testing and commissioning period shall be 3 months. Unless otherwise stated in the Particular Conditions, the Tests on Completion shall be carried out in the following sequence:

- a. pre-commissioning tests, which shall include the appropriate inspections and ("dry" or "cold") functional tests to demonstrate that each item of project/ scheme can safely under-take the next stage,
- b. commissioning tests, which shall include the specified operational tests to demonstrate that the Works or Section can be operated safely and as specified, under all available operating conditions; and
- c. trial operation, which shall demonstrate that the Works or Section perform reliably and in accordance with the Contract.

During trial operation, when the Works are operating under stable conditions, the CONTRACTOR shall give notice to the EMPLOYER that the Works are ready for any other Tests on Completion, including performance tests to demonstrate whether the Works conform with criteria specified in the EMPLOYER's Requirements and to the Performance Guarantees.

Trial operation shall not constitute a taking-over. Unless otherwise stated in the Particular Conditions, any product produced by the Works during trial operation shall be the property of the EMPLOYER.

In considering the results of the Tests on Completion, appropriate allowances shall be made for the effect of any use of the Works by the EMPLOYER on the performance or other characteristics of the Works. As soon as the Works, or a Section, have passed each of the Tests on Completion described in sub-paragraph a), b) or c), the CONTRACTOR shall submit a certified report of the results of these Tests to the EMPLOYER.

17.3 If the Tests on Completion are being unduly delayed

If the Tests on Completion are being unduly delayed by the CONTRACTOR, the EMPLOYER may:

- a. by notice require the CONTRACTOR to carry out the Tests within 21 days after receiving the notice. The CONTRACTOR shall carry out the Tests on such day or

days within that period as the CONTRACTOR may fix and of which he shall give notice to the EMPLOYER.

- b. If the CONTRACTOR fails to carry out the Tests on Completion; within the period of 21 days, the EMPLOYER's Personnel may proceed with the Tests at the risk and cost of the CONTRACTOR. These Tests on Completion shall then be deemed to have been carried out in the presence of the CONTRACTOR and the results of the Tests shall be accepted as accurate.

17.4 Retesting If the Works fail to pass the Tests on Completion

Retesting If the Works, or a Section, fail to pass the Tests on Completion and the EMPLOYER or the CONTRACTOR may require the failed Tests and Tests on Completion on any related work, to be repeated under the same terms and conditions.

17.5 Failure to Pass Tests on Completion

If the Works, or a Section, fail to pass the Tests on Completion repeated, the EMPLOYER shall be entitled to:

- a. order further repetition of Tests on Completion;
- b. if the failure deprives the EMPLOYER of substantially the whole benefit of the Works or Section, reject the Works or Section (as the case may be), in which event the EMPLOYER shall have the same remedies as are provided in Failure to Remedy Defects; or
- c. issue a Taking-Over Certificate.

In the event of sub-paragraph (c), the CONTRACTOR shall proceed in accordance with all other obligations under the Contract, and the Contract Price shall be reduced by such amount as shall be appropriate to cover the reduced value to the EMPLOYER as a result of this failure. Unless the relevant reduction for this failure is stated (or its method of calculation is defined) in the Contract, the EMPLOYER may require the reduction to be

- a. agreed by both Parties (in full satisfaction of this failure only) and paid before this Taking-Over Certificate is issued, or
- b. determined by arbitration, or
- c. determined by the EMPLOYER.

18.0 OPERATIONS AND MAINTENANCE

18.1 General

Operator shall perform each of the services listed in this chapter as part of 'Operations and Maintenance'.

This chapter is based on Pakistan Engineering Council's (PEC) recommended document for 'Operations and Maintenance Contract', available at PEC's website.

18.2 Programs

In addition to those responsibilities described in the Agreement, Operator shall be responsible for the establishment and implementation of the following programs, standards and procedures, which require Owner approval and which are included in the "Services" to be provided by the Operator.

The program for establishing specific operating goals for each functional Project area, for managing resources to minimize personnel turnover, and for qualifying personnel, to operate and maintain the Project (including the basis for qualification of personnel).

The program for communicating and cooperating with Owner and governmental agencies.

The Project management standards for conduct of operations, Project safety, Project security conduct of maintenance, housekeeping, material condition, and records management.

The program for preparing supporting documentation, meter readings and information necessary to accurately prepare, justify and support monthly invoices in accordance with the terms and conditions of the Project Agreements.

Developing the procedures used to operate the Project as well as monitoring, evaluating, and proposing revisions to such procedures.

The Project operations and monitoring program which provides the requirements for:

- a. Monitoring of Project Performance
- b. Monthly Project Performance Calculations and Report
- c. Monthly Fuel Consumption Calculations and Report
- d. Project Permitting and Environmental Reporting
- e. Shift Routines / Operating Practices
- f. Control of Equipment
- g. Project Chemistry Control and Water Treatment
- h. Training Programs
- i. Operator Qualifications
- j. Operating Procedures
- k. Status of Major Equipment

The maintenance program which provides the requirements for:

- a. Maintenance Planning
- b. Maintenance Procedures
- c. Preventive Maintenance

- d. Predictive Maintenance
- e. Maintenance Training

The materials management program which provides the requirements for:

- a. Procuring Materials and Tools
- b. Inventory Levels and Control
- c. Renewal of Inventories

The diagnostic testing program for maintaining the Project and Project equipment, including both system and component level testing.

The housekeeping / cleanliness program which provides the requirements for:

- a. Hazardous Material Control
- b. General Project Cleanliness
- c. Equipment Condition Inspections
- d. Hazardous Waste Program

The problem assessment program which provides the procedure for determining the cause(s) of operational or equipment failures and preventing future failures through recommended improvements, including justification for such recommendations (i.e., basis of recommendation and economic analysis).

The records management program for maintaining the traceability and documentation of Project performance.

The Project safety program which provides the requirements for establishing:

- a. Safety Monitoring
- b. Accident Prevention Program
- c. Accident Reporting

Monthly and yearly reporting systems of Project performance to Owner.

The security program for maintaining the security of the Project and surrounding area.

18.3 Specific Requirements

Operator's scope of Services is based on the Project design as described in certain of the Project Agreements, the Project Operating Manuals, vendor manuals and design/ as built drawings. Operator will prepare Annual Project Operating Plans, which, in part, will define the operations procedural requirements for the Project to meet the requirements of the Project Agreements. Operator, as part of the Services, is responsible for:

Providing such trained personnel as is reasonably necessary to operate and maintain the Project and provide the Services set forth in this Agreement.

Operating and maintaining the Project in accordance with the approved Annual Project Operating Plan.

Submitting an Annual Project Operating Plan. Not later than ninety (90) days prior to the first day of each Contract Year, Operator will submit an Annual Project Operating Plan to Owner.

The Annual Project Operating Plan will detail maintenance, outage, and overhaul schedules, Project staffing, known capital and expense budget items, operating plans, and will provide the underlying assumptions used in developing the proposed budgets and anticipated availability for the period. Owner will review and approve the Annual Project Operating Plan. Such approval will become the basis for reimbursement under the Annual Budget.

Planning and managing on-site operations and maintenance activities, including:

- a. Assuring that operational goals and operating plans are consistent with the Annual Project Operating Plan.
- b. Assuring that the Project is operated in accordance with this Agreement and in a safe, reliable, efficient, and prudent manner.
- c. Assuring that operations and maintenance personnel are trained and qualified for their assigned responsibilities and tasks, and that such qualification is maintained.
- d. Assuring that the Project meets contract, regulatory, and environmental requirements set forth in the Project Agreements or otherwise identified by Owner or Operator.
- e. Managing and controlling costs consistent with budget requirements.
- f. Planning, scheduling and managing work and maintenance activities.
- g. Defining and documenting operational technical requirements.
- h. Defining and delineating responsibilities between Operator and Owner and identifying reporting requirements.
- i. Establishing labor relations and personnel programs that will meet state federal and provincial requirements and encourage employee retention.
- j. Maintaining a current inventory of materials and procuring all services, spare parts, operational materials, consumables, office equipment, tools and shop equipment, or any other items or materials required to operate or maintain the Project. Operator will identify required items, cost, quantity and need date. The cost of any item or service shall be reimbursed by Owner in accordance with this Agreement.
- k. Controlling outages, both planned and unplanned, by using detailed and integrated plans and schedules, and resource management.
- l. Maintaining Project performance levels by using routine system and component performance testing.
- m. Maintaining a file of pre-planned outage-related work to allow for efficient use of any forced outage downtime.
- n. Establishing open purchase order or contract agreements with Project equipment vendors, industrial suppliers, jobbers, and maintenance CONTRACTORS in accordance with Project Agreements to ensure timely response to Project maintenance needs in compliance with public procurement rules.
- o. Promptly notifying Owner in writing of any tear-downs and overhauls of major equipment or capital improvements that Operator believes are necessary or advisable together with a proposed schedule for completing such repairs or improvements.
- p. Performing such other tasks which Operator deems appropriate, from time to time, in connection with operation of the project.
- q. Performing such other tasks and services which Owner may reasonably request from time to time in connection with operation of the Project.

19.0 EARTHWORKS

19.1 General

The CONTRACTOR shall make excavations and embankments up to required depth, by mechanical means or manual, including trimming and dressing sides to true alignment/ design sections/ profiles and shape levelling of beds to correct level and grade, and dispose off excavated materials all as specified here in, shown on Drawings or ordered by the ENGINEER and referred to herein as earthworks.

Except at paved road crossings, no heavy equipment shall be allowed on top of and within 1.5 m of the existing services, nor shall any material be allowed to be stored within this area. The CONTRACTOR shall exercise all care and take special measures to avoid any damage due to his operations to the existing services. Any harm to the existing services or development of any cracks from it shall be promptly notified to the ENGINEER and immediate control measures shall be taken to prevent loss of water and/ or aggravation of the damage. Necessary repairs shall be carried out as directed by the ENGINEER before proceeding further with the work. Before starting the excavation works, the CONTRACTOR shall arrange, provide and store at site materials and equipment which may be required to deal with any such emergency situation, in consultation with the ENGINEER.

Any damage caused to the existing services or structures due to CONTRACTOR's negligence shall be remedied and made good at no cost to the EMPLOYER.

19.2 Notice of Earthworks

Before commencing any earthworks on the Site, by machinery or manual work, the CONTRACTOR shall give the ENGINEER at least 7 days written notice of the proposed date, which shall not be less than 7 days after the appropriate part of the site has been cleared. Within this period the CONTRACTOR shall make a record of the ground levels and topography to the satisfaction of the ENGINEER for the measurement of the Works.

19.3 Ground Level

The actual ground levels will be recorded jointly with the ENGINEER after clearance of site as per Clause 2.4.

19.3.1 Disposal of excavated material

Any excavated material from previous construction work if disposed near the existing or proposed works shall be removed by the CONTRACTOR and shall be disposed of outside the limit of works as provided for in clause 19.16 hereof. Cost of this work shall be deemed to have been included in the quoted rates.

19.4 Excavation of Unsound Material

If any unsound material occurs in the bottom of any excavation, or on the foundation to an embankment, the CONTRACTOR shall remove it and dispose of it to the satisfaction of the ENGINEER. The CONTRACTOR shall fill the voids so formed with concrete Class E or suitable granular material as directed by the ENGINEER.

If the CONTRACTOR encounters material which to his opinion may be unsound, he shall immediately inform the ENGINEER, who will instruct the CONTRACTOR in writing as to whether the said material shall be treated as unsound, provided that the ENGINEER will give

no such instruction except in accordance with Conditions of Contract. The omission by the ENGINEER to give an instruction shall not relieve the CONTRACTOR from any responsibility for defects in the work, if, prior to construction, the CONTRACTOR shall have failed to request the ENGINEER in writing to inspect the exposed foundation.

19.5 Safety of Excavation and Adjacent Structures

The CONTRACTOR shall provide support necessary to ensure the stability of the excavation and any existing underground services and utility lines.

Unless otherwise approved (e.g. when both foundations are in sound rock), where separate excavations are made to different depths for parts of the works close to each other, whether concurrently or not, then the foundation of the one shall be deepened and filled with concrete Class “E” or the backfill to the other made with concrete Class “E”, whichever shall be constructed first, such that foundation pressure stress lines drawn at 40 degrees to the horizontal lie either entirely in undisturbed ground or in concrete Class “E” or better.

19.5.1 Field Test of soil samples

If in the opinion of ENGINEER the soil encountered at the base level is considered unsound, the ENGINEER may order for taking out samples and carry out field test as per AASHTO T-180 (modified).

19.6 Slips, Falls and Excess Excavation

The CONTRACTOR shall prevent slips and falls of material from the sides of the excavation and embankments.

In the event of slips or falls occurring in the excavations, and where excavations are made in excess of the dimensions of the permanent works, the voids so formed shall be filled by the CONTRACTOR. When such voids, in the opinion of the ENGINEER, may affect the stability of the ground for the support of the works, or of the adjacent structures and services, the CONTRACTOR shall fill the void solid with concrete Class “E”. In other cases the CONTRACTOR shall fill the voids with selected excavated material placed and compacted to the approval of the ENGINEER. This shall be at no extra cost to the EMPLOYER.

CONTRACTOR shall exercise due diligence and care and shall ensure that excavation is precisely carried out to indicated trench levels.

Particular care shall be exercised by the CONTRACTOR to ensure that over excavation beyond specified levels is not carried out. In case of over excavation the volume excavated shall be replaced by Concrete of Class “E” at his cost. Filling of voids due to over excavation shall be in accordance with para 4.4 hereof.

19.7 Dewatering

The CONTRACTOR shall keep each structure and excavation clear of water during construction and, in the case of structures being constructed in saline groundwater for such further period as may be necessary to avoid the submersion of concrete within 3 days of its being placed. The method of keeping excavations clear of water, dewatering, and disposal of water, shall be subject to the approval of the ENGINEER. The CONTRACTOR shall ensure that sufficient standby plant is on Site at all times to avoid any interruption in continuity of the dewatering. In the vicinity of the existing water mains and other structures, dewatering shall be carried out by establishing well points, lowering of the groundwater level to below the

required excavation level and maintaining the same till the pipes are laid or the concrete is cast and is minimum 3 days old.

The well points for dewatering shall be located at safe distance from the foundation of existing pipe lines or other structures to avoid any settlement or other damage to the same.

The CONTRACTOR shall submit his dewatering plan with details of equipment, for approval of the ENGINEER minimum 15 days in advance of excavation work.

19.8 Preparation of Formations for Structures

All excavation within 600mm of existing structures shall be carried out very carefully by hand. Where the formation of any excavation, being other than rock, is to support the foundations or floor of a structure, a depth of 150 mm above the bottom of trench level, shall be carefully excavated and trimmed immediately before placing the permanent work upon it. Formation in granular material shall be compacted using suitable type compactors. Foundation of associated structures shall be compacted to 95% of the modified proctor density determined in accordance with AASHTO T-180 (D) while for other structures to the density of adjacent ground.

19.9 Backfill and Fill

Unless otherwise specified or approved the material used for backfill and fill shall be material selected from the excavated material of particle size not exceeding 100 mm.

Backfilling against the permanent work shall be selected, and free from boulders, cobbles, rock fragments and the like greater than 50 mm nominal size, unless otherwise specified or approved.

After approval has been given by the ENGINEER in accordance with the contract for filling or backfilling to commence, the operation shall start with the minimum delay and shall continue until the work is completed in the part of the Works for which the approval is given.

Unless otherwise specified, CONTRACTOR at all times must ensure that due to fill, backfill or for any other reason, the soil depth does not exceed 1 m over any existing conduit at any location.

19.10 Scarification

The CONTRACTOR shall scarify to a depth of 150 mm the ground upon which compaction of fill is specified. He shall ensure that no vegetation remains in the area to be covered by the Works, and shall if necessary bring the moisture content of the specified surface material to its optimum value before placing and compacting any fill thereon.

The CONTRACTOR shall similarly treat the surface of any fill which in the opinion of the ENGINEER has been exposed too long before the placing of subsequent fill thereon.

19.11 Compaction of Fill and Backfill

Unless otherwise specified or shown on the drawing, the CONTRACTOR shall deposit fill or backfill in layers of uniform depth not exceeding 150 mm thick and shall compact it by methods and with the use of such Constructional Plant as are necessary to achieve the degree of compaction specified. The layers shall have a slight cross-fall away from the

permanent work. Where no degree of compaction is specified the fill or backfill shall be compacted by the even distribution over it of the passage of earthmoving plant and labour.

Where the degree of compaction is expressed as a percentage, it is the percent ratio of the dry density of the compacted material to the maximum dry density as determined by the modified compaction test (AASHTO T-180 Method D-modified). At least one month before commencing such compaction of the fill in the Works, the CONTRACTOR shall submit to the ENGINEER details of the method and Constructional Plant proposed to be used, and shall make such tests of the materials before and after compaction as the ENGINEER considers necessary, both of the trials and of the permanent work, to ascertain to his satisfaction that the degree of compaction specified is achieved. The modified compaction requirement will be 95% of Maximum Dry Density unless otherwise specified or shown on the drawing. All testing shall be in accordance with AASHTO T-191 and according to Modified Proctor Test.

The CONTRACTOR shall if necessary wet the fill material prior to and during compaction so that its moisture content lies within a range of values suitable for the fill material and the adopted method of compaction as may be established by prior trials on Site.

19.12 Hardcore Filling

Hardcore shall be clean, broken stone that will pass in all directions through a 100 mm ring. Hardcore shall be well packed and compacted to a CBR value of at least 25% as measured in accordance with AASHTO T-193. Sand may be added to hardcore to achieve this degree of compaction.

19.13 Allowance for Settlement

The CONTRACTOR shall make due allowance for consolidation and settlement of fill and compacted fill such that the levels and dimensions of the finished surfaces at the end of the Period of Maintenance are not less than those specified, shown on Drawings or ordered by the ENGINEER.

19.14 Location of Borrow Pits

The CONTRACTOR shall select and obtain permission of owner of sites of borrow Pits from outside the Site all subject to the written approval of the ENGINEER.

Borrow pits from these areas shall be subject to the written approval of the owner or concerned local authority.

19.15 Works at Borrow Pits

The CONTRACTOR shall excavate at the site of borrow pits to expose the material required for fill and shall select and excavate the said material. After the required amount of material has been excavated from each borrow pit, the CONTRACTOR shall reinstate its site by spreading the previously removed superficial materials in layers not exceeding 0.25 m deep over the area of the excavation and by grading and trimming the surfaces all to the satisfaction of the ENGINEER. Where practicable such grading shall be made to prevent accumulation of surface water.

The CONTRACTOR shall prepare and submit in detail for the approval of the ENGINEER his proposal for the use of borrow pits and shall give notice to the ENGINEER in writing at least one month before the proposed date of starting earthworks at the site of each borrow pit.

Where water table is encountered most of the material from borrow areas may have to be excavated from below the water table. The CONTRACTOR must include for this in his rates and allow suitable drainage periods before the material can be reworked to form embankments.

19.16 Disposal of Surplus Material

Surplus material will be disposed of away from site as directed by the ENGINEER. All surplus rock shall be disposed of to designated locations as directed by the ENGINEER, and be considered the property of the EMPLOYER. The CONTRACTOR shall prepare and submit his proposals for disposal of surplus excavated materials giving details of disposal sites and approximate quantities. The CONTRACTOR shall be responsible to obtain permission from owners of disposal sites and pay costs thereof.

19.17 Surplus Material Dumps

Unless otherwise approved, soil dumps shall on completion, be graded to slight crossfalls and even side slopes, the maximum height of such dumps shall be 2 m.

19.18 Construction Methods

Excavation shall be carried out using only suitable excavation equipment of such types and in such numbers as is appropriate to a contract of the scale and complexity of this Contract, all subject to the approval of the ENGINEER. The heavy earthmoving equipment shall not be brought within a distance of 1.5 meter from the face of any existing structure and no equipment shall be allowed over the roof of any existing structure/ conduit. Full details of the CONTRACTOR's proposed method of working and earth moving plant shall be provided in accordance with the instructions for bidding.

19.19 Excavation and Disposal

Material excavated for the construction may be placed alongside, if suitable, for use in back fill. Excess material over and above that required shall be re used in other areas or disposed of in spoil embankments off site as directed by the ENGINEER and in accordance with Clause 4.16 above.

The CONTRACTOR shall prepare in advance a plan of earthworks operation for each particular part of the Works to be constructed at any one time, detailing the location and programme of excavation and of placing the spoil in banks etc. The CONTRACTOR shall submit his proposed plan at least 28 days before his intended date to commence earthworks on each particular part of the system for ENGINEER's approval.

19.20 Rock

Before commencement of excavation in rock the CONTRACTOR shall demonstrate to the satisfaction of the ENGINEER his inability to excavate without resort to heavy percussion tools complete with rock bits, or hydraulic wedges. Where reasonable progress can be made with the aid of ripping tools the material will not be considered to be rock. The decision of the ENGINEER about the material to be excavated being rock or not shall be final & binding.

Use of jack hammers, and vibratory tools in proximity of existing structures shall not be allowed. No blasting is permitted within the limits of site.

Prior to the commencement of the excavation of any material which the CONTRACTOR considers may be rock, the CONTRACTOR shall advise the ENGINEER of the presence of

such material and the said material shall not be classified as rock unless the ENGINEER has agreed to such classification before excavation commences. The ENGINEER's agreement shall be subject to reservations on the extent of the rock so classified and the extent of the rock excavation shall be determined after examination of the excavated faces. Excavations where rock has been encountered and classified as such shall not be backfilled before examination of the excavated faces by the ENGINEER to enable the extent of the rock excavation to be determined.

19.21 Rubble and Loose Rock

Where stone pitching rip-rap or scour protection and rockfill vehicle barriers on existing conduit and structures are to be removed, the stones shall be stockpiled outside the work area for later use in the same works. Additional quantities of stone and granular filter layer shall be provided by the CONTRACTOR to complete the work as shown on Drawings.

Where backfill or fill is shown as "rubble" or "loose rock", for example for soakaways from septic tanks, the material shall consist of durable gravel, broken stone or crushed concrete with a particle size not exceeding 100 mm. The grading of the material shall be such that there is no migration of fines into the fill and not more than 10% of material shall pass a BS sieve with 5 mm apertures.

The method of placing shall be to the approval of the ENGINEER and shall ensure that fines separating out during transportation are discarded or selectively placed.

There shall be no compaction or working of the material except that necessary to give a stable fill.

Before covering rubble or loose rock with other fill the surface shall be blinded with a layer of selected fill that closes the surface voids only. The initial layer of covering fill shall not be watered.

19.22 Excavation by Blasting

In view of the alignment in proximity to inhabited areas, the excavation by blasting may not be permitted by the ENGINEER. In the event of the use of explosives is permitted, the safety of existing services and structures shall be guaranteed by the CONTRACTOR. The CONTRACTOR shall comply with the requirements, and give at least 48 hours notice of blasting to all relevant authorities and the ENGINEER.

The CONTRACTOR shall be solely responsible for obtaining a license to obtain, store & use of explosives.

However, excavation by blasting with explosives is not allowed nor any blasting within 20 m of any existing service(s) or any other structure.

19.23 Storage of Explosives

Explosives shall be stored in appropriate magazines clear of the Works. Detonators shall be stored separately from explosives. The CONTRACTOR shall appoint a responsible person to the approval of the ENGINEER and the Police Authorities, to be in charge of storing and issuing of explosives. The CONTRACTOR shall employ only experienced and responsible men to handle explosives for blasting purposes.

19.24 Earthwork: Measurement and Payments

All excavation and backfilling in Common Material or rock, to be paid for shall be the number of cubic meters of materials measured in its original position computed by average end-area method and excavated to the satisfaction of the ENGINEER. The pay line for structural excavation shall be as shown on drawings, having no side slopes.

Measurement for excavation shall not include material removed below the formation level and beyond specified pay-line, as described above or shown on drawings, as a result of anticipated swell, additional materials resulting from sliding, slips, caves-ins, silting or filling, whether due to the action of the elements or the carelessness of the CONTRACTOR.

No separate measurements for payment will be made inter alia for site clearance, removal of bush, trees, debri, solid waste etc. making records of ground levels and topography, supporting excavations, making good slips, falls and excess excavation, making benching for excavations in greater depth, working space beyond pay-line, trimming surface of excavations for structure and embankments (other than pavements), making allowance for settlements, special compaction trials, control of moisture contents, preparation and restoration of borrow pits, scarification, location and shaping of disposal heaps and embankments, trenches for pipes and cable within a structure, supplying samples and testing for the ENGINEER evaluation, interruptions and delays whilst carrying out tests.

The quantities determined shall be paid for at the contract unit price respectively for each of the particular pay item shown in the Bill of Quantities, which price and payment shall be the full compensation for all the costs involved in the proper completion of the work prescribed in that particular item.

19.25 References

Following publications have been referred:

1. AASHTO T-180: Standard Method of Test for Moisture-Density Relations of Soils
2. AASHTO T-191: Standard Method of Test for Density of Soil In-Place by the Sand- Cone Method
3. AASHTO T-193: Standard Method of Test for Determining California Bearing Ratio

20.0 CONCRETE & REINFORCEMENT

Design of the reinforced concrete structures has been carried out in accordance with ACI 315, ACI 318, ACI 350, UBC & ASCE (7-10). Construction of reinforced and water retaining structures is therefore to be carried out generally in accordance with the relevant provisions of ACI Code. The specific requirements made in this Chapter take precedence over those specified above.

20.1 Cement

20.1.1 General

Unless otherwise specified the cement used in the Superstructure Works shall be Ordinary Portland Cement (OPC) complying with ASTM C 150 (Type I) or BS 12 and whereas, in the Substructure Works, and where specified and/ or ordered, Sulphate Resisting Cement (SRC) complying with ASTM C 150 (Type V) or BS 4027, at the time of use. For the purpose of BS 12, the Site shall be deemed to be in a tropical climate. The CONTRACTOR shall supply the manufacturer's test certificate for each consignment of cement received at the Site as provided for in Section 15 of ASTM C 150 or Clause 10 of BS 12. He shall maintain a record available for inspection by the ENGINEER of the locations of concrete from each consignment.

Where specified or ordered sulphate resisting cement (SRC) complying with ASTM C 150 (Type V) or BS 4027, shall be used in place of OPC.

The CONTRACTOR shall supply samples of cement, when requested by the ENGINEER's Representative, both from any store on Site and the place of manufacture.

These specifications cover five types of Portland cement, as follows:

Table 20-1: Types of Portland cement

No	Applicable Specifications		Application
	ASTM	BS	
a.	C150 (Type I)	BS 12	Ordinary Portland Cement: For use in general concrete construction when the special properties specified for Type II, III, IV and V are not required.
b.	C150 (Type II)	BS 1370	Moderate Heat Portland Cement: For use in general concrete construction exposed to moderate sulfate action, or when moderate heat of hydration is required.
c.	C150 (Type III)	BS 12	Rapid Hardening Portland Cement: For use when high early strength is required.
d.	C150 (Type IV)	BS 1370	Low Heat Portland Cement: For use when low heat of hydration is required.
e.	C150 (Type V)	BS 4027	Sulfate Resisting Portland Cement: For use when high sulfate resistance is required.

20.1.2 Packing and Marking

- a. Cement shall be furnished in sacks or in bulk form, as approved by the Engineer.
- b. Cement in sacks shall be delivered in strong, well made, paper or cloth bags, each plainly marked with the manufacturer's name, brand, type of cement and the weight of cement contained therein, except that, in the case of Type-I cement, the type need not be identified.
- c. A bag shall contain 50 Kg. net.
- d. When the cement is delivered in bulk; this information shall be contained in the shipping invoice, accompanying the shipment.

20.1.3 Inspection

The Contractor shall facilitate the Engineer, in all respects, for careful sampling and inspection, either at the mill or at the site of work, as may be specified by the Engineer. The following periods, in days, from the time of sampling shall be allowed for completion of testing.

- | | |
|----------------|----|
| a. 1-day test | 6 |
| b. 3-day test | 8 |
| c. 7-day test | 12 |
| d. 28-day test | 33 |

20.1.4 Rejection

- a. Cement may be rejected if it fails to meet any of the requirements of these specifications.
- b. Cement remaining in bulk storage at the mill, prior to shipment, for a period greater than six months after completion to the tests, may be tested and may be rejected if it fails to conform to any of the requirements of these specifications.
- c. Packages varying more than 3% from the weight marked thereon may be rejected and if the average weight of packages in any consignment as determined by weighing fifty packages taken at random, is less than that marked on the packages, the entire consignment may be rejected.
- d. Packages received in broken or damaged condition shall be rejected or may be accepted only as fractional packages as determined by the Engineer.
- e. Cement that is found to be adversely affected by moisture, as determined by the Engineer, shall be rejected.

20.1.5 Method of Sampling and Testing

- a. The sampling and testing of Portland cement shall be in accordance with relevant BS or ASTM standard specifications.
- b. Contractor shall carry out all tests on Portland cement, at his own cost, if required by the Engineer.

20.1.6 Transportation of Cement

Transportation of the cement from the mill to the site stores and to the point of use shall be accomplished in such a manner that the cement is completely protected from exposure to moisture.

20.1.7 Storage

- a. Cement shall be stored in dry, weather tight and properly ventilated structures. All storage facilities shall be subject to approval and shall be such as to permit easy access for inspection and identification of each consignment.
- b. The sacks should be stacked closely on a damp proof floor or on timber planks, raised by a minimum of 12" (300 mm), from the ground, with air space below. There should be similar air space between the stacks and walls.
- c. To avoid bursting of bags and setting under pressure, the height of the stacks shall be limited 8 bags.
- d. Adequate storage capacity shall be furnished to provide sufficient cement to meet the peak needs of the project.
- e. Cement storage facilities shall be emptied and cleaned by the Contractor when so directed, however, the interval between required cleaning normally will not be less than four months.

20.1.8 Usage

- a. The Contractor shall use cement in the approximate chronological order in which it is received at the site. All empty sacks shall be promptly disposed off as approved by the Engineer.
- b. No cement stored through a monsoon, or for a period of more than six months, should be used, unless tests have been applied and cement found up to the requisite standard.
- c. Suitable, accurate scales shall be provided by the Contractor for weighing the cement in stores and elsewhere on the work, if required, and he shall also furnish all necessary test weights.

20.1.9 Delivery and Usage Record:

Accurate records of delivery of cement and its use in the works shall be kept by the Contractor. Copies of these records shall be supplied to the Engineer in such a form as he may require.

20.2 Aggregates

Aggregates for concrete shall comply with ASTM C-33, Specification for Concrete Aggregates.

Fine aggregate shall consist of natural sand. The Contractor shall obtain concrete aggregate from deposits of natural sand and gravel or shall procure crushed aggregate from approved quarries, which produce aggregates meeting with the Specifications contained herein. The ENGINEER will permit the addition of suitable crushed rock fine aggregate, as necessary, to the sand where in his opinion it is impracticable to obtain the specified grading of the combined aggregate, otherwise than by such addition. The maximum quantities of clay, silt and Fine dust shall, in any event, not exceed 3 % by weight when tested in accordance with ASTM C-117. Fineness modulus shall range between 1.9 and 2.78. The sand equivalent value, as determined by ASTM Designation D 2419, "Standard Test Method for Sand Equivalence Value of Soils and Fine Aggregate", shall not be less than 75.

The grading of fine aggregate shall conform to the following requirements:

Table 20-2: Grading requirement of Fine aggregate.

U.S. Standard Sieve Mesh	Percent Passing
0.375" (9.50 mm)	100
No.4 (4.75 mm)	95-100
No.8 (2.37 mm)	80-100
No.16 (1.18 mm)	50-85
No.30 (0.60 mm)	25-60
No.50 (0.30 mm)	5-30
No.100 (0.15 mm)	0-10

The grading of the coarse aggregate, within the separated size groups, shall conform to the following requirements:

Table 20-3: Grading requirement of the coarse aggregate.

US Standard Sieve Size (Nominal Size)	Percent Passing by Weight Finer than Each Laboratory Sieve (Single Size Aggregate)			
	10 mm	20 mm	25 mm	40 mm
2.00" (50.00 mm)	-	-	-	100
1.50" (37.50 mm)	-	-	100	90-100
1.00" (25.00 mm)	-	100	90-100	20-55
0.75" (19.00 mm)	-	90-100	20-55	0-15
0.50" (12.50 mm)	100	20-55	0-10	-
0.375" (9.50 mm)	85-100	0-15	0-5	0-5
No. 4 (4.75 mm)	10-30	0-5	-	-
No. 8 (2.37 mm)	0-10	-	-	-
No. 16 (1.18 mm)	0-5	-	-	-

20.2.1 Coarse Aggregate Shape:

- A flat particle is one having a ratio of width to thickness greater than three. An elongated particle is one having a ratio of length to width greater than three.
- The shape of the particles shall generally be spherical or cubical.
- The quantity of flat and elongated particles, in the separated size groups of coarse aggregate, as defined and determined by standard tests, approved by the Engineer, shall not exceed 15% by weight in any size group.

The 10% fine value shall be greater than 50 kN.

The aggregates shall be such that concrete when made and tested in accordance with Building Research Establishment Digest 35 (2nd series) shall not show a drying shrinkage greater than 0.065%.

The water absorption of aggregates to be used for Class A concrete shall not exceed 3 %.

The soundness of the aggregate, as determined in accordance with ASTM C 88 using magnesium sulphate with 5 cycles, shall not show a loss of greater than 15% for fine aggregate and 18% for coarse aggregate.

Immediately after commencement of the Works, the CONTRACTOR shall supply samples of proposed aggregates for preliminary tests of compliance with the Specification to the satisfaction of the ENGINEER before the ENGINEER will give approval to the source of aggregates proposed by the CONTRACTOR. Alternatively, and subject to the approval of the circumstances by the ENGINEER, the CONTRACTOR may submit a Certificate from an independent laboratory acceptable to the ENGINEER.

Where 40 mm nominal maximum size coarse aggregate is specified it shall consist of a mix of 40 mm single sized aggregate, 20 mm single sized aggregate and 10 mm single sized aggregate.

During the performance of the Contract, the CONTRACTOR shall supply samples of aggregates when required by the ENGINEER for testing. Testing of all specified requirements will be performed weekly for each source at each grading approved by the ENGINEER, unless otherwise instructed by the ENGINEER.

Any rejected aggregate shall be removed from Site within 3 days.

To determine the potential reactivity of the aggregate and the cement aggregate combinations, the CONTRACTOR shall carry out tests in accordance with ASTM C 227 and ASTM C 289.

Should the results of the tests prove unsatisfactory the CONTRACTOR shall make provision for the employment of a low alkali content cement to the approval of the ENGINEER.

20.2.2 Storage

- a. Aggregate shall be stored, at the site, in such a manner as to prevent its deterioration or the inclusion of foreign matter.
- b. Aggregate, which has deteriorated or which has been contaminated, shall not be used for concrete.
- c. All methods employed by the Contractor for loading, unloading, handling and stock-piling aggregates shall be subject to the approval of the Engineer, at all times.
- d. Sufficient aggregate shall be maintained at the site, at all times, to assure continuous placement and completion of any lift of concrete started.

20.3 Water

The water used for making and curing concrete shall generally be of drinking water quality and shall be from a source approved by the ENGINEER and at the time of use shall be free from polluting matter in any quantity which. The water shall conform to the requirements of ASTM C1602, as to its suitability, for construction.

- a) affects the initial setting time of the cement by more than 30 minutes or reduces the compressive strength of test cubes by more than 20%.
- b) prevents the achievement of the specified test cube strengths at 28 days for the appropriate class of concrete.
- c) produces discoloration or efflorescence on the surface of the hardened concrete.

The water shall be free from hydrocarbons and from suspended organic matter. Inorganic matter in solution shall not exceed 500 mg/l by weight and in suspension shall not exceed 50 mg/l by weight.

The water which the CONTRACTOR proposes shall be tested to the approval of the ENGINEER before use in the permanent works.

Regular tests of the water shall be made during construction of the Works. The water shall be sampled at the point of discharge into the mix and the frequency of sampling shall be as approved by the ENGINEER. The CONTRACTOR shall supply two copies of each test result to ENGINEER's Representative.

20.4 Admixtures

Concrete shall be made from cement, aggregates and water as specified. No other ingredient shall be mixed with the concrete or mortar without the ENGINEER's approval.

If the CONTRACTOR proposes to use retarding or workability agents in accordance with ASTM C-494, then the manufacturer's literature must be supplied giving typical dosage, effects of incorrect dosage, the amount of air entrainment associated with its use. The ENGINEER's approval to the use of admixtures shall be subject to the following conditions:

- a) Under no circumstances calcium chloride or chloride based admixtures be used in any concrete mix, grout or mortar.
- b) No reduction of target mean strength compared with additive-free concrete of the same class.
- c) No change in specified cement or effective water cement ratio.
- d) No corrosive effect on reinforcement steel.
- e) Dosage and admixture strictly in accordance with the manufacturer's instruction in respect of the specific conditions obtaining. Dosage to be by approved dispenser, to within 3% of the required amount.

If air entrainment is approved the air content shall be 4% for concrete with a maximum aggregate size of 40mm and 5% of concrete with maximum aggregate size of 20mm, an allowable tolerance of $\pm 1.5\%$.

The method of determining the air content shall be in accordance with ASTM C-231 and the CONTRACTOR shall supply the necessary apparatus so that the ENGINEER may check the air content. If the average air content is greater or less than that specified or the range is greater than 2%, before any further concrete is used in the Works the CONTRACTOR shall take such steps as may be agreed with the ENGINEER to adjust the air content of the concrete or improve its uniformity.

20.5 Chemicals in Concrete Materials

The total sulphate content, whether as gypsum or more soluble salts, of concrete ingredients when measured as sulphur trioxide shall together not exceed 4.0% of the weight of cement in the concrete.

The chloride content of concrete ingredients when measured as Cl shall together not exceed 0.3 % of the weight of cement in concrete using OPC cement and 0.06% of the weight of cement in concrete using SRC.

The sulphate and chloride contents shall be established using the following tests:

Table 20-4: Tests for establishing sulphate and chloride content.

	Sulphate	Chloride
Aggregate	BS 1377, Test 9	ASTM C-1524
Cement	ASTM C-114	ASTM C-114
Water	ASTM D-516	ASTM D-512

The contribution of any admixture must also be included. Testing will be weekly, or as directed by the ENGINEER. When the acid soluble alkali content of the cement is greater than 0.6% (calculated as $\text{Na}_2\text{O} + 0.658 \text{ K}_2\text{O}$) the CONTRACTOR must demonstrate that no adverse alkali-silica reaction is likely. Any concrete containing less than 3.0 kg/m^3 may be considered not at risk. In the event of higher alkali contents a sample of aggregate from each source must be tested in accordance with ASTM C 227. Any aggregate source showing an expansion greater than 0.05% at 3 months shall not be approved.

20.6 Reinforcement

Reinforcement shall be Type 2 deformed bars, either hot rolled high yield steel to ASTM A-615 or cold worked steel to BS 4449.

The CONTRACTOR shall supply the ENGINEER's Representative with certificates of the manufacturer issued in accordance with relevant international standards, for all the required tests including the re-bend test in respect of each consignment delivered to Site.

Steel fabric reinforcement shall comply with BS 4483.

The reinforcement at the time of incorporation in the Permanent Works shall be clean and free from damage, oil or grease, loose mill scale and loose rust. Bars which have become bent shall not be straightened or reheat for incorporation in the Works without the approval of the ENGINEER.

Steel reinforcement shall be stored clear of the ground and supported to prevent distortion. The Contractor shall provide all measuring and testing facilities to ascertain quality, weight and quantity of steel, at his own expense, if so directed by the Engineer, in presence of ENGINEER's Representative at a laboratory approved by the ENGINEER.

20.7 Reinforcement Details

The CONTRACTOR shall ascertain for himself from the information given on the Drawings and in the Specification the precise requirements of steel reinforcement to be obtained for the Permanent Works. The CONTRACTOR shall prepare bending schedules and submit them to the ENGINEER at least 28 days prior to fixing the respective reinforcement.

All concrete other than that described on the Drawings or in the Bill of Quantities as mass, blinding or screed, shall be assumed to be reinforced.

20.8 Bituminous Paint

Bituminous paint shall comply with BS 3416, Type 11 for materials in contact with raw or treated water and Type I for all other cases.

Prior to application of the bituminous paint the concrete faces must be clean and dry. A minimum of two coats of paint shall be applied and each coating shall be a dry film mass of $35 \pm 5 \text{ g/m}^2$ after 48 hours drying.

20.9 Classes of Concrete

The class of concrete is defined by the characteristic cube crushing strength and the nominal maximum aggregate size, with additional suffix defining any additional requirements. The requirements for each class of concrete are given in Table 20-8.

The main classes of concrete used will be as follows:

Table 20-5: Main classes of concrete.

Location	Class
Structural	A
Structural	A (1)
Structural / Plain Concrete	B
Structural / Plain Concrete	B (1)
Blinding Concrete	E
Blinding Concrete	E (1)

Table 20-6: The requirements for each class of concrete.

Concrete class	Maximum Aggregate Size (mm)	Cement type	Workability*
Class "A"	20	OPC	Medium / High
Class "A (1)"	20	SRC	Medium / High
Class "B"	20	OPC	Medium
Class "B (1)"	20	SRC	Medium
Class "E"	20	OPC	-
Class "E (1)"	20	SRC	-

Note: - *High workability : slump 65 to 135 mm
Medium workability: slump 50 to 100 mm

Quoted slump values are a guide only and may be varied subject to the approval of the ENGINEER.

The concrete class is defined as the 28 day cube crushing strength (psi) below which no more than 5% of results are expected to fall.

Except where otherwise specified herein, the mix design, concrete ingredients, manufacture, testing and workmanship shall conform to the requirements of relevant sections of ACI & ASTM.

Adjustments to the concrete mix proportions shall be made during the contract if in the opinion of the ENGINEER, such adjustments are necessary. The CONTRACTOR shall neither alter the mix proportions nor the source of supply of any of the ingredients without prior approval of the ENGINEER.

20.10 Concrete Mix Design

The CONTRACTOR shall determine to the approval of the ENGINEER the actual proportions of ingredients for each class of concrete to be used to the Permanent Works.

The concrete shall meet the requirements given in Table 20-9.

Table 20-7: Requirements of Classes of Concrete.

Class	Cement content (kg/m ³)		Maximum W/C ratio	Cylinder Crushing Strengths Kg/cm ² (Psi)	
	Minimum	Maximum		Design	Working
Class "A"	360	440	0.50	386 (5500)	316 (4500)
Class "A(1)"	420	460	0.48	386 (5500)	316 (4500)
Class "B"	300	380	0.58	275 (3900)	225 (3200)
Class "B (1)"	320	400	0.52	275 (3900)	225 (3200)
Class "E"	240	-	0.70	140 (2000)	123 (1750)
Class "E(1)"	300	-	0.70	140 (2000)	123 (1750)

Water/cement (W/C) ratio is the ratio of weight of free water to cement in the mix based on aggregates being in a saturated surface dry condition.

Unless otherwise specified or agreed by the ENGINEER for concrete Class "A" & "A(1)" the proportions of coarse and fine aggregates shall be selected to achieve one of the grading curves defined in Table 5-10, within an allowable tolerance of generally 5%. A change from a maximum positive tolerance to a maximum negative tolerance in consecutive sieve sizes should be avoided.

The CONTRACTOR shall submit details of the source of all material and the proposed quantities of each ingredient per cubic meter of fully compacted concrete. The CONTRACTOR shall then make trial mixes for each class of concrete using the same type of Constructional Plant and the same materials as are proposed for the Permanent Works. The CONTRACTOR shall give 24 hours notice of such trials to enable the ENGINEER's Representative to attend. For each trial mix, three separate batches of concrete shall be made by the CONTRACTOR and will be tested at 28 days all in accordance with BS 1881. Such trial mixes shall not be the first batch through the plant in any one sequence of concrete production.

The CONTRACTOR shall not commence concreting in the Permanent Works until details of trial mixes and test results for each class of concrete have been submitted to, and approved by, the ENGINEER.

A trial mix design will be approved by the ENGINEER with respect to strength if the average compressive strength of the nine cubes so tested is more than the design strength appropriate to the class as given in Table 5-9.

For concrete Class "A" & "A(1)", the CONTRACTOR shall cast sample wall panels in two phases. In the first, three different mixes from adjacent aggregate grading curve zones shall be cast into wall panels. When the CONTRACTOR has demonstrated that the mix from the middle of the three grading zones is the most practical mix he shall proceed with phase two on the basis of this preferred mix. In the second phase two batches, mixed 48 hours apart, utilizing the preferred mix, shall be cast in two equal lifts to form a wall panel having one horizontal construction joint formed to the manner proposed by the CONTRACTOR for the

Works. The top surface of the second lift shall have a Type U3 finish. The panels shall not be touched up after stripping.

The panels shall be 300 mm thick and 1.5 m long by 1.5 m high. The CONTRACTOR shall not commence concreting to the Permanent Works until the test panels have been approved by the ENGINEER.

The CONTRACTOR shall not alter the approved mix proportions nor the approved source of supply of any of the ingredients without having previously obtained the approval of the ENGINEER.

During production the ENGINEER may require trial mixes to be made before a substantial change is made to the materials or in the proportions of the materials to be used.

20.10.1 Concrete Exposed to Sulphate Attack

Before commencing any concreting on Site the CONTRACTOR shall conduct tests to the satisfaction of the ENGINEER to determine the concentration of sulphate in the soil and groundwater in order to determine the concrete exposure class.

The CONTRACTOR shall ensure that all concrete susceptible to sulphate attack shall be designed to satisfy the additional requirements for the particular exposure class. This shall be taken to include all concrete from below finished ground level up to 1.0m above finished ground level.

SRPC cement shall be used for following concentration of sulphates in soil and ground water if approved by the ENGINEER.

- a) In soil : 0.2% or more
- b) In groundwater : 0.3 g/l or more
- c) In 2:1 water
Soil extract : 1.0 g/l or more

**Table 20-8: Combined Aggregate Gradings:
a) 40 mm maximum aggregate size grading curves**

Sieve size (mm)	1	2	3	4
50	100	100	100	100
37.5	95	97	99	100
20	50	59	67	75
10	36	44	52	60
5	24	32	40	47
2.36	18	25	31	38
1.18	12	18	24	30
0.60	7	12	17	23
0.30	3	7	11	15
0.15	0	0	2	5

b) 20 mm maximum aggregate size grading curves

Sieve size (mm)	1	2	3	4
37.5	100	100	100	100
20	95	97	99	100
10	45	55	65	75
5	30	35	42	48
2.36	23	28	35	42
1.18	16	21	28	34
0.60	9	14	21	27
0.30	2	3	5	12
0.15	0	0	0	1.5

c) 10 mm maximum aggregate size grading curves

Sieve size (mm)	1	2	3	4
10	95	97	99	100
5	30	45	60	75
2.36	20	33	46	60
1.18	16	26	37	46
0.60	12	19	28	34
0.30	4	8	14	20
0.15	0	1	3	6

20.11 Storage of Materials

The CONTRACTOR's arrangements for storing and handling the materials for concrete shall be to the approval of the ENGINEER. Such arrangements shall be directed towards preventing the deterioration or adulteration of the various materials or segregation of the ingredients thereof.

20.12 Control and Mixing of Ingredients

The CONTRACTOR shall measure the moisture content in the aggregates and so determine the amount of water to be added to each batch of fresh concrete. Such determinations shall be to the approval of the ENGINEER and the results and calculations shall be available for inspection by him. The frequency of such determinations shall be as directed by the ENGINEER and shall depend on the quality of control of storage and handling, weather conditions and variability of aggregate supplied.

The CONTRACTOR shall proportion the ingredients of each batch of concrete by weight. The measuring equipment should give an accuracy of $\pm 3\%$ for each ingredient. The water shall be added to the aggregates and cement in a mechanical batch mixer; it shall not exceed the maximum ratio with regard to cement given in Table 5-9 hereof, and shall otherwise be the minimum amount necessary consistent with complete compaction. The device for measuring the water shall show accurately the weight required with a given moisture content of the aggregate and shall be so designed that the water supply will be automatically stopped when the correct quantity has been discharged into the mix. The concrete ingredients shall then be thoroughly mixed.

The minimum mixing time shall be:

- (i) For mixes of 1.5 m³ Capacity or less - 1½ minutes.

- (ii) For mixes of larger capacity than 1.5 m³ the time shall be increased by 15 seconds for each additional 0.75 m³ capacity. For intermediate sizes the time shall be assessed by proportion.

In special circumstances, for quantities not exceeding one cubic meter and at the sole discretion of the ENGINEER, the proportioning of materials by volume may be approved. In such circumstances the cement content of the concrete shall be increased by 10% over the amount in the approved mix. The boxes used for proportioning shall be deep and narrow to the approval of the ENGINEER, and shall be separately constructed for each class of concrete to be proportioned by volume.

20.13 Concrete Sampling and Testing

The temperature of concrete, concrete constituents, reinforcement formwork and the atmosphere shall be monitored continuously for every concrete pour. All sampling and testing of fresh and of hardened concrete shall be carried out in accordance with the relevant provision of ASTM or equivalent international standard unless such provision is at variance with the Specification.

Table 5-11 gives the programme for sampling and testing of concrete for each class of concrete from each batching centre in each active day.

The CONTRACTOR shall establish a plan for sampling and testing to the approval of the ENGINEER. Samples shall be taken at the place of deposition from each class of concrete at random. The frequency of sampling shall in general be in accordance with Table 20-11, but the actual rate of sampling may vary with the approval of the ENGINEER and shall be increased when ordered by the ENGINEER in appropriate circumstances. From each such sample three test cylinders shall be prepared; each cylinder shall be marked indelibly for identification when it is in the mould. After retention at the site for 24 hours the cylinder shall be delivered to the testing laboratory for curing and testing.

Table 20-9: Programme for Works Sampling and Testing.

	Class "A" & "A(1)"	Class "E" & "E(1)"
Workability (slump test)	1	0
Workability (compacting factor test)	2	0
Compressive strength	2	3

Where:

- 0 - no testing required
- 1 - every batch at point of deposit
- 2 - one sample from every 10 batches, one sample per 20m³ of concrete or one sample from each day's concrete, whichever involves the maximum number of samples.
- 3 - one sample from every 50 batches, one sample per 50m³ of concrete or one sample from every three day's concrete, whichever involves the maximum number of samples.

20.14 Compliance with Specified Concrete Requirements

Of the three cylinders made from each sample of fresh concrete in accordance with the Specification, one will be crushed at 7 days and the other two at 28 days. The average of the

two 28 day strengths will be taken as the test result. Compliance with the specified strength requirements shall always be judged on the 28 days test results.

Concrete shall be considered to have failed to comply with the Specification:

- a) if a test result is less than by 5% of working strength specified in Table 5-9 for that class of concrete, to which case the concrete which it represents shall be broken out and disposed of away from the Site by the CONTRACTOR unless at his sole discretion the ENGINEER approves otherwise;
- b) if the average of four consecutive test results for that class of concrete shall have failed to exceed the working strength as specified in Table 5-9 in which case no further concrete of that class shall be placed in the Permanent Works until the CONTRACTOR shall have discovered the cause of such failure and rectified it to the satisfaction of the ENGINEER.

If a mix fails to achieve the requirements for fresh concrete the batch shall be rejected and no further concrete of that class shall be placed in the Permanent Works until the cause of failure has been rectified.

If test results for strength of concrete of any class are consistently and significantly in excess of the target mean strength the ENGINEER may on the application of the CONTRACTOR agree to a reduction in the cement content in the mix for that class, provided the cement content is not lowered below the minimum specified for that class, nor the maximum water/cement ratio exceeded.

20.14.1 Further Testing

When the ENGINEER agrees to or requires testing of the hardened concrete in a structure or precast element all such testing shall be carried out in accordance with the requirement of ASTM Designation C42, "Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete".

In the event that the core-boring test indicates that the concrete placed does not conform to the Drawings and Specifications; the Engineer shall have the authority to prescribe corrective measures which may include removal and reconstruction of representative structure at Contractor's risk and cost, the Contractor shall take such measures, to correct the deficiency.

20.15 Transporting, Placing and Compacting Concrete

The concrete shall be handled so that at the point of deposition it is of the specified quality and approved consistency, nothing having been added to it or lost from it since leaving the mixer. Any free water shall have been removed from the section to be concreted before concrete is deposited.

The CONTRACTOR shall obtain the approval of the ENGINEER to the arrangements he proposes to use for concreting before commencing concrete work.

The CONTRACTOR shall regard the compaction of the concrete as work of fundamental importance and shall produce a watertight concrete of maximum density compatible with the approved mix. Compaction shall be assisted by the use of mechanical vibrators of the immersion type, but shall not involve the vibration of reinforcement or shutters except that vibration of shutters may be allowed in precast concrete, with the approval of the ENGINEER. Vibrators shall be inserted at least to the full depth of the newly deposited concrete, kept in position for about a quarter of a minute and then slowly withdrawn to

prevent the formation of voids. The procedure shall be continuous with points of insertion 150 to 225 mm apart. The number and type of vibrators available for use during each period of concreting shall be to the approval of the ENGINEER, which will not be given if sufficient stand-by vibrators in good working order are not readily available. If concreting is in the dark, ample lighting shall be provided at the mixing stations and at every place where concrete is being deposited.

Concrete without a retarder which is not deposited in the Works within 30 minutes after the start of mixing shall not be used unless the ENGINEER approves otherwise.

Concrete may be pumped provided the mix design and the nature of pumping comply with the recommendations given in the 'Guide to Concrete Pumping' as published by the Building Research Establishment (UK) and are not in conflict with any specified requirements.

The first batch of concrete to be made every time work is commenced shall contain 10% more cement than the normal amount.

Concrete shall be placed continuously up to positions of joints prepared prior to commencement of concreting. No concrete shall be dropped or chuted into the shuttering in such a manner as to cause segregation of the ingredients. In no case the concrete shall be allowed to fall freely from a height of 1.2 m or more. The deposited layers of concrete shall not exceed 600 mm in thickness. Shallow beams may be concreted to full height in one operation as directed by the ENGINEER. Care shall be taken to ensure that reinforcement projecting from concrete recently placed is not shaken or disturbed.

Where steps, splays and kickers occur these shall be cast in one with the slab and additional care shall be taken in the vibration and finishing techniques and procedures to ensure that thorough compaction is achieved and the unset concrete is not subjected to tension and no cracks are formed. The techniques and procedures to be adopted shall be discussed with the ENGINEER's Representative and his approval received before any such concreting is commenced.

20.16 Concreting in Unfavourable Conditions

The CONTRACTOR shall not place concrete in the Permanent Works:

- (a) During heavy rains or dust storms.
- (b) When the air temperature is more than 32°C.
- (c) When the air temperature is less than 2°C.
- (d) If the temperature of the concrete on discharge from the mixer is less than 4°C or more than 32°C.
- (e) When the air temperature exceeds 25°C, without taking precautions and demonstrating to the approval of the ENGINEER that the maximum internal temperature of the concrete within 24 hours after casting in place is unlikely to be more than 30°C in excess of the ambient temperature or more than 60°C.
- (f) If the temperature of the shutters or reinforcement exceeds 30°C.

To keep within these limits the CONTRACTOR may, among other means, spray aggregates with water, and use chilled mixing water, or add crushed ice direct to the mixer provided that no ice is present in the mix when discharged from the mixer.

When concreting in hot weather all material used shall be kept in the shade. Water tanks, mixers and chutes should be shaded, but where this is not possible they shall be painted white and kept white.

20.17 Concreting Records

A written record of the concrete works shall be made each day by the CONTRACTOR and kept available for inspection by the ENGINEER's Representative. The diary shall contain notes and records of:

- (a) The names of the CONTRACTOR's engineers who are responsible for the different phases of the concrete work, and also the names of their assistants.
- (b) The temperatures of air, water, cement, aggregates and concrete, together with the air humidity and type of weather.
- (c) (Deliveries to the Site of concrete materials (quantity, brand of cement, etc).
- (d) Inspections carried out, tests performed, etc, and their results.
- (e) Times of commencement and completion of different parts of the concrete works, and times of erection and striking of forms.
- (f) Quantity of cement, fine and coarse aggregate and admixture used for each section of work, and the number and kind of test samples taken on these ingredients and water.

20.18 Shuttering

The terms shuttering and formwork shall be interpreted as meaning one and the same thing, namely Temporary Works set up to obtain the required profiles and surface textures of the concrete. Shuttering shall be such that it remains rigid during the placing and setting of the concrete and prevents the loss of any concrete ingredients.

The shuttering shall be fixed in correct alignment and to the true shape and dimensions of the Permanent Works and shall be designed so that it can easily be removed for curing of concrete to commence as soon as practicable. Where necessary, shuttering should be so arranged that the soffit form, properly supported on props only, can be retained in position for such periods as may be required to allow the concrete to mature as specified in Clause 5.35. A method of support which would involve holes or tie wires extending the whole width from face to face of work to be concreted will not be permitted, unless authorised by the ENGINEER in writing. No plugs, bolts, wire ties, holdfasts or any other appliance whatsoever for the purpose of supporting the shuttering or reinforcement shall be fixed permanently into the structure so that they have less cover than that specified for the reinforcement or in any way impair the strength or appearance of the work, nor shall they be placed in such a manner that damage to the work would result in the removal of the same at the time of striking the shuttering.

Before the concrete is placed the retaining surfaces shall be cleaned of sawdust and shavings, dirt, other debris and standing water.

The inside of shuttering shall be coated with a release agent of non-staining mineral oil, mould cream emulsion or with other approved material. Adjacent concrete or reinforcement shall not be contaminated. The release agent must be compatible with any applied finish.

Temporary openings for cleaning and inspection before concreting shall be provided at the base of column and wall shuttering and where necessary. Shuttering for walls or other thin sections may have openings where approved by the ENGINEER for the placing and compacting of the concrete.

No concreting shall be started before the shuttering has been inspected by the ENGINEER's Representative. Unless otherwise approved, top shuttering shall be provided to concrete faces where the slope exceeds one vertical to three horizontal. Exposed arises shall be formed with a chamfer measuring 20 mm x 20 mm.

20.19 Surface Finishes

The faces of all concrete shall be left sound, solid, free from voids and to the class of finish specified.

No treatment to the finished concrete other than that specified in the class of finish shall be carried out unless approval to do so has been given by the ENGINEER.

Bolt bobbin holes shall be filled with cement and suitable fine aggregate mortar to match the colour of the concrete. The mortar shall be well worked in and thoroughly cured.

Classes for formed surfaces:

Class F1 - This finish requires no special treatment and is for surfaces which will remain hidden in the permanent Works.

Class F2 - This finish is for all exposed surfaces unless otherwise shown on the Drawings. The formwork shall be faced with plywood or equivalent material in large sheets rigidly supported so as to prevent distortion under load. The sheets shall be arranged to coincide with architectural features, or changes in direction of the surface. All joints between panels shall be straight and either vertical or horizontal unless otherwise directed and the joints between panels to slab soffits shall be parallel to the supports. Suitable joints shall be provided between sheets to minimize joint marks and to maintain accurate alignment in the plane of the sheets. Facing sheets shall be free from blemishes which would affect the concrete surface.

Class F3 - This finish is identical to Class F2 finish except that the permitted deviations for irregularities are more stringent as given in Table 5-12.

Where a surface is partly below and partly above the final ground level the finish for exposed surfaces shall extend for 500 mm below the final ground level.

Classes for unformed surfaces:

Type U1 - This finish is for surface, where a superior finish is not required. It is also the first stage for finishes U2 and U3. The finishing operations shall consist of grading, tamping and screeding the concrete to produce a uniform, plain or ridged surface.

Type U2 - This is a smooth matt finish such as may be achieved by a wood trowel, as required, inter alia, to receive mastic paving, or block or tile paving, bedded in mastic. Smoothing shall be done only after the concrete has hardened sufficiently, and may be by hand or machine. Care shall be taken that the concrete is worked no more than is necessary to produce a uniform surface free from marks.

Type U3 - This is a smooth steel-trowelled finish for surfaces of concrete paving,, tops of walls, copings and other members exposed to weathering or water, surfaces to receive thin flexible sheet, tile paving, bedded in adhesive, and seatings for bearing plates and the like where the metal is in direct contact with the concrete. Trowelling shall not commence until the moisture film has disappeared and the concrete hardened sufficiently to prevent excess laitance from being worked to the surface. The surfaces shall be trowelled by hand or machine under firm pressure and left free from trowel marks.

20.20 Permitted Deviations in Finished Work

The irregularities in formed and unformed surfaces for the various classes of finish shall be within the target limits shown in Table 5-12. If irregularities exceed the target the CONTRACTOR shall take the necessary steps to bring subsequent work within the target. If, however, the irregularities exceed the maximum allowable shown in the table it shall be sufficient cause for the structure, member or section of a member of the structure to be removed and properly reconstructed.

In Table 20-12, the type of irregularity is defined as follows:

- (1) Departure from alignment, and grade and dimension shown on the Drawings.
- (2) The cross-sectional dimensions of structural members less than 600mm, such as walls, columns, beams, etc., where, for structural reasons, it is desirable to keep the tolerances within closer limits than those for alignment and grade.
- (3) Gradual irregularities measured from a 3 m long template placed against the concrete.
- (4) Abrupt irregularities such as those resulting from defective or displaced facing or movement of supports.

Table 20-10: Permitted Deviations for Irregularities of Concrete Surfaces.

a) Formed finish

Type of Irregularity	Target			Maximum allowed		
	F1	F2	F3	F1	F2	F3
1	± 20	± 5	± 1	± 40	± 10	± 2
2	± 7	± 5	± 1	± 15	± 10	± 2
3	7	5	± 1	15	10	± 2
4	7	3	± 1	10	5	± 2

b) Unformed finish

Type of Irregularity	Target			Maximum allowed		
	U1	U2	U3	U1	U2	U3
1	± 20	± 10	± 3	± 35	± 20	± 6
2	± 7	± 5	± 3	± 15	± 10	± 6
3	10	5	3	20	10	6

20.21 Fixing Reinforcement

Steel reinforcement shall be cut from straight bars free from kinks and bends or other damage, and cold bent by experienced competent workmen. Bars shall be bent in a bending machine approved by the ENGINEER. Cutting, bending and marking shall be to the tolerances and format given in BS 4466 unless otherwise specified or ordered by the ENGINEER.

The distance between any two parallel bars shall not be less than 5 mm more than the nominal maximum size of aggregate in the concrete, except at approved laps. The length of lap shall be as shown on the Drawings or ordered by the ENGINEER.

The CONTRACTOR shall place and fix steel reinforcement accurately in the positions shown on the Drawings and shall ensure that it remains rigidly in that position during the placing of concrete. Tack welding shall not normally be permitted, however, in particular cases it may be allowed with the prior approval of the ENGINEER. Supports, spacers, including PVC spacers, and ties shall be subject to the approval of the ENGINEER. Concrete spacers shall be made of the same quality concrete as that for the work in which they will be embedded with any tying wires galvanised and located to give a minimum cover specified for the reinforcement. Metallic spacers, fixing clips and tying wire shall be compatible with the material of the reinforcement, and the specified cover shall be maintained.

Spacers should be of such materials and designs as will be durable, not lead to corrosion of the reinforcement and not cause spalling of the concrete.

Reinforcement projecting from previously cast concrete shall not be bent so as to require rebending without the prior approval of the ENGINEER.

The main wires of adjacent sheets of steel fabric reinforcement shall be lapped at least 300 mm and the transverse wires at least 150 mm.

The CONTRACTOR shall not place concrete around reinforcement until the reinforcement has been inspected by the ENGINEER's Representative.

20.22 Cover to Reinforcement

Except where otherwise shown on the Drawings the nominal concrete cover to the nearest reinforcement (exclusive of concrete blinding and rendering) shall be 40 mm. However, for internal faces in buildings the minimum cover shall be 20 mm exclusive of plaster or decorative finishes. This requirement does not apply to concrete faces in box-outs left for the installation of fixtures.

The actual concrete cover shall not differ from the nominal cover by more than ± 5 mm for bars up to and including 12 mm size and ± 10 mm for bars greater than 12 mm size.

20.23 Construction joints

Where not shown on the Drawings, the details and positions of construction joints shall be submitted to the ENGINEER for approval before any concreting takes place. They shall be located so that, when considered with the sequence of concreting, the effects of shrinkage and temperature are minimised.

Construction joints shall be watertight. They shall be formed in straight lines with rigid shuttering perpendicular to the principal line of stress and as far as practicable at points of least shear. They shall be the plain butt type unless otherwise specified or approved.

As soon as the exposed concrete has sufficiently hardened the surface of the joint shall be brushed with a stiff brush to expose the larger aggregate without it being disturbed. Roughening of the surface by chipping or hacking will not generally be approved. Before placing fresh concrete against a construction joint all loose material shall be removed and the surface sluiced with water until it is perfectly clean, thereafter all ponded water should be removed.

A period of at least 3 days and not more than 14 days, except under special circumstances and with the approval of the ENGINEER, shall elapse between the casting of successive lifts of concrete.

In the case of water retaining structures a maximum period of 7 days will be permitted to elapse between casting of the base or footing to a wall panel and the casting of the stem of the wall on such base or footing.

In case any joints have been shown on the Drawings, the CONTRACTOR will not be permitted to alter these joints or their positions or to increase or decrease their number.

20.24 Dowel Bar

Where dowel bars are to be provided through movement joints they shall be mild steel plain round bars with sawn cut ends and complying with ASTM A615/BS 4449.

In expansion joints the part of the bar to be free to move shall be coated with bond breaking compound as specified, encased in a rigid PVC or metal sleeve and fitted with a compressible cap of joint filler or other materials approved by the ENGINEER. The diameter of the sleeve should be the minimum necessary to allow free movement of the bar after concreting.

In full contraction joints the part of the bar to be free shall be coated with bond breaking compound as specified.

In joints between roofs and walls of reservoirs vertical dowel bars shall be provided with a rigid PVC or metal sleeve so packed with compressible material so as to allow a free movement of 5 mm in any direction in the horizontal plane.

20.25 Reinforcement at Partial Contraction Joints

Only 50% of the longitudinal reinforcement will be continuous at partial contraction joints in the walls of the conduit unless shown otherwise on drawings.

20.26 Pipes through Concrete Sections

All pipes passing through concrete to water retaining structures or where a thrust load has to be transmitted to the concrete shall be fixed in position before and rigidly held in position during concreting. Boxing out in either of the above circumstances will not be permitted, unless approved by the ENGINEER.

20.27 Protection and Curing of Concrete

The CONTRACTOR shall take measures to the approval of the ENGINEER for the protection of concrete from the harmful effects of wind, sun, high and low temperatures, rapid temperature changes, premature loading, deflection, impact and aggressive

groundwater. Such measures shall continue from the time of the concrete is placed for a minimum of 7 days.

Concrete shall also be cured as follows. Unless otherwise approved by the ENGINEER, exposed concrete surfaces shall be kept continuously moist after casting for not less than 7 days after placing. Such surfaces, immediately upon exposure, shall be covered with thick hessian or sand or other material as may be approved by the ENGINEER, which shall be in continuous contact with the concrete and which shall be kept wet to the satisfaction of the ENGINEER.

For horizontal members such as slabs, exposed to wind and /or sun, special measures to prevent occurrence of shrinkage cracks shall be taken immediately after placing of concrete and until it is hard enough to commence curing as specified above. The measures shall include:

- a) Erection of wind barriers and sun shades of suitable construction to provide adequate protection.
- b) Application of water as a fog spray to keep the concrete surface moist without in any way damaging the fresh concrete or surface finish.

The ENGINEER may deny permission to place concrete unless necessary arrangements are available at the location of work to ensure compliance with above requirements.

20.28 Removal of Shuttering

Shuttering shall be removed in accordance with principles agreed by the ENGINEER and with the permission of the ENGINEER's Representative. Unless the soffit shuttering to beams and slabs has been designed so that it can be struck without disturbing the props, it shall be retained in position for the minimum period given in Table 20-13 for the retention of the props. Great care shall be exercised during the removal to avoid shocks to, or reversal of stress in, the concrete.

Earlier removal of formwork may be permitted by the ENGINEER by determination of the early strength of the concrete, in accordance with BS 8110 1985 Cl 6.9.3.

Table 20-11: Minimum Period before Striking Formwork.

Type of formwork	Minimum period before Striking surface Temperature of concrete	
	16° C	7°C
i) Vertical formwork to columns, walls and large beams	18 hours	24 hours
ii) Soffit formwork to slabs	4 days	7 days
iii) Props to slabs	11 days	14 days
iv) Soffit formwork to beams	8 days	14 days
v) Props to beams	15 days	21 days

20.29 Cement Mortar

Unless otherwise specified the dry ingredients of cement mortar shall consist of one part of ordinary Portland cement to three parts of sand. The sand shall comply with BS 1200 with a grading complying with Table 1 thereof. The cement and sand shall be thoroughly mixed with just sufficient water to make it workable. With the approval of the ENGINEER a non-shrink admixture may be used subject to the provision of Clause 5.4.

Cement mortar which has begun to set shall not be used or reworked for use in the Works.

20.30 Precast Concrete

Unless otherwise specified or described all precast concrete work shall be of Class “A” & “A(1)”.

Each mould for concrete work which is specified or approved by the ENGINEER to be precast shall have a different embossed or recessed identification mark in a position to the approval of the ENGINEER. Each precast unit shall be indelibly marked with the date of casting and after the mould is removed shall not be disturbed for 28 days. Each precast unit shall, where required, be provided with lifting eyes and holes located to avoid excess stress during handling to the approval of the ENGINEER.

Precast units must be of a sufficient age and handled with sufficient care to avoid permanent damage.

20.31 Building Ground Slabs

The position of all joints shall be indicated on the CONTRACTOR's Drawings. The joint types shall be indicated on the assumption that the slabs will be cast in chequer board fashion as defined in Cement and Concrete Association Publication 48.034 'Concrete Ground Floors.

Control joints may be substituted for transverse construction joints to permit the use of long strip casting in accordance with Cement and Concrete Association Publication 48.034 provided that:

- a) The CONTRACTOR can demonstrate previous experience using this technique in ambient conditions similar to those prevailing on Site.
- b) The joints layout is approved by the ENGINEER.
- c) The joint is as detailed by the CONTRACTOR and approved by the ENGINEER and the crack inducer is in one piece between the side forms.
- d) The groove is straight and sawn before random cracking occurs.

Fabric reinforcement may be located in the top face of a ground slab either by the use of chairs or, provided the concrete remains workable for an adequate period, by placing and compacting the concrete to the design level of the fabric, placing the fabric on the compacted concrete and placing and compacting the top layer of concrete to such a manner as to ensure the mixing of the layers.

The top layer of concrete not exceeding 50 mm deep shall be compacted using a double beam vibrating screed compactor.

Where the surface of a slab is to be sealed at a later date any curing membrane used shall be compatible with the use of the specified sealant.

20.32 Screeds

20.32.1 Concrete Mix

Screeds placed on concrete made with sulphate resisting cement shall themselves be made with sulphate resisting cement. The ENGINEER may at his discretion direct that the maximum aggregate size be reduced from 20 mm to 10 mm and that the maximum water cement ratio be reduced to not lower than 0.48 at no additional cost.

20.32.2 Mixing

Mixing shall be done in pan or paddle type mixers of a capacity matched to the rate of placing.

20.32.3 Surface Preparation

Where the screed concrete is placed more than 1 hour and less than 12 hours after the base concrete, the base concrete shall be brushed with brooms or wire brushes to remove laitance and expose clean aggregate.

Where the screed is placed more than 12 hours after the base concrete, the base concrete shall be well roughened to give a fresh face over the whole surface. Loose particles and dust shall be cleaned away and the surface then soaked with water. Immediately before placing the screed concrete the water shall be mopped from the surface and a stiff cement/water grout shall be brushed in.

Where the screed concrete is placed less than one hour after the base concrete and provided that no curing compound has been used the screed shall be placed directly on the concrete.

20.32.4 Screed Bay

Screed bays shall whenever possible be rectangular and shall not exceed 15 m², the length of a bay shall not exceed 1½ times its width. Screed bay shall not span joints in base concrete. Alternate bays shall be cast initially and no screed concrete shall be placed against other screed concrete placed less than 48 hours previously.

20.32.5 Screed Battens

Screed battens shall have a thickness the full depth of the adjoining screed and shall be fixed firmly to the base concrete so that they do not move under the action of the screening battens. Fixing shall be such that screening battens can be removed without disturbing the screed concrete. Battens shall not be removed until adjoining screed concrete has been placed for at least 12 hours.

20.32.6 Placing and Finishing

The screed concrete shall be placed as soon as possible after mixing. It shall be worked into place with a screening board with the screed alongside the battens trowelled into the corners. A preliminary pass with a vibrating screed board shall be made if conditions permit. The surface shall be worked with a power float if conditions permit. Unless otherwise shown the finish of screeds shall be Type U3.

20.33 Protective Coatings to Concrete

Where ordered by the ENGINEER or shown on the Drawings, waterproof coatings shall be applied to concrete structures in order to protect the concrete against the aggressive effects of saline groundwater. Generally, protective coatings will be applied to surfaces of structures which are close to or in contact with groundwater.

Before applying any coating the surface of the concrete shall be cleaned of all dirt, dust and loose material and where necessary any surface shall be made good so that the surface is smooth and free from air or water holes. No coating shall be applied until the ENGINEER has approved the preparatory work.

The coating shall be applied using Bituproof bituminous coatings as manufactured by Colas Products Limited, Riverside, saltney, Chester, UK, or similar approved coatings. The grades of coating and the method of application shall be as follows:

20.33.1 Priming Coat

An application of Bituproof Type 3 diluted with an equal volume of water, shall be well scrubbed into the concrete and allowed to dry.

20.33.2 First Coat

A heavy brush coat of Bituproof Type 5 containing a cement slurry, consisting of 1 volume of sulphate resisting cement, 1 volume of water and 10 volumes of Type 5, shall be laid on in one direction and allowed to dry. To introduce the cement slurry to the Bituproof, the cement shall be mixed thoroughly with the water, the whole being added to the Bituproof, stirring thoroughly to ensure uniform dispersion. The Bituproof/cement slurry mix shall be used within one hour of preparation.

20.33.3 Second and Subsequent Coats

A heavy brush coat of Bituproof Type 5/cement slurry mix prepared as for the previous coat shall be laid on at right angles to the previous coat and allowed to dry.

The application rate for the above primer and subsequent coats shall provide not less than 0.75 kg of Bituproof per m².

Each coat shall be thoroughly dry before applying a subsequent coat and shall be considered as dry when no staining occurs on a wet finger which is rubbed vigorously over the coating. No coat shall be immersed in water for at least ten days after it is dry.

The coating shall only be applied to the surfaces when shaded from direct sunlight and the coated surfaces shall continue to be shielded until the final coat is dry.

In order to provide protection to the underside of structures, the bituminous coatings shall be applied to the blinding layer before the placing of the structural concrete. The blinding layer shall be given a Type U2 finish.

The blinding and protection shall extend beyond the outer edge of the structural concrete at least 0.1 m so that subsequent coatings applied to the structural concrete can overlap the blinding layer and provide unbroken protection. The structural concrete shall not be placed on the blinding layer until the protection is thoroughly dry nor in any case until 60 hours have elapsed following the completion of the protection.

20.34 Provision of Hydrophilic Waterstop in Joints between existing & New Construction

The joint between existing and new concrete shall be provided with hydrophilic water proofing compound strip of size 25mm x 20 mm at the locations shown in drawings. These stripes comprise of rubber based bentonite compounds and are marked in Pakistan under trade names of supercast SW or expandastop. However, other equivalent Hydrophilic Water proofing compound strips which are old tested products and (are with similar properties & functions) will also be acceptable.

The hydrophilic waterstop strip shall be fixed by experienced personel as per manufacturers recommendations using recommended adhesives to provide excellent adhesion to the concrete. No nails or steel fixtures are to be used and these should be minimum cover of 100 mm concrete over the hydrophilic waterstop.

The CONTRACTOR is required to submit for approval necessary test report about the suitability and compatibility of the material for use in the project under Karachi climatic conditions. The CONTRACTOR shall also provide manufacture's guarantee for performance and durability of the product for at least 20 years.

20.35 Water Tightness of the Chambers / Structures

The CONTRACTOR is responsible to construct the structures water tight and take necessary precautions at every stage of construction so as to ensure that no leakage or seepage occurs when filled with running water. The CONTRACTOR may also engage a specialist firm to advise him on how to ensure water tight construction and, if required and approved by ENGINEER, supplement water proofing arrangement of the joints provided in the drawings. Costs of all such measures are deemed to be included in the quoted rates / overheads of the CONTRACTOR.

20.36 Measurement for Concrete Work

20.36.1 Portland Cement Concrete

- a. Measurement, for Portland cement concrete, will be made in the specified units of volume, of concrete, of specified class, acceptably placed, on the basis of the dimensions, for the neat concrete finish lines, in accordance with the Drawings or directions of the ENGINEER.

No deductions will be made, from the above computed concrete volumes, for the following:

- i. for reinforcement steel
- ii. for water stops and joint materials

20.36.2 Formwork

Formwork will not be measured and paid for separate from concrete and deemed to be included in the cost of the rates of concrete.

20.36.3 Reinforcement Work

- a. Measurement, for concrete reinforcement, will be made in the specified units of weight, of reinforcing steel, of specified quality, acceptably placed, on the basis of the lengths of bars, actually installed, in accordance with the Drawings or bar schedules or as directed.

Following unit weights will be used for converting the length of bars, of different sizes, to determine the weight of concrete reinforcement, for the purpose of measurement:

Table 20-12: Unit Weights for determining the weight of concrete reinforcement.

Bar Designation	Unit Weight kg/m (lb/ft)	Bar Size (mm)	Unit Weight kg/m
# 2	0.249 (0.167)	8	0.395
# 3	0.560 (0.376)	10	0.616
# 4	0.994 (0.668)	12	0.888
# 5	1.553 (1.043)	16	1.579
# 6	2.236 (1.502)	20	2.467
# 7	3.043 (2.044)	22	2.984
# 8	3.975 (2.670)	25	3.854
# 9	5.061 (3.400)	28	4.834
# 10	6.406 (4.303)	32	6.313
# 11	7.909 (5.313)	36	7.990
# 14	11.388 (7.650)		
# 18	20.246 (13.60)		

Overlaps, unless clearly shown in the Drawings or approved by ENGINEER, for the purpose of payment, shall not be measured and allowed.

20.36.4 Waterstop

- a. Measurement, for PVC water stops, will be made in the specified units of length, of the water stops, of specified type and size, acceptably placed, on the basis of the dimensions, in accordance with the Drawings or directions of the ENGINEER.
No allowance will be made, in the above computed lengths, for the laps and splices.

20.37 Rate and Payment

20.37.1 Portland Cement Concrete

- a) Payment for, Portland cement concrete, of specified class, will be made for the quantity of concrete, measured in accordance with Article 5.42.1, at the unit rates, tendered in the priced Bill of Quantities.
- b) The unit rates tendered, for all items of concrete, shall be deemed to be inclusive of, but not limited to the following:
 - i. Providing all materials
 - ii. All operations related with transportation, involved in the process
 - iii. All operations related with storage of materials
 - iv. All sorts of wastages
 - v. All operations including batching, mixing, cooling, conveying, placing, compacting, curing and repair of concrete
 - vi. Preparing concrete mix design
 - vii. Carrying out all sampling and testing
 - viii. All other operations, procedures and requirements necessary to complete the work in accordance with these specifications.
 - ix. Unless otherwise specifically stated in the Bill of Quantities, formwork for concrete will not be measured and paid, separately.

Unless otherwise specifically stated in the Bill of Quantities, concrete reinforcement will be measured and paid, separately.

20.37.2 Formwork

Unless otherwise specifically stated in the Bill of Quantities, the unit rates tendered, for all items of formwork, shall be deemed to be inclusive of, but not limited to the following:

- i. Formwork and scaffoldings including materials, transport, storage, fabrication, installation, lubrication and removal
- ii. Preparing formwork design, where required
- iii. All other operations, procedures and requirements necessary to complete the work in accordance with these specifications.

20.37.3 Reinforcement Work

- a) Payment for concrete reinforcement, of specified quality, will be made for the weight of reinforcement, at the unit rates, tendered in the priced Bill of Quantities.
- b) Should the CONTRACTOR provide lengths of reinforcement, which are greater than those shown on the drawings or directed by the ENGINEER, no payment for extra lengths shall be made.
- c) The CONTRACTOR shall not claim for the difference in the actual weights of bars and their standard weights given in the above standard tables.
- d) The unit rates tendered, for all items of reinforcement, shall be deemed to be inclusive of, but not limited to the following:
 - i. Providing reinforcement bars
 - ii. Providing M.S. binding wire and concrete, metal and plastic chairs, spacers and hangers, necessary to support the reinforcement.
 - iii. All sorts of transportation involved in the process
 - iv. All sorts of wastages
 - v. All operations including cleaning, cutting, bending, placing and fixing, in position, of reinforcement; binding with wire; and placing supports and spacers
 - vi. Preparing bar bending schedules
 - vii. Carrying out all sampling and testing
 - viii. All other operations, procedures and requirements necessary to complete the work in accordance with these specifications.

20.37.4 Waterstop

- a) Payment for, PVC water stops, of specified type and size, will be made for the quantity of water stops, measured in accordance with Article 5.42.4, at the unit rates, tendered in the priced Bill of Quantities.
- b) The unit rates tendered, for all items of waterstops, shall be deemed to be inclusive of, but not limited to the following:
 - i. Providing all materials including splicing, sealing, jointing and filler materials
 - ii. All operations related with transportation, involved in the process
 - iii. All operations related with storage of materials
 - iv. All sorts of wastages
 - v. All operations including installing, splicing, sealing, jointing and securing water stops; laying of sealants and fillers in expansion joints; and protection, maintenance and repairs, of the water stops
 - vi. Carrying out all sampling and testing
 - vii. All other operations, procedures and requirements necessary to complete the work in accordance with these specifications.

21.0 PRESSURE PIPELINES – MS

21.1 Application

This chapter shall apply to the Carbon Steel API Specification 5L Grade A/Grade B pipelines and washout pipelines.

21.2 Definitions

The following words and expressions shall have the meanings hereby assigned to them except where the context otherwise requires:

‘pipeline’ shall have the definition assigned to it in CP 2010 and means a line of pipes having an appreciable length, it may have branch line, but these would not normally be numerous. It does not include piping systems such as process plant piping within refineries, factories or treatment plant, short connections between adjacent plant and distribution and service mains which are characterised by numerous branch connections. Pipe work shall mean all pipes excluded from the definition pipeline.

‘pressure pipelines’ shall mean pipelines in which the nominal internal working pressure exceeds 3 m of water (0.3 bar) and such other Pipework as may be so designated.

‘pipes’ shall mean straight tubes having plain ends or bevelled ends to suite butt welding.

‘flexible pipes’ shall mean pipes having a specific stiffness of:

$$E' = (EI)/D^3$$

of less than 11 kN/m per unit length of pipe.

Where E = Young’s modulus of pipe wall material

I = moment of inertia of pipe wall per unit length

D = pipe diameter

‘fittings’ shall mean bends, junctions, reducers, tapers, joint adaptors and similar items which are not joints but used to control/divert flows.

‘internal’ shall mean those parts of pipes or fittings which are to be in contact with the liquid being conveyed.

‘chamber’ shall mean structures on the pipeline housing pipes, fittings and valves, including fittings through the chamber walls.

‘raw water’ is water from river before it has received any treatment other than that inherent in pumping and conveyance.

21.3 General

Pipes and fittings of any approved quality shall not be supplied by more than one manufacturer except with the approval of the ENGINEER.

They shall be of the class or grade having a factory or works internal hydraulic pressure test rating not less than the pressure rating as defined in the appropriate Standard Specification.

No pipes or fittings shall be ordered without the agreement of the ENGINEER.

Materials used in the Works which are or can be in contact with the untreated or treated water shall not contain any matter which could impart taste or odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed.

21.4 Test Certificates

Each consignment of pipes and fittings delivered to the Site shall have been tested at the manufacturer's works or other approved place in accordance with the appropriate British or other approved standard (such test being referred to here as Works tests). The CONTRACTOR shall provide the ENGINEER with the manufacturer's test report for each such consignment before delivery to Site begins.

The ENGINEER reserves the right to inspect the pipes and fittings to be supplied for the Works at the place of manufacturer and to witness works tests at all CONTRACTOR cost.

21.4.1 Pipeline Materials

The Steel for both seamless and welded pipe shall be made by one or more of the following processes: Open hearth, electric furnace or basic oxygen.

The weld seam of electric resistance welded pipe in Grade B shall be heat treated after welding to a minimum temperature of 1000 F (540 C) or processed in such a manner that no untempered martensite remains.

21.4.2 Specifications

As with other steels, API 5L has a specific gravity of approximately 7.85, and therefore a density of approximately 7850 kg/m³.

The grades covered by this specification are the standard grades A-25, A, B, X-42, X-46, X-52, X-56, X-60 or higher than X-42.

21.5 Steel Pipe and Specials

21.5.1 Pipes

Steel pipes for the pipeline shall be of seamless or welded construction complying with API 5L Grade B Carbon Steel Pipe having a wall thickness 8.7 mm.

Table 21-13: Minimum tensile strength for Steel pipeline

Pipeline	Steel grade	Minimum Tensile yield stress	Minimum Tensile ultimate strength
API 5L	Grade A	30,000Psi (207 Mpa)	48,000 Psi (331 Mpa)
API 5L	Grade B	35,000 Psi (241 Mpa)	60,000 Psi (414 Mpa)

Note: 1 psi= 6.8948 Kpa

Full length pipes shall be supplied in uniform effective length more than 11m.

Tests and test certificates will be required for the pipes and specials supplied under this Contract.

For Grades A and B in sizes 2 in and larger, determine the test pressure from the following equation:

Table 21-14: Test Pressure for API 5L Grade B.

Grade	U.S Customary Equation	SI Unit Equation
API 5L Grade A/ B	$P = 2St/D$	$P = 2000 St/D$

Where,

P	=	minimum hydrostatic test pressure
S	=	0.60 times the minimum specified yield points, Psi
T	=	specified wall thickness in and
D	=	specified outside diameter in

The pipe manufacturer shall carry out fracture toughness tests in accordance with API 5L Grade B Specification and shall provide test certificate to show that the pipe is suitable for use under the operating conditions specified herein operating temperatures between -5°C and 80°C .

21.5.2 Smooth Bore for Optimum Hydraulic Performance:

Pipes intended for fabrication at Site by welding and for cutting into closing lengths shall be referred to as 'truly circular pipes and shall be truly circular and sized uniform throughout their length, within the tolerance applicable to their outside diameter in accordance with Clause 15.3 of BS 534 enabling them to be suitable for use with collars and couplings.

They shall be marked 'truly circular' and identified by painting a 25 mm wide red stripe along each of two diametrically opposite locations throughout the external surface of the pipe length.

21.5.3 Specials

Steel specials for butt-welding shall comply with BS 1640 and BS 534. All specials shall have the same strength and be compatible in all other respects with the line pipe with which they are to be used.

Bends shall be of even curvature type only unless otherwise approved by the ENGINEER.

Specials shall be hydraulically tested and certified by the manufacturer.

21.5.4 Marking

- Manufacturer name or mark shall be the first identifying mark.
- 5L shall be marked when the product is complete in compliance with this specification.
- Products in compliance with multiple compatible standards may be marked with the name of the each standard.
- The specified outside diameter and specified wall thickness shall be marked except that for the specified outside diameter, any ending zero digits to the right of the decimal need not be included in such marking.
- Grade and class symbols to be used are as follows:

Table 21-15: Grade and Class Symbols for Markings.

Grade	Symbols
A-25 Class-I	A-25
A-25 Class II	A-25 (R)
A	A
B	B
X-42	X-42
X-46	X-46
X-52	X-52
X-56	X-56
X-60	X-60
X-65	X-65
X-70	X-70
X-80	X-80

21.5.5 Certification

The manufacturer shall upon request by the Purchase, furnish to the Purchaser a certificate of compliance stating that the material has been manufactured, sampled, tested and inspected according to specification and has been found to meet the requirements.

A material test report certificate of compliance or similar documents, Hydrostatic pressure test at mill shall be attached at the time of supply of 5L grade B Carbon steel pipe.

21.5.6 Preparation of Pipe Ends

The preparation of pipe ends for slip on type joints shall be in accordance with the requirements of and to the tolerances specified by the joint manufacturer.

21.6 Welded Joints

Welded joints in the pipeline shall generally be butt welded but between two fixed pipes / fittings these shall be lap welded slip type joints welded inside and outside the pipe or as shown on Drawing. All welding in joints shall comply with BS 1640: Part 3 or ANSI B16.25.

All parts to be welded shall have loose scale, slag, rust, paint and other foreign matter removed by means of a wire brush and shall be left clean and dry. All scale and slag shall be removed from each weld run when it is completed. Pipes manufactured with longitudinal or spiral welds shall be lined up before jointing so that these welds are at least 15° apart around the joint circumference.

No weld or adjacent parts of the pipe shall be painted prior to inspection by the ENGINEER.

The CONTRACTOR shall submit his proposals and welding procedures giving details of equipment, electrodes, welder qualifications and detailed methods for ENGINEER's approval before commencing the jointing work.

21.7 Flanged Joints

Flanges connecting to valves and Fittings shall be compatible with the flanges attached to them.

One complete set of bolts and nuts conforming to Table 18 of BS 1560: Part 2 together with gaskets shall be supplied with each flange for welding, each flange ended pipe or each flange end of a special or valve.

After cleaning the flanges, the gasket shall be fitted smoothly to the flange and the joint made by tightening the nuts to finger pressure first. Thereafter the final tightening of the nuts shall be made by gradually and evenly tightening bolts in diametrically opposite positions using spanners of a type approved by the ENGINEER.

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

Flanges shall wherever practicable be attached in the factory and field welding of flanges will only be allowed with the approval of the ENGINEER.

21.8 Welding

The metal arc process shall be employed for the welding of joints to pipes and specials and shall comply with BS 4515 or API 1104.

Before commencing any welding on Site the CONTRACTOR shall submit to the ENGINEER for approval details of the plant, materials and the method he proposes to employ. When required by the ENGINEER, the CONTRACTOR shall carry out Site trials in demonstration of his method, to prove the suitability of the materials and the adequacy of his plant.

The approval of a welder may be revoked by the ENGINEER at any time if he considers the welder's workmanship is inconsistent or below a reasonable standard.

The throat thickness of full fillet welds shall be not less than 0.7 times the pipe wall thickness and the throat thickness of butt welds shall not be less than the pipe wall thickness.

Seamed or spiral welded pipes shall be laid such that the manufacturer's longitudinal seams or spiral welds shall not coincide at the ends of the adjacent pipes but shall be opposed by at least 45 degrees.

No welding shall be carried out until the portion of the pipeline to be jointed has been properly prepared and set up, and inspected and approved by the ENGINEER.

Welded joints shall be welded on Site by the metal arc process, using portable welding sets of 300/400 A, 30/35 V capacity.

The type of welding electrodes to be adopted on Site and the site welding procedure shall be as stated in Appendix to the Form of Bid and approved by the ENGINEER.

21.9 Weld inspection

All welding and in particular the deposition of the root run, will be subject to stringent examination by the ENGINEER. The CONTRACTOR shall give adequate advance advice of welding operations and provide test equipment for the welds i.e. radiological inspection equipment. The homogeneity of weld seams examined by radiological methods shall be determined by means of X-rays directed through the weld material in order to create a suitable image or radiographic film or fluorescent screen or a television screen provided adequate sensitivity can be obtained. Radiographical examination is capable of detecting weld imperfections and defects i.e. cracks, lack of complete penetration, lack of complete fusion and discontinuities greater in size etc. Radiographic inspection of welds shall be

made by the CONTRACTOR in the presence of the ENGINEER in accordance with BS4515 or API 1104 to a maximum of 10% of total run of weld and 100% for tie in joints and weld joints at road crossings, deflection joints and closure welds (golden welds). Each joint to be radiographed shall be cleaned, and weld spatter removed. Any defective weld shall be repaired by approved means or cut out if necessary.

21.10 Internal Pipe Protection

Internal protection to the steel pipes and fittings shall be provided by cement mortar lining. The lining shall be placed in situ after the pipe is laid and shall be carried out in accordance with AWWA C602.

The normal finished thickness of lining shall be 8 mm, with no minus tolerance. The cement for the mortar lining shall be Portland cement to BS 4027.

The lining shall be smoothed with a drag trowel with integral tensioning mechanism drawn through the main in tandem with the lining machine. The trowel should be wetted before use.

The CONTRACTOR shall supply special roll out pipe section to give access to the main for the lining equipment generally as specified and as shown on the Drawings. These shall be spaced at approximately 180 m centres along the pipeline but the spacings may be varied with the ENGINEER's approval to suit the lining CONTRACTOR's methods of application.

The roll-out pipe sections shall be lined in the same manner as the main pipes and the ends and all other unlined parts exposed and liable to corrode shall be coated with an approved epoxy compound before installation.

Curing of the lining shall commence as soon as a section of lining has been completed between access points. The ends of the pipe shall be sealed with an approved type cap. After about 8 to 10 hours the pipe shall be part filled with clean water sufficient to keep the lining moist and left to stand for 24 hours after which time the water shall be removed and the 'roll-out' pieces installed. After lining of pipe sections is completed no open ends will be allowed at any time without the ENGINEER's approval. The CONTRACTOR shall be responsible for maintaining a moist draught free atmosphere for at least 7 days after closure of the pipe.

The CONTRACTOR shall provide and maintain in good working order the necessary equipment to allow inspection by the ENGINEER of the lined pipe in accordance with Section 5 of AWWA C602. On completion of the lining on each section of main in addition to a visual inspection in accordance with Section 5.4 of AWWA C602 checks will be made of the lining thickness. This shall be carried out with a needle indenter or other approved type thickness gauge to be provided and maintained by the CONTRACTOR for the exclusive use of the ENGINEER.

All pipe or fittings lined by hand trowelling shall be inspected in the same manner.

Prior to commencement of lining the pipeline the CONTRACTOR shall line a trial section of pipe of at least 5 m length using the same equipment, material and techniques as proposed for the lining operations. On satisfactory completion of the trial section this shall be cured, capped and retained in a safe place on the Site for comparison purposes.

Any section of lining that is rejected by the ENGINEER as unsatisfactory on inspection shall be removed by the CONTRACTOR and the section re-lined at the CONTRACTOR's

expense. Lining washed out of a pipe section shall be disposed of by the CONTRACTOR in a manner that will not adversely affect the local environment, crops or animals.

Internal protection to pipes and fittings smaller than DN 100 shall be protected with bitumen in accordance with Section 31 of BS 534 or with an approved epoxy compound. The lining on branches, tees, etc, shall be carried through into the main pipe section to give continuity of protection after installation of the cement mortar lining.

Any damage to the bitumen or epoxy lining shall be repaired in accordance with the manufacturer's instructions.

21.11 External Pipe Protection:

The pipe shall be protected externally by applying 3 layers external polyethylene coating according to DIN 30670 specifications.

The CONTRACTOR shall submit samples of all materials for the approval of the Engineer. Where coating is damaged, the damaged coating will be removed and fresh layer of coating will be applied with directions of ENGINEER, as per requirement. Approval of external pipe protection shall be subject to 100% Holiday Detection testing of each pipe. Any defect found then shall be made good by the CONTRACTOR and will again be subject to Holiday Detection test.

21.12 Transmission Mains, Distribution Systems, Piping & Appurtenances

21.12.1 General

Transmission mains and water distribution systems must be designed to maintain treated water quality. Special consideration should be given to distribution main sizing, providing for design of multidirectional flow, adequate valving for distribution system control, and provision for adequate flushing. Systems should be designed to maximize turnover and to minimize residence times.

21.12.2 Materials

21.12.2.1 Standards, materials selection

All materials including pipe, fittings, valves and fire hydrants must conform to the latest standards issued by the AWWA and ANSI/NSF, where such standards exist. In the absence of such standards, materials meeting applicable Product Standards and acceptable to ENGINEER may be selected.

Special attention must be given to selecting pipe materials, which will protect against both internal and external corrosion. Pipes and pipe fittings containing more than 8% lead must not be used. All products must comply with ANSI/NSF standards. All materials used for the rehabilitation of water mains must meet ANSI/NSF standards.

Where lines are to be slip-lined, slip-lining material must be approved for potable water applications, be installed in accordance with the manufacturer's guidelines, and be installed in a manner that minimizes service interruption.

21.12.2.2 Used materials

Water mains, which have been previously used for conveying potable water, may be reused provided they meet the above standards and have been restored practically to their original condition.

21.12.2.3 Joints

Packing and jointing materials used in the joints of pipe must meet the standards of the AWWA. Pipe having mechanical joints or slip-on joints with rubber gaskets is preferred. Gaskets containing lead must not be used. Repairs to lead-joint pipe must be made using alternative methods. Manufacturer approved transition joints must be used between dissimilar piping materials.

21.13 Water Main Design

21.13.1 Pressure

The Helical seam submerged arc welded (spiral) in double random length, end bevelled as per API specification 5L latest edition.

Table 21-16: Tested pressure for water mains.

Dia. of pipe	Thickness	Tested Pressure	
Inches (mm)	mm	psi	bars
24" (600 mm)	6.4 mm	440	30.34
32" (800 mm)	7.9 mm	400	27.58
36" (900 mm)	8.9 mm	360	24.82

21.13.2 Diameter

The minimum size of water main for providing fire protection and serving fire hydrants must be six-inch diameter. Larger size mains will be required if necessary to allow the withdrawal of the required fire flow while maintaining the minimum residual pressure specified in Clause 7.13.1.

The minimum size of water main in the distribution system where fire protection is not to be provided should be a minimum of three (3) inch diameter. Any departure from minimum requirements must be justified by hydraulic analysis and future water use, and can be considered only in special circumstances.

21.13.3 Fire protection

When fire protection is to be provided, system design must be such that fire flows and facilities are in accordance with the recommendations of the fire protection agency in which the water system is being developed. Water mains not designed to carry fire-flows may not have fire hydrants connected to them.

21.13.4 Dead ends

Dead ends must be minimized by making appropriate tie-ins whenever practical, in order to provide increased reliability of service and reduce head loss.

Where dead-end mains occur, they must be provided with a fire hydrant if flow and pressure are sufficient, or with an approved flushing hydrant or blow-off for flushing purposes. Flushing devices should be sized to provide flows, which will give a velocity of at least 2.5 feet per second in the water main being flushed, and must be sized to provide at least the minimum pressure of 20 psi as required in Clause 7.13.1, when the flushing device is fully open. Flushing devices may not be directly connected to any sewer.

21.14 Valve, Meter, and Blow-Off Chambers

Wherever possible, chambers, pits or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, must not be located in areas subject to flooding or in areas of high groundwater. Such chambers or pits should drain to the ground surface, or to absorption pits underground. The chambers, pits, and manholes must not connect to any storm drain or sanitary sewer.

21.15 Valves – General

21.15.1 Description

This work shall consist of providing, installing, testing, commissioning furnish all labor, equipment, materials, tools, supplies, fittings, including gasket, steel nuts, bolts & washer and appurtenances required for the support, installation, protective coating, and testing of valve in the locations shown, and all appurtenant work, for a complete and workable installation as specified herein, in accordance with the requirements of the Contract Documents (where included in the BOQ), in accordance with these specifications and to the layouts and details, shown on the Drawings and/or as directed by the Engineer.

The items specified under this Section shall be furnished by manufacturers having experience in the manufacture of similar products for a period of at least 5 years.

All valve items shall be manufactured of material suitable for the water, wastewater, sludge and air they serve, and shall be certified for such use on the shop drawings.

21.15.2 General Requirements

Shop Drawings: The CONTRACTOR shall furnish shop drawings of all items and accessories in accordance with the General Requirements. Shop drawings shall include detailed design calculations stamped by a registered engineer, bill of materials listing all valve components, materials, tools, supplies, fittings, and appurtenances, etc., with manufacturer's name, trade and identification marks.

All manufactured items provided under this Section shall be new, of current manufacture, and shall be the products of reputable manufacturers specializing in the manufacture of such products; such manufacturers shall have had previous experience in such manufacture and shall, upon request of the ENGINEER, furnish the names of not less than 5 successful installations of its equipment of comparable nature to that offered under this contract.

All combinations of manufactured equipment which are provided under these Specifications shall be entirely compatible, and the CONTRACTOR and the listed manufacturer shall be responsible for the compatible and successful operation of the various components of the units conforming to specified requirements. All necessary mountings and appurtenances shall be included.

All materials employed in the manufacture and installation of the valves shall be suitable for the intended application; material shall be high-grade, standard commercial quality, free from all defects and avoid imperfection that might affect the serviceability of the product.

Wetted parts of all valves shall be selected by the manufacturer to ensure optimum, corrosion-free, and erosion-free operation for the fluid involved.

Data Requirements: The drawings and data submitted shall include the following:

- Name of manufacturer.
- Dimensions of Valve.
- Data sheet for pressure test.
- Equipment weights.
- All materials of construction listed and applied coating.

Sufficient valves must be provided on water mains so that inconvenience and sanitary hazards will be minimized during repairs. Valves should be located at not more than 500 foot intervals in commercial districts and at not more than one block or 800 foot intervals in other districts. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should not exceed one mile.

All valve and equipment shall be of the highest quality from an approved manufacturers and shall conform in all respect to standard specifications referred to in this contract.

The technical and production capability of the manufacturer shall be provided with documentary evidence that the valves and sluice gates offered have been in production in for at least 20 years. The minimum numbers of these types of valves and sluice have been sold in South Asia, especially in Pakistan.

Previous approvals of manufacturer from Consultants and water authorities shall be provided.

No of units sold on water supply projects and have been in operation satisfactory for at least 10 years.

The manufacturer should have certified quality control produces in accordance with ISO 9000/9001/9002 and 1400, as appropriate and the CONTRACTOR should submit evidence and get approval prior to placing of order to manufacturer of their distributor.

The valve parts shall be so designed that they may be easily replaced and shall be constructed of wear resistant materials.

Flanges on valves are to be full faced and drilled in accordance with B.S 4504 PN-10 and shall be compatible with flanges of meter, fittings and pipes provided for this contract.

Valves shall open by counter clockwise rotations of wheels.

All valves and equipments shall be pressure tested in accordance with the appropriate British Standard/ and test report provided.

All valves shall be fitted with opening wheels. All valves and other equipment shall be providing with required accessories and jointing materials, including nuts, bolts gaskets etc, as per site requirement.

21.15.3 Sluice/ Gate Valves Approved Manufacturers as directed by Engineer

- a) Glenfield valves Ltd.
- b) Golden Anderson valves
- c) KITZ
- d) SIAM

e) Zhejiang Oudian valves (Wenzhou China)

Original Hydrotest result, chemical composition, certification from manufacturer etc. must be submitted for approval of the Engineer.

21.15.4 General Installation Requirements

General: Valves shall be installed in accordance with procedures submitted with the CONTRACTOR approved shop drawings and as shown, unless otherwise acceptable to the ENGINEER.

Alignment: Equipment shall be field tested to verify proper alignment, operation as specified, and freedom from binding, scraping, or other defects. Equipment shall be secure in position and neat in appearance.

21.15.5 Testing and Commissioning

Each valve shall be test in presence of Engineer according to the manufacture pressure rating. Any kind of leakage from the valve is not acceptable. The valve shall be operate, by the Contractor, to demonstrate, to the satisfaction of the Engineer, that it is working, satisfactorily, in accordance with the specifications.

21.15.6 Measurement

Measurement for valve of specified type, materials, characteristics and dimensions will be made in the number of these items, acceptably installed, in accordance with the approved Drawings or directions of the Engineer.

21.15.7 Rates and Payment

21.15.7.1 Payment

Payment for valve, of specified type, materials, characteristics and dimensions will be made for their respective quantities, measured in accordance with Article 7.15.6, at the unit rates, tendered in the priced Bill of Quantities.

21.15.7.2 Rates

The unit rates tendered, for valve, shall be deemed to be inclusive of but not limited to the following:

Providing, installing complete valve, comprising main their support structure, painting/coating works; all fixing & installation accessories including bolts, nuts, washers, gasket, fittings, and leveling materials; and a complete set of special tools, test equipment and essential spare parts etc:

- a) All sorts of transportation involved in the process
- b) All sorts of wastages
- c) Operations including injecting initial charges of lubricant and maintenance, protection and repairs, of the work
- d) Carrying out designs and preparing shop drawings
- e) Carrying out all sampling and testing
- f) All other operations, procedures and requirements necessary to complete the work in accordance with these specifications

21.16 Gate Valves

21.16.1.1 General:

All gates shall be new and of current manufacture. They shall be adequately braced to prevent warping and bending under the intended usage. Sluice gates shall be furnished with a handwheel floor stand, having a 2:1 gear ratio, except as otherwise specified herein.

Gate valves shall comply with BS5150, BS 5163, amended BSEN 1171:2002, AWWA C509 or other approved standards.

Certain clauses of BS 5150 are amplified as follows:

Clause 14 Operation: Manually Operated valves shall not require a force of greater than 20 kg on the outer rim to operate with balance pressure across the valve, unless otherwise specified. To achieve this, gearing may be used in which case the time required to operate the valve under normal working conditions shall not exceed 20 minutes.

Clause 14.4 Indicators: Indicators showing both OPEN and SHUT Positions shall be supplied.

By Pass: Valves 400mm and over shall be fitted with integral by passess as follows:
400 mm nominal diameter Valve: 50 mm diameter bypass
500 mm nominal diameter Valve: 80 mm diameter bypass
800 mm nominal diameter Valve: 100 mm diameter bypass

Body ends shall be flanged and drilled to BS 4504.

All valves shall be manually operated, unless specified otherwise or to suit the system operation, and shall close clockwise.

All valves in open chamber or above ground shall be supplied to site with a fusion bonded epoxy coating to WIS 4-52-01 class A or approved equivalent. All valves in enclosed chambers or below ground, unless otherwise specified, shall be supplied to site painted with two coats of black bitumen paint to BS 3416 Type II or approved equivalent, suitable for use in tropical climates.

21.16.2 General Installation Requirements

- a) Sluice and shear gates shall be installed in strict accordance with the manufacturer's printed recommendations and the requirements herein. Operators shall be located to avoid interference with handrails and structural members.
- b) Just prior to setting each gate, a 1/8-inch thick layer of mastic grade polysulfide elastomeric sealant shall be applied to the back of the gate frame. After setting the gate, the nuts shall be run down on the anchor bolts just far enough to make them snug and to cause the rubber sealant to begin to ooze out, but not far enough to produce any significant stress to the frame. Any excess sealant at the edges shall be removed. The sealant shall be allowed to cure for at least 7 days, after which the anchor bolt nuts shall be tightened to their final positions. If gaskets are being used, they shall be installed over the studs in one piece, or dovetailed and cemented with a liquid-type gasket material.

- c) All damage to surface coatings incurred during shipment and/or installation shall be repaired by the contractor to the satisfaction of the ENGINEER prior to installation.

21.16.3 Testing and Commissioning

The sluice gate shall be operated, by the Contractor, to demonstrate, to the satisfaction of the Engineer, that it is working, satisfactorily, in accordance with the specifications.

21.16.4 Measurement

Measurement for sluice gate, of specified type, materials, characteristics and dimensions will be made in the number of these items, acceptably installed, in accordance with the approved Drawings or directions of the Engineer.

21.16.5 Rates and Payment

21.16.5.1 Payment

Payment for sluice gate, of specified type, materials, characteristics and dimensions will be made for their respective quantities, measured in accordance with Article 6, at the unit rates, tendered in the priced Bill of Quantities.

21.16.5.2 Rates

The unit rates tendered, for sluice gate, shall be deemed to be inclusive of but not limited to the following:

- b. Providing all the equipment, including sluice gate support base/frame and all fixing & installation accessories including bolts, nuts, washers, shims, fittings, grout, leveling materials (where specified in the BOQ); a complete set of special tools, test equipment & essential spare parts and etc:
 - i. All sorts of transportation involved in the process
 - ii. All sorts of wastages
 - iii. Operations including injecting initial charges of lubricant and maintenance, protection and repairs, of the work
 - iv. Carrying out designs and preparing shop drawings
 - v. Carrying out all sampling and testing
 - vi. All other operations, procedures and requirements necessary to complete the work in accordance with these specifications

21.17 Installation of Mains

21.17.1 Standards

Specifications must incorporate the provisions of the AWWA standards and manufacturer's recommended installation procedures. Where AWWA standards are not available the ENGINEER may allow installation per manufacturer's and industry standards on a case-by-case basis.

21.17.2 Sand Bedding Materials for Water mains

21.17.2.1 General:

All bedding and backfill material shall be free from boulders, cobbles, rock fragments, organic matter and debris.

A continuous and uniform bedding must be provided in the trench for all buried pipe. Backfill material must be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stones found in the trench must be removed for a depth of at least six inches below the bottom of the pipe.

21.17.2.2 Pipe Bedding

Bedding material shall conform to the following requirements:

a) **Bedding Material:**

Bedding material shall not contain boulders, cinders, cobbles, rock fragments, and organic matters.

The minimum depth of bedding material below the pipe shall be 100mm and minimum depth of overlay material above the pipe shall vary depending upon pipe material and size in accordance with the following table:

Table 21-17: Minimum depth of overlay material above the pipe.

Pipe Material	Overlay Material Depth	
	Dia. 100-450	Dia. 450-900 and above
Steel Pipe	150mm	150mm
PVC, GRP or HDPE	200mm	300mm

b) **Compaction:**

The degree of compaction of the trench fill material will vary from zone to zone and whether the trench is in a trafficable or non-trafficable area. The bedding material shall be placed in layers not more than 150mm thick and compacted by approved means to uniformly support the pipe and to achieve a uniform density throughout, whilst ensuring that the pipe is not damaged or distorted.

Trafficable Areas

The bedding material shall be compacted to achieve not less than 70% of the modified Proctor maximum dry density as specified in BS 1377, Test13.

Non-Trafficable Areas

The bedding material shall be compacted to achieve not less than 60% of the modified Proctor maximum dry density as specified in BS 1377, Test13.

c) **Granular Bedding Material for Water Mains :**

All granular bedding material shall be placed in layers not more than 150 mm thick and compacted by approved mechanical means.

The CONTRACTOR shall ensure that the material is adequately compacted, and the method of compaction used will be required to achieve not less than 90% of the modified Proctor maximum dry density as specified in BS 1377, Test13. This material shall be well graded crushed stone/sand in conformance to gradation given in Table 7-8 below:

Table 21-18: Granular Bedding Material for Water Mains.

Sieve Size or Designation	Total Passing (Percent by Weight)
1/2"	100%
3/8"	85-100%

No.4	10-30%
No.8	0-10%

d) Backfill

The backfill material shall be placed and compacted in 150mm thick layers to achieve the required density uniformly throughout the depth of each layer.

Mechanical compaction directly above the pipe shall not commence until at least 200mm of cover is provided when using hand-held equipment or 300mm when using self-propelled equipment.

Trafficable Areas

The backfill material shall be compacted to achieve not less than 95% of the modified Proctor maximum dry density as specified in BS 1377, Test13.

Non-Trafficable Areas

The backfill material shall be compacted to achieve not less than 90% of the modified Proctor maximum dry density as specified in BS 1377, Test13.

21.17.3 Cover

All water mains must be covered with sufficient earth or other insulation to prevent freezing.

21.17.4 Blocking

All tees, bends, reducers, plugs and hydrants must be provided with reaction blocking, tie rods or joints designed to prevent movement.

21.17.5 Pressure and leakage testing

All types of installed pipe must be pressure tested and leakage tested in accordance with the appropriate AWWA Standards.

21.17.6 External Corrosion

- a) Where external corrosion may be a concern, a system of records by which the nature and frequency of corrosion problems are recorded must be provided. On a plat map of the distribution system, show the location of each problem so that follow-up investigations and improvements can be made when a cluster of problems is identified.
- b) If needed, perform a survey to determine the existence of facilities or installations that would provide the potential for stray, direct electric currents. Also, determine whether problems are caused by the use of water pipes as grounds for the electrical system.
- c) In areas where aggressive soil conditions are suspect, or in areas where there are known aggressive soil conditions, analyses must be performed to determine the actual aggressiveness of the soil.
- d) If soils are found to aggressive, take necessary action to protect the water main such as by encasement of the water main in polyethylene, provision of cathodic protection (in very severe instances), or using corrosion resistant water main materials.

21.18 Marking and Protection of Pipes and Fittings for Shipment

Except where otherwise specified all items shall have received their complete protective coatings before dispatch from the manufacturer's works and shall be additionally protected

by approved means for the period of transit, storage and erection, against corrosion and accidental damage.

For the protection of pipe linings and in particular for protecting cement mortar linings from drying out, protective metal or timber discs shall be fitted over the ends of pipes and fittings. Similar timber protective discs shall be attached to all flanges of pipes and fittings, by means of bolts specifically provided for the purpose and which shall be discarded when the item is incorporated in the Works. The sleeves and flanges of flexible joints shall be wired together in suitable bundles.

21.19 Storage of Pipeline Materials

Pipes and fittings shall be stored raised off the ground, and shall be carefully supported, cushioned and wedged. Pipes shall not rest directly on one another and shall not be stacked more than 4 pipes high or 2 pipes high in the case of pipes of 500 mm diameter or over. Special care shall be taken to ensure that flexible pipes are cradled and supported in a manner that prevents any distortion of the pipes.

Couplings and joints (and all components thereof) and other similar items shall be stored in dry conditions, raised from the ground in sheds or covered areas.

Storage areas shall be carefully set out to facilitate unloading, and checking of materials with different consignments stacked or stored separately with identification marks clearly visible.

Where items to be stored have a limited shelf life or require special storage arrangements, the method of storage shall be to the approval of the ENGINEER and in accordance with the manufacturer's instructions.

All pipes and fittings supplied as spares shall have end covers which are proof against the entry of sand and vermin. Mortar lined pipes and fittings shall have end covers which form a complete seal, provision being made to accommodate the effects of temperature changes. Pipes and fittings supplied as spares shall have a temporary white external finish and shall be stored sheltered from the direct rays of the sun.

End covers and protection shall not be removed until incorporation of the pipes and fittings into the Works.

21.20 Transportation of Pipes and Fittings

Any vehicle on which pipes are transported shall have a body of such length that the pipes do not overhang. Large pipes shall be placed on cradles and the loads properly secured during transit. The pipes shall be handled in accordance with the manufacturer's recommendations.

Approved slings shall be used and all hooks and dogs and other metal devices shall be well padded. Hooks engaged on the inner wall surface at pipe ends shall not be used. Steadying ropes shall be employed. The positions of lifting slings shall ensure that stresses and tendency towards deformation in the pipes are kept at a minimum.

Pipe handling equipment shall be maintained in good repair and any equipment which in the opinion of the ENGINEER may cause damage to the pipes shall be discarded.

Under no circumstances shall pipes be dropped, be allowed to strike one another, be rolled freely or dragged along the ground.

21.21 Inspection of Pipes and Fittings

Transportation of pipes to Site over extremely rough terrain may give rise to a high proportion arriving damaged. Before incorporating into the pipeline each pipe shall be brushed out and carefully examined for soundness. Damaged pipes which in the opinion of the ENGINEER cannot be satisfactorily repaired, shall be rejected and removed from Site.

If under line test, the ENGINEER considers that an unacceptable proportion of the pipes within a test length has failed the CONTRACTOR may be required to test hydraulically to the Site test pressure each pipe and joint before pipelaying. In this event, test results shall be submitted to and approved by the ENGINEER before any further pipes are laid.

The cost of such individual pipe testing shall be borne by the CONTRACTOR.

21.22 Survey of the Pipeline Route

The CONTRACTOR in conjunction with the ENGINEER will set out and agree the final pipeline route and shall undertake a detailed survey of the agreed route prior to the commencement of construction work. The CONTRACTOR shall submit the results of the survey to the ENGINEER in the form of longitudinal sections drawn to a scale to be decided by the ENGINEER. They shall conform to the following:

- (i) The length of the route shall be accurately measured and approved type Chainage markers fixed at 50 m intervals and clearly marked with the Chainage at that point.
- (ii) Using modern survey equipment approved by the ENGINEER, ground levels shall be taken at intervals agreed with the ENGINEER. Generally a 25 m interval will be acceptable though this is to be reduced as necessary to ensure any abrupt changes in ground level are recorded.
- (iii) Levels shall relate to an approved datum, and permanent bench marks shall be established, clear of the proposed pipeline, at intervals along the pipeline route.

The ENGINEER will review the pipeline profile and amend it where necessary including any revisions to the number and positions of air valves and washouts.

At all times the route surveying shall be sufficiently ahead of excavation and pipe laying by at least one further week's work to permit the ENGINEER's review to be carried out and revisions to be issued to the CONTRACTOR on the pipeline between high and low points on the section under construction and the next section to be opened up for construction.

21.23 Earthwork

In addition to the requirements of Chapter 4, the following sub-clauses shall apply:

21.23.1 Excavation

Where trenches for pipelines are constructed with vertical, sloping or stepped sides, that portion of the trench which extends from the formation level to not less than 2.0m above the crown of the pipe when laid in its correct position, shall, unless otherwise specified or

ordered by the ENGINEER be formed with vertical sides the minimum practicable distance apart and shall be such that the distance between the side of the trench and the barrel of the pipe does not exceed 300 mm inclusive of any allowances required for temporary supports.

21.23.2 Backfilling

The excavation for pipelines shall be backfilled in two stages. Trench supports shall be withdrawn gradually in accordance with the progress of the fill subject at all times to the provision that such withdrawal will not prejudice the safety of the Works.

It is the CONTRACTOR's responsibility to provide suitable material for backfilling in accordance with the Specification.

a) First Stage

The pipe and pipe bedding or concrete surround (if any) shall be carefully covered leaving the joints exposed at the CONTRACTOR's discretion. Selected materials with particle size not exceeding 20 mm shall be evenly placed and compacted in layers not exceeding 100 mm thick after compaction.

The layers shall be compacted by hand controlled vibration on each side of the pipe only and not over the top of the pipe.

The backfill shall be compacted to achieve not less than 90% of the modified Proctor maximum dry density as specified in B. 1377, Test 13. This work shall commence as soon as possible after pipe laying and bedding is complete in the section or length concerned. Initially Site tests shall be made to prove the effectiveness of the method of compaction and thereafter at intervals of approximately 250 m.

Concrete bedding or surround (if any) shall be at least 72 hours old before backfilling commences.

b) Second Stage

After the section of pipeline concerned has passed the preliminary test, any holes left at exposed joints shall be filled and compacted to achieve not less than 90% maximum dry density as specified for the appropriate levels.

The remainder of the trench shall then be filled with excavated material with particle size not exceeding 100 mm evenly placed and compacted in layers not exceeding 200 mm thick after compaction. The method of compaction shall achieve not less than 90% maximum dry density as specified in BS 1377 Test 13.

This work shall be commenced and completed without delay.

21.24 Pipe laying

Pipe shall be laid in accordance with CP 2010 unless otherwise specified herein.

The pipeline shall be constructed in lengths with a separate full time gang working on each length. The work on the lengths may proceed concurrently. The programme for pipe laying shall be submitted to and be approved by the ENGINEER, at the start of the Contract. Any subsequent change in programme shall be submitted to and approved by the ENGINEER, before work to a different programme is started. Excavation for the pipeline in any one length shall not at any time proceed more than 2 km beyond the end of a tested, completed and

backfilled length of pipeline unless otherwise approved by the ENGINEER. The exposed joints between test lengths shall be disregarded in the above definition.

No metal tools or heavy objects shall be permitted to come into contact with the pipes or fittings. Externally coated pipe shall be handled at all times with wide non-abrasive canvas, rubber or leather belts or other equipment designed to prevent damage to the coating. The use of chains, wire slings, or any other handling equipment found to be injurious to the coating shall not be permitted. The timbers or skids used to support the coated pipe prior to lowering into the trench shall be properly padded with sufficient bags stuffed with sand or straw for the purpose of protecting the coating.

Alternatively, the pipe may be supported alongside the trench on mounds of sand. Any injury to the protective coating from any cause must be repaired before the pipes are tested. Every precaution shall be taken to prevent foreign material from entering the pipes or fittings. During laying operations, no debris, tools, cloth or other material shall be placed in the pipe. Pipes and fittings shall be lowered into the trench with equipment suitable for the weight of the pipes and fittings, and in such a manner to ensure that the pipe is not laid in a stressed condition.

Pipe alignments shall be straight except at bends or when laid to curves.

The CONTRACTOR may submit to the ENGINEER for his approval an alternative method for the control of pipe laying to the correct levels and alignment, for example: on Non-controlled Sections as 1 m long properly graduated bubble level may be used to ensure minimum gradients and a measuring rod and cross straight edge used to determine minimum cover.

A 'badger' or 'bung' about 5 mm smaller than the internal diameter of the pipe shall be kept in the pipe at all times and pulled forward as the work progresses. When pipe laying is not in progress, including overnight, the open end of the pipeline shall be blanked off with a temporary watertight fitting approved by the ENGINEER. The pipe shall be suitably held down so that the pipe does not become buoyant in the event of the trench becoming flooded.

To restrict the flow of rain runoff along the trench the CONTRACTOR shall plug the trench with backfill material at distances not exceeding 250 m until the pipeline can be filled in. The plugs shall be removed when trench filling is taking place.

21.25 Pipe laying - Controlled and Non-Controlled Section

The criteria for the level and gradient to which pipes shall be laid are divided into two categories as follows:

'Controlled Sections' shall comprise the sections so designated on the Drawings, and such extra sections which shall be determined from the CONTRACTOR's detailed survey of the route, and approved by the ENGINEER.

'Non-controlled Sections' comprise the remaining sections of the pipeline where pipe gradients will normally correspond to ground slope and be subject to the following:

- (i) The cover above the crown of the pipe to ground level shall normally be a minimum of 2.0m except where the pipe is in a situation requiring a greater depth of cover as shown on the Drawings.

- (ii) The upward gradient shall be steeper as shown in drawings.
- (iii) The position of high and low points shall be determined from the CONTRACTOR's detailed route survey and shall be as far apart as ground levels permit, with the depth of the pipe being increased from the minimum as per ground situations.

The CONTRACTOR shall ensure that the required pipe levels and gradients along 'Non-controlled Sections' comply with the above criteria. If after the route survey he considers that high or low points additional to those on the Drawings are essential the ENGINEER must be informed immediately. Failure to inform the ENGINEER of proposed variations may result in the CONTRACTOR being required to excavation to extra depths to avoid additional high points without any extra payment.

21.26 Laying to Curves

Lengths laid to curves shall only be allowed where shown on the Drawings or in accordance with detailed proposals approved by the ENGINEER.

21.27 Classes of Bedding Material

The classes of bedding to be used are indicated below:

Table 21-19: Classes of bedding.

Class of Bedding	Brief Description of Bedding Material
A (Deleted)	Mass concrete
A2 (Deleted)	Reinforced concrete
B (Deleted)	Granular material
S	Granular material (bed & surround)

Class S pipe bedding shall be constructed as indicated on the Drawings.

The granular material for use in Class S bedding shall consist of durable gravel, broken or crushed stone to the approval of the ENGINEER. Not more than 10% of such material shall pass a BS test sieve with 5 mm apertures and all the material shall pass BS test sieve having 14 mm apertures.

In clays, silts or fine sands and when ordered by the ENGINEER, one part of free draining sand shall be added to and well mixed with each two parts of the granular materials specified above. Alternatively, where approved by the ENGINEER, the granular materials may be 'all-in' gravel mixture of similar size or comprise a layer of coarse sand on the formation covered by granular material as specified. In all cases the sulphate and chloride content of the granular material shall not exceed 0.5% and 0.06% by weight respectively.

The granular material shall be evenly spread over the full width of the formation and lightly hand compacted to a level slightly higher than the level corresponding to the underside of the pipe barrel to allow for settlement of the pipe to the correct level.

Further granular material shall be placed in the trench, special care being taken to fill under the sides of the pipes to ensure full contact with the barrel of the pipe. The granular material shall then be compacted evenly on both sides and over the pipes to an overall thickness as shown on the Drawings.

The CONTRACTOR shall ensure that the material is adequately compacted, and the method of compaction used will be required to achieve not less than 90% of the modified Proctor maximum dry density as specified in BS 1377, Test 13.

Pipe cut-off structures as shown on the Drawings shall be constructed to limit the uninterrupted length of a granular bed to a maximum of 500 m, and the cost of this provision shall be deemed to be included in the granular bedding.

Where Cut-off structures are not opposite pipeline markers, additional markers shall be placed opposite cut-off structures.

21.28 Puddle and Thrust Flanges

Where a water barrier is required in the wall of a structure or a structure is required to take the thrust resulting from a pipe passing through it, a puddle or thrust flange or anchor ring shall be fitted as specified or indicated on the Drawings.

Thrust and anchor blocks on pipeline to be provided where indicated and as specified elsewhere in these specifications.

21.29 Pipeline Surrounded by Concrete

When pipework is surrounded by concrete at thrust blocks, anchor blocks, road and wadi crossings, etc the pipes shall be given the specified external protection approved by Site ENGINEER.

21.30 Pipework Built into Concrete

The external protection to pipes built into concrete walls of chambers and structures shall extend at least 75 mm in to the wall from the concrete face.

21.31 Washouts

The design and locations of washout are shown on the Drawings. Exact positioning shall be determined with regard to topography and be to the approval of the ENGINEER. At least 3m of the washout pipework, inclusive for the isolating valve, measured from the centre line of the pipeline shall be laid at the same time as the pipeline and suitably capped to prevent ingress of foreign material. The minimum gradient for the washout pipework shall be 1 in 100.

Washout pipework shall be steel complying with ASTM A-53 Grade B Specification for high test line pipe, A-53 Grade B, having an outside diameter and minimum wall thickness as shown on the drawings.

21.32 Pipe Cleaning

Pipelines shall be manually cleaned of all debris, stones and sand prior to testing. Before testing the mains on completion a foam swab shall be passed through the pipeline between adjacent swabbing points.

21.33 Testing - General

The CONTRACTOR shall carry out preliminary air tests on pipeline sections as construction work proceeds and a final hydraulic test on the completed pipeline.

Unless otherwise specified or directed by the ENGINEER pipes of different materials in a pipeline shall be tested separately.

The CONTRACTOR shall supply all things necessary for carrying out the tests and shall be responsible for all work on the test site and for meeting all the requirements of all relevant regulations.

The hydraulic testing shall be carried out by an experienced specialist sub-contractor or specialist section of the CONTRACTOR's Organisation to the approval of the ENGINEER.

A Specialist Test ENGINEER shall be appointed by and specifically named by, the CONTRACTOR to be in full charge of all tests to be performed.

The Specialist Test ENGINEER shall prepare a schedule of operations for the tests stating the responsibilities of his subordinates during all phases of the work. The schedule shall include details of the following:

- (a) Safety precautions to be observed during testing.
- (b) The design and supply of any test fitting required.
- (c) The locations of the test cabin, pumps, air compressors and any other equipment.
- (d) Filling and pressurising, including sources of water, test connections and vent points.
- (e) Air leak testing procedure.
- (f) Hydraulic testing procedure.
- (g) Depressurising and emptying and details of disposal of water.
- (h) Fully detailed programme giving proposed dates of tests.
- (i) List of nominated personnel supervising tests with dates and time of duty.

The schedule shall be submitted to the ENGINEER for approval at least 28 days prior to commencement of testing and written approval shall be given by the ENGINEER before any testing may commence.

21.34 Testing-Safety

The CONTRACTOR shall be responsible for all safely precautions and shall adequately protect all personnel on Site and the general public during the course of the tests.

Prior to testing the CONTRACTOR shall certify in writing to the ENGINEER that he has instructed all employees engaged on testing work, or any work associated with testing, of the possible consequences of a pipeline test fitting failure under pressure test conditions.

The CONTRACTOR shall ensure that no work is carried out on the pressurised sections during the period of the tests and during subsequent pressure reducing operations. If any work is essential on a section under test the pressure shall be reduced to a safe level to be approved by the ENGINEER before commencement.

No pressurisation shall be commenced without the approval of the ENGINEER.

The CONTRACTOR shall ensure that no person approaches within 100 m of the test end or section under test during the period of testing. If it is not possible owing to site restrictions for persons to avoid encroachment within this distance the CONTRACTOR shall provide suitable protective barriers. The CONTRACTOR shall also provide suitable barriers or walls for protection of property within 100 m of the section under test.

21.35 Testing-Sequence

Testing shall be carried out as follows:

a) Initial air test

To detect lack of continuity or gross defects in the pipeline section under test. This test may be carried out in sections as construction proceeds.

b) Hydraulic test

To prove structural integrity and to detect lack of continuity in the complete pipeline. This test shall be carried out as a final test after the pipeline has been completed.

21.35.1 General

Testing shall be carried out in two stages:

- (i) test of sections as construction proceeds;
- (ii) a final test of the whole of the pipework or pipeline on completion.

The CONTRACTOR shall supply all plant, equipment, fittings etc including gas, necessary for the hydraulic, tests. He shall submit to the ENGINEER, well in advance of the time for tests, details of his proposals for transporting the test water from the point of supply at the inlet works to the pipeline to be tested. No connections to the pipeline or pipework which would involve cutting, tapping or otherwise permanently altering the Permanent Works, will be allowed.

Test gauges shall be of approved manufacture having dials at least 200 mm diameter, graduated such that the test pressure is at least 75 % of the gauge reading. If necessary different gauges shall be supplied for different pipeline sections. Two gauges of each type shall be provided for the sole use of the ENGINEER and shall remain in the ENGINEER's possession for the duration of the Contract.

All gauges shall be dead weight tested and proved at the commencement of use and at regular intervals thereafter as required by the ENGINEER.

The CONTRACTOR's arrangements for testing shall include a suitable means of quick installation and removal of the ENGINEER's gauges during testing.

21.35.2 Test Pressures

The test pressure in any pipeline shall be 1.5 times the maximum working pressure, measured at the lowest point on the pipeline.

The CONTRACTOR shall submit a schedule of pipeline test pressures to the ENGINEER for approval prior to commencing testing.

21.35.3 Sectional Hydraulic Test

The sectional hydraulic test shall be carried out after the pipeline or pipework section to be tested has been laid, jointed and backfilled to a depth of at least 300 mm above the crown of the pipe but leaving the joints exposed. The sections to be tested shall be approved by the ENGINEER. The joints between each tested section shall then be left exposed until the pipeline has passed the Test on Completion.

After all lengths have been joined together on completion of sectional testing, hydraulic tests shall be carried out on the complete length of the pipeline or pipework, or such other length as may be determined or approved by the ENGINEER.

21.36 Testing Structures on pipelines

Unless otherwise approved by the ENGINEER, water retaining structures on the pipelines which are not tested with the pipelines shall be separately tested in the presence of the ENGINEER for watertightness.

The structures shall be filled with water to ground level, the underside of the cover slab, or to give a head over the pipeline of 2 m whichever is the less. After a period to the approval of the ENGINEER to allow for absorption of water by the structure, there shall be no discernible loss of water over a period of 30 minutes as measures by a Vernier gauge or other approved device.

After depressurising the test section shall be carefully emptied and the water disposed of to the ENGINEER's approval.

21.37 Pipeline Markers

Marker Posts shall be of precast concrete Class A to the dimensions and locations shown on the Drawings, reinforced with 4 Nr 10 mm diameter high yield steel reinforcing bars tied to give 25 mm cover to each face.

Marker plates shall be 5 mm thick mild steel plate with dressed and bevelled face edges engraved to a depth of 2 mm x 3 mm x 150 mm mild steel fish tail plates shall be provided bent, split and welded to the back of the plate and the whole hot dip galvanised before casting into the marker post.