ELARD

Groupe MERLIN

UNDP- SOCIAL AND LOCAL DEVELOPMENT PROGRAMME

PROVISION OF PROFESSIONAL SERVICES FOR THE DESIGN AND SUPERVISIONS' SITE VISITS OF INFRASTRUCTURE, WATER AND SEWAGE PROJECTS ON LONG TERM AGREEMENT (LTA) BASIS

TECHNICAL ROOM AND TRANSFER LINE FROM THE WELL TO THE EXISTING RESERVOIR IN MAZBOUD

GENERAL SPECIFICATIONS

VOLUME 3

September 2017

ELARD LEBANON			
UNDP- Social and Local Development Programme		**Document Type:**	**Draft Report**
		ELARD	
Provision of Professional Services for the Design and Supervisions' Site Visits of Infrastructure, Water and Sewage Projects on Long Term Agreement (LTA) basis		**No. of Pages:**	**422**
General Specifications		**Revision no.:**	**A**
Document Control			
Revision / Date	**Issued by:**	**Reviewed by:**	**Approved by:**
A-for Client Review **04-09-2017**	Antoine Abou Rached Abeer Haddad	Antoine Abou Rached	Farid Karam Joseph Eid
Disclaimer			
This report has been prepared by ELARD , with all reasonable skill, care and diligence within the terms of the contract with the client, incorporating our General Terms and Conditions of Business and taking account of the resources devoted to it by agreement with the client. The in Formation contained in this report is, to the best of our knowledge, correct at the time of printing. The interpretations and recommendations are based on our experience, using reasonable professional skill and judgment, and based upon the information that was available to us. This report is confidential to the client and we accept no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known. Any such party relies on the report at their own risk.			

ELARD Lebanon
Amaret Chalhoub – Zalka Highway
2614 1407 - Fallas Building – 3rd Floor,
T : +961 1 888 305
T : +961 1 896 793
F : ext. 146
M: +961 3 910 032

Beirut | Abu Dhabi | Damascus | Tripoli | Baghdad
www.elard-group.com

TABLE OF CONTENTS

GENERAL REQUIREMENTS

1 GENERAL REQUIREMENTS

1.1 GENERAL REQUIREMENTS AND PARTICULAR SPECIFICATION

These General Requirements shall form an integral part of the General Specifications. In addition to these General Requirements, the Contract contains a Particular Specification, to supplement and/or modify the General Specification as may be necessary in each particular case.

The provisions of the Particular Specification for any specific section or number of sections shall prevail over those of the General Specification. Whenever the term "Specification" without further qualification is used in the Contract Documents, it shall mean this General Specification together with the Particular Specification.

1.2 REQUIREMENTS OF SPECIFICATION

The Contractor shall fulfil all requirements and obligations of all clauses of the Specification applicable to the construction work involved in the Contract. Neither the following clauses of this Specification nor the Bill of Quantities shall limit the obligations of the Contractor under the accompanying Conditions of Contract. Where items are not included in the Bill of Quantities for any such requirements or obligations the cost of such requirements or obligations shall be deemed to be spread over all the items of the Bill of Quantities unless otherwise stated.

1.3 ISO 9000 CERTIFICATION

Imported manufactured products and equipment shall comply with their relevant international standards. The quality assurance of all imported goods shall be granted the ISO 9000 certification.

Locally manufactured products and equipment shall comply with US or Western European Standards. ISO 9000 certification for locally manufactured goods is not essential, however these good shall be subject to the approval of the Engineer.

1.4 DRAWINGS, RECORDS AND DOCUMENTS

1.4.1 Drawings

All works shall be performed in accordance with the drawings furnished with the Contract documents and any such additional drawings as may be issued by the

Engineer from time to time during the progress of the work or any drawing furnished by the Contractor and approved by the Engineer. Additional drawings (if any) will be furnished to the Contractor in due time so as to enable him to perform the work shown thereon in its proper sequence and for any advance planning that may be necessary for the efficient performance of such work. The Engineer will decide in each instance whether additional drawings are required for advance planning of the works and determine the time required for same.

In all cases, detailed shop drawings for all components of the Works shall be prepared by the contractor, after the approval of all related equipment items. The design and the shop drawings shall be submitted to the Engineer who shall within 21 days approve, reject or ask the Contractor to revise or modify such documents and resubmit them for approval. All these documents shall be approved by the Engineer prior to commencement of the work. The structural design will be in accordance to the recommendations based on soil investigations.

1.4.2 Records and "As-built" Drawings

After the work has been completed, the Contractor shall furnish "as-built" drawings prepared whilst surveying during construction, showing the Works as constructed together with all other information that may either be required or be useful for the operation and maintenance of the Works in the future, such as alignment and depth of cover of pipelines, type of soil, type, dimensions and location of structures, size of pipelines and cables encountered during excavation.

Unless specific items are included in the bill of Quantities, the cost of preparing the shop drawings, "as-built" Drawings and Records shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately. The As-built Drawings shall be submitted, if required by the Engineer, on computer diskettes.

1.4.3 Ownership of Drawings and Documents

The Drawings and documents are issued to the Contractor for the purpose of the execution of the Works under the Contract and shall remain the property of the Employer to whom they are to be returned by the Contractor after completion of the work, as a precondition for the issue of the Certificate of Completion.

1.5 BOREHOLE INFORMATION

The Contractor shall satisfy himself as to the nature of the strata underlying the sites of the works. He may carry out at his own expense borings, tests and investigations as he may consider necessary and utilize the information thus gained for the preparation of his tender.

Any subsoil information and test results provided by the Employer shall be given to the Contractor for his preliminary information only. Such information shall not relieve the Contractor in any way of his obligation to inspect the sites and of his sole responsibility for carrying out the works as specified and required by the Engineer and at the rates set out in the Bill of Quantities. No claims for additional payment and/or extensions of time shall be entertained in respect of data furnished to the Contractor by the Employer or the Engineer.

1.6 METEOROLOGICAL AND HYDROLOGICAL CONDITIONS

The Contractor's attention is directed to the meteorological and hydrological conditions prevailing in the project area and its vicinity. In his planning of the work and in his unit rates, the Contractor shall take these factors into account. No increase in prices and/or extension of time shall be granted due to rains, floods and/or other adverse climatological conditions in the project area and along the roads to it.

For information, the climatic conditions in Lebanon can be summarized as follows:

	Temperature (deg C°)						Relative humidity					
	Coastal zones		Mountanious zones		Bekaa Valley		Coastal zones		Mountanious zones		Bekaa Valley	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Summer	20	35	15	25	10	35	65	85	50	60	40	65
Winter	7	15	-5	10	-1	15	60	75	55	75	55	80

1.7 BILL OF QUANTITIES

1.7.1 Rates and Prices

The rates and prices inserted by the Contractor in the Bill of Quantities are to be the full and inclusive value of the work described. They are to cover all costs, expenses and general risks which may be involved, together with all liabilities and obligations set forth or implied in the Specification and other documents on which the Tender is based. They must include all plant, tools, materials, transport of men and materials, insurance and labour of every description. They must also take into account the conditions referred to in the general Conditions, and include time lost due to weather, payment of guaranteed minimum and holidays with pay. The cost of any travelling time subsistence and incentives such as overtime etc. must be included in the rates and prices. Where any special risks, liabilities and obligations, mentioned above or otherwise, cannot be dealt within the rates, then the price thereof is to be separately stated in items provided for the purpose or added by the Tenderer.

Any item left unpriced shall be held to have had its cost included in the unit rates for other items of work.

1.7.2 Provisional Items and Quantities

Care shall be taken to distinguish between "Provisional items" which represent work they may not be required, and "Provisional Quantities" which represent work that will be required but the quantity of which cannot be closely estimated in preparing the Bill of Quantities and details of which will be given on site.

1.7.3 Methods of Measurement and Payment

The methods of measurement and payment for each trade are normaly specified in the General Specification, provided that where a different method of measurement is indicated in the Bill of Quantities or specified in the Particular Specification, the Bill of Quantities and the Particular Specification, in that order, take precedence over the General Specification.

Where no method of measurement is specified in any of the foregoing documents, the work will be measured in accordance with the latest edition of the Standard Method of Measurement of Civil Engineering Quantities, published by the Institution of Civil Engineers of London, U.K.

1.8 UNITS

In this Specification, on the Drawings and in the Bill of Quantities the S.I. (Systeme International d'Unites) metric system of dimensioning has been employed.

Where dimensions are given in metric units for materials which are only available in Imperial dimensions, the Contractor may, subject to his obtaining prior approval of the Engineer, substitute suitable sizes of materials as are available in the Imperial system. Such approval shall not unreasonably be withheld, provided that there is no difficulty in making interface connections with any other parts of the Works.

1.9 STANDARDS

For convenience and in order to establish the necessary standards of quality, reference has been made in the Contract Documents, to specifications issued by International Standards. Such specifications shall be defined and referred to hereinafter as "Standard Specifications" and shall be the latest editions of such Standard Specifications issued prior to the issue of Tender Documents together with such additions and amendments to such editions as may have been issued prior to the same date. Subject to the approval of the Engineer, any other internationally accepted Standard which specifies an equal quality of work may be used.

In reference to Standard Specifications, the following abbreviations have been employed:

B.S. British Standard

A.S.T.M.	American Society for Testing Materials
D.I.N.	Deutsche Industrie Normen
I.S.O.	International Organization for Standardisation
A.A.S.H.T.O.	American Association of State Highway and Transport Officials
A.W.W.A.	American Water Works Association
N.F.	Normes Française
AFNOR	Association Française de Normalisation

1.10 SURVEY AND SETTING OUT

1.10.1 Engineer's Benchmarks and Survey Markers

Prior to the commencement of the work, the Contractor will receive from the Engineer a number of benchmarks and survey markers on the Site. Before starting any work, the Contractor shall check the alignment and levels of the benchmarks and markers in the presence of the Engineer's Representative and shall correct any error or mis-alignment which may be discovered during such checking with the consent of the Engineer's Representative. Thereafter, the Contractor shall establish from these corrected benchmarks and markers all levels and lines necessary for the performance of the work.

The Contractor shall be responsible for the preservation of the benchmarks and markers during the entire period of construction, and shall at his own cost repair or replace any of them that may be damaged, destroyed, or removed by any cause whatsoever.

1.10.2 Setting Out

The Contractor shall appoint and employ the necessary qualified and experienced staff to set out the work accurately and shall establish and locate all lines and levels and be responsible for the correct location of all works.

Whether or not directed by the Engineer's Representative, the Contractor shall take such levels and dimensions as may be required prior to disturbance of the ground for the purpose of measurement and these shall be agreed between the Contractor and the Engineer's Representative in writing before any of the surface is disturbed or covered up.

The Contractor shall establish parallel survey lines or other points of reference at a safe distance, permitting the re-establishment of lines and points, wherever the original lines and points must inevitably be destroyed or removed during the progress of work.

1.10.3 Surveying for Measurement of Earthwork

All intermediate and final surveying necessary for the establishment of quantities of excavation and earthfill will be done by the Contractor, who shall establish elevation points and prepare cross-sections sufficient to permit an accurate calculation of the quantities of earthwork. The Contractor shall notify the Engineer's Representative at least three days in advance of his intention to perform such measurements. The cross-sections prepared by the Contractor and approved by the Engineer's Representative shall be basis for the measurement and payment of earthworks.

1.10.4 Payment

Unless specific items are included in the Bill of Quantities, the cost of all surveying, modifications to drawings, setting out, and measuring to be done by the Contractor and all other expenses incurred by him in complying with the requirements of this section shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.11 PROGRAMME OF WORKS AND PROGRESS REPORTS

The time allocated for the performance and completion of all works under this Contract shall be as stated in the Appendix to Form of Tender (Volume 2 of Contract Documents).

The Contractor shall submit to the Engineer, before commencing work on site, a fully detailed programme showing the order or procedure and method by which he proposes to carry out the construction and completion of the Works, and particularly of the organisation and staff proposed to direct and administer the performance of the Contract.

The information to be supplied to the Engineer shall also include drawings showing the general arrangement of his temporary offices, camps, storage sheds, building and access roads, and details of Construction Plant and Temporary Works proposed.

The Contractor when preparing his programme shall take due account of the time required for the delivery of materials.

The Engineer will check the proposed programme and will return same to the Contractor within 14 days of its receipt with his approval or comments and requirements for changes (if any). The Contractor shall make all requested corrections and changes not later than 7 days after having received the Engineer's comments. The programme as finally agreed to and approved by the Engineer will serve as the only basis for the carrying out of the Works.

After the commencement of each and any part of the Contract, the Contractor shall forward to the Engineer in triplicate, for each calendar month, a progress report and a chart showing the approved programme, the work completed to date and the progress made during the month. Such monthly progress reports and charts shall be submitted by the Contractor to the Engineer or his Representative not later than the 6th day of the month following that to which the report and chart refer.

1.12 WORK SITES

1.12.1 Right of Way and Sites of Works

The Employer will provide all the necessary rights of way, lands and sites on which the Works are to be carried out and will designate the access roads to the sites which the Contractor will be permitted to use.

In no case shall the Contractor occupy lands, right-of-ways or way-leaves without the previous written permission of the Engineer.

1.12.2 Contractor's Work Area

The location of the Contractor's work area, i.e. the area or areas where the Contractor may set up his offices, stores, workshops, yards for mechanical plant, etc., and transport depots, shall be agreed beforehand with the Engineer and shall be such as to avoid obstruction and nuisance to the public. The Contractor shall provide, within his work area, a Site Office for the use of his agent where written instructions from the Engineer may be delivered.

The Contractor shall make his own arrangements for and pay all costs incurred in the use of such areas of land as he may require for work areas for the purpose of the Contract.

1.12.3 Access and Construction Roads

The Contractor shall at his own expense construct and maintain within the right of way any temporary access roads and construction roads on the work sites that he deems necessary for the proper performance of the works, but the routes of such temporary roads and the method of their construction shall be subject to the Engineer's approval.

The Contractor will be permitted the use of existing roads on the Site provided that such use is co-ordinated with other users.

The Contractor will be permitted to use public roads as access roads to the Works only after having obtained permission in writing from the relevant Authorities and from the Engineer. The Contractor shall strictly adhere to all requirements and conditions prescribed by the relevant Authorities and set out in Clauses 29 and 30 of the Conditions of Contract.

The cost of preparation and maintenance of all access and construction roads and all costs incurred in complying with the requirements of this subsection shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.12.4 Existing Services

The Contractor shall make himself acquainted with the position of all existing works and services inter alia roads, sewers, stormwater drains, cables for electricity and the telephone lines, telephone and lighting poles, and water mains, before any excavation is commenced.

The Contractor will be held responsible for damage caused in the course of the execution of the Works to such existing works and services and shall indemnify the Employer, the Engineer and their agents against any claims arising from such damage (including consequential damages). Any damage caused must be made good at the Contractor's own expense.

Where the works required the crossing of existing roads, railways, fuel pipelines and services, the Contractor shall obtain the prior permission of and shall make all necessary arrangements with the relevant authorities and/or owners of said utilities and shall obtain their consent to the time and manner of execution of all work connected with such crossings.

When crossing a road in public use the Contractor shall either leave half the width of the road free for traffic or shall construct a bypass, as may be required by the road authority. The length, width and shape of any such bypass and the mode of its construction shall be as directed by the Engineer, but shall at all times permit for the passage of traffic using the main road. The Contractor shall put up warning and traffic signs, and shall employ flagmen to direct the traffic and shall mark the road crossings and put up lights from sunset to sunrise.

The Engineer's Representative may order the Contractor to repair bypasses, strengthen any temporary structures, put up additional signs or lights and generally improve the arrangements as he may deem necessary, and the Contractor shall forthwith comply with such orders. Regardless of whether or not the Engineer's Representative orders any such repairs of improvements, the Contractor shall remain solely responsible for the proper performance of all work in connection with the erection, maintenance and subsequent removal of all temporary structures required under this Clause, to the complete satisfaction of the Engineer.

Where the Works cross existing pipes, sewers, drains, channels, telephone or power lines and cables, the Contractor shall be responsible for the preservation of all such utilities in a good and serviceable condition during the execution of the Works and shall see to it that any damage done to any of the services be immediately repaired. Inasfar as necessary, the Contractor shall construct temporary bypasses for such pipes, channels and cables and restore them to their original position after the work at the junction or crossing has been completed.

The Contractor shall construct all bypasses and do all repairs to roads, pipes, channels and cables in accordance with the requirements of the proper authorities and/or the owners thereof or shall bear the expenses of all such work done by them.

Existing access to lands, property and all other facilities shall be maintained by the Contractor during the continuance of the Works to the Engineer's satisfaction.
Where work is being carried out in the vicinity of overhead power lines the Contractor shall take special measures to ensure that all persons working in such areas are aware of the relatively large distance that high voltage electricity can "short" to earth when cranes or other large masses of steel are in the vicinity of power lines and that adequate safety precautions are being taken. The Contractor shall ensure that none

of his employees commits any act which will cause damage from, or to, overhead power lines.

Unless specific items are included in the Bill of Quantities, the cost of all works required under this section shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.13 WATER AND POWER FOR USE IN THE WORKS

The Contractor shall be solely responsible for the location, procurement and maintenance of water supplies adequate in quality and quantity to meet his obligations under the Contract.

The Contractor shall be responsible for the supply of all electric power to meet his obligations under the Contract and for the distribution thereof.

All costs associated with the supply of water and power shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.14 BUILDING REGULATIONS

All buildings erected by the Contractor upon the Site and Work Area shall comply with all Laws and local By-laws insofar as they are applicable.

1.15 WORKS IN THE DRY

All parts of the Works are to be carried out in the dry, and shall be kept free at all times from surface or groundwater from whatever source it may come to the satisfaction of the Engineer. Keeping the Works dry shall include all pumping and diversion of water that may be necessary in carrying out the Works, also provision and filling-in of sump holes, installation and operation of drains, pumps, well points etc., in a manner and with equipment and materials satisfactory to the Engineer.

The Contractor shall, at his own expense, make such provision for the discharge of any water from the Works as shall be satisfactory to the Engineer and to any person having rights over the lands or watercourses over or down which such water is discharged. He shall hold the Employer indemnified against any claim that may be made through non-compliance with this section. In the event of any interference with existing land or road drains due to the construction of the Works or to the dumping of spoil, etc., within or without the limit of the Works, the Contractor shall take immediately steps to restore the drainage to the satisfaction of the Engineer and the Owners, occupiers, or Authority concerned.

Unless specific items are included in the Bill of Quantities, the cost of keeping the Works dry as specified in this section, shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.16 WATCHING, FENCING AND LIGHTING

The Contractor shall employ competent watchmen and guard the Works by day and night.

From the time that any portion of the Works shall be commenced, until the end of the works, the Contractor shall be responsible for protecting the public and his workmen from anything dangerous to persons or property and for the safe and easy passage of pedestrian, animal and vehicular traffic.

Any excavation, material dumps, soil dumps or other obstructions likely to cause injury to any person or thing shall be suitably fenced off and at night protected by red warning lights. The Contractor shall, at his own expense, and immediately upon completion of any part of the Works, fill up all holes and trenches, and level all mounds and heaps of earth which have been excavated or made in connection with the Works. The Contractor shall be responsible for the payment of all costs, charges, damages and expenses incurred or sustained on account or in consequence of any accident which may happen by reason of holes and trenches being dug and left or placed in improper locations.

Fencing shall consist of at least three 15 mm diameter hemp ropes or 4 mm diameter wires, or more, if required, stretched tightly between poles, standards, etc., securely planted in solid ground, well clear of the excavation and enclosing the spoil from the excavation. The poles, standards, etc., shall not be more than 15 m apart. If circumstances require it, they shall be placed closer and the ropes or wires shall be stretched tight, approximately 0.40 m, 0.80 m and 1.20m, respectively, above the ground.

Banks of spoil of suitable height and form may be accepted by the Engineer in lieu of fencing.

Fences and spoil banks shall be clearly marked at the ends, all corners and along the length at intervals of not more than 15 m, by means of white lime-washed boards, discs, stones or oil drums during the day and by red lamps kept burning at night. Markers shall be freshly lime-washed at regular intervals to ensure that they are white and clean.

The Contractor shall detail a man to trim and fill the lamps during the day and they shall be lit at least one half hour before sunset and not extinguished until at least one half hour after sunrise.

If a road is closed, or partly closed, to traffic, temporary traffic signs and barricades shall be erected by the Contractor, to the satisfaction of the Engineer and the Police, to give proper warning to traffic and to the public. Road signs shall be not less than 1.20 m x 0.80 m in size, surmounted by a red circle. Lettering shall be black, on a yellow ground and shall incorporate reflective material. The signs shall be adequately illuminated at night. The Contractor shall be solely responsible for the proper control of all traffic.

The cost of watching, fencing and lighting and all other costs incurred in complying with the requirements of this section shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.17 PRESERVATION OF TREES

No trees shall be cut down without prior permission of the Engineer who will limit the removal of trees to the minimum necessary to accommodate the Permanent Works.

If trees are cut down or damaged by the Contractor or his employees and without approval, then the Contractor shall replace such trees at his own expense with trees of not less than two years of age obtained from a reputable nursery and of species to be approved by the Engineer. The Contractor shall plant, water and ensure that the replacement trees are properly established all at his own expense.

All costs incurred in complying with the requirements of this section shall be deemed to be included by the Contractor in his unit rates for the various items on the Bill of Quantities and shall not be paid for separately.

1.18 WORKS EXECUTED BY THE EMPLOYER OR BY OTHER CONTRACTORS

The Employer reserves the right to execute on the Site works not included under this Contract and to employ for this purpose either his own employees or another Contractor whose contract may be either a sub-contract under this Contract, or an entirely separate Contract. The Contractor shall ensure that neither his own operations nor trespass by his employees shall interfere with the operations of the Employer or his Contractor employed on such Works and the same obligations shall be imposed on the Employer or other Contractor in respect of work being executed under this Contract.

1.19 MATERIALS

1.19.1 General

All materials shall be of the best quality throughout. Materials delivered to the Works shall be equal in all respects to the samples approved by the Engineer. The methods of stocking, mixing, transporting, fixing, placing and applying all materials shall be in compliance with the specifications and to the approval of the Engineer, who shall be kept advised of any change of plan. Materials failing to comply with the Specifications shall be immediately removed from the Works, at the Contractor's expense.

All goods and materials used in the execution of the Contract shall comply in all respects with ISO 9000 Standards or other equivalent standards approved by the Engineer.

1.19.2 Approval of Materials

Before entering into any sub-contract for the supply of any material or goods, the Contractor shall obtain the Engineer's approval in writing of the manufacturers and/or suppliers from whom he proposes to obtain such materials or goods. If requested, the Contractor shall submit to the Engineer samples of such materials and shall have them tested in approved laboratories. Such tests shall be carried out at least seven days prior to the inclusion of such materials in the Works. The cost of all samples and tests shall be borne by the Contractor.

Should the Engineer, at any time, be dissatisfied with such material or goods or with the methods of production or operation carried out at the manufacturer's or supplier's works or place of business, he shall be empowered to cancel his previously given approval of such supplier and to specify any other supplier whom he may choose for the supply of such material or goods. The Contractor shall then obtain such said material or goods from such other supplier and shall bear any additional costs thereof.

Materials which, in the opinion of the Engineer, do not comply with the Specification, shall be classified as rejected materials and shall be cut out and removed from the Works and replaced as directed by the Engineer, at the Contractor's own expense.

1.19.3 Alternative Materials

Where brand names or products of a specific manufacturer are specified in the Contract, the Contractor may, subject to the Engineer's approval (which shall not be unreasonably withheld) supply alternative materials, having similar characteristics and showing performance and quality at least equal to those specified.

Whenever the Contractor wishes to propose an alternative material he shall submit detailed information concerning the type of material and/or product, the Vendor's name, drawings if required, test certificate, etc. If the alternative material is not approved by the Engineer, the Contractor shall supply the material originally specified in the Contract.

If the price of the approved alternative material is in excess of the material specified in the Contract, the Contractor shall not be entitled to extra payment over the rates in the Bill of Quantities.

1.19.4 Supply by Contractor

Pursuant to Clause 36 of the Conditions of Contract, all materials required in the Works, except as otherwise provided for in the Contract, shall be supplied by the Contractor and the cost thereof shall be included by the Contractor in his rates in the Bill of Quantities.

The Contractor's Tender shall be construed as an undertaking that all the materials and equipment to be provided by the Contractor are in his possession, or readily available and will be delivered to the Site in accordance with the Time Schedule.

1.20 MAINTENANCE OF WORKS

During the period of maintenance the Contractor shall maintain the Works and make all repairs, as defined in clauses 49 and 50 of the Conditions of Contract.

After the commencement of the Period of Maintenance, the Contractor shall do nothing which might endanger the safety of the Public and he shall carry out all instructions of the Engineer or other duly authorised person or authority in this regard. Throughout the Period of Maintenance the Contractor shall notify the Engineer what work or operations it is intended to be carried out on the Site and he shall carry out any instruction which the Engineer may give as to times and manner of working so that any inconvenience to the Public is kept to a minimum.

The Engineer will give the Contractor due notice of his intention to carry out any inspections during the Period of Maintenance and the Contractor shall upon receipt of such notice arrange for a responsible representative to be present at the times and dates named by the Engineer. This representative shall render all necessary assistance and take note of all matters and things to which his attention is directed by the Engineer.

1.21 WORKS LOG BOOK

The Engineer's Representative will keep a Works Log Book on the Site.

To assist the Engineer's Representative in keeping the Log Book, the Contractor shall supply daily to him full details in writing on the following:

1. The number of workmen of the various trades and grades employed in carrying out the Works.
2. Quantities of the various materials brought to or removed from the Site.
3. Quantities of the materials incorporated by the Contractor in the Works.
4. Constructional Plants and Contractor's equipment brought to and removed from the Site.
5. The use of Constructional Plant in the Performance of the Works.
6. Other details as requested by the Engineer's Representative.

The Engineer's Representative may, if he so desires, use the above data to conduct the Log Book. However, such data shall not bind the Employer or the Engineer in any manner whatsoever.

The Log Book will be signed by the Engineer's Representative, and a signed copy of the daily entries will be handed to the Contractor or his authorized representative, who within 48 hours from the receipt of said copy, may object to any of the entries therein by written notice to the Engineer's Representative. Such objections by the Contractor shall be recorded in the Log Book. If the Contractor or his authorized representative has not made any such objection within 48 hours as aforesaid, he shall be deemed to have confirmed the correctness of the data entered in the Log Book.

The Contractor may enter in the Log Book his remarks regarding the performance of the Works. However, such remarks shall not bind the Employer or the Engineer.

Entries in the Log Book, except those to which the Contractor has objected in writing as described above, shall serve as evidence between the parties as to facts included therein; however, they shall not in themselves from the basis for a demand for any payment under the Contract.

1.22 RESIDENT ENGINEER'S OFFICE

1.22.1 Construction

The Contractor shall, within 4 weeks of the award of the Contract, hand over to the Engineer a fully completed, furnished and equipped Engineer's office. The Contractor shall provide suitable temporary office space for the Engineer until the office is completed.

The office shall be of weather-proof construction, provided with burglar-proofed windows and suitably insulated against heat and cold, all to the satisfaction of the Engineer in respect of design, construction and siting and shall be set-up on land provided by the Contractor. The office shall have a minimum floor area of 30 square metres partitioned into at least three rooms and one toilet with a clear inside height of not less than 2.8 metres. The floor shall be of floated concrete or raised timber adequately damp, termite and ant proofed. The doors are to be fitted with both a Yale type and a rim lock with two keys to each.

The office shall be provided with adequate air conditioners and heaters.

A 24 hour electrical supply shall be made available, either from mains or from Contractor's generating plant. The office shall be wired for electricity and provided with a minimum of two ceiling light fixtures and two electrical outlets per room. The cost of maintaining this lighting and paying for the power consumed shall be borne by the Contractor.

The office of the Resident Engineer shall be completely separate from that of the Contractor and located as specified by the Engineer. If so directed by the Engineer, the office shall be fenced with 2 metres high barbed wire or other approved fencing and a gate with padlock and chain.

A latrine and washroom, a potable water supply and water-borne sewage disposal system shall be provided for the office.

The Contractor shall provide an access road not less than three metres wide to the Resident Engineer's main office and a car parking area of adequate size, constructed to a minimum of 150 mm consolidated thickness of gravel, properly graded, cambered and drained.

1.22.2 Furnishings

The Contractor shall provide the following satisfactory and serviceable furniture fittings and equipment in the office:

- One tilt-top drawing table with tee square;
- Scales;
- One lockable plan cabinet of six drawers;
- Three desks containing drawers with locks complete with desk chair;
- One four drawers steel filing cabinet of foolscap size;
- Two calculating machines of battery or rechargeable type;
- Six sq.m. of wall boarding for maps and plans;
- One conference table with six chairs;
- Six lineal metres of shelving;
- Sets of curtains for all windows.

1.22.3 Miscellaneous Facilities and Services

The Resident Engineer's office shall be cleaned daily and provided with clean towels (every other day), soap, glasses and at all times with a fresh and adequate supply of drinking water. The cost of these services shall be paid for by the Contractor.

The Contractor shall be responsible for the security of all plans, papers, books, instruments from theft or fire during the continuance of the Contract and his insurance policies shall cover the office of the Resident Engineer.

The Contractor shall provide for the use of the Engineer when required by the Engineer, one total station surveying equipment, all of approved type and make, complete with accessories and all instruments, tapes, staffs, poles, pegs, stagings, moulds, templates, profiles, and all other requisites for checking and setting out and measurement of the Work. The Contractor shall also provide, when required by the Engineer, the services of two experienced chainmen.

1.22.4 Maintenance and Removal

The Contractor shall fully maintain the Resident Engineer's office throughout the Contract Period and effect all repairs, painting etc. required during that period.

At the end of the Contract, the office with all its furnishings and facilities will revert to the Contractor who, upon receiving the Engineer's instructions to do so, shall dismantle the office and remove it, leaving the Site neat and tidy to the Engineer's satisfaction.

1.22.5 Payment

Unless specific items are provided in the Bill of Quantities, the cost of the use by the Engineer and his staff of the office, its furnishings and all facilities and the cost of their maintenance etc., all as specified in this Section, shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

1.23 DAYWORKS

When Dayworks are authorized by the Engineer all equipment, labour and materials shall be paid for at the rates listed in the Schedule of Dayworks in the Bill of Quantities.

All major materials for Dayworks authorized by the Engineer but not included in the Schedule of Dayworks shall be paid for on a Prime Cost basis. The Contractor shall be paid on the basis of paid invoices showing cost of materials less any discount, paid receipts for transportation and handling charges and paid receipts for insurance on materials and delivery of materials. Before authorizing the use of materials in Dayworks the Engineer may require the Contractor to supply estimates of the costs of the materials.

The Contractor shall be compensated for his expenses, overhead, labour and profit involved in procuring and delivering the materials by an amount equal to a percentage of the actual cost of the Prime Cost Sum.

1.24 WATER SAMPLES AND ANALYSES

1.24.1 Procedure

Water samples shall be out from the well. For the physico-chemical analyses, it is advisable to take a minimum of 2 liters of water. Whereas for the dosage of heavy metals and trace elements, it is necessary to take a minimum of 5 liters of water. Water will be sampled according to the indications of the laboratory and/or of the Engineer, in one or several small polyethylene flasks, with an eventual adjunction of certain substances.

The Contractor will install a regulating valve on the upper part of the pipe. The regulating valve will be fixed at a minimum height of 0.50 m above the ground. The flask in which water is sampled will be rinsed 3 times with pumped water before being filled. Each flask will be hermetically sealed and carefully labeled.

Water samples for bacteriological analyses will be taken in sterilized flasks of 250 to 500 ml. The regulating valve should be imperatively previously sterilized. Sampling flasks should not be exposed to direct sunlight and kept at a temperature of + 4 °C, before being transported to the laboratory within a maximum delay of 24 hours.

Physico-chemical and bacteriological analyses should be carried out by a laboratory approved by the Engineer.

1.24.2 Water analyses

Water analyses will be carried out and defined according to the French regulation method (decree N° 89.3 of January 3, 1989).

The required analyses are defined in accordance with:

- The origin of water: Ground or surface
- The treatment performed (if any)
- The sampling point.

At each well head, a sample of raw water will be taken to undergo a complete analysis. According to the sampling point:

- First analysis before starting works: Type P2P - C3 + B3
- Second analysis upon completion of works: Type P1 - C2 + B2.

1.24.3 Essential elements, measurements and criteria for each type of analysis (Tables 1, 2 and 3).

Table 1: **Bacteriological analysis**

BACTERIOLOGICAL ANALYSES		
Limited (B1)	Summary (B2)	Completed (B3)
Thermoduric coliforms. Fecal streptococci	Thermoduric coliforms. Fecal streptococci. Count of aerobic bacteria revivable at 22 °C et 37 °C.	Thermoduric coliforms. Fecal streptococci. Coliforms. Count of anaerobic bacteria revivable at 22 °C et 37 °C. Spores of sulfite-reducing anaerobic bacteria.

Table 2: Standard analyses defined in accordance with the sampling point.

Site	**Source**		**Production**				**Distribution**	
	At point of withdrawal, treatment performed (R)		After treatment and prior to discharge, or at the point of withdrawal if no treatment is performed (P)				In network (D)	
	(R.P.)	(R.S.)	(P1)	(P2)		(P3)	(D1)	(D2)
Origin of the water	Ground water	Surfac e water	Ground water and surface water	Ground water (P2P)	Surface water (P2S)	Ground water and surface water	Ground water and surface water	Ground water and surface water
Standard Analyses	B1 - - - - C3 - -	B1 - - - - C3 C4a C4c	- - B3 - C2 - - -	- - - - - C3 - -	- - - - - C3 C4a -	- - - - - - C4a C4c	- B2 - C1 - - - -	- - - - C2 - - C4b

Table 3: Types of physico-chemical analyses

PHYSICO-CHEMICAL ANALYSES						
	Limited physico-chemical analyses (C1)	Summary physico-chemical analyses (C2)	Complete physico-chemical analyses (C3)	Specific physico-chemical analyses (C4)		
				C4a	C4b	C4c
Organoleptic parameters	- Appearance (qualitative): odour, taste, colour - Turbidity	- Appearance (qualitative): odour, taste, colour - Turbidity	- Appearance (quantitative): odour, taste, colour - Turbidity			
Physico-chemical parameters Natural structure of the water	- pH - Conductivity	- Temperature - pH - Conductivity - Nitrates - 3 of the following parameters: nitrates, ammonium, chlorides, sulfates, permangante value,, metyl orange alkalinity or total hardness.	- Temperature - pH - Conductivity - Chlorides - Sulphates - Silica - Calcium - Magnesium - Sodium - Potassium - Aluminium - DS - Dissolved oxygen - Free carbon dioxide (marble test) or calculation of carbonate balance - Carbonates - Hydrogen-carbonates.			
Parameters concerning undesirable substances	- Residual chlorine or any other parameter relating to the disinfection treatment	- Residual chlorine or any other parameter relating to the disinfection treatment	- Nitrates -Nitrites - Ammonium - Permanganate value, hot, in acid medium - Hydrogen sulphide - Iron - Copper - Zinc - Manganese - Phosphorus - Fluorine - Residual chlorine or any other parameter relating to the disinfection treatment.	- Kjeldahl nitrogen . - Dissolved hydro-carbons - Surface agents - Phenol index	- Iron - Copper - Zinc.	
Parameters concerning toxic substances					- Cadmium - Lead	- Arsenic - Cyanides

					- PAH	- Chromium - Mercury - Selenium.
Other parameters						- Pesticides - Volatile halogenated organic compounds.

1.24.4 Interpretation of analyses (Potability)

The results will be compared to the values set by:

– EEC directives/No/ 80/779/EEC-Official Journal of the European Communities, August 30, 1980. This directive groups together 62 admissible value parameters (guide level and maximum admissible concentration).

– WHO recommendations (Geneva 1986). Grouping parameters into five categories.

– French regulations (Decree No. 89.3-Official Journal of January 3, 1989). This decree groups analyses types and tables of admissible physico-chemical and bacteriological parameters relating to the definition of water potability.

These analyses will be given to the administration for the interpretation of data and the follow up.

1.24.5 Interpretation of analyses (corrosion)

During its transportation or use, water may cause various changes to the materials with which it is in contact. The most frequent deterioration is metal corrosion.

– Effects of aeration conditions (O_2H):
  - Corrosion in a non aerated place: corrosion caused by hydrogen
  - Corrosion in an aerated place: corrosion caused by oxygen.

The iron-water equilibrium potential in the absence of oxygen, and the oxygen and hydrogen electrodes equilibrium potentials will be controlled according to the pH value of the water.

– Effects of the mineralization influence (T.D.S.-T.A.C.)
  - The global mineralization of water increases its conductivity and decreases its resistance to corrosion. In particular, the concentration of chloride shall be verified (RYZNAR index).

– Effect of temperature variation

In conclusion, the approved laboratory should confirm, according to total mineralization and pH, the action of water and temperature on the different metals.

1.25 OPERATION AND MAINTENANCE MANUALS

The Contractor shall submit to the Supervisor for approval draft copies of the Operation and Maintenance Manuals. A separate set of instructions shall be provided for each installation. The Contractor shall incorporate any amendments or additions required by the Supervisor in the production of the final Manuals.

The draft O & M Manuals shall be available on site always during Tests on Completion for the instructions to be verified. Any modifications found necessary shall be incorporated in the final version.

The Contractor shall supply the final version of the Operation and Maintenance Manuals prior to the issue of the Taking over Certificate for either the whole of the works or the respective section or part of the works.

The Contractor shall, as necessary, carry out survey work, take measurements, collect details, produce drawings and undertake all other work required to enable him to prepare the manuals.

Operation and Maintenance Manuals shall be supplied written in the English and Arabic languages, and all parts and equipment listings shall be in English.

EARTHWORKS

2 EARTHWORKS

2.1 GENERAL

2.1.1 Scope

Earthworks under this Specification include excavation and backfill for pipelines, excavation for ponds and open canals, excavation and backfill for structures, excavation from borrow areas, construction of embankments, compacted fill and surfaces and other earthworks and works related thereto, as required in the Works.

2.1.2 Classification of Excavation

Unless specific items for Rock Excavation are included in the Bill of Quantities, earthwork will not be classified in accordance with the hardness of the excavated material and all excavation will be deemed to consist of Common Excavation, as defined hereafter, regardless of the actual hardness of the excavated material.

Where excavation is classified according to hardness of excavated materials, the following definitions shall apply:

- Rock excavation shall include hard and solid rock that cannot be broken up by mechanical excavating equipment, including a heavy tractor equipped with a rooter, but which necessitates the use of pneumatic tools or blasting for its loosening and removal. Rock excavation shall also include detached boulders exceeding one half of a cubic meter in volume.

- Common excavation shall include all material other than rock as defined above and also detached boulders less than one half of a cubic meter in volume.

No material, except the aforesaid, will be defined as rock and classified as such for the purpose of payment, whether actually loosened by blasting, pneumatic tools or otherwise.

The decision as to the classification of any excavation into “rock” or “common” shall be at the sole discretion of the Engineer’s Representative, subject only to Clause 2 of the General Conditions of Contract.

Where specific items for Rock Excavation are included in the Bill of Quantities, the Contractor shall not be entitled to be paid for excavation in rock unless, at the time the excavation is open and visible, the Contractor shall give notice in writing to the Engineer's Representative that he claims to be paid for excavation in rock. After giving such notice the Contractor shall not fill in the excavation or otherwise prevent it from being inspected by the Engineer's Representative for the purpose of classification and determination of payline in respect of same.

2.1.3 Natural Ground Levels

The natural ground levels, as marked on the Drawings, shall form the basis of measurement for payment for excavation, fill and all other works where the site levels have bearing and no field surveys will be made. Natural ground levels at intermediate points shall be checked on the field by the Contractor.

The Contractor shall check the natural ground levels before the commencement of earthworks, and such checking shall be made by the Contractor at his own expense, in the presence of the Engineer. The results, approvals in writing by the Engineer, shall thereafter prevail.

The cost of checking natural ground levels shall be borne by the Contractor alone, whether checking is carried out at the Engineer's request or at the Contractor's own request. No allowance will be made for normal bulking or shrinking of the soil and the Contractor shall make allowance for this in his rates.

2.1.4 Dewatering, Supporting and Fencing of Excavations

The Contractor shall, during the whole period of construction, keep the work area and all excavations dry and protected from the influx of water from any source whatsoever (rain and seepage water, water from surface and subsurface streams, groundwater, etc.) and shall provide and operate all pipes, pumps, well points and other apparatus and materials and all labor required for this purpose. The Contractor shall, throughout the period of construction, prevent structures and/or pipelines from flotation either by keeping the work area dry or by temporarily filling the structure and/or pipeline with water, all as approved by the Engineer.

The provisions that the Contractor shall make for the discharge of any water from the Site of the Works shall be satisfactory to the Engineer and to any persons or authorities having rights over the lands through which such water is discharged. The Contractor shall keep the Employer indemnified against any claim or damage that may be caused by non-compliance with the requirements.

The sides of excavations shall be supported whenever necessary or directed by the Engineer's Representative by means of timber, steel or other type of struts, walling, boards, sheeting or any other approved system. No support work shall be removed without the approval of the Engineer.

Every precaution shall be taken by the Contractor against slips, falls, or subsidence in the excavations, but if any slips, falls, or subsidence should occur the Contractor must at once make good the same including all surface restoration and reinstatement, all at his own cost. Should any such fall, slip or subsidence disturb or weaken any foundation or support to the Works or to any adjacent structure or facility, or create empty spaces and gaps near the new works, the Contractor shall carry out such additional works as the Engineer may require in consequence thereof, such as filling the gaps so caused with concrete or other suitable material as the Engineer may direct, all at the Contractor's own expense.

Steel sheet piling may be used by the Contractor in his supporting, bracing and dewatering operations, as specified above, of his own choice or at the direction of the Engineer, or where shown on the Drawings as a permanent part of a structure. The sizes and types of sheet piles used for temporary supporting and bracing shall be determined by the Contractor but will be subject to the Engineer's approval. Where sheet piles form a permanent part of a structure, their sizes and types shall be as shown on the Drawings or as directed by the Engineer.

The Contractor shall take all the necessary precautions during the excavation to protect his workmen and the publics. This may include, but shall not be limited to the supporting of the sides of the excavations, fencing the areas, providing warning lights and providing watchmen.

The Contractor shall be entirely responsible for the proper dewatering, supporting, fencing, lighting, watching, etc. of excavations, trenches and pits and shall not be relieved of his responsibilities under the Contract even though no objection has been raised by the Engineer to the conditions of the work.

Unless specific items are included in the Bill of Quantities, the cost of dewatering, supporting, bracing and timbering (including steel sheet piles), fencing, lighting, watching, etc. of excavations, trenches and pits and any extra earthworks and labour, materials and apparatus required for them shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

2.1.5 Use of Explosives

The Contractor shall use explosives only with the written express permission of the Engineer's Representative and all blasting shall be carried out by properly licensed and qualified workmen under experienced supervision. When using explosives, the Contractor shall abide by and conform to all the Laws pertaining to the purchase, transportation, storage and handling of explosives and shall obtain all required licences from and make all necessary arrangements with the relevant authorities prior to commencing blasting operations.

When blasting operations are in progress, all precautions shall be taken to protect all persons and livestock, the Works, and any other property from injury or damage.

The Engineer's Representative shall have the power to regulate, restrict or prohibit blasting if in his opinion it is necessary to do so for the safety of persons or property, or to safeguard the foundations or sides of the excavation, and the Contractor shall have no claim against the Employer in respect of such regulations or prohibitions. Explosives shall not be used within 20 metres or any other distance as the Engineer's Representative may direct, of concrete in permanent structures.

Notwithstanding anything said in this Sub-Section, the Contractor shall be held solely and entirely responsible for any injuries to persons and livestock and damage to public or private property.

2.1.6 Programme and Methods of Work

In addition to the information furnished by the Contractor with his Tender, the Contractor shall, after award of Contract but no later than two weeks prior to commencement of Works, submit for the Engineer's approval detailed proposed methods of excavating, transporting and placing earthfill material, watering and compacting and any subsequent modifications thereof, together with a detailed list of quantities and type of plant to be used for all these operations. Amendments shall be made by the Contractor in accordance with any instructions issued by the Engineer before commencement of works and from time to time.

2.1.7 Excavated Materials - Handling and Disposal

As far as practicable and as determined by the Engineer's Representative, all suitable materials from excavations shall be used in the permanent construction required under the Contract.

The Contractor's operations in excavations shall be such as to yield the maximum of suitable materials for construction purposes, and shall be subject to the approval of the Engineer's Representative. Where practicable, and as determined by the Engineer's Representative, suitable materials shall be excavated separately from those considered unsuitable, and the suitable materials shall be segregated by loads during the excavation operations and shall be placed in the designated final locations either directly from the excavation, or shall be placed in temporary stockpiles for later placing in the designated locations, all as directed by the Engineer's Representative.

Excavated materials that are considered unsuitable or are in excess of those required for permanent construction, shall be removed from the Site. The Contractor shall be entirely responsible for the removal of all surplus excavated material from the Site to such disposal areas as he shall have obtained at his own cost and responsibility and shall keep the Employer indemnified against any claims, charges or proceedings arising out of the transportation and disposal of such surplus excavated material.

Spoil heaps shall be located where they will not interfere with the progress of the Works, or with the flow of water in natural streams or drainage courses, and where they will neither detract from the appearance of the completed project and environment, nor interfere with access to the structures. Spoil heaps shall be levelled and trimmed to reasonable regular lines, as determined by the Engineer's Representative.

The cost of complying with all requirements of this Sub-Section shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

2.1.8 Earthworks in Urban Areas

When working in urban areas, under heavy traffic conditions (pedestrian and/or vehicular), the Contractor shall pay particular attention to all safety measures necessary to avoid accidents resulting from open trenches, construction materials and/or equipment stored in the streets, etc. without adequate protection. The Contractor shall arrange temporary crossovers to all open excavations. The Contractor shall co-ordinate his work with the traffic police, public transport companies and municipal authorities and make proper and adequate traffic and safety arrangements for the duration of the Works. The Contractor shall take into account the restrictive urban and specific local conditions and shall make due allowance in his rates in respect thereof as no claim arising from this clause or contingency will be either admitted, entertained or considered.

When excavating trenches along city streets, the storage of excavated material along the trench may be impossible or prohibited by the authorities. In such cases the Contractor shall remove the excavated materials to areas of his own choice and at his own responsibility and shall bring such materials back when required for backfill or shall import instead other suitable material for backfill from some other source. The entire cost of such removal and return or replacement of backfill material irrespective of the hauling distance shall be included by the Contractor in his unit rates for trench excavation and shall not be paid for separately.

2.1.9 Restoration of Waterways and Pipelines

The Contractor shall clean out and restore to their original condition all waterways or pipelines which may have been cut by the excavation or in any way damaged or silted up as a result of his operations.

Unless specific items are provided in the Bill of Quantities the cost of all additional work involved in crossing under or cutting through any waterways and pipelines and reinstating to their original condition shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

2.1.10 Restoration of Surfaces

The Contractor shall be responsible for the temporary and permanent restoration of all surfaces of roads, fields, paths, gardens, verges etc. whether public or private which are affected by his operations.

Temporary restoration shall be carried out immediately after the excavations have been refilled by returning the excavated material to the position from which it was removed and adding such suitable materials as may be required and consolidating the various materials as the work proceeds in order to provide a surface that is adequate for the purpose that the original surface fulfilled. Temporary surfaces shall be maintained in a condition satisfactory to the Engineer and responsible Authority until the permanent reinstatement is made.

The Contractor shall be responsible for the permanent reinstatement of all surfaces already described including asphalt surfaced public roads as specified in Section 201.3.11.

Should, at any time, any trench become dangerous, the Engineer will be at liberty to call upon the Contractor to restore it to a proper condition at three hours notice and, should the Contractor fail to carry out the work, have it done at the Contractor's expense.

The Contractor shall include in his rates for all materials and labour which he may have to employ in reinstating the trenches and surfaces to the satisfaction of the responsible Authority concerned.

Restoration shall be deemed to be included by the Contractor in his various unit rates for earthworks and shall not be paid for separately, except where specific items have been provided in the Bill of Quantities.

2.1.11 Equipment for Earthworks

Generally, equipment for earthworks, shall be of a modern type and of a design suited for each specific purpose. Only equipment and machinery approved by the Engineer shall be used in the Works.

Grading equipment shall be of any type of earthmoving equipment the Contractor may desire or has at his disposal, provided the equipment is in a satisfactory condition and of such capacity that the programme can be maintained. The Contractor shall furnish, operate and maintain such equipment as is necessary to control uniform layers, section and smoothness of grade for compaction and drainage.

Compacting equipment shall be of a design, weight and quantity so as to obtain the required density.

Pneumatic Roller shall consist of pneumatic tires arranged in a manner so as to provide a satisfactory compacting unit. The roller shall have an effective rolling width of at least 150 cm. and shall give a compression of at least 130 kg. per cm. of width of tread when fully loaded. The tires shall be uniformly inflated.

Smooth Roller shall be self-propelled or power roller and shall weigh at least 10 tons and may be of the tandem or three-wheel type. The wheels of the roller shall be equipped with adjustable scrapers.

Other equipment, such as vibrating machines, may be used for compacting and consolidating the embankments, subgrades, and other areas, upon approval of the Engineer. Such equipment shall be routed over the area being compacted and shall be operated until the required density is obtained.

Watering shall be carried out by means of tank wagons, tank trucks, or distributors equipped with a suitable sprinkling device. Satisfactory equipment shall be maintained on the site at all times when embankment construction is in progress.

2.2 CLEARING AND STRIPPING

2.2.1 Clearing

The areas upon which new construction is to take place, the rights-of-way along which pipelines are to be laid and all other such areas as may be designated by the Engineer and/or indicated on drawings as required for auxiliary purposes, (site offices and workshops, transport and machinery yards, borrow pits, stockpile sites, etc.), shall be cleared of all vegetation, shrubs and small and large trees, together with their roots, and from all other foreign and deleterious matter that may affect and interfere with the progress of the Works.

Trees and shrubs shall be cut or burnt down under strict control to ground level, the roots grubbed up to a depth of not less than 1.0m and removed from the area. All other scrub, vegetation, rubbish, etc., shall be cleared or burnt down to ground level and removed from the area to any distance.

All trees shall remain the property of the Employer and the Contractor shall collect these trees and store them until required by the Employer. All trees near to and about the Works except such as are to be removed, shall be carefully protected from damage by the Contractor during the period of maintenance and no trees shall be removed without the prior consent of the Engineer.

The Contractor shall take particular care at all times to prevent erosion on every site and elsewhere on land which may be affected by his operations and the Engineer may impose such reasonable limitations and restrictions upon the method of clearance and upon the timing and season of the year when clearance is carried out as the circumstances seem to him to warrant.

Unless otherwise specified in the Contract, clearing shall be measured by square meters. The unit rate shall include for all operations required under this Sub-Section, including removal of trees (see also Sub-Section 201.2.2 hereafter).

No clearing shall be carried out without prior written approval of the Engineer's Representative and only such areas approved or ordered to be cleared shall be measured and paid for.

2.2.2 Removal of Trees

Clearing as defined in Sub-Section 201.2.1 shall include the removal of small and of large trees. Trees of a girth of 40 cms. or less when measured at a height of 1.0m above ground shall be classified as small trees. Trees of a girth exceeding 40 cms when measured at a height of 1.0m above ground shall be classified as large trees and shall be removed only at the express order of the Engineer's Representative.

The removal of large trees, except where a specific item is provided in the Bill of Quantities, and the removal of small trees will be deemed to be included in Clearing and will not be paid for separately.

Where a specific item is included in the Bill of Quantities for the removal of large trees, they will be measured for payment by number.

2.2.3 Stripping

Areas on which compacted fill is to be placed and areas of excavations from which material for fill is to be extracted, including borrow areas, shall be stripped of top soil containing organic or otherwise deleterious and objectionable matter to a depth of at least 15 cm. or to such greater depth as may be determined by the Engineer. The stripped soil shall be stored in separate dumps for subsequent re-use in covering the slopes of embankments or the borrow areas after excavation therein has been finished, or shall be otherwise disposed of as directed. Under no circumstances shall such stripped material be used as compacted fill.

Stripping shall not be carried out unless the Contractor is able to proceed immediately with the further earthworks upon the stripped areas. Overstripping shall be backfilled and compacted, at the Contractor's own expense, to the satisfaction of the Engineer.

Stripping shall be measured in cubic metres, computed by multiplying the area stripped by the depth of stripping. The unit rate shall include for all excavation, stacking-re-spreading and running excess to spoil.

No stripping shall be carried out without prior written approval of the Engineer's Representative and only such areas approved or ordered to be stripped shall be measured and paid for.

Unless otherwise specified, stripping of borrow areas shall not be measured for payment and the cost of such stripping shall be deemed to be included by the Contractor in his unit rates for earthwork in the Bill of Quantities.

2.3 EXCAVATION AND BACKFILL FOR PIPELINES

2.3.1 Surface Excavation to Reduce Levels

Where shown on the Drawings or required or approved by the Engineer, the Contractor shall execute surface excavation in advance of trench excavation, to the lines and grades shown on the Drawings or ordered by the Engineer.

Any surface excavation not shown on the drawings and not ordered by the Engineer that the Contractor may wish to execute for the convenience of his work shall be subject to the Engineer's approval, but shall be done entirely at the Contractor's expense.

Surface excavation shall be measured in cubic metres according to the dimensions, lines and levels shown on the Drawings or directed by the Engineer. The unit rate shall include also for hauling the excavated material to fill areas, at any distance, and spreading them in layers of thickness not exceeding 20 cm. after compaction and disposal of the surplus material, all in accordance with the Drawings or as directed by the Engineer.

2.3.2 Trench Excavation for Pipelines

Pipe trenches shall be excavated to the typical cross-sections shown on the Drawings, and in no case shall the trench width up to the level specified exceed that shown on the Drawings. The Contractor shall ensure that at any point the width of the pipe trench is sufficient to permit the pipeline to be laid, jointed, bedded/surrounded and backfilling to be placed and compacted around the pipeline to the Engineer's satisfaction.

The trench invert shall, at any location, be at the proper level and trench width of the proper dimensions to allow for sand and/or concrete bedding or surrounds as shown on the Drawings and directed by the Engineer. Where pipes are laid directly on the bottom of the trench, the latter shall be straight and even so as to provide a good support for the pipe over its entire length and shall be free of roots, stones, lumps and other hard objects that may injure the pipe or its coating.

Where welding or jointing of pipes and/or accessories is required to be done in the trench, the same shall be widened and/or deepened to form bell-holes of sufficient size as directed by the Engineer's Representative so as to easily permit the proper execution of all welding, connecting and fixing works in all their stages, all necessary repairs to the pipe and coating, and for the thorough inspection of all these operations.

The length of trench to be kept open at one time shall be determined by the Engineer and shall in no case be exceeded. Should there by any danger that trenches may erode, then sections shall be left unexcavated for as long as possible and the laying and backfilling of pipelines shall follow excavation as soon as possible.

The excavated material shall be placed alongside the trench in such a manner as not to interfere with the work and to prevent its falling into same.

Should any part of a trench be excavated, in error, deeper than required, the extra depth shall be filled up with concrete, solely at the Contractor's expense.

Trench formations shall be in undisturbed ground. Where in the opinion of the Engineer, the formation is unsuitable for bearing, extra excavation shall be carried out under the direction of the Engineer and the level made up again with sound soil material carefully compacted or with concrete. This work shall be paid for by the Employer provided that the unsuitability of the formation is not due to the method of working of the Contractor, in which case the Contractor shall carry out the work at his own expense.

Trench walls excavated in rock shall be as nearly vertical as possible, and the Contractor shall consolidate the walls wherever they have been loosened by blasting or other reasons, and shall remove all loosened material. If rock occurs at a level higher than the required level of the trench bottom, the clearance between the pipe and the trench sides and bottom shall, where in rock, be made to the dimensions shown on the Drawings or directed by the Engineer, to allow for sand or concrete bedding or surround.

In confined areas, where the passage of excavating equipment is impossible, or where the Engineer's Representative deems the use of such equipment impracticable or undesirable for any reason whatsoever, trench excavation shall be done by hand. All requirements specified above shall apply to trench excavation by hand. No extra payment shall be made for works in confined areas. All excavation, whether in confined or unconfined areas, shall be paid for at uniform rates as specified hereafter.

If, in the opinion of the Engineer, there is undue delay in testing the pipelines; removing surplus material; general tidying up of areas where pipes have been laid; partial restoration of maintenance of surfaces; or similar operations, then the Engineer may order that no further trenches shall be opened until the outstanding work has been carried out to his satisfaction and the Contractor shall have no ground for a claim against the Employer on this account.

No work will be started on the laying of pipes or bedding in any section of trench, until the trench formation of that particular section has been approved by the Engineer.

Once the pipeline section has been tested and the bedding and surround approved by the Engineer, the trenches shall be backfilled by layers as specified hereafter. Each layer shall be separately compacted and any subsidence resulting from insufficient compaction shall be the Contractor's liability and he shall forthwith add the necessary extra material which shall then be thoroughly compacted.

Unless otherwise specified, items for trench excavation shall apply to all kinds of soil, including rock, and the excavation will be measured for payment in linear metres measured along the centreline of the pipeline, classified by pipe diameter and for each section by average depth to invert of pipes. The average depth of a section shall be the average between adjacent manholes or as directed by the Engineer's Representative. The cost of trench excavation shall be deemed to include for excavation, drilling and blasting, to the required width and depth to underside of pipe barrel, finishing the trench bottom as specified, digging boreholes where required, removing excavated material and storing it alongside the trench for backfilling whenever permitted, removal of material that may result from land slides, removal of loosened earth or rock, removal and disposal of all excess spoil to any distance, timbering and dewatering as and where required if no specific items have been provided in the Bill of Quantities.

2.3.3 General Backfill

The excavated material or selected material which can be classified as suitable for backfilling shall be in accordance with the requirements of Section 201.5.

Where necessary, excavated material shall be sieved or sorted to remove large stones, rocks, or other particles which, in the opinion of the Engineer's Representative, may impede compaction.

2.3.4 Type A Fill

Type A fill shall be good hard well graded material screened and crushed as necessary to lie within the grading envelope given in Table 1.1. The material shall have a CBR greater than ~~30%.~~25%.

The liquid limit should not be more than ~~40%~~25% and the plasticity index should not exceed ~~10%.~~6%.

The minimum value of the sand equivalent should be 50%. The maximum value of abrasion test should be 40%.

Table 1.1: Grading Envelope for Type A Fill

Sieve Size	% by Mass Passing
75 mm	100
37.5 mm	85 - 100
10 mm	45 - 100
5 mm	20 - 65
600 microns	8 - 45
75 microns	0 -20

2.3.5 Type B Fill

Type B fill shall be clean hard fill free from deleterious material and free from stones greater than 150mm in~~size.~~

size. The material shall have a CBR greater than ~~20%.~~15%. The liquid limit should not be more than 40% and the plasticity index should not exceed 10%.

2.3.6 Hardcore

Hardcore shall consist of broken stone or other suitable hard material. It shall be free from clay, dust or other deleterious matter, shall not contain pieces exceeding 100mm and not more than 5% of the material shall pass through a 20mm sieve.

2.3.7 Beddings and Surrounds - Sand and Granular Material

(a) Sand Bedding and Surrounds for Concrete, A.C. and Metal Pipes -

Where shown on Drawings, pipes shall be laid in sand bedding or surround.

The bedding and surrounds material shall be fine, uniformly graded sand (sand comply with BS 882 grading zone c), clean and free of stones, rubbish, clay or organic matter. Free draining, incompressible, fine granular material may be used instead of sand, subject to written approval of the Engineer.

The beddings and surrounds up to 30 cm above the pipe shall be wetted and thoroughly compacted in layers not exceeding 15 cm in thickness after compaction. Special care shall be taken to obtain proper compaction under and around the pipe.

Sand beddings and surrounds at any depth shall be measured in linear metres of trench in which surround has been placed, classified by diameter of pipe. The unit rates inserted in the Bill of Quantities for surrounds shall include the additional excavation in trench bottom, supplying the necessary materials, spreading, levelling and compacting the materials.

(b) Granular Material Beddings and Surrounds for P.V.C. and G.R.P. Pipes

All P.V.C. and G.R.P. pipes shall be laid in suitable granular material bedding or surround. Suitable bedding and surround material shall be broken stone or gravel from 3/8" (9.5 mm) to 3/16" (4.8 mm) size, sand (as specified in Section 201.3.7(a)) or other material having a compaction factor not exceeding 0.1. The compaction factor shall be obtained by the following test:

Equipment

1. Open-ended cylinder 225 mm long and 150 mm internal diameter (a pitch fibre or P.V.C. pipe is suitable).
2. Metal rammer with striking face 40 mm diameter and weighing 0.9 to 1.1 kg.
3. Rule.

Method

Obtain a representative sample more than sufficient to fill the cylinder viz. about 11.5 kg. It is important that the moisture content of the sample should not differ materially from that of the main body of material at the time of its use in the trench.

Place the cylinder on a firm surface and gently pour the sample material into it, loosely and without tamping. Strike off the top surface level with the top of the cylinder and removal all surplus spilled material. Lift the cylinder up clear of its contents and place on a fresh area of flat surface. Place about one-quarter of the material back in the cylinder and tamp vigorously until no further compaction can be obtained. Repeat with the second quarter, tamping as before, and so on for the third and fourth quarters, tamping the final surface as level as possible.

Measure from the top of the cylinder to the surface of the compacted material. This distance divided by the height of the cylinder (255 mm) is referred to as the Compaction Factor.

Interpretation of Values

Compaction Factor	Suitability for Use
0.1 or less	Material suitable
Over 0.1	Material unsuitable

For each batch of material, three (3) Compaction Factor tests shall be made and the average value used. Material sufficient for the surround of two hundred linear metres of pipe shall be considered to comprise one batch.

The granular material bedding and surround shall be wetted and thoroughly hand-tamped in layers not exceeding 15 cm in thickness after compaction. Special care shall be taken to obtain proper compaction under and around the pipe.

Granular material beddings and surrounds for pipes, at any depth, shall be measured for payment in linear metres of pipe, classified by diameter. The rates shall include additional excavation in trench bottom, supplying the necessary material, spreading, levelling, compacting and carrying out Compaction Factor tests.

2.3.8 Beddings and Surrounds - Concrete

Where required, pipes shall be bedded on or surrounded by concrete, to the dimensions, lines and levels shown on the Drawings or determined by the Engineer. All concrete used for bedding and surround of pipelines shall comply, in all respects, with the provisions of Division 202 hereafter. Plain concrete and reinforced concrete shall be of Grade C20P.

Pipes shall be supported and jointed at the correct level, clear of the trench bottom upon two blocks of precast concrete of suitable height, each supporting one end of the pipe. Concrete shall then be poured and rammed beneath and around the pipes in one operation and finished off to the level and dimensions shown on the drawings.

The precast blocks shall first be properly set on the trench bottom and boned to the correct position and level. The pipes shall then be laid on the blocks and properly centred, socketed and finally brought to the correct gradient by the application of wooden wedges one on each side of the pipe and between the pipe and the concrete blocks. These wedges shall remain left-in whilst the pipes are jointed and tested, as herein specified and during the pouring of the concrete beneath and around the pipes. Where the concrete while being poured would otherwise cause the pipes to float, pipes shall be effectively anchored to prevent such flotation.

The Contractor may, according to his own choice, pour concrete either with or without forms. Whatever the Contractor chooses; the concrete for payments shall be measured as per Drawings and no extras shall be paid for dimensions in excess of those required according to the Drawings.

Concrete beddings and surrounds shall be measured for payment in linear metres, classified according to diameter of pipe and according to type of bedding and surround. The rates shall be valid for any depth and shall include all additional excavation in trench bottom, concrete, reinforcement, formwork, materials, labour, etc.

2.3.9 Backfilling of Pipe Trenches

Backfilling of pipe trenches (except at joints) shall be done as soon as practicable after the pipes have been satisfactorily laid in position and jointed and in no case shall more than five pipe lengths be left uncovered after laying. Where shown on Drawings, the first stage of the backfill, up to 30 cm above the crown of the pipe, shall consist of selected material. Selected material shall be granular, free from stones, rubbish, clay and organic matter. It shall be free-draining and readily compactable. This backfill shall be spread in layers not exceeding 15 cm in thickness after compaction, and compacted at least to 92% of modified A.A.S.H.T.O. density as defined in Part 2 Section 201.7.

The remainder of the pipe trench (from 30 cm above the crown of the pipe to the sub-base coarse of the road or to the top of the trench) shall be backfilled, after the completion of testing, by one of the following methods:

(a) Where the pipeline crosses or runs underneath roads or pavements, backfilling shall be of type B, type A will be used when directed by the Engineer or shown on the Drawings, and shall be placed in layers not exceeding 15 cm after compaction, wetted as necessary and compacted at least 90% of modified A.A.S.H.T.O. and the last 60 cm below the road sub-base course shall be compacted at least 95% of modified A.A.S.H.T.O. density as defined in Section 201.7.

(b) In open areas, where the requirements of para. (a) do not apply, the second stage backfill may be done with excavated material dumped into the trench by means of a bulldozer or similar equipment, provided that the fill material does not contain any large stones, that the trench is completely filled without leaving any voids, and the fill is finished with a neat mound raised to about 30 cm above the trench edges to allow for future subsidence.

All joints and other accessories shall be left uncovered until after the pipeline shall have passed any pressure or leakage tests that may be prescribed by the Specification.

Where the backfill cover over the pipes is less than 70 cm, the travel of the tracks or wheels of heavy equipment thereon will be strictly prohibited, and the Contractor shall use suitable small compactor, and shall be responsible for any damage caused to the pipe by non-compliance with this requirement.

The Contractor shall be responsible for any subsidence of trench backfill and shall make good any damage to road or structures caused thereby during the Period of Maintenance.

Where lengths of trench are excavated partly in rock, stony ground, or in other material unsuitable for backfilling, there may not be sufficient suitable material available from the excavation for backfilling as specified above and in such cases the Contractor shall transport suitable material from other parts of the work or from borrow areas.

The Contractor shall make arrangements for sites for tipping the spoil and shall include in his rates for excavation the cost of haulage and tipping of spoil and all expenses in connection with the obtaining of suitable backfilling material.

Backfilling of pipe trenches will be measured for payment in linear metres along the centreline of the pipeline, classified by pipe diameter and for each section by average depth to the top of surrounds material which is placed to 30 cm above the top of the pipe. The average depth of a section shall be the average between adjacent manholes in case of gravity pipelines, and the average between adjacent stations in case of pressure pipelines. The cost of trench backfilling shall be deemed to include supplying of material and compaction in layers not exceeding 15 cm after compaction.

2.3.10 Cased Borings

Where shown on the Drawings or instructed by the Engineer, pipes shall be installed in casings inserted into horizontal borings across embankments at existing installations or in road crossings. The casing pipe shall be of sufficient strength to withstand the forces acting on it during insertion in the bore and the external pressure of the earth, and shall have a nominal diameter as shown on Drawings but at least 6" larger than that of the line pipe. Where the soil is sufficiently cohesive and stable, the casing may be pushed into a bore previously drilled through the embankment to a diameter slightly larger (by 2-3 cm) than the external diameter of the casing. Where the nature of the soil does not permit such a procedure, the casing shall be jacked through the embankment or under the road with simultaneous drilling and removing the material from the interior of the casing pipe. In both cases, the casing pipe may be inserted in successive sections welded to each other as the work proceeds. The Contractor shall choose the most suitable and efficient method for drilling and casing and shall submit the procedure proposed by him for the Engineer's approval. Drilling and casing shall be done at the exact locations and to the lines and grades shown on the drawings or determined by the Engineer. After the casing has been installed in position and approved by the Engineer, the line pipe shall be installed therein. To protect the line pipe and especially its coating against abrasion and other injury or damage during installation and thereafter, the Contractor shall use specially designed spacers of timber or plastic or shall produce such spacers. The distances between spacers of either kind shall not exceed 3.00 m. After the line pipe has been installed in its final position, the annular space at each end of the casing shall be filled with a mixture of bitumen and sand to seal off the interior of the casing against the entry of water, mud, small animals, vermin and other foreign bodies.

Cased borings shall be measured, separately for each diameter of casing, in linear metres by the actual length of cased boring through embankment as approved by the Engineer.

The unit rates for cased borings shall include: open-cut excavation and preparation of work area at both ends of boring, drilling through embankment, supply of casing pipe, welding of casing pipe sections, inserting of casing pipe in bore, installation line pipe in casings, supply and placing of spacers and sealing of openings at the ends, supply, transport and removal from Site of boring equipment and backfill of open-cut excavation connected with boring.

2.3.11 Road Reinstatement

a) Cutting into Paved Areas

Where pipes have to be laid under existing paved areas such as roads or sidewalks, cutting into the pavement shall be done with appropriate tools, to ensure straight and neat cuts. The trench shall be vertical and its width across the top edges shall not exceed the following values:

MAXIMUM WIDTH OF THE TRENCHES AT THE TOP IN PAVED AREAS (IN m)

Depth of trench from paved surface to pipe invert (m)	Maximum width of trench at the top in paved areas (m)
≤ 1.50	O.D(*) + 0.55
1.51 - 2.50	O.D(*) + 0.85
2.51 - 3.50	O.D(*) + 1.15
3.51 - 4.50	O.D(*) + 1.45
4.51 - 5.50	O.D(*) + 1.85
5.51 - 6.50	O.D(*) + 2.25
6.51 - 7.50	O.D(*) + 3.00

(*)O.D = Outer diameter of pipe barrel.

The Contractor shall take all necessary measures, such as shoring, bracing, etc. to keep the width of the trenches within the limits given in the table.

Cutting into paved areas will be measured for payment in linear metres of cut pavement.

b) Reinstatement of Surfaces

All surfaces whether public or private which are affected by the Works shall be reinstated in two stages, the first stage shall be carried-out in the first instance, and when the ground has consolidated fully the Contractor shall proceed with the second stage at the order of the Engineer.

First stage and second stage reinstatement of all surfaces, affected by the operations of the Contractor shall be carried out and maintained to the satisfaction of the Engineer and the responsible authority or owner.

First stage reinstatement shall be carried out immediately the trenches are backfilled.

Second stage reinstatement shall not be carried out until the ground has consolidated completely. The Contractor shall inform the Engineer before carrying out this work. In the event of further settlement occurring after the completion of the second stage reinstatement the Contractor shall forthwith make good the reinstatement to the approval of the Engineer or responsible authority.

For the purposes of first and second stage reinstatement in bitumen and surfaced roads the surface width of trenches shall be increased by recutting 15cm on each side of the trench for a depth of 8 cm to provide a solid abutment for the surfacing material.

Reinstatement of surfaced roads shall be carried out to the approval of the relevant authority.

The responsible authority shall have the right to carry out final reinstatement at the Contractors expense.

Trenches in open ground shall be reinstated to the condition in which the ground was before excavation was commenced. The final surface of the trench shall be flush with the surrounding ground.

In verges and other grass surfaces and after the backfilling has been thoroughly consolidated the topsoil shall be relaid rolled and planted with grass or other vegetation as-directed by the Engineer as may be necessary and watered until the grass has become well established. Should the planting fail it shall be replanted as required until a satisfactory growth is obtained.

If at any time any reinstatement deteriorates the Contractor, shall restore it to a proper condition immediately.

Should the Contractor not remedy the defect to the Engineer's satisfaction forthwith any remedial work considered necessary may be undertaken by the Employer and/or the responsible authority at the Contractor's expense.

All trees, shrubs and plants shall be carefully transplanted and shall be returned to their original location after the refilling of the excavations. Return of old or mature trees may be waived in cases where the age of the tree makes return impracticable.

Top soil shall be carefully set aside and replaced at the surface of the backfilling.

The trenches shall be refilled and rammed solid as specified in the Contract and shall not be topped up above the original surface level to allow for settlement.

If any trench becomes dangerous the Engineer may call upon the Contractor for its reinstatement at three hours' notice and failing this to have the work done by others at the Contractor's expense.

c) Safety of Excavation in Roads

Where the surface of the road (other than that which lies immediately above the trench) is damaged either by the concentration of traffic caused by an open trench, by subsidence or other causes arising from the operations of the Contractor, he shall permanently reinstate the whole of the surface so damaged to its original condition.

The Contractor shall ensure that trenches and reinstatement are maintained in a safe condition and shall take immediate action to remedy any deterioration which renders the works unsafe. If in the opinion of the Engineer any excavation or reinstatement is in a dangerous condition the Contractor shall immediately remedy the defect. Should the Contractor fail to carry at the reinstatement promptly the work may be carried out by others at the Contractor's expense.

d) First Stage Reinstatement

In all paved roads the trenches shall be refilled and compacted to the underside of the sub-base layer of the road at 48 cm below the road finished level.

A sub-base layer of 20 cm thick shall then be laid consisting of approved free draining granular material conforming to section 218.1.3 requirements.

A base layer of 20 cm thick shall then be laid consisting of approved crushed limestone material conforming to section 218.1.3 requirements.

Prior to application of the first stage reinstatement the surface of the road foundation shall be cleared of all dust, debris and other deleterious matter and shall then be primed with one application of prime coat MC-70 or similar approved. All joints with adjacent road surfacing shall be cut straight and vertical and primed.

The road surfacing of the first stage consists of 5 cm thick of finished asphalted concrete layer.

The surface shall be maintained with the end of the period of Maintenance or until instructions are given for the final reinstatement to be carried out.

f) Reinstatement of unmade roads

In all unmade roads the trenches shall be refilled and compacted as specified in the Contract to within 15 cm of the surface.

The trench shall be surfaced with 15 cm compacted thickness of base layer material as specified above.

The surface shall be maintained until the end of the Period of Maintenance and shall not be topped up above the level of the original surface to allow for settlement.

e) Second Stage Reinstatement

Second and final reinstatement consists of a wearing course of 4 cm compacted thickness of 14 mm nominal size dense wearing course macadam. The laying and finishing of the coated macadam shall be carried out so as to achieve a dense, smooth and even surface using a roller of not less than 12 tonnes mass.

2.4 EXCAVATION FOR PONDS AND CANALS

Excavation for ponds and canals shall be carried out and finished to the lines, grades and dimensions shown on the Drawings and to the tolerances specified hereafter.

Excavated material shall be used for earthfill in embankments and in other locations, as shown on Drawings, except for material rejected by the Engineer as unsuitable, which shall be run to spoil. Under this Section, suitable material shall be excavated, moved to fill areas, dumped and spread, as specified. The Engineer shall be entitled to designate the earthfill where individual loads of material shall be deposited.

The Contractor shall take all necessary precautions to prevent excavation beyond and below the lines and levels indicated on Drawings. Any damage to the work due to the Contractor's operations, including shattering of the material beyond the required depths and lines, shall be made good by the Contractor at his own expense. Any and all excess excavation for the convenience of the Contractor or any overexcavation performed by the Contractor for any purpose or reason, except as may be directed by the Engineer in writing, shall be at the expense of the Contractor. Where required to complete the work, all excess excavation and overexcavation shall be refilled, consolidated and made good with materials provided by the Contractor at his own expense, as directed by the Engineer's Representative.

Unless otherwise specified, items for excavation for ponds and canals shall equally apply to all kinds of soil, including rock, and excavation shall be measured by cubic metres of excavated material, to the lines and levels shown on the Drawings or as directed by the Engineer. The unit rate shall include for excavation, drilling and blasting, stacking, hauling excavated material in fill areas, and disposal of spoil material, all as specified in this Section.

2.5 EXCAVATION AND BACKFILL FOR STRUCTURES

All excavation for structures shall be carried out to the dimensions, lines and grades shown on the Drawings or directed by the Engineer.

Excavations on or against which concrete or compacted fill is to be placed, shall be clean and free from stones, clods, debris and other loose material. Where the bottom of an excavation does not provide a solid basis for casting concrete, it shall be consolidated by tamping and/or watering as necessary until the required density is obtained.

Any overexcavation in the bottom of the structure shall be cleaned and backfilled with concrete or selected backfill compacted to the density of the adjacent natural soil. Overexcavation in rock shall be backfilled with the concrete of the structure or with dry stone pack, as directed by the Engineer. Any and all excess excavation for the convenience of the Contractor for any purpose or reason, except as may be directed by the Engineer in writing, and all refilling of such overexcavation as specified, shall be at the expense of the Contractor.

Where possible, concrete foundations and blocks shall be cast against the undisturbed sides of the excavation. Where overexcavation beyond the lines of the structure is unavoidable due to the nature of the ground, because of the shape of the structure or for any other reason, the space between the structure and the faces of the excavation shall be backfilled to the original ground level (whether natural or reduced) as specified hereafter for backfilling.

Excavated material, to the extent that it is required and suitable, shall be put aside for use in backfill. Surplus excavated material shall be either used for backfill in other locations on the site, or shall be otherwise disposed. Wherever required, the Contractor shall obtain suitable material for compacted backfill from borrow areas.

Backfill shall be carried out to the lines and grades shown on the Drawings. The backfill material shall be placed in horizontal layers not exceeding 15 cm in thickness after compaction. The backfill material shall completely and firmly fill the spaces between the excavation lines and the structure without leaving any voids, and shall be compacted to the density of the adjacent natural earth. The sides and bottom of the excavation shall be moistened before backfilling and so shall the backfill material, in order to obtain the moisture content necessary for the required compaction. Every layer shall be compacted by pneumatic tampers approved by the Engineer.

Unless otherwise specified, items for excavation and backfill for structures shall equally apply to all kinds of soil, including rock.

Excavation shall be measured by cubic metres to the neat lines and dimensions of the structures, as shown on the Drawings or described in the Specification, with no allowance whatsoever so actual side-slopes, working space, etc. The unit rates for excavation shall include for excavation, drilling and blasting, stacking, hauling of excavated material to any distance, spreading and compacting and running surplus to spoil.

Backfill will be measured for payment by cubic metres, and the unit rates for backfill shall include for supplying of material, spreading and compaction of material in layers not exceeding 15 cm after compaction.

2.6 EXCAVATION FROM BORROW AREAS

Wherever required or directed by the Engineer, the Contractor shall obtain suitable material for compacted fill from borrow areas. Such suitable borrow material shall be excavated, moved to fill areas and spared as specified. The locations and boundaries of the borrow areas as well as the depths and slopes of excavation therein shall be as determined or approved by the Engineer's Representative. Before commencing to extract filling material from any borrow area, the Contractor shall strip its surface as specified in Sub-Section 201.2.3 above and shall also remove therefrom all material which is, in the Engineer's opinion, unsuitable for filling. The surface of the borrow shall be left in a reasonably smooth and even condition, as approved by the Engineer's Representative.

No excess borrow material shall be brought to fill areas. Unnecessary material shall be rejected and dumped and shall not be measured for payment.

Measurement for payment of excavation in borrow areas shall be made only for excavation of borrow material actually used as fill, to the lines and dimensions prescribed by the Engineer's Representative. Measurement shall be by cubic metres and the unit rate shall include for stripping (which shall not be measured and paid for) and for removing unsuitable material, hauling to fill areas at any distance. All materials from borrow pits placed in embankments and compacted backfill will again be included for payment under the applicable rates of the Bills of Quantities for compacting such earthwork. Provided always that the cost of borrowed material has not been specified to be included in those relevant pay items for which the same borrowed material is to be supplied.

2.7 EMBANKMENTS AND COMPACTED FILL

2.7.1 General

Wherever the term "embankment" is employed it shall also mean "compacted fill", unless the distinction between those two terms is clearly emphasized.

Embankments shall be constructed to the lines and grades shown on the Drawings. Where grassing is required, a compacted fill embankment shall be constructed up to the underside of the layer of top soil, as shown on the Drawings.

No brush, roots, sod, or other perishable or unsuitable materials shall be placed in the embankments. The suitability of each part of the foundation for placing embankment materials thereon and of all materials for use in embankment construction will be determined by the Engineer. The Contractor shall maintain the embankment in an approved manner until the final completion and handing over of all the Works.

The embankment operations shall be so conducted and the various soil strata shall be placed so as to produce a soil structure as shown on the typical cross sections, or as directed by the Engineer. The slopes of the division lines between zones and/or portions of the embankment are tentative and shall be subject to variation, at any time prior to or during construction, and the Contractor shall be entitled to no additional allowance above the unit rates in the Bill of Quantities, by reason of such variations. The embankment for each portion shall be maintained approximately level throughout the entire length of each layer from abutment to abutment. All openings through the embankment required for construction purposes shall be subject to approval, and such openings shall be constructed so that the slope of the bonding surface between embankment in place and embankment to be placed is not steeper than 1:4. The bonding surface of the embankment in place shall be prepared as provided for embankment foundations.

The Contractor shall be responsible for the stability of all embankments made under the contract and shall replace any portion which, in the opinion of the Engineer, has become displaced due to carelessness or negligence on the part of the Contractor.

Where excess spoil, or other material for which compaction is not specified, is dumped and spread, the Contractor shall route his equipment, both when loaded and when empty, to travel over the entire area of the above mentioned material. No payment will be made for this operation, and its cost shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities.

When the state of the weather is such that it would adversely affect the placing of fill, all embanking shall be stopped. In particular, embanking work will not be permitted during rain nor for such time afterwards as the Engineer may judge to be necessary to allow the upper layers in the embankment to dry to their correct moisture content as directed by the Engineer.

At all times during dry weather, whether embanking is taking place or not, the surface of the embankment is to be watered everywhere as directed by the Engineer, or protected to his satisfaction to prevent undue cracking of the surface. Watering is to be done by means of tankers, sprinklers or other methods approved by the Engineer.

Any material not complying with the specified density or moisture content shall be replaced in the embankment at the Contractor's own expense notwithstanding the fact that it may be overlaid by more recently placed material.

2.7.2 Preparation of Foundation

No material shall be placed in any section of the embankment until the foundation for that section has been suitably prepared and approved by the Engineer's Representative.

All excavation made for test pits or other subsurface investigations, and all other existing cavities found within the area to be covered with earthfill which extend below the established lines of excavations for the embankment foundations shall be filled with compacted earthfill. The foundation for earthfill, where in clayey soil, shall be scarified, wetted and compacted as specified for the earthfill to be placed thereon. Where the foundation is granular material it shall be compacted by vibrating rollers to a depth of not less than 30 cm to the same density as specified by the overlaying earthfill. Surfaces upon or against which the earthfill portions of the embankment are to be placed shall be cleaned of all loose and objectionable materials in an approved manner by hand-work or other effective means immediately prior to placing the first layer of earthfill. The surfaces of each portion of the foundation, immediately prior to placing the earthfill, shall have all water removed from depressions and shall be properly moistened and sufficiently clean to obtain a suitable bond with the earthfill. Where compaction of fill is to be started, or continued after the previous layer has been in place for over 6 hours, the area shall be harrowed to a depth of 20 cms, wetted and compacted to the required degree of compaction.

2.7.3 Compaction Control

Compaction shall be controlled by field density and field moisture tests, or by such other tests as prescribed by the Engineer.

The densities of the compacted earth materials shall be defined as follows:

(a) Modified A.A.S.H.T.O. Density shall mean the maximum dry density obtained from the compaction test in accordance with the A.A.S.H.T.O.-T-180-61 (method D) test or the (identical) A.S.T.M.-D-1557 (method D) test.

(b) Relative Density shall be defined by the following formula (in accordance with the U.S. Bureau of Reclamation Earth Manual Designation E-12):

$$D_d = \frac{Y_d \max (Y_d - Y_d \min)}{Y_d (Y_d \max - Y_d \min)} \times 100$$

where

D_d = Relative density
$Y_d max$ = greatest dry density obtained by laboratory
$Y_d min$ = least dry density obtained by laboratory
Y_d = the dry density at which the soil is to be placed or the inplace dry density

The field density of compacted material in place shall be determined by the A.A.S.H.T.O.-T-191-61 method or by the identical A.S.T.M.-D-1556-64 method. Field moisture content shall be determined by the A.S.T.M.-D-2216-63-T method.

Samples of all fill materials, both before and during placement, shall be taken for testing at frequent intervals. The following tests shall be performed:

(a) Tests to determine the maximum dry density and the optimum moisture content. The number of samples for these tests shall be as determined by the Engineer but not less than one sample per 1,000 m^3 of fill shall be taken.

(b) Field density tests. The number of samples for these tests shall be as determined by the Engineer, but not less than one sample per 1,000 m^3 of compacted fill or one sample per day, whichever is larger.

For the performance of all the above-mentioned tests, the Contractor shall provide a fully-equipped field laboratory and the necessary trained personnel for sampling and testing, all subject to the Engineer's prior approval. All costs for providing the field laboratory and the necessary personnel and for sampling, testing, transportation, etc., shall be deemed to be included by the Contractor in his unit rates for the various items of earthworks in the Bill of Quantities and shall not be paid for separately.

2.7.4 Placing and Compacting - General

Embankment materials shall be deposited in horizontal layers over the entire width of the embankment and compacted to the required densities as shown on the Drawings or as specified.

Embankments shall be formed of satisfactory materials. The thickness of each layer shall not exceed the thickness shown on the Drawings or as specified. In the construction of embankments, starting layers shall be placed in the deepest portion of the fill, and as placement progresses, layers shall be constructed approximately parallel to the finished grade line.

The material in the layers shall be brought to the optimum moisture content before rolling is started to obtain the prescribed compaction. Wetting or drying of the material and manipulation to secure a uniform moisture content throughout the layer shall be required. Should the material be too wet to permit proper compaction or rolling, all work on all portions of the embankments thus affected shall be delayed until the material has dried to the required moisture content. Sprinkling shall be done with sprinkling wagons, pressure distributors, or other approved equipment that will sufficiently distribute the water. Sufficient equipment to apply the required water shall be available at all times.

The optimum moisture content shall be determined by the Engineer and the actual content shall not vary from the required one by more than plus 4 or minus 2 percent. This optimum moisture content, determined by the Engineer as required for compaction purposes, shall be uniform throughout each layer of the earth-fill prior to and during the compacting.

The distribution of materials shall be such that the compacted fill be homogeneous and free from lenses, pockets streaks or other imperfections.

The number of successive passes of the compacting equipment over each and every point in any layer shall be not less than six (6). The overlapping of two adjacent passes shall be not less than 30 cm. The Engineer's Representative shall have the right to test every layer. However, the Contractor shall not be permitted to start work on the successive layers without the Engineer's Representative's permission, irrespective of whether tests have been made or not.

Where due to small width of required fill or any other reason, compaction of material in horizontal layers by sheeps foot rollers or pneumatic rollers will in the Engineer's opinion be impracticable, the Engineer may permit the use of other equipment and procedures such as compaction by mechanical tampers or spreading the material in small quantities in layers parallel to the slope and compacting same by cylindrical rollers applied along the slopes, or otherwise. Compaction shall be carried out to the Engineer's satisfaction and to the specified density.

After compaction has been completed as specified, all surfaces and slopes shall be trimmed and smoothed to accuracy specified hereafter. The cost of such trimming and smoothing shall be deemed to be included in the various rates for construction of embankments.

2.7.5 Compaction of Clayey and Silty Materials

Clayey and silty materials shall be deposited in horizontal layers of thickness not exceeding 15 cm, after compaction. The excavating and placing operations shall be such that the materials when compacted will be blended sufficiently to secure the best practicable degree of compaction, impermeability and stability. Prior to and during compaction, the materials shall have the optimum moisture content as determined by the Engineer, and the moisture content shall be uniform throughout each layer.

Insofar as practicable, as determined by the Engineer's Representative, moistering of the material shall be performed at the site of excavation, but if necessary shall be supplemented by sprinkling at the Site. Should the actual moisture content not be within the limits prescribed in Subsection 201.7.4 above, compacting operations shall not proceed until the layer has been brought to optimum moisture content, whether by wetting or scarifying and drying. No additional payment shall be made on account of any operation by the Contractor in drying or wetting the materials or on account of delays occasioned thereby.

When the filling material has been conditioned as specified, it shall be compacted by tamping with sheeps foot rollers having staggered and uniformly spaced knobs and of sufficient weight for proper compaction, by tyre rollers, by hand or power tampers, or by other compacting equipment approved by the Engineer. When tamping rollers are used, the tamping knobs and cleaner bars shall be properly maintained and the space between the tamping feet shall be kept clear of anything which may impair the effectiveness of the roller. Unless otherwise specified, the dry density of the soil fraction in the compacted material shall not be less than 92 percent of the Modified A.A.S.H.T.O. Density as defined in Subsection 201.7.3 above.

2.7.6 Compaction of Cohesionless Free-Draining Materials

Cohesionless free-draining materials, such as sand and gravel, shall be deposited in horizontal layers of not more than 15 cm if compacted by tampers or rollers, not more than 30 cm if by treads of crawler-type tractors, surface vibrators or similar equipment and not more than the penetrating depth of the vibrator if compacted by internal vibrators.

Unless otherwise specified, the relative density of the compacted materials, as defined in Subsection 201.7.3 above, shall be not less than 70 percent.

2.7.7 Compaction of Intermediate Soil Types

Unless otherwise specified, in borderline cases between clayey and silty soils and those that fall under the definition of cohesionless free-draining materials, the density shall be either 92 percent of the Modified A.A.S.H.T.O. Density or 70 percent relative density, whichever value is the higher.

2.7.8 Pipelines and Structures in Embankments and in Compacted Fill

Where pipelines are to be laid in embankments or in compacted fill, the embankment or fill will first be constructed to the lines and levels shown on the Drawings, to a height of 1.5 m above the crown of the pipe or to the top of the embankment or fill. After the embankment or fill have been constructed to the height specified above, the Contractor shall excavate in the compacted fill a trench to the Typical Trench Cross Sections; shall lay, joint, etc., the pipes in it; shall backfill the trench, as specified, to the top of the embankment and shall complete all other operations of constructing and covering the pipeline. After all the above operations have been completed, the Contractor shall resume, where necessary, the construction of the embankment or fill and its compaction.

Where steel pipes are to be laid in compacted embankments, the work shall be carried out as specified above, except that the embankment shall be completed to a level of 50 cm above the crown of the pipes.

Where structures, such as manholes, chambers, channels, etc., are to be constructed in compacted embankments or fill, the embankment or fill will first be completed to the lines and levels shown on the Drawings. The required excavation for the structures shall then be made and the structures constructed in it. After the completion and testing of such structures, the excavation shall be backfilled and compacted to the specified density.

2.7.9 Methods of Measurement and Payment

The supply of fill material, including its hauling and spreading and running of surplus to spoil, shall not be paid for separately and shall be deemed to be included in the relevant pay items for excavation, whether from borrow areas or form excavations for pipelines, structures, etc.

Compaction of Embankments shall be paid for separately and measured by cubic metres of the volume of compacted fill in place. No payment shall be made for additional material required to be added due to Settlement, and the Contractor shall make due allowance for this in his rates. The unit rate shall include wetting and compacting and the performance of all field and laboratory tests as specified. The unit rate shall also cover all additional costs of scarifying, harrowing, etc., where and when needed and trimming and smoothing of surfaces.

No additional payment shall be made in case of stockpiling of excavated materials and later rehandling of such material if directed by the Engineer in order to produce the specified embankment structure and the cost thereof shall be deemed to be included by the Contractor in his unit rates for the various items in the Bill of Quantities and shall not be paid for separately.

2.8 TOLERANCES OF FINISHED EARTHWORKS

All earthworks shall be finished to the dimensions and elevations shown on the Drawings. Unless otherwise specified, the following variations shall be acceptable:

(a) Embankment width - not more than 20 cm over the specified widths and not more than 10 cm less than the specified widths. Embankment elevations - not more than 5 cm.

(b) Elevations of bottoms of ponds - no more than 5 cm.

(c) Channel invert elevations - not more than 3 cm, provided a continuous slope is maintained in the direction of flow so as to prevent the formation of puddles on bottom of channel.

(d) Irregularities in surfaces of all earthworks - not more than 1.5 cm when checked by a straight edge.

2.9 SOIL INVESTIGATIONS

The Contractor shall carry out soil investigations according to BS 1377 (Methods of test for soil for civil engineering purposes) at the stations, buildings, reservoirs and water towers construction site, whenever he is requested to do so by the Contract and as directed by the Engineer's Representative. These investigations shall comprise various boreholes (according to the nature of the soil) as well as reports determining the specifications of the layers, the bearing capacity of the soil, the nature of foundations and the retaining structures if needed.

2.9.1 Borings

According to the nature of the soil or rocks, one of the three following borings shall be carried out:

a) <u>Alluvial soils</u>

(loose soils or slightly to fairly consistent)

Borings shall be:

- Either, penetrometric borings performed by a penetrometer ≥ 100 KN, static-dynamic with a measurement of the cone resistance and the lateral friction.

- or, core-borings ∅ ≥ 76 mm performed with core samplings and in-situ-SPT. The number of borings is conditional upon the area of the structures, and shall be carried out at the rate of one boring for every 200 m^2, with a minimum of two borings. Depths shall be conditional upon the nature of the soil and the loads, and shall be fixed according to each site but shall not, in principle, exceed 15m.

In case underground water was found at a slight depth, a piezometer shall be installed. Moreover, in some cases, a trench shall be dug with a mechanical shovel down to 1 to 2 m beneath the aquifer and a permeability test performed by pumping shall be carried out (watertable drawdown and recovery).

b) <u>Calcarous rocks</u>

Destructive soil investigation shall be carried out with a measurement of the rate of drilling progress and the pressure exerted on the bit. These borings aim at locating the fractures and fissures in rocks, since these fissures and not the hardness of the rocky matrix limit the bearing capacity of the foundations. Borings shall reach 5 m beneath the level of the foundation.

The number of borings shall be conditional upon the surface of the structures and shall be carried out at the rate of one boring every $100m^2$, with a minimum of five borings. In case borings show cavities or considerable cracks, supplementary and closely distributed borings shall be carried out after the beginning of earthworks.

In case groundwater was found, a piezometer shall be installed.

c) Extremely consolidated soils or very soft rocks (Sandstone, marl, clay)

Continuous core samplings shall be performed with a double core-driller. The diameters of borings shall be 76mm as a minimum.

A representative sample of each layer and boring shall be taken from the core-samples and shall undergo unconfined compression tests. Some samples shall eventually undergo free swelling tests.

The number of borings shall be conditional upon the surface of the structures, and shall be carried out at the rate of one boring every 200 m^2, with a minimum of two borings.

The depths shall be conditional upon the nature of the soil and the loads, and shall be fixed according to each site, but shall not in principle, exceed 15m.

In case underground water was found, a piezometer shall be installed.

2.9.2 Report

After carrying out borings and taking measurements, a report shall be drawn. It shall treat of the following issues:

- Opening and stability of excavations and the drainage methods.
- Treatment of the foundations soil, if need be.
- The permissible constraint exerted on the soil, in terms of the nature of foundations and differential settlements.
- Special recommendations concerning problems such as drainage, etc...

2.9.3 Methods of Measurement and Payment

The soil investigation shall be measured for payment by linear meter of borehole depth, the unit rate shall include mobilization and demobilization of equipment, labor, boreholes, tests, report, etc...

PIPELINES AND PIPEWORKS

3 PIPELINES AND PIPEWORKS

3.1 SCOPE

This part of the specification shall apply to the supply, delivery, laying, jointing and testing of all pipes, fittings and accessories, and includes:

Concrete pipes
Asbestos-Cement pipes
Steel pipes
Cast Iron and ductile Iron pipes
G.R.P. pipes
P.V.C. pipes
HDPE pipes

3.2 CONCRETE PIPES

3.2.1 Quality Requirements

Concrete pipes, fittings and junctions shall comply in all respects with B.S. 5911 or DIN 4032. The pipes shall be truly circular and have bell joints, or spigot and socket joints, or rubber gasket joints, as noted on the Drawings or in the Bill of Quantities, and as specified hereafter.

Concrete pipes, fittings and junctions shall be tested for compliance with B.S. 5911 (and BS 2494 or DIN 4060/2 for jointing system) in approved laboratories or in their place of manufacture. The pipes shall be subjected to Hydraulic and Crushing Tests. The number and selection of samples for testing, the test procedures and the requirements shall all be as specified in B.S. 5911.

The selection of samples and the Tests shall be witnessed by a representative of the Engineer, who shall be informed at least 48 hours in advance of any sampling or testing.

The cost of samples, their transportation to the test site and their testing shall be deemed to be included in the unit rates and shall not be paid for separately.

Alternatively, the Contractor may submit to the Engineer certificates from approved laboratories certifying that the pipes have been subjected to and have satisfactorily undergone the required tests according to the specified standards. In that case the Engineer shall be entitled (but shall not be bound) to renounce any further testing.

The concrete pipes should be protected by HDPE lining, (according to DIN 50 049-2.2) or PVC lining or should have an epoxy coal tar interior coating not less than 1000 microns thick.

3.2.2 Hauling and Handling of Pipes

The entire curing period of the pipes shall be completed before any pipe shall be loaded and transported. The Contractor shall check each pipe before loading and shall reject all damaged or defective pipes. The Contractor shall load with the greatest care and properly secure the pipes on the vehicles for transportation and take all necessary measures to prevent any damage to the pipes during transport. The Contractor shall be responsible for the quality of the pipes and for their condition upon and after delivery to the Site. The Engineer will check the pipes upon their delivery to the Site and the Contractor shall forthwith remove from the Site all rejected pipes and replace them at his own expenses by pipes acceptable to the Engineer. Only pipes inspected and accepted on the Site by the Engineer shall be incorporated in the Works.

The Contractor shall ensure that all pipes are properly handled by his staff. During transport, pipes shall not be allowed to rest on their joints, narrow cross-members of vehicles, or anything else that might give rise to concentrated loads due to the weight of the pipe or bumping of the vehicle but shall be properly supported on soft material. Sufficient labour and equipment shall be on hand before loading and unloading is commenced and under no circumstances shall any pipe be dropped from a vehicle. For storage on site, the ground must be level and free from loose stones.

The Engineer shall have the right to reject consignments or stocks of pipes from which failed pipes have been drawn, or order them to be pressure-tested outside the pipelines, even though no defects are apparent, if there is reason to believe that mishandling has taken place. All costs incurred in this respect shall be borne by the Contractor.

3.2.3 Laying of Pipes

After the excavation and preparation of a section of pipe trench has been completed by the contractor, it shall be inspected by the Engineer. No pipe shall be laid before the excavation has been approved by the Engineer. Just before pipelaying, the trench shall be cleaned of all stones, soil and other debris that might have fallen therein.

All pipelaying shall be carried out by experienced pipe-layers well skilled in this work. Pipes shall be laid true to line by means of a line stretched along the side of the pipes and true to level by means of a straight edge of 4 meters in length kept inside the pipes and pulled forward to pegs boned in at suitable intervals between sight rails set to the proper levels.

Immediately before being laid, each pipe and fitting shall be carefully examined both inside and outside for any damage, and all dust, dirt and foreign matter shall be removed. Care shall be taken to ensure that they remain clean during laying. The use of a badger will be ordered by the Engineer, if, in his opinion, dirt is not being satisfactorily excluded. The badger on a sound rope is to remain within the bore of the pipe previously laid and jointed and is to be drawn forward as the work proceeds throughout the whole length of the conduit. The badger is to be of soft material which will not damage the internal surfaces of the pipes.

In order to prevent stones, soil or small animals from entering the pipe, a suitable cap end or plug shall be provided with which the last pipe laid shall be sealed when pipelaying is not actually in progress. The plug shall be of the screw-up expanding type or of tapered wood.

The completed section between two manholes shall form one continuous tube well supported over its entire length and with a straight and even invert according to the lines and grades shown on the Drawings. The straightness of each section between manholes shall be checked externally by means of a string stretched parallel to the designed invert line and supported at intervals not exceeding 7.5 m, and internally by means of a beam of light. The maximum permissible deviation in invert level in one section shall not exceed 2.0 cm or 1 mm per pipe, whichever is less. The alignment and location in plan shall not deviate by more than 20 cm from the design line. The axial displacement of pipes entering any manhole and issuing from it shall not exceed 2 cm. Pipelaying shall proceed upstream with the bells or sockets of the pipes pointing upstream.

Where shown on the Drawings or required by the Engineer, concrete pipes shall be laid on a sand bedding, or concrete bedding or with concrete surround.

3.2.4 Jointing

<u>Rubber Gasket Joints</u> - Where pipes with bell and spigot joints and rubber sealing gaskets are approved by the Engineer, the following provisions shall apply to jointing: rubber gaskets shall be of synthetic rubber resistant to oils and fats, and shall meet the requirements of (B.S. 2494 or DIN 4060/2) - Elastomeric Joint Rings for Pipework and Pipelines (Types 1 and 2) or of I.S.O. 1398.

> All pipes, and especially the bells and spigots, as well as the rubber gaskets shall be carefully inspected before being incorporated into the work, and no defective pipes or gaskets shall be used. Before making any joints, the rubber gaskets, spigot and bell shall be well cleaned and thoroughly covered with a special lubricating compound not harmful to rubber, as approved by the Engineer. After lubrication, the rubber gasket shall be stretched around the spigot of the pipe to be laid and fitted into the groove, care being taken to ensure uniform tension and to prevent twisting of the gasket. The spigot with the gasket on it shall then be inserted into the bell of the previously laid pipe and the new pipe shoved into position. Shoving-in may be done while the pipe is still suspended from the crane or lifting tackle to minimize friction between pipe barrel and trench bottom.

The bell, spigot, and gasket shall be protected from contact with earth, dirt, or any other deleterious matter until the joint is completed. The use of undue force to overcome improper fitting of the gasket into the spigot groove shall not be permitted, since this may cause twisting or dislocation of the gasket resulting in a faulty joint. If the pipes are properly aligned, the gasket properly fitted and the gasket and bell well lubricated, the pipe should slide in smoothly without the application of much force.

3.2.5 Cast-in-Situ R.C. Conduits

Cast-in-Situ R.C. conduits shall conform to all relevant sections of this Specification with regard to concrete, reinforcement, shuttering, etc. All cast-in-situ R.C. conduits shall be made of grade C30P, unless otherwise noted.

Cast-in-situ R.C. conduits shall be perfectly true to dimensions in cross section. Construction joints shall be installed along the conduit at intervals shown on the

Drawings and between joints the conduit shall be cast continuously, with no interruption.

The bottom of the trench shall be excavated by hand to the longitudinal slope of the conduit, and to the exact shape of the bottom of the conduit, moistened and well compacted. On the ground, a 5 cm blinding layer of lean concrete grade C7P shall be cast, to the longitudinal slope of the conduit, as a base for the bottom horizontal and inclined surfaces of the conduit, as shown on the Drawings.

Generally, conduits shall be cast in two vertical lifts, with a keyed construction joint separating these lifts, in accordance with the Drawings. Great care shall be exercised in pouring the lower lift, to ensure that the space directly under the interior form is completely and densely filled with concrete. In pouring the upper lift, concrete shall be placed equally on both sides of the form, to minimize lateral pressures on it. The internal surface of the conduits shall be smooth, perfectly true, and free of any irregularities.

Where permitted in writing by the Engineer, precast elements may be incorporated in cast-in-situ R.C. conduits. Such precast elements shall be manufactured and installed in the cast-in-situ conduit in accordance with the specification and the instructions of the Engineer.

3.2.6 Inspection and Testing of Concrete Gravity Pipelines

(a) General - After the laying and jointing of a section of pipeline (defined as the length of pipeline between two adjoining manholes) has been completed, that section shall be inspected and tested, as specified hereafter. The joints shall remain exposed, joint grooves shall not be filled and any bedding or surround or backfill shall be carried no higher than the invert of the pipe until all inspections and tests have been completed to the satisfaction of the Engineer and until he has given permission in writing to proceed with the covering-up of the pipeline.

The following inspections and tests shall be carried out:

Visual Inspection, in which the Engineer shall inspect the section for grade, direction, line, appearance of inner surface, depth and correct jointing.

Hydrostatic Test, as specified hereafter, which will be carried out in the presence of the Engineer.

After the completion of the above inspection and test to the satisfaction of the Engineer, any required beddings and/or surrounds shall be completed and backfilling shall be carried out as specified in Part 2 Section 201.3 of this Specification.

The Contractor shall inform the Engineer at least 24 hours before a section is ready for inspection and testing.

(b) Hydrostatic Test - The water tightness of every completed section between two manholes shall be tested by a hydrostatic test as hereinafter described. The section to be tested shall be cleared of any material or object that may be lying in it and all bellholes shall be cleaned so that the joints may be observed from the outside. The two ends of the section shall be hermetically sealed by suitable temporary plugs provided with pipe nipples. The upstream plug shall be connected to a standpipe extending at least 4 m above the top of the highest pipe. Water shall then be introduced through the opening in the lower pipe end to fill the pipe and expel the air through the standpipe, until the water level in the standpipe is 4 m above the top of the highest pipe. The section shall then be permitted to absorb water for 24-48 hours and all visible leaks in the joints shall be repaired. After this period the water level shall be restored and the pipe observed for 2 hours, while the water level in the standpipe is being maintained at 4 m above the highest pipe. The quantity of water that must be added to maintain the water level in the standpipe shall be measured and this will be considered as the leakage of the tested section. The leakage under test, for pipeline diameter ≤ 400 mm, shall not exceed 0.8 litre/m2 of internal wall pipe area per hour and for pipeline diameter > 400 mm, the leakage shall not exceed 0.8% of inside pipe volume per hour. If the leakage during the test period exceeds the permissible rate, the Contractor shall search for and make good all defects causing such leakage. The test and repairs shall be repeated as often as necessary until all visible leaks have been repaired and the leakage does not exceed the permitted limit.

All necessary testing apparatus, expanding plugs, stoppers, bladders etc., labour, water and any other materials necessary shall be provided by the Contractor at his own expense.

(c) <u>Infiltration Test</u> - Where the line has been laid in groundwater, after the trench has been backfilled, the interior of the pipe shall be tested for infiltration of external water through the joints into the interior of the pipe. Any leak so detected shall be repaired as instructed by the Engineer and to his entire satisfaction and the pipeline shall be retested, all at the Contractor's own expense.

3.2.7 Final Cleaning and Inspection

Before the works are accepted by the Engineer, the entire pipe system, including all structures, shall be thoroughly cleaned by flushing or by passing a brush, sphere or other suitable tool through it, or by any other approved method, to ensure that it is clean, and free of obstructions and that pipe runs are perfectly straight. Before taking over, the pipeline will be finally inspected by the Engineer.

3.2.8 Methods of Measurement and Payment

Precast concrete pipes and cast-in-situ R.C. conduits shall be classified for payment according to type and diameter and shall be measured for payment in linear meters of completed pipeline in place, measured along the crown of the pipeline, between internal surfaces of manholes or chambers and the length measured for payment shall include the lengths of all fittings, specials, junctions, bends, etc. installed in the pipeline.

The price of fittings, specials, bends, junctions, etc. for precast concrete pipes and cast-in-situ R.C. conduits shall be, unless otherwise specified in the particular specifications or the B.O.Q. considered as included in the cost of pipes.

Alternatively, if so stated in the Particular Specification and/or in the Bill of Quantities, precast concrete pipes and fittings may be measured by number of pipes of defined net lengths and by number of fittings.

Payment for precast concrete pipes and for fittings, specials, etc., shall include:

(a) Supply, hauling, handling, unloading and stacking of pipes and fittings including all necessary jointing materials.

(b) Removal from stacks; hauling and stringing alongside trench; laying, jointing and testing at any depth of trench; connections to manholes and chambers; and final cleaning and flushing of pipeline. The unit rates for this item, for each type and diameter of pipe and fitting, shall be the same for all depths of trench in which the pipes and fittings are to be installed.

Payment for each type and diameter of cast-in-situ R.C. conduits shall be made under a single item in the Bill of Quantities and payment for each type and diameter of bend, junction etc. for cast-in-situ conduits shall be made under a single "extra-over" item in the Bill of Quantities, and each of these unit rates shall include for the blinding layer, formwork, concrete, reinforcing steel, joints, curing, testing and all labour and materials necessary to construct and complete the cast-in-situ R.C. conduit.

The unit rates for constructing each type and diameter of cast-in-situ conduit and fittings, junctions etc. shall be the same for all depths of trench in which the conduits and fittings are to be constructed.
Only pipes, fittings, junctions, bends, etc. actually laid in trench, and tested and accepted by the Engineer, shall be measured for payment above, and no allowance whatsoever will be made for any breakage, loss, etc. en route.

Excavation and backfill, special beddings, surrounds and manholes shall be paid for under separate items in the Bill of Quantities, unless otherwise noted.

3.3 ASBESTOS CEMENT PIPES AND FITTINGS

3.3.1 Quality Requirements

All asbestos cement pipes, joints, specials and fittings shall be supplied by the Contractor unless otherwise stated. They shall be made by an approved manufacturer and shall be of the class and nominal diameter as shown on the Drawings and shall comply in all respects with the following standards:

Gravity Flow Pipes - for conveying fluids at working pressures up to but not exceeding 1.0 kg/cm^2 - B.S. 3656 or I.S.O. R-881

Pressure Flow Pipes - for conveying fluids at working pressures exceeding 1.0 kg/cm^2- B.S. 486 or I.S.O. R-160

The standard joint used on the A.C. pipes shall be the "Simplex", or "Supersimplex" (Comet, kaltite, Reka or similar) type coupling consisting of asbestos-cement sleeves and self-sealing rubber gaskets, and complying with the above standards.

Cast iron detachable joints and long collar detachable joints and other cast iron fittings for use with asbestos cement pipes shall comply with the requirements of B.S. 486 and shall be supplied with rubber rings, bolts and nuts, etc. The external diameters of all cast iron joints and fittings shall be adapted to the external diameter of the asbestos cement pipes of the corresponding nominal diameters.

Unless otherwise stated, A.C. pipes shall be coated and lined as provided under Clause 2.3 of B.S. 486. Cast iron joints and fittings for A.C. pipes shall be coated and lined as specified for C.I. pipes.

Rubber gaskets shall be of synthetic rubber and shall meet the requirements of B.S. 2494 or I.S.O. 1398, for water pipes or drainage, whichever is applicable.

The Contractor shall supply all the necessary asbestos-cement and cast iron fittings, such as reducers, bends, tees, crosses, end caps, adaptors, etc. All such fittings shall match the pipes they are to be connected to in diameter and class. All pipes, fittings, couplings, and gaskets shall be obtained from approved manufacturers who shall supervise the transportation and laying of the pipes and shall guarantee the quality of the pipes and fittings for a period not less than the period of maintenance specified in this Contract.

The Contractor shall submit to the Engineer certificates from approved laboratories that the pipes have been subjected to and have satisfactorily undergone the tests specified in the above-mentioned standards and have satisfied all their requirements.

3.3.2 Hauling and Handling of Pipes and Couplings

No pipe shall be loaded for transportation or transported until after the end of the curing period. The Contractor shall check each pipe before loading and shall reject every pipe found to be damaged or defective. The Contractor shall properly secure all the pipes on the vehicles and take all necessary measures to prevent any damage to the pipes. The Contractor will be held responsible for the quality of the pipes and for their condition after delivery to the Site. The loading, transportation and unloading of the pipes shall be done with the greatest care. Under no circumstances shall pipes be thrown down on the ground or dragged along it. Pipes up to 6” in diameter may be unloaded by two workmen standing on the vehicle and handing them down to two other workers standing below who shall place them and stack them gently on the ground. Alternatively these pipes may be unloaded by rolling them down gently and carefully from the truck on two strong planks and placing them alongside the trench in which they are to be laid. Larger pipes shall be handled by suitable cranes. Care shall be taken not to damage the edges of the pipes during unloading operations. The rubber rings of the joints shall be supplied separately from the couplings and shall be stored in the shade and in dustproof containers. Where conditions do not allow for the stringing of pipes alongside the trench into which they are to be laid, they may be unloaded at a central point, stacked on planks and secured by stop blocks until they are required in the Works.

The Engineer will check the pipes on the Site and the Contractor shall mark all defective or damaged pipes in accordance with the Engineer’s instructions and shall remove them from the Site immediately and replace them with acceptable pipes at his own expense. Only pipes marked as accepted by the Engineer after inspection on the Site shall be incorporated in the Works.

3.3.3 Mounting of Joint Couplings

The rubber gaskets shall be brought to the Site separately and shall not be inserted into the joint couplings until immediately before the mounting of the joint. As far as practicable, the coupling shall be mounted on the pipe end before the pipe is lowered into the trench. Before assembly, the coupling grooves, rubber gaskets and pipe ends shall be thoroughly cleaned and lubricated with a lubricant provided or approved by the pipe manufacturer. One sealing gasket and the central spacing ring (or spacers) shall be inserted in their respective grooves. Since the sealing gaskets have a special asymmetric cross section, care shall be taken to insert them in the correct direction. Gaskets and spacing rings shall be placed in their grooves neatly and evenly without twists, distortion or bulges. The coupling shall then be slipped on to the pipe end until the spacing ring or spacers rest against the edge of the pipe. On large diameter pipes (450 mm and above) a mounting tool operated by a screwed rod or similar device shall be used to pull the coupling over the pipe end. Where no spacing rings or spacers are provided a special fixing clip shall be used to keep the coupling in place while the next pipe is inserted into it.

3.3.4 Laying and Jointing of Asbestos-Cement Pipelines - General

Attention is drawn to the necessity of ensuring a perfectly even bed for the pipes. Where shown on the Drawings or required by the Engineer, asbestos-cement pipes shall be laid on a sand bedding placed in accordance with Part 2 Section 201.3.7. Bellholes sufficient in size to permit jointing of pipes as described hereinafter shall be excavated in the trench bottom, bedding and trench walls as necessary. No pipe shall be laid until the surface of the excavated trench bottom or that of the sand bedding, as the case may be, has been inspected by the Engineer and approved for pipelaying.

Before the line is handed over to the Employer, the inside of all pipes shall be cleaned of all dirt, mortar and other foreign matter. At the end of each work day and after a pipeline section is completed, the open pipe ends shall be suitably plugged to prevent entry of dirt or small animals.

All pipes shall be placed in position carefully and shall be laid true to line and grade. Under no circumstances shall pipes be thrown into the trench. Lowering shall be carried out manually or by means of lifting tackle and/or ropes. Before any pipe is lowered into the trench, it shall be cleaned and examined for cracks and flaws. If undamaged it shall be placed in position ready for jointing in accordance with the requirements hereinafter.

3.3.5 Laying A.C. Gravity Flow Pipes

Asbestos-cement pipes in gravity flow lines shall be laid consecutively in straight lines between adjacent inspection manholes. Special joint couplings shall be built into the walls of the manholes to ensure a tight joint between pipe and manhole. After being laid and jointed the completed section between two manholes shall form one continuous tube, well supported over its entire length and with a straight and even invert according to the lines and grades shown on the Drawings. The straightness of each section between manholes shall be checked externally by means of a string stretched parallel to the designed invert line and supported at intervals not exceeding 7.5 m, and internally by means of a beam of light (either torch or sunlight reflected by a mirror).

All pipes and manholes shall be laid and constructed according to the lines and grades shown on the Drawings, or as instructed by the Engineer, with the following tolerances:

The maximum permissible deviation in invert level in one section shall not exceed 2.0 cm or 1 mm per pipe, whichever is less. The alignment and location in plan shall not deviate by more than 20 cm from the design line. The axial displacement of pipes entering any manhole and issuing from it shall not exceed 2 cm.

3.3.6 Laying A.C. Pressure Pipes

In pressure lines the pipes shall be laid in straight lines where possible, but curves of long radius may be required, and these shall be obtained by deflection at the joints. Such deflections, however, unless specifically otherwise ordered by the Engineer, shall comply with the following:

ND (mm)	80 - 250	300 - 350	400 - 600	700 - 1200	≥ 1300
α Less than	4°	3°	2°	1 ½°	1°

Where a change in direction cannot be made by deflection at the joints of ordinary straight pipes, prefabricated bends shall be used. The approximate locations of such bends and other specials are indicated upon the Drawings, and their exact positions will be determined by the Engineer on the Site.

3.3.7 Jointing Asbestos-Cement Pipes

Before jointing a new pipe to one already laid in the trench, the second gasket shall be installed in the free end of the coupling mounted on the pipe in place, in the manner described above. The new pipe, with the joint coupling mounted on it shall be lowered into the trench, its free end cleaned, lubricated and inserted into the open end of the coupling on the pipe already in place. The pipe shall then be shoved home until its end abuts against the central spacing ring or spacers in the coupling. Small to medium size pipes may be shoved home by hand with or without the aid of crowbars. Larger size pipes, which are handled by means of cranes or hoists, may be shoved in while being suspended at balance point slightly lifted above the ground, thus eliminating friction with the trench bottom. Large size pipes may require the use of a special pulling device. Jointing shall always be done coaxially, any deflection in the joint as described in Subsection 217.3.6 above being produced after the joint has been completed.

3.3.8 Cutting of Asbestos-Cement Pipes

For closing lengths it will be necessary to cut asbestos-cement pipes. For this purpose, the Engineer may allow, at his discretion, the use of pipes with damaged ends but otherwise sound. Asbestos-cement pipes shall be cut by a suitable cutting machine, care being taken that the cut ends are truly perpendicular to the pipe axis and that no breaking or cracking occurs. Cutting by hammer and chisel will not be allowed.

For jointing, the outside diameter of the pipe ends shall then be reduced to the required distance, unless special pipes turned to the correct diameter are supplied by the manufacturer. Such reduction of outside diameter of pipe ends shall always be done with an approved machine mounted on or inside the pipe barrel; filing down by hand shall not be permitted. In every case the edges of the cut pipe ends shall be given the correct shape required for jointing.

3.3.9 Backfilling

As each pipe is placed in its final position and jointed, the trench shall be filled, leaving only the joints uncovered. The materials used for backfilling and their placing and compacting shall be in accordance with the Drawings and the requirements of the Specification. The joints shall be left uncovered until the hydrostatic tests have been successfully completed and the Engineer has given permission to cover the joints.

3.3.10 Testing of Asbestos-Cement Pipelines

A.C. pipelines shall be tested in accordance with standard I.S.O. 4483, and as specified hereafter and as directed by the Engineer:

(a) Gravity Pipelines - Gravity pipelines shall be subjected to the tests and shall meet the requirements prescribed for concrete gravity lines in Subsection 217.2.6.

(b) Pressure Pipelines - Pressure pipelines shall undergo a hydrostatic pressure test. They shall be tested in sections not larger than 500 m, or as may be directed by the Engineer, and tests shall be made only on sections which are completed, except for backfilling over joints and fittings which are to be left exposed for inspection. Weights and thrust blocks intended to prevent lateral and vertical displacement of the pipes or specials must be completed and must have attained their design strength before tests are commenced.

Test sections shall be preferably carried out between shut-off or sectioning valves. Where this is not practicable, test sections shall be sealed off by suitable bulkheads, properly braced.

Prior to testing, air shall be evacuated from the line by filling it with water with all valves and taps open. After the first filling and the closing of all valves and taps, the water shall remain in the line for at least 48 hours to allow for absorption, and water being added as required to make up for losses. During this period the Contractor shall inspect the line and all fittings and valves installed on it for leaks. Any leaks found shall be promptly repaired by the Contractor, who shall then proceed with the test, unless otherwise noted on the drawings, in the particular specifications, or by the Engineer, the "Test presssure" measured at the lowest point of the section shall be equal to one of the following values:

For pressure gravity driven pipelines:

(a) (1.5 x Rated Working Pressure) for rated working pressure equal to or less than 10 kg/cm^2 or the static pressure whichever is higher.
(b) (Rated Working Pressure + 5.0 kg/cm^2.) for rated working pressures exceeding 10kg/cm^2 or the static pressure whichever is higher.

For lift pipelines:

Rated working pressure plus calculated water hammer surge plus 2Kgf/cm^2. The water hammer surge will be calculated as follows: $\Delta H = \frac{a \, \Delta V}{g}$

where:

ΔH = Water hammer surge
ΔV = design velocity as indicated on the drawings expressed as meter per second.
a = surge velocity expressed as meter per second (a = 1100m/s).
g = acceleration due to gravity in meters per second per second = 9.81 m/s^2.

The pressure shall be slowly raised by pumping to the required "Test Pressure". Pumping shall then be discontinued, the pump disconnected, and the line kept under pressure for at least 15 minutes. For the line to be accepted, the pressure shall not drop by more than 10% during the said 15 minute period and there shall be no visible leaks at joints, fittings, valves, etc. Should the drop of pressure exceed this value, the Contractor shall search for the defects causing such pressure drop, shall make all necessary repairs and repeat the test until the section under test meets the requirements. Provided always that all visible leaks must be repaired whatever the loss of pressure. The Contractor shall at his own cost provide all necessary test pumps, pressure gauges, cocks and other accessories and shall make such temporary connections as may be required for filling and testing the line in the manner herein specified.

The water used for pressure testing shall be provided by the Contractor and shall be free from inpurities and of such a quality which will not pollute or injure the pipeline. The Contractor shall be responsible for obtaining the water, transporting it and for its safe disposal on completion.

3.3.11 Methods of Measurement and Payment

Asbestos-Cement pipes shall be classified for payment according to type, diameter and class and shall be measured in linear meters of completed pipeline in place measured along the crown of the pipeline as follows:

- In gravity flow lines: between internal surfaces of manhole or chambers.
- In pressure flow lines: between stations.

The length measured for payment shall include the lengths of all fittings, valves and specials installed in the line.

The price of fittings, specials, junctions, bends, etc. shall be considered as included in the cost of pipes, unless otherwise specified in the particular specifications or the B.O.Q.

Alternatively, if so stated in the Particular Specification and/or in the Bill of Quantities, pipes and fittings may be measured by numbers of pipes of defined net lengths and by number of fittings.

Payment for asbestos-cement pipes and for fittings, specials, etc. shall include:

- Supply, hauling, handling, unloading and stacking of pipes and fittings including all necessary A.C. joints and jointing materials for pipes and all A.C. and C.I. joints and jointing materials for fittings, specials, valves, etc.

- Removal from stacks; hauling and stringing alongside trench; laying and jointing of pipes and fittings at any depth of trench; connections to manholes and/or chambers, and final cleaning and flushing of pipeline. The unit rates for this item, for each type, class and diameter of pipe and fitting, shall be the same for all depths of trench in which the pipes and fittings are to be installed.

- Testing of complete pipeline:
    - For gravity pipelines: the cost of testing shall be included in the unit rates for pipes and shall not be paid separately.
    - For pressure pipelines: the cost of testing shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

Only pipes, fittings, junctions, bends etc. actually laid in trench and tested and accepted by the Engineer shall be measured for payment under the above items, and no allowance whatsoever will be made for any breakage, loss, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers and site test shall be paid for under separate items in the Bill of Quantities, unless otherwise noted.

3.4 STEEL PIPES AND FITTINGS

3.4.1 Quality Requirements

Steel pipes for use in the Works shall be made by an approved manufacturer and shall meet the requirements of B.S. 534, 1387, 3600 and 3601 or American Water Works Association Standard C202, or equivalent European standards, carbon content shall not exceed 25 percent. Unless specified otherwise all steel pipes shall have minimum pipe wall thickness schedule 40 for nominal pressures up to PN 40, for higher pressures NP 64 and more wall thickness should comply with schedule 80.

Pipe ends shall generally be plain squared for jointing with Viking-Johnson type couplings, or bevelled for butt welding joints or flanged with flanges according to B.S. 4504 for flanged joints or with a bell on one end for fillet welded lap joints.

Unless otherwise specified or directed by the Engineer, fittings, bends, branches, specials etc. for use with steel pipes shall be prefabricated, factory made and shall be equal in quality and strength to steel pipes. Ends of fittings etc. shall be plain squared, bevelled or flanged to fit pipe ends.

Steel pipes and specials intended for laying below ground shall be cement-mortar lined or epoxy lined internally, and epoxy or bitumen coated externally not less than 150 micron thick. The hot bitumen of the coating shall be wrapped with bitumen saturated asbestos felt or glass-fibre mat and whitewashed. Other types of linings or coatings which may be required shall be as detailed in the Particular Specification. The ends of pipes shall be left uncoated for jointing. Sufficient lining, coating and wrapping materials and implements thereto shall be provided to complete coating on uncoated sections after jointing and to make good after laying of pipes.

Steel pipes and specials to be laid above ground in open air shall be epoxy or cement mortar on the inside and painted on the outside not less than 150 micron thick.

Steel pipes and specials to be laid inside buildings shall be epoxy coated internally and externally 150 microns minimum thickness.

Mechanical joints for use with steel pipes shall be of the Viking-Johnson sleeve type made by an approved manufacturer. The joints shall be watertight when assembled and shall be sufficiently flexible to permit small deflections without impairing their watertightness. Rubber rings to be used with joints shall comply with the requirements of B.S 2494. The Contractor shall supply sufficient quantities of specially sized pipes for cutting of closure pieces and of Johnson Couplings without centre register to permit the insertion of closing sections in the pipelines.

Galvanized and black iron pipes and fittings shall comply with B.S. 1387 (Steel Tubes and Tubulars Suitable for Screwing to B.S. 21 pipe threads). Fittings not included in B.S. 1387 shall comply with B.S. 143 (Malleable Pipe Fittings) heavy quality. Pipes and fittings ordered galvanized shall comply with the requirements of the applicable Clauses of the above-mentioned British Standards.

The Contractor shall submit to the Engineer certificates from approved laboratories certifying that the pipes and fittings supplied comply with the requirements of the relevant specifications.

3.4.2 Hauling and Handling of Pipes and Fittings

Pipes and fittings shall not be allowed to drop, roll freely or strike objects which may damage them. When fitting pipes or fittings by their open ends, special hooks or plates shaped to fit the wall shall be used. Chaining will be allowed on bare pipes only; wrapped pipes shall be lifted by padded straps at least 20 centimeters wide. Care shall be exercised in transporting, handling or storing pipes and fittings in order to avoid distortion, flattening, denting, scoring or any other damage to pipes and fittings and to their outer coating and/or inner lining.

3.4.3 Stringing of Pipes

Pipes of the various diameters and wall thickness shall be strung along the alignment as closely as possible to their final position.

Pipes and fittings strung along the alignment shall be protected against intrusion of earth, mud, dirt and other foreign bodies, and against damage to the outer coating. Pipes shall not be strung on the side of the trench where excavation material has been or is to be placed. Where necessary or as directed by the Engineer gaps shall be left in stringing in order to allow movement of vehicles or men across the alignment. Wrapped pipes shall be whitewashed unless they have been supplied with whitewash and the latter is in good condition after stringing.

3.4.4 Handling of Mortar-Lined Steel Pipes

No internal hooks or similar equipment likely to damage the mortar lining shall be used. Excessive bending of the pipe that may cause cracking of the mortar lining shall be prevented.

3.4.5 Repairs of Defective Pipes

Should laminations, cracks or other defects be discovered on any pipe or its coating or its lining, the Engineer will issue instructions as to whether such defects shall be repaired or the defective part cut out or the defective pipe removed. Where the pipes were supplied by the Employer, he will pay the Contractor the cost of the repairs or other extra work necessitated thereby, but otherwise pipes shall be repaired or replaced by the Contractor at his own cost.

3.4.6 Welding of Pipes

(a) <u>Welding Methods</u> - All welds shall be made by the manual shielded metal-arc method. The welding procedure to be applied by the Contractor shall be submitted to the Engineer for approval, before the commencement of the work. All welding works shall be carried out by welders having passed the welders qualification tests in accordance with B.S. 4871 part 1 and B.S. 4872 part 1, whichever is applicable. Welds will be either butt welds for plain-ended pipe joints or fillet welds for lap joints (bell and spigot). The use of welding machines with two outlets will not be permitted; every welder shall work with a separate machine.

(b) Electrodes - Electrodes used for welding shall meet the requirements of B.S. 639 and B.S. 4215. Generally, with D.C. generators, Class E-100 (DCRP) electrodes shall be used. In any case, the electrodes proposed by the Contractor shall be subject to the Engineer's approval prior to their use.

Electrodes shall be stored in the unopened original containers in such a manner as to prevent absorption or loss of moisture or mechanical damage to the coating. Electrodes in open containers shall be protected against moisture. Electrodes that have been damaged, moistened or otherwise deteriorated, shall be rejected.

(c) Cleaning of Pipes - Pipe ends to be welded together shall be thoroughly cleaned of any dirt, oil, residues of paint and asphalt, and any other foreign matter that may adversely affect the quality of the weld. Paint and oil residues shall be removed with kerosene or gasoline.

(d) Welding of Joints - The number of beads in each weld seam shall be not less than two, and their thickness shall not exceed 3.0 mm.

In butt welds, the thickness and number of the beads shall be so adjusted that the height of the weld reinforcement shall be not less than 0.8 mm and not more than 1.5 mm above the pipe surface. The width of the cover bead shall be approximately 3.0 mm more than the width of the groove before welding. In fillet welds the thickness of the throat shall be at least $0.5\sqrt{2}$ (= 0.707) of the pipe wall thickness. Cutting back of the edge of the bell shall be kept to a minimum. All weld metal shall be thoroughly fused to the parent metal and to the previously placed weld metal.

After the completion of each bend, the weld shall be thoroughly cleaned of all scale, slag, or dirt. All spots on the weld where electrodes are changed shall also be cleaned. A peening hammer and steel brush may be used for cleaning, provided it is done to sound and bright metal. The finished seam shall be thoroughly cleaned by means of steel brushes.

(e) Fitting -up of Pipes - In butt joints the root opening between the pipes shall be such as will ensure full penetration without burn-through in accordance with the approved welding procedure. When aligning pipes, the offset between pipe ends about to be joined shall be reduced to a minimum. External line-up clamps shall be used to centre pipes. Internal clamps may be used when approved by the Engineer.

The external line-up clamp may be removed only after 50% of the root bead has already been welded, in segments equally distributed around the pipe, not shorter than 7 cm each; their quality and thickness shall not be inferior to those required for root welding. The internal clamp may be removed only after the whole of the root bead has been welded.

In lap joints the plain end of one pipe shall be shoved in until it abuts against the shoulder of the bell, so that the gap between the mortar lining of the two pipes is reduced to a minimum.

(f) Welding Positions - The welds shall be made either by roll welding or position welding. Roll welding will be permitted, provided alignment is maintained by the use of skids and roller dollies supporting two or more lengths of pipe. Position welding shall be done with the pipes resting on skids at the proper height over or alongside the trench, so as to permit the completion of the weld on the whole circumference. All requirements as to the quality of the welds shall apply equally to roll welding and position welding.

(g) Jointing of Line Sections - Pipes shall be connected to each other by welding as specified above, while they are placed on suitable supports on the trench bottom or on the ground beside the trench.

The length of sections to be welded together before lowering them into the trench shall be as directed by the Engineer. The position of every pipe or elbow in the section shall be such that, when the section has been lowered to the trench bottom the longitudinal seams will be located between the figures 10 and 2 on the clock face, so that repairs on the seams can be done in the trench without necessitating deep excavation.

Before being connected to the line, the inside of each pipe and each elbow shall be cleaned.

(h) Welding Mortar-lined Pipes - When butt-welding mortar-lined pipes, the Contractor shall take steps to ensure the continuity of the lining at the joints. The materials and methods employed to this end shall be as recommended by the manufacturers of the pipes, and approved by the Engineer or as directed by the Engineer. The cost of all materials and work required to ensure the continuity of the cement-mortar lining shall be deemed to be included in the unit rates for supply, laying and jointing of the pipes and shall not be paid for separately.

In pipes with lap joints which are not accessible from the inside, a sufficient quantity of mortar shall be placed in the bell just before the new pipe is shoved in. After the new pipe is laid in place, excessive mortar shall be removed and the inside of the joint finished by pulling a rubber ball or equivalent through the joint. Where the inside of the pipe is accessible, the mortar lining at the joint shall be completed by plastering on with a good bond to the existing lining and trowelling smooth and flush with the adjacent mortar lining. The mortar employed as specified above shall conform in all respects to requirements of Subsection 217.4.9 of this Specification.

(i) Repair of Weld Defects - The Engineer may permit repairs of defects in the root or filler beads to be made, but any weld that shows evidence of repair work having been done without such permission may be rejected. Pinholes and undercuts in the final bead may be repaired but such repairs shall be subject to the Engineer's approval. Undercuts not exceeding 1.0 mm in depth will not be considered as defects.

Before repairs are made, the defective areas shall be removed by chipping, grinding, or flame gouging. Any slag and scale shall be removed by wire brushing. When cracks are found, the entire seam shall be cut away and rewelded.

The Contractor shall clearly mark with oil paint on top of the pipe any defect that has been discovered in the pipe or weld.

3.4.7 Miscellaneous Welding Works

(a) Cutting and Preparing Pipes for Welding - The plane of square cuts shall be perpendicular to the pipe axis. Oblique cuts shall be accurately made to the required angle and in such a manner that the cut edge is in one plane. Pipe ends for butt welding shall be bevelled to an angle of 30° with the plane of the edge, with a permissible deviation of 0° to +5°. All cutting shall be done by mechanical tools, or by acetylene flame-cutting by means of a special cutting device or by Arc-air (carbon electrode with air jet). Flame cut surfaces shall be perfectly clean, and where necessary, the cut surfaces shall be filed smooth. Mortar-lined pipes shall always be cut by Arc-air cutting equipment. After the metal has been cut through to the mortar lining, the latter shall be carefully broken along the cut and the pipe edge prepared for welding as required above.

(b) Welding of Flanges - The welding of flanges to pipes shall be of the same quality as that specified for pipe welds. Slip-on flanges shall receive an interior weld inside the flange opening, in addition to the external weld. Weld-neck flanges shall be attached to pipe ends as specified above for the welding together of pipes, care being taken to ensure a perfect concentric alignment between pipe and flange.

Flanges shall be welded to pipes very carefully, so that the faces of the flanges shall be truly perpendicular to the pipe axes. Flange faces shall be kept free from weld material or other defects such as splutter, dirt, etc. All defects in flange faces that may interfere with the proper sealing of flanges shall be repaired.

(c) Fabricated Fittings - Where shown on the Drawings or where directed by the Engineer, fabricated fittings, specials, etc., as specified hereafter, will be used instead of factory-made fittings.

Welded elbows shall consist of suitable obliquely cut pieces of pipe ("mitres") welded together. The mitres shall be cut to the exact dimensions shown on the Drawings and accurately fitted together so that after welding the completed elbow will have the exact shape and dimensions shown on the Drawings. The ends of mitres shall be bevelled for welding as specified above. In all elbows of 12" (300 mm) diameter and larger the seams between mitres shall also receive an internal weld pass which shall be made after the weld root has been thoroughly cleaned.

Fabricated T and Y branch connections shall be produced by cutting the branch pipe to the correct intersection fitting the curvature of the main pipe, cutting the required opening in the main pipe and welding the branch to the main pipe. Where shown on the Drawings or instructed by the Engineer the fabricated T and Y branches shall be reinforced by welded saddles. The saddle shall be cut and bent to the required shape and slipped over the branch, its outside edges shall be welded to the main pipe while the edge of its opening shall be welded to the branch pipe.

The quality of welds shall be as specified for pipe connections. The inside of the pipe intersection shall be cleaned and smoothed to ensure unobstructed flow in the pipe.

Pipe reducers shall be fabricated from steel plate properly cut, rolled and welded or by cutting out wedge-shaped pieces from a length of pipe the diameter of which shall be equal to the larger diameter of the required reducer, squeezing the pipe together to the shape of the reducer and welding along the cut edges, which shall be straight and bevelled for welding, the gap between them being of uniform width over the whole length. On reducers of 12" (300 mm) diameter and larger an internal pass shall be added to each weld, which shall not protrude more than 1.5 mm into the inside of the pipe. The end planes of the reducer shall be parallel to each other and truly perpendicular to the pipe axis and shall be bevelled for butt welding.

In all fabricated fittings, the quality of welds shall be as specified for welded pipe connections and the insides of intersections shall be cleaned and smoothed to ensure unobstructed flow in the pipe.

(d) Prefabricated Fittings - Prefabricated elbows, tees and reducers shall be jointed to pipes by square butt welds or by lap welds or by flanges, all as specified above for pipe-welding, care being taken that the true alignment and correct position of the fitting are ensured.

3.4.8 Installation of Valves and Fittings

(a) General - Before being installed, valves, fittings, and especially valve seats, shall be cleaned of any dirt. The correct positioning of valves shall be ensured by means of a spirit level. Flanges shall be welded to the pipes in accordance with the requirements of Subsection 217.4.7 (b) above.

Fitting the valves to pipes shall be done accurately, but without using force. Fitting of valves by tightening bolts forcibly or by any other method that may cause internal stresses in valves or flanges will not be permitted.

(b) Bolts - Only bolts of the correct diameter shall be used. All bolts used on a valve shall be of equal length, which shall be such that after the nut has been tightened not less than one thread and not more than three threads of the bolt will protrude from the nut. Bolts shall be tightened crosswise, gradually and uniformly.

(c) Gaskets - Only one sealing gasket shall be used between each pair of flanges. Gaskets shall be of the ring type, i.e. their outer rim shall just touch the bolt holes and their inside diameter shall be equal to that of the corresponding pipe.

Gasket material shall be either fabric reinforced rubber or compressed asbestos sheets of a type and make approved by the Engineer. Gaskets shall be fabricated by cutting from sheets. Cutting gaskets by hammering on the flange will be strictly prohibited. When being installed, the gaskets shall be absolutely clean. Each gasket shall be used only once.

(d) Gate Valves - Before installation, each valve shall be fully opened and cleaned on the inside with a clean rag soaked in kerosene. Then the valve shall be completely closed and the flange faces also cleaned with kerosene. After cleaning, the flange faces shall be protected with wooden or cardboard covers, which may be removed only just prior to installation of the valve.

(e) Butterfly Valves shall be installed between companion flanges welded to the pipe ends, in accordance with manufacturer's instructions.

(f) Mechanical Couplings shall be of the "Dresser", "Viking-Johnson" or "Victaulic" type, as shown on the Drawings. Ends of pipes to be jointed by Victaulic couplings shall be fitted with accurately machined rings. Ends of pipes to be jointed by

Dresser couplings shall be clean of paint, coating or other foreign matter and shall be sufficiently round for at least 20 cm from the pipe edge so that joint rings and couplings shall slide freely onto pipes; no forcing on rings by hammer blows will be permitted. All joint components and pipe ends shall be cleaned and inspected before installation of joint. Rubber gaskets shall be kept in a clean and dry place and protected against sunshine until immediately before installation. Coupling bolts shall be tightened evenly and gradually with sufficient force to attain a tight joint but without causing undue stresses in bolts or joint components. All mechanical coupling shall be bonded and bridged for electrical continuity.

3.4.9 Lining, Coating and Painting of Pipes

(a) General - Where noted on the Drawings, and/or required in the Specification or Bill of Quantities and/or directed by the Engineer, steel pipes, fittings and specials shall be protected against corrosion by internal linings or external coatings or by both internal linings and external coatings. Internal protection shall be provided by cement-mortar, or bitumen linings. External protection shall be provided by reinforced bitumen, or point coatings. Other types of linings and coatings may be required in the Particular Specification.

(b) Cement-Mortar Lining -Where required, steel pipes, fittings and specials shall be internally cement-mortar lined in accordance with the provisions of B.S. 534. Cement-mortar lining for specials and short unlined pipe sections, and repairs to damaged existing lining shall be carried out by hand, to the approval of the Engineer.

Where hand applied lining is approved by the Engineer, the materials, the preparation and the application of the cement-mortar shall conform in all respects to B.S. 534. The mixing of mortar shall be done in a suitable mechanical mixer until a homogeneous mixture of uniform colour and of the required consistency is obtained. The quantity of mortar prepared at a time shall not exceed that required for a half an hour’s work.

The steel surfaces to be lined with cement-mortar shall be cleaned thoroughly from dirt, oil, grease, traces of paint or mortar, slag, heavy rust and mill scale. Light rust adhering to the steel surface can be left. Immediately before applying mortar, the steel surface shall be wetted.

Cement-mortar shall be applied to the inter surface of the pipe or special by a steel trowel to the thicknesses specified in B.S. 534. The cement-mortar lining shall be given a smooth surface with a steel trowel and shall be finished off flush with the ends of the pipe or special. Curing compound shall be applied to the lining immediately after its completion to prevent its rapid drying.

The cement-mortar lining at pipe ends shall be of full thickness and shall end flush with the pipe edge. Small defects and depressions not exceeding 1.5 mm in depth are permissible, provided that their aggregate length does not exceed half the pipe circumference. When larger defects or cracks are found in the lining, the pipe will be rejected unless the Engineer permits repair of the lining or cutting away of the defective sections of the pipes. To repair defects in the cement-mortar lining, the defective portion of lining shall be removed to sound and undisturbed mortar, the metal shall be cleaned and new cement-mortar shall be applied as specified. The thickness of the new lining shall be equal to that of the existing lining and shall be finished smooth and flush with it. The mortar of the repair shall be well bonded to the pipe metal and to the existing lining.

(c) Bitumen Lining - Where required, steel pipes, fittings and specials shall be internally bitumen-lined in accordance with B.S. 534 and B.S. 4147.

(d) Bitumen Coating on Underground Piping - Underground steel pipes shall be externally protected by a fiberglass reinforced bitumen coating, in accordance with B.S. 534, B.S. 3415 and B.S. 4147.

The coating will be of the Single Wrap or Double Wrap, or Multiple Wrap type as indicated on the Drawings or in the Particular Specification. Pipe ends to be welded shall be bare. All valves, fittings and pipe to be laid below ground and which have not been factory-coated shall be supplied with an anticorrosive priming and receive a bitumen coating in-situ.

The Contractor's work under this Subsection shall include coating of weld joints; the repair of defects in factory-applied coating and the coating of primed or bare pipes, fittings and valves.

In-situ coating applied by the Contractor shall be equal in all respects to factory-made coatings. Repairs, coating of welds on coated pipes and the coating of bare pipes and fittings shall be bonded to the existing pipe coating so that a continuous uninterrupted coating over the entire length of pipeline is achieved. No joint shall be coated before the Engineer's approval to proceed with coating has been given.

After all joints, bare sections, valves and fittings and defects in coating have been coated and repaired as specified and before lowering the coated steel pipe into the trench, the continuity and integrity of the coating shall be tested by means of an electric Holiday detector, in accordance with A.W.W.A. Specification C203-62 Section 3.13, in application to a single bitumen coat. Test voltages for multiple coats shall be specified by the Engineer.

All defects in coating shall be repaired and retested.

(e) Painting of Exposed Piping - The metal surfaces of all pipes laid above ground together with valves, straps and supports as well as all steel structures shall be painted as specified in Subsection 207.1.7 of this Specification.

The outside surface of coated bitumen pipes shall be given a coat of water-resistant whitewash to protect the bitumen from sunlight and overheating.

3.4.10 Laying of Steel Pipelines

Steel pipes shall be laid underground in trenches, or above ground on supports, or built-in in earth or concrete works, as shown on Drawings or directed by the Engineer. All joints between pipes and between pipes and fittings shall be done by welding or by flanges or by mechanical joints, as shown on Drawings or as directed by the Engineer.

Before lowering in, the pipe coating shall be inspected and all defects repaired. Lowering the pipes into the trench shall be done by pipelayers or other equipment acceptable to the Engineer, so that no damage or deformation is caused to the pipes or the coating and lining. Welded pipes shall be laid on the finished trench bottom, so that each pipe is supported over its entire length.

Where valves, or flanges or mechanical joints are to be installed, or overhead welds are to be made in the trench, the latter shall be widened and deepened by additional excavation around the pipe in order to provide working space (bell holes). Before joining each pipe to the line a cleaning swab with a cable attached to it shall be introduced into the pipe last welded before the new pipe. When the welding to the line has been completed the swab shall be pulled forward by means of the cable through the new pipe, thus cleaning and removing all slag, metal, dirt and foreign matter which may have accumulated inside the pipe. Where pipes are large enough to be entered by workmen, the said cleaning shall be done by hand.

At the end of each working day and whenever work is discontinued for a considerable time, the ends of each welded section whether in or alongside the trench shall be closed by a suitable cover snapping onto the pipe end.
Lowering-in of pipes or placing them on permanent supports shall be done carefully to prevent damage to pipe coating or paint. To prevent pipes from slipping out of mechanical joints or excessive stresses building up in welds as a result of temperature changes, lowering-in of pipes and joining of sections shall be carried out in the early morning only.

The first stage backfill of the trench shall be done before the final tie-in welds or bolted connections (in the case of mechanical joints or flanges) are made, leaving a stretch of about 20 m uncovered on either side of such final joint.

3.4.11 Weld Inspection and Tests

(a) General - The Engineer will exercise a continuous control of the welding work and will inspect the quality of the welds. In addition to routine supervision and visual inspection of the completed welds, the Engineer will have the right to request samples to be cut out from welds for destructive tests and to order the welds to be tested by radiography.

(b) Destructive Tests - Destructive tests shall include all or some of the following, at the discretion of the Engineer:

- Break Test
- Bend Test
- Tensile Test (in special cases only)

Both the Contractor and the Engineer will endeavour to ensure the proper execution of welds, so as to avoid altogether or minimize the number of destructive tests.

Should one of the samples taken for the destructive tests fail to meet the standards of acceptability set out below, the Contractor will be required to cut additional samples from the same weld or from other welds made by the same welder. If any of the new samples fails to meet the requirements, the Contractor will cut more samples for testing until a clear picture of the extent of defective welds is obtained.

Should such additional tests show that the quality of the welds is unacceptable, as determined by the Engineer, the Engineer may require the Contractor to remove and reweld all welds made by the welder concerned.

Unless otherwise specified, the cost of cutting the sample and preparing and testing the specimens, and that of patching the pipe where the sample has been cut out, as well as the cost of all additional tests that may be required to determine the extent of defective welds as aforesaid, shall be borne by the Contractor and deemed to be included in the various unit rates.

Samples for Bending, Breaking and Tensile Tests shall be cut out from the pipe in the form of strips 5 cm wide, perpendicular to the weld seam and extending 10 cm on either side of the weld, so that the weld will be located in the centre of the sample. The opening resulting from cutting the sample shall be closed by welding on a patch of steel plate having a thickness not less than that of the pipe wall. The cost of patching up openings as herein described shall be included in the cost of taking samples as specified above.

The bend test samples shall be bent in a suitable jig in the field or in the shop. The bend shall be located exactly over the weld with the weld face on the convex side. The sample shall be considered to have met the requirements if it does not break and no cracks larger than 3 mm in any direction appear on the convex side of the bend.

The break test samples shall be hacksaw-notched on both edges across the centre of the weld to ensure breaking of the sample in the weld. The sample shall be supported on both sides of the weld and broken by a strong hammer blow. For the weld to be acceptable, the broken surface shall show full penetration of the weld and no burns or excessive slag inclusions. The breaked surface shall show no more than one gas pocket per square centimeter, provided that no gas pocket has a diameter larger than 1.5 mm.

Samples for tensile strength and elongation tests shall be sent for testing to an authorized laboratory. These tests will serve as a control of the welding procedure and of the quality of the electrodes, but not to test the welder's ability. In this test the samples shall show a tensile strength not less than that required of the steel of which the pipes are made.

(c) Radiographic Tests - Where required, radiographic tests shall be performed in accordance with B.S. 2910. Unless otherwise specified, 10 (ten) percent of all weld seams shall be radiographed. If these primary tests should not give satisfactory results, the Engineer will conduct additional radiographic tests to ascertain the quality of the welding work. All weld defects discovered by the tests shall be repaired as directed by the Engineer and all repaired welds shall be retested.

The cost of the routine radiographic test (10 percent), as well as any additional tests which the Engineer may think it necessary to conduct because of the defective quality of the welds, shall be borne by the Contractor and deemed to be included in the various unit rates. The Contractor shall also bear the cost of repair of all welds found defective under test as well as the cost of retesting such repaired welds.

3.4.12 Hydrostatic Pressure Test

After pipelaying, casting of concrete structures on the line and partial backfill have been completed, the pipeline shall be subjected to a hydrostatic pressure test. The line shall be tested over its entire length or, in the case of long lines, in sections, as approved by the Engineer. Pressure tests shall be performed only in the presence of the Engineer.

The magnitude of the test pressure, the testing procedure and all other requirements shall be as described in Subsection 217.3.10 (b) of this Specification, except that the Hydrostatic Pressure Test can commence 24 hours after the completion of filling, if permitted by the Engineer.

3.4.13 Methods of Measurement and Payment

Steel pipes shall be classified for payment according to type of joint, diameter and nominal pressure, and shall be measured in linear meters of completed pipeline in place measured along the crown of the pipeline. The length measured for payment shall include the lengths of all fittings, valves and specials installed in the line.

Price for fittings, bends, junctions, specials, detachable joints, flanges (where not an integral part of pipe or fitting), etc., shall be considered as included in the cost of pipes, unless otherwise specified in the particular specifications on the B.O.Q..

Payment for steel pipes and for fittings, specials etc... shall include:

– Supply, hauling, handling, unloading and stacking of pipes and fittings including all necessary jointing materials, electrodes, gaskets, nuts and bolts etc. for pipes and fittings and factory coating and lining up of all pipes and fittings.

– Removal from stacks; hauling and stringing alongside trench; laying and jointing of pipes and fittings by welding (including square and mitred welds, both in and above trench) and/or mechanical joints; field coating and lining of joints and of pipes and fittings where required and all repairs to factory coatings and linings, including supply of all necessary materials; inspection and testing of coating, weld inspections and welders' qualification tests; and final cleaning and flushing of pipeline. The unit rates for this item, for each type, wall thickness and diameter of pipe and fitting, shall be the same for all depths of trench in which the pipes and fittings are to be installed.

Only pipes, fittings, junctions, bends etc. actually laid in trench and tested and accepted by the Engineer shall be measured for payment under the above items, and no allowance whatsoever will be made for any waste, loss, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers shall be paid for under separate items in the Bill of Quantities, unless otherwise noted.

a) Testing of completed pipeline - the cost of carrying out hydrostatic pressure test, as specified, shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

b) Valve Assemblies for which items have been included in the Bill of Quantities shall be classified according to their diameter and measured for payment by the number of complete units as described.

The unit rate for a valve assembly shall include for: the supply of the valves complete with counter-flanges and accessories; supply of gaskets, bolts and nuts, all welding electrodes, paints and coating materials; cleaning and complete installation of the assemblies, inclusive of all cuts and welds; fitting up of flanges and fittings, placing them in their exact position and completing the joints, inclusive of tightening of bolts and anchors; bridging of mechanical joints; making good of paint and coating and sealing off pipes passing through chamber walls.

c) Pipe Assemblies that are described as such in the Bill of Quantities shall, for purposes of payment, be measured by the number of complete units within the limits shown in the Drawings and/or defined in the relevant items of the Bill of Quantities.

The price of each assembly shall include for the necessary excavation and backfill; supply of all pipes, accessories, joints, valves, supports and all other parts of the assembly; cutting, fitting, welding, jointing and installation of pipes in position; fixing of supports for pipes; internal and/or external coating as required; testing of welds; pressure tests of the assembly and all other works required for the fitting of the completed assembly between the limiting points.

d) Various Welding and Installation Works - In case of measurement of welding and installation works - whether as separate items in the Bill of Quantities or for the purpose of varying any of the rates for complete assemblies under Subsection (d) and (e), or if the Engineer should deem such separate measurement necessary for any other reason - such works shall be measured and paid for as provided in the following paragraphs (1) and (5).

The necessity for such measurement will in each case be determined by the Engineer. Measurement will be by number, classified by type and size as detailed in the Bill of Quantities. The unit rates shall include everything as detailed below and in addition also the supply of all materials and all additional excavation necessary for installation.

1) Square and Mitre Welds: The unit rates shall include for the necessary cutting, bevelling, fitting-up and welding of pipes as specified.

2) Welding of Tee, Y and Weld-O-Let Outlets: The unit rates shall include for cutting, shaping, bevelling, and welding the outlet pipe to the main pipe, as well as for cutting the opening in the main pipe.

3) Welding Flanges: The unit rate shall include for squaring the pipe end as required, welding-on the flange to the pipe at right angles to the pipe axis and for both the external and the internal welds. Welding of weld-neck flanges will be considered as a square weld under (1).

4) Fabrication of Pipe Reducers: The unit rate for fabricating a pipe reducer shall include for cutting the pipe to required length, cutting out wedges in the pipe wall, tapering the reducer to the correct shape and welding the longitudinal seams.

5) Making of Flanged Connection and Mechanical Joints and Installation of Valves and Fittings: The work shall include cleaning and fitting-up of flanges, joints, valves, etc., installation of joint rings, gaskets etc.; insertion and

tightening up of bolts, nuts and washers; and welding on of anchor lugs and installing of threaded rods in anchored "Dresser" couplings, where required.

The cost of the work described in Paragraphs (1)-(5) above shall be deemed to be included in the various items of supply, laying and jointing of steel pipes and fittings and shall not be paid for separately.

e) <u>Inserting of Line Pipe in Casing</u> shall be measured, separately for each diameter of line pipe, in linear meters by the length of the casings and shall be paid as an extra over the price for pipelaying. The unit rate inserted in the Bill(s) of Quantities for inserting line pipes in casing shall be deemed to cover the cost of the supply and hauling of casing pipe, welding of casing pipe sections, supply and spacing of spacers, coating of casing pipe where practicable, installing line pipe in casing and sealing of openings at both ends of casing pipe.

3.5 CAST IRON AND DUCTILE IRON PIPES AND FITTINGS

3.5.1 Quality Requirements

All cast iron and ductile iron pipes and fittings to be supplied under this Specification shall be obtained from approved manufacturers. They shall be of the class and shall have joint ends as shown on the Drawings or as specified and shall otherwise comply in all respects with B.S. 4622 - Grey Iron Pipes and Fittings, and B.S. 4772 - Ductile Iron Pipes and Fittings.

- External Coating: pipes and fittings shall be given an external coating of zinc in accordance with ISO 8179 or BS 4772 and a finishing coating of either cold applied bitumen complying with the performance requirements of BS 3416 Type II material, or hot applied bitumen to BS 4147 Type I Grade C.

- Internal Lining: All pipes and fittings shall be lined internally with cement motar and shall comply with ISO 4179 or BS 4772. The inside of the sockets shall be coated with bitumen as used for the finishing coating to the pipes.

While the pipes are still suspended over the trench before lowering or before mounting, they shall be inspected for defects and rung with a light hammer to detect cracks. Defective pipes shall be dismounted, removed from the site and replaced by flawless pipes. Only pipes inspected and accepted on the site by the Engineer shall be incorporated into the works.

3.5.2 Hauling and Handling of Pipes

The Contractor shall check each pipe before loading and shall reject all damaged or defective pipes. The Contractor shall load and properly secure the pipes on the vehicles and take all necessary measures to prevent any damage to the pipes during transport. The Contractor shall be responsible for the quality of the pipes and for their condition upon and after delivery to the site, and shall immediately remove from the site any damaged or defective pipes and replace them at his own expense.

No pipes or fittings shall be allowed to drop, roll freely or strike objects which are likely to damage them. Special care shall be taken not to spoil the tar or bitumen coating.

3.5.3 Laying and Jointing

(a) <u>Laying</u> - Before C.I. or Ductile pipes are laid, all dirt and foreign matter shall be removed from inside and all lumps blisters, excess coal tar, oil, grease and moisture shall be eliminated from the surfaces of the joints. After the pipe is laid and mounted, care shall be taken to avoid entrance of dirt, water and foreign matter from the trench or from elsewhere by the use of tight bulkheads.

(b) <u>Jointing of cast iron pipes and fittings</u> - Joints shall be flanged; or mechanical joints; or rubber gasket "push-in" flexible joints, all as specified and/or shown on Drawings.

(c) Jointing of ductile iron pipes and fittings - Joints in ductile iron pipes and fittings shall be of one of the following types according to the Drawing and the Particular Specification:

- Spigot and socket joint with rubber gasket
- Flanged joints
- Mechanical joints

All joints shall conform to B.S. 4772.

3.5.4 Testing

Testing instructions and requirements for Cast Iron and Ductile Iron pipelines shall be as specified in Subsection 217.4.12 for steel pipelines.

3.5.5 Methods of Measurement and Payment

Cast Iron pipes and Ductile Iron pipes and fittings shall be classified for payment according to type, diameter and class and shall be measured in linear meters of completed pipeline in place, measured along the crown of the pipeline. The length measured for payment shall include the lengths of all fittings, valves and specials installed in the line.

The price for fittings, bends, junctions, specials, detachable joints, flanges (when not integral part of pipe or fitting) etc. shall be considered as included in the cost of pipes, unless otherwise specified in the particular specifications or the B.O.Q.

Alternatively, if so stated in the Particular Specification and/or in the Bill of Quantities, C.I. and Ductile Iron pipes and fittings may be measured by number of pipes of defined net lengths and by number of fittings.

The payment for C.I. and Ductile Iron pipes and (under separate items) for fittings, bends, junctions etc. shall include:

- Supply, hauling, unloading and stacking of pipes and fittings including all necessary joints and jointing materials.

- Removal from stacks, hauling and stringing alongside the trench, laying and jointing of pipes and fittings at any depth of trench, connections to manholes and/or chambers and final cleaning and flushing of pipeline. The unit rates for this item for each type, class and diameter of pipe and fitting shall be the same for all depths of trench in which the pipes and fittings are to be installed.

- Testing of completed pipeline
    - For pressure and gravity pipelines shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

Only pipes, fittings, junctions, bends etc. actually laid, jointed and tested and accepted by the Engineer shall be taken into account for payment under items and no allowance whatsoever will be made for any breakage, loss, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers shall be paid for under separate items in the Bill of Quantities, unless otherwise noted.

3.6 G.R.P. PIPES

3.6.1 Quality Requirements

a- Manufacturers Pre-qualification

GRP pipes and fittings shall be manufactured by an established pipe Manufacturer in a purpose-built facility for the production of such materials. The Manufacturer shall have at least 5 years experience at the facility in the production of the full range of pipe diameters (25 - 3000 mm) pipe, fittings and related products. Evidence of previous experience shall be presented. The Manufacturer shall have an approved Quality Management System complying with ISO 9001 which shall cover all activities being undertaken during the manufacturing, supervision and installation of the subject pipe systems.

b- Applicable Codes and Standards

The following internationally accepted standards are the minimum requirements for the manufacture of GRP Pipe Systems and should be referenced throughout the Project Specification where appropriate.

AWWA C950	Glass Fiber Reinforced Thermosetting Resin Pressure (Latest Edition).
ASTM D3262	"Fiberglass" (Glass - Fiber - Reinforced Thermosetting - Resin) Gravity Sewer pipe.
BS 5480	6 bars reinforced plastics (GRP) pipes, joints and fittings for use for water supply or sewerage.
ASTM D3517	Specification for Glass Fiber Reinforced thermosetting resin pressure pipe.

c- Product Description

c.1- General

The GRP pipe shall consist of a corrosion resistant liner, a structural wall and a resin rich exterior layer. The resin to be used is of the Isophtalic type.

Liner
Pipe and Fittings shall have a resin rich internal liner of a 0.75mm thickness with a resin to glass ration of 70 : 30. This liner will be reinforced with a "C" Veil and Glass Reinforcement.

Structural Wall
The pipe structural wall shall be as specified in AWWA C950 for Grade 1 or 2 with the resin systems to be the appropriate grade of Isophtalic as required by the system type and operating conditions.

External Layer

Pipe shall have a 0.01" (0.25mm) thick resin rich exterior surface impregnated with Isophtalic resin as required by the system type and operating conditions.

c.2- Materials

- Glass Reinforcements shall be compatible with the impregnating resin used.
- Resins used shall be a commercial high grade thermosetting Isophtalic type as specified under Section c.1 above.
- No dark pigments shall be used in the GRP pipe or joints. No additives shall be used except when required for viscosity control.
- Aggregates and Fillers use shall be limited to 30% maximum for any Pressure Application. Care should be taken to ensure no aggregate becomes embedded in the resin rich liners.
- All GRP pipes and fittings conveying potable water shall be certified and listed for potable water use by internationally recognized independent water authority such as the Water Research Council "WRc", the DVGW, KIWA, Lyonnaises Des Eaux, etc..

d- Requirements

d.1- Wall Thickness
GRP pipe systems up to and including 2000 mm diameter shall be of the solid wall type. The wall thickness required for each size/pressure class shall be established by the Manufacturer to meet the design requirements but in no case shall wall thickness be less than (0.010 x ND); where ND is the nominal pipe inside diameter. The pipe working pressure class shall be based on the Hydrostatic design basis (HDB) of the pipe with a design (service) factor of 0.5.

d.2- Length
GRP (Standard = 6 or 12 Meters) pipe shall be manufactured in standard laying lengths of not greater than 12 meters. Random short lengths, if supplied, shall not exceed 5% of the quantity supplied of each size. The tolerance on the Manufacturer's declared laying length shall not exceed ± 25 mm.

d.3- Diameters
Pipe shall be manufactured in standard metric sizes based on the pipe nominal inside diameter in sizes 25mm and larger. The actual inside diameter shall not vary from the nominal inside diameter by more than 1% or 4 mm whichever is greater.

d.4- Stiffness
The pipe stiffness shall be determined by the Manufacturer to meet the design requirement with particular regard to installation method, burial depths, deflection limits, buckling and vacuum requirements, in accordance with AWWA M45. However, stiffness shall be at least 5000 N/m^2 or as stated in the drawings or in the particular specifications.

d.7- Joints
Standard buried pipe with unrestrained joints shall be filament wound GRP coupling, with confined rubber ring gaskets. Rubber rings shall be suitable for the intended application. Joints shall allow for at least 0.75 degree deviation while remaining water tight at 1.5 times the pipe operating pressure. The rubber rings shall be the sole element depended upon for water tightness. This system will require thrust blocks at changes in direction to accommodate thrust loads.

d.8- Workmanship
- GRP pipe, fittings and joints shall be free from de-laminations, cracks, bubbles, pinholes, pits, blisters, foreign inclusions and resin-starved areas that due to their

nature, degree or extent detrimentally affect the strength and serviceability of the pipe. No glass fiber reinforcements shall penetrate the interior surface of the pipe wall.

- Joint sealing surfaces shall be free of dents, gouges, de-laminations, or other surface irregularities that will affect the integrity of the joints.
- GRP pipe, fittings and joints shall be as uniform as commercially practicable in color, capacity, density and other physical properties.

d.9- Fittings

- GRP fittings such as bends, tees, junctions and reducers shall be equal or superior in performance to the GRP pipe of the same diameter and pressure. All fittings shall be have a smooth internal surface with similar wall construction.
- For GRP fittings, the deviation from the stated value of the angle of change of direction of a bend, tee, junction etc. shall not exceed ± 1 degree.
- The tolerance on the Manufacturer's declared length of fitting shall be ± 10 mm taken from the point of intersection to the end of the fitting or ± 10 mm on a straight fittings.
- All GRP fittings shall be fabricated in the factory to ensure Quality Control (under no circumstance shall fabrication of fittings be allowed on site by Contractor). Complex fittings arrangements may be pre-assembled by the pipe Manufacturer in the factory such that field joints are kept to a minimum.

e- Design Parameters

Pipe shall meet the following minimum design requirements:

– Operating Pressure (Pw)	As specified; Min 1000 Kpa for Pressure pipes
– Surge Pressure (Ps)	40% of 'Pw' unless otherwise specified.
– Vacuum (Pc)	As specified.
– Minimum Earth Cover	1.0 m or as shown on drawings for buried pipe.
– Initial Installed Deflection for Buried pipe	2.0% Max.
– Long Term Installed Deflection for Buried Pipe	4.0% Max
– Safety factors	
Pressure Rating	>= 1.8
Ring Bending Strain (stress)	>= 1.5
Combined Strain (stress)	>= 1.5
Buckling	>= 2.5

The Contractor shall be responsible for implementing / installing the correct design for each GRP pipe system.

f- Inspection & Testing

f.1- The Manufacturer shall take adequate measures in the production of the products covered by this specifications to assure compliance with the requirements herein. An Inspection and Testing Plan (ITP) should be established by the Manufacturer. Plant inspection by the Engineer and/or the Contractor's qualified personnel or the omission of such inspections shall not relieve the Manufacturer of the responsibility to furnish products complying with the requirements of the minimum manufacturing requirements given herein.

f.2- Production and Testing Notice - When plant inspection is required by the Engineer or the Contractor, the Manufacturer shall provide adequate advance notice of when and where production and testing of ordered products will commence.

f.3- The Engineer and the Contractor shall have free access with reasonable advance notice to the Manufacturer's plant areas that are necessary to assure that products comply with all requirements herein.

f.4- As a minimum the following tests shall be performed at the indicated intervals unless otherwise agreed-upon, and shall form a part of the Manufacturers overall quality control program.

The following tests shall be conducted on every pipe;

- Visual Inspection, as per manufacturer standard
- Dimension Measurements, as per manufacturer standard
- Resin cure (Barcol Hardness), ASTM D2583
- Hydrostatic Pressure test for pipe up to 2000 mm in diameter, ASTM D3517

The following tests shall be conducted on pipe samples at a frequency of not less than one per 50 pipes (one lot) of the same Diameter and Pressure.

- Stiffness, ASTM D24313 or BS5480 App. H.
- Hoop Tensile Strength by split disc, ASTM D2290 or BS5480 App. C or D.
- Longitudinal Tensile Strength, ASTM D638 or BS5480 App. A
- Loss on ignition (composition), ASTM D2584

The Supplier shall submit to the consultant qualification test reports for the following test:

- HDB in accordance with ASTM D2992 procedure B or BS5480 App. E
- HDB reconfirmation in accordance with ASTM D2992 section 12
- Cyclic test
- Long term ring bending test in accordance with ASTM D5365-93
- Coupling tightness in accordance with ASTM D4161 or BS5480 App. M

The supplier shall give evidence that the GRP pipe produced in his own plant has successfully passed the above mentioned tests. All these tests should be conducted in the plant and witnessed by a third party. If so directed by the Engineer, the selection of samples and the tests shall be witnessed also by a representative of the Engineer, who shall be informed at least 48 hours in advance of any sampling or testing.

Test methods shall be in accordance with AWWA C950 and BS 5480. Copies of all test reports shall be submitted to the Engineer for each lot delivered to Site.

The cost of samples, their transportation to the laboratory and their testing shall be deemed to be included in the unit rates and shall not be paid for separately.

f.5- Pipe Data Sheet should be as follows:

<u>Nominal Diameter (ND)</u>	(mm)
Service (Specify) Underground / Aboveground	KPa
Rated Working Pressure	KPa
Allowable Vacuum	Kpa

Pipe Wall

Nominal total thickness		mm
Inner Liner	Thickness	mm
	Resin Type	
	Glass Type	
Structural Wall	Thickness	mm
	Resin Type	
	Glass Type	
	(Aggregate type)	
Exterior Layer	Thickness	mm

Mechanical Properties

Minimum initial specific stiffness STIS	N/M^2
Initial longitudinal tensile strength	KN/M^2
Initial Hoop tensile strength	KN/M^2

3.6.2 Hauling, Handling and Storage

GRP pipes shall be handled, stored and installed in strict accordance to the Manufacturer written instructions.

Rough handling of pipes shall at all times be avoided, pipes shall not be dropped or thrown on the ground. Severe impact with other pipes or object must be avoided. All pipes should be lifted at their mid-point. Pipes must not be lifted with chains, wire ropes etc, a suitable textile sling must be used.

During unloading the pipes, joints and specials must be carefully inspected to verify the following:

a) Products are not damaged
b) Joints are positioned correctly
c) Classification is as specified

Attention shall be paid to stack heights to avoid the possible deformation of the pipe diameter. No stacking of pipe larger than 1.8m in diameter shall be allowed on site or during transport.

3.6.3 Laying and Jointing

After the excavation and preparation of a section of pipe trench has been completed, it shall be inspected by the Engineer. Just before pipe laying, the trench shall be cleaned of all stones, soil and other debris that might have fallen therein.

All pipe laying shall be carried out by experienced pipe-layers, well skilled in this work.

The Contractor shall submit the pipe Manufacturer's Installation Manual and associated Data for Engineer review. A site meeting to include Engineer, Contractor and Manufacturer is to occur to clarify any outstanding issues / questions on the given installation procedures.

The pipe installation procedures and practices chosen shall meet the design requirements specified.

Immediately before being laid, each pipe and fittings shall be carefully examined both inside and outside for any damage, and all dust, dirt and foreign matter shall be removed. Care shall be taken to ensure that they remain clean during laying.

In order to prevent stones and soil from entering the pipe, a suitable cap or plug shall be provided with which the last pipe laid shall be closed when pipelaying is not actually in progress. The plug will be of the screw-up expanding type or of tapered wood.

Where bends are required, performed bends of the desired radius shall be used. Hot bending on site is not permitted.

All joints shall be flexible, with approved rubber rings. Rubber rings shall comply with B.S. 2494 (Elastomeric Joint Rings for Pipework and Pipelines) and shall be of the type designated on the Drawings, or in the Particular Specification, or as directed by the Engineer.

Prior to laying, the pipe and joint must be thoroughly inspected. Check for damage, joint position, pressure classification and cleanliness.

To ensure clean assembly and to prevent the weight of the pipe being taken on the joint, a hole should be excavated at the joint position prior to laying the pipe. When the joint has been made, fill and compact the hole with bedding material to provide continuous support to the pipe along its entire length.

Reinforced Concrete Thrust Blocks shall be used at all changes in direction, size reduction / expansion. Thrust blocks shall encase the entire GRP fitting at the directional change and should be constructed to fully absorb all thrust loads.

Pipe Deflection readings shall be taken and recorded on all buried pipe at two meter intervals. Initial deflections shall not show a reduction in internal vertical diameter for over 2.0 percent of the pipe ID.

For standard buried unrestrained pipeline sections, a flexibly jointed short pipe shall be incorporated outside rigid structures to provide pipeline flexibility against differential settlement. A minimum of two (2) flexible joints on either side of a rigid structure is required. The length of the short pipe shall be in accordance with the Manufacturers recommendation.

3.6.4 Testing

Testing instructions and requirements for GRP gravity pipelines shall be as specified in Subsection 217.2.6 for concrete pipelines. Testing instructions and requirements for GRP pressure pipelines shall be as specified in Subsection 217.3.10 (b) for A.C. pressure pipes, except that the Hydrostatic pressure test can commence 24 hours after the completion of filling if permitted by the Engineer.

3.6.5 Methods of Measurement and Payment

GRP pipes shall be classified for payment according to type, diameter and class and shall be measured in linear meters of completed pipeline in place, along the crown of the pipeline, as follows:

– In gravity flow lines: between internal surfaces of manholes or chambers.
– In pressure flow lines: between stations.

The length measured for payment shall include the length of all fittings, valves and specials installed in the line.

Payment for GRP pipes and for fittings; specials etc. shall include:

– Supply, hauling, handling, unloading and staking of pipes and fittings including all necessary GRP joints and jointing materials for pipes and all GRP joints and jointing materials for fittings, specials, valves, etc.

– Removal from stacks; hauling and stringing alongside trench; laying and jointing of pipes and fittings, at any depth of trench; connections to manholes and/or chambers and final cleaning and flushing of pipeline. The unit rates for this item, for each type, class and diameter of pipe and fitting, shall be the same for all depths of trench in which the pipes and fittings are to be installed.

– Testing of completed pipeline
  - For gravity pipelines: the cost of testing shall be included in the unit rates for pipes and shall not be paid for separately.
  - For pressure pipelines: the cost of testing shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

Only pipes, fittings, junctions, bends etc. actually laid in trench and tested and accepted by the Engineer can be measured for payment under the above items, and no allowance whatsoever will be made for any breakage, loss, waste, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers shall be paid for under separate items in the Bill of Quantities, unless otherwise stated.

3.7 P.V.C. PIPES

3.7.1 Quality Requirements

P.V.C. pipes and fittings shall comply in all respects with the following standards:

– B.S. 3506 Unplasticized P.V.C. pipes for industrial uses.
– B.S. 3867 Outside Diameters and Pressure Ratings of Pipe of Plastics Materials.
– B.S. 4514 Unplasticized P.V.C. Underground Drain Pipe and Fittings.
– B.S. 5481 Unplasticized P.V.C. Pipe and Fittings for Gravity Sewers.

All pipes and fittings shall be supplied by approved manufacturers. Class of pipes shall be as stated in the Drawings or in the Particular Specification. The nominal length of pipes shall be not less than 6.0 m and not greater than 9.0 m.

P.V.C. pipes shall be factory tested and shall be subjected to Hydraulic and to Impact (Falling Weight) Tests. The number and selection of samples for testing, the test procedure and the requirements shall all be as specified in the relevant B.S. If so directed by the Engineer, the selection of samples and the Tests shall be witnessed by a representative of the Engineer, who shall be informed at least 48 hours in advance of any sampling or testing.

The cost of samples, their transportation to the laboratory and their testing shall be deemed to be included in the unit rates and shall not be paid for separately.

3.7.2 Hauling, Handling and Storage

Rough handling of pipes shall at all times be avoided, especially at low temperatures. During storage and transport, rigid P.V.C. pipes shall have as near continuous support as possible at all times, and care shall be taken to avoid damage to pipe by sharp edged angle irons, exposed nail heads, etc.

For long term storage in average ambient temperature, attention shall be paid to stack heights to avoid the possible deformation of the pipe diameters. A maximum stack height of 1 meter is recommended. For temporary storage on site, care shall be taken to ensure that the ground is level and free from bricks, stones and sharp edges. At high temperatures, rigid P.V.C. pipes shall be kept in the shade during long term storage. P.V.C. pipes with spigot and socket shall be stacked with the sockets protruding in alternate layers. Pipes bent, deformed in any way or changed in colour shall be rejected and no payment whatsoever shall be made for such pipes.

While transporting, the pipes shall not overhang the vehicle by more than 0.6 m. Pipe loads shall not be stacked higher than 2.0 m.

Where pipes are transported one inside another, care shall be taken that:

(a) The pipes are clean and free from grit.

(b) Suitable covering be provided over the exposed ends of the pipes to prevent the entry of grit during transport.

(c) The pipes in the lower layers are not excessively loaded to such a degree as would cause damage or undue distortion.

3.7.3 Laying and Jointing

After the excavation and preparation of a section of pipe trench has been completed, it shall be inspected by the Engineer. Just before pipelaying the trench shall be cleaned of all stones, soil and other debris that might have fallen therein.

All pipelaying shall be carried out by experienced pipe-layers, well skilled in this work.

Immediately before being laid, each pipe and fittings shall be carefully examined both inside and outside for any damage, and all dust, dirt and foreign matter shall be removed. Care shall be taken to ensure that they remain clean during laying. The use of a badger will be ordered by the Engineer, if in his opinion, dirt is not being satisfactorily excluded. The badger, on a sound rope, is to remain within the bore of the pipe previously laid and jointed and it is to be drawn forward as the work proceeds throughout the whole length of the sewer. The badger is to be of soft material which will not damage the internal surface of the pipes.

In order to prevent stones and soil from entering the pipe, a suitable cap or plug shall be provided with which the last pipe laid shall be closed when pipelaying is not actually in progress. The plug will be of the screw-up expanding type or of tapered wood.

Where bends are required, performed bends of the desired radii shall be used. Hot bending on site is not permitted.

All joints shall be flexible, with approved rubber rings. Rubber rings shall comply with B.S. 2494 (Elastomeric Joint Rings for Pipework and Pipelines) and shall be of the type designated on the Drawings, or in the Particular Specification, or as directed by the Engineer.

Pipe lengths and fittings shall be supplied with a chamfer on the spigot end. Where pipes have to be cut to length, the pipe shall be cut square and a chamfer formed on the spigot end using a medium file. Any saw flushing shall be scraped off with a knife. The spigot and socket shall be free from mud or grit, and the ring correctly located in its groove. A lubricant approved by the Engineer shall be applied to the chamfered portion of the spigot before its insertion in the socket.

Flanges complying with B.S. 4504 (flanges and Bolting for Pipes, Valves and Fittings, metric units) shall be used for the jointing of P.V.C. pipes with steel pipes and for the connection of valves and other appurtenances. The joint shall be made by compression of a gasket or ring seal set in the face of the flange.

Pipes shall be laid true to line by means of a line stretched along the sides of the pipes and true to level by means of a straight edge of suitable length kept inside the pipes and pulled forward to pegs boned in at suitable intervals between sight rails set to the proper levels.

3.7.4 Testing

Testing instructions and requirements for P.V.C. gravity pipelines shall be as specified in Subsection 217.2.6 for concrete pipelines except that the leakage under test shall not exceed 0.08 litre/m2 of internal wall pipe area/hour. Testing instructions and requirements for P.V.C. pressure pipelines shall be as specified in Subsection 217.3.10(b) for A.C. pressure pipes, except that the Hydrostatic pressure test can commence 24 hours after the completion of filing if permitted by the Engineer.

3.7.5 Methods of Measurements and Payment

P.V.C. pipes shall be classified for payment according to type, diameter and class and shall be measured in linear meters of completed pipeline in place, along the crown of the pipeline, as follows:

– In gravity flow lines: between internal surfaces of manholes or chambers.
– In pressure flow lines: between stations.

The length measured for payment shall include the length of all fittings, valves and specials installed in the line.

The price for fittings, specials, junctions, bends, detachable joints, valves, etc., shall be classified for payment according to type, diameter and class; shall be considered as included in the cost of pipes, unless otherwise specified in the particular specifications or the B.O.Q.

Alternatively, if so stated in the Particular Specification and/or in the Bill of Quantities, pipe and fittings may be measured by number of pipes of defined net lengths and by number of fittings.

Payment for P.V.C. pipes and for fittings; specials etc. shall include:

– Supply, hauling, unloading and staking of pipes and fittings including all necessary P.V.C. joints and jointing materials for pipes and all P.V.C. joints and jointing materials for fittings, specials, valves, etc.

– Removal from stacks, hauling and stringing alongside the trench, laying and jointing of pipes and fittings at any depth of trench, connections to manholes and/or chambers and final cleaning and flushing of pipeline. The unit rates for this item for each type, class and diameter of pipe and fitting shall be the same for all depths of trench in which the pipes and fittings are to be installed.

– Testing of completed pipeline

  - For gravity pipelines: the cost of testing shall be included in the unit rates for pipes and shall not be paid for separately.

  - For pressure pipelines: the cost of testing shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

Only pipes, fittings, junctions, bends etc. actually laid, in trench and tested and accepted by the Engineer shall be measured for payment under the above items, and no allowance whatsoever will be made for any breakage, loss, waste, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers shall be paid for under separate items in the Bill of Quantities, unless otherwise noted.

3.8 HIGH DENSITY POLYEHYLENE (HDPE)

3.8.1 Quality Requirements

HDPE pipes and fittings shall comply in all respects with the following standards.

BS 6572Specification for blue polythylene pipes up to nominal size 63 for below
- 1984 - ground use for potable water.

WIS 4-32-02 Specification for polyethylene pressure pipe for cold potable water (underground use).

WIS 4-32-04 drawn pipes. Specification for polyethylene socket and spigot fittings, saddless and bends for fusion jointing for use with cold potable water PE pressure

WIS 4-32-06P cold - 1989 - Specification for polyethylene electrofusion couplers and fittings for potable water supply for nominal sizes up to and including 180.

WIS 4-32-13P 100) - 1991 - use for Interim specification for higher performance blue polyethylene(PE/MRS pressure pipes (nominal sizes 90 to 500) for underground or protected the conveyance of water intended for human consumption.

(WIS Water Industry Specifications UK).

DIN 8074/ DIN 8075 or the most recent ISO standards or European Norms (EN).

All pipes and fittings shall be manufactured from approved raw materials and shall be supplied by approved manufacturers. Manufacturers shall have and maintain permanent Quality Control program and records.

Unless otherwise stated, pipes with OD up to 63mm must be produced from PE80 (MDPE) or PE100 (HDPE) material. Pipes with OD 75 mm and up must be produced from PE100 (HDPE) material. Pressure class for all diameters should be PN16.

Pipes with OD up to 63mm shall be supplied in coils where the inside diameter of the coil is 30 times OD. Pipes with OD 75mm and up shall be supplied in coils if possible or in straight length not less than 6 m.

The pipes shall be clearly and indelibly marked to show the name of the manufacturer, nominal diameter, wall thickness, PE designation, pressure class, standard (BS, DIN, EN, ...) and date of manufacture. The marking shall remain legible during normal handling, storage, installation, and service life and shall be applied in a manner that will not reduce the strength nor otherwise damage the products. The marking shall not initiate any defects in the surface and will not provide leakage channels when elastomeric gasket compression fittings are used to make joints. Both hot tape marking and Ink Jet printing are acceptable.

For instant identification as potable water service pipes, PE pipes shall be colored blue or black permanently color-coded with blue stripes. Stripes shall be provided by co-extruding four (or more) equally spaced blue color stripes into the pipe outside surface. The striping material shall be the same material as the pipe material except for color. Stripes printed on the pipe outside surface shall not be acceptable.
For applications other than potable water, i.e. Irrigation and drainage, pipes are to be colored black.

Pipes and fittings intended to be used for the conveyance of potable water shall be approved by an internationally recognized independent water authority such as WRC, DVGW, KIWA, Lyonnaise Des Eaux, etc... The effect on water quality test shall fulfill the requirements of BS 6920 or equivalent.

HDPE pipes shall be factory tested and shall be subjected to Hydraulic, Impact (Falling Weight) and acceptance Tests. The number and selection of samples for testing, the test procedure and the requirements shall all be as specified in the relevant EN. If so directed by the Engineer, the selection of samples and the Tests shall be witnessed by a representative of the Engineer, who shall be informed at least 48 hours in advance of any sampling or testing.

The cost of samples, their transportation to the laboratory and their testing shall be deemed to be included in the unit rates and shall not be paid for separately.

3.8.2 Hauling, Handling and Storage

Rough handling of pipes shall at all times be avoided, especially at low temperature, and care should be taken to prevent damage to pipes and fittings at all stages of handling, transporting and storage.

Pipes must be transported by a suitable vehicule and properly loaded and unloaded. Straight pipes should be supported along their full length.

When lifting with slings, only wide fabric choker slings shall be used to lift, move, or lower pipe and fittings. Wire rope or chains shall not be used. Slings shall be of sufficient capacity for the load, and shall be inspected before use. Worn or defective equipment shall not be used.

During storage, care must be taken to ensure that pipes do not become distorted or damaged. This can occur if pipe stacks are not properly constructed and are not limited in height. Pipe stacks must not exceed 1.5m and storage areas must be flat throughout the entire length of the pipe.

Pipes must be protected from materials which may soften or damage polyethylene, such as strong solvents.

Pipes must not be dragged across ground, which might damage the surface.

Similar precautions should be taken with fittings and these should be kept in protective wrappings until required for use. This is particularly important for all electrofusion fittings, each one of which should be individually wrapped and sealed immediately after manufacture.

It is similarly important to protect spigot ends of pipes and fittings to be jointed by Electrofusion or Mechanical jointing methods.

3.8.3 Weathering

Blue and yellow polyethylene should not be permanently installed above ground where it is exposed to direct UV light.

3.8.4 Laying

After the excavation and preparation of a section of pipe trench has been completed, it shall be inspected by the Engineer. Just before pipelaying the trench shall be cleaned of all stones, soil and other debris that might have fallen therein.

All pipelaying shall be carried out by experienced pipe-layers, well skilled in this work and in the presence of the Engineer unless prior permission has been received.

Immediately before being laid, each pipe and fittings shall be carefully examined both inside and outside for any damage, and all dust, dirt and foreign matter shall be removed. Care shall be taken to ensure that they remain clean during laying. The use of a badger will be ordered by the Engineer, if in his opinion, dirt is not being satisfactorily excluded. The badger, on a sound rope, is to remain within the bore of the pipe previously laid and joined and it is to be drawn forward as the work proceeds throughout the whole length of the pipe. The badger is to be of soft material which will not damage the internal surface of the pipes.

In order to prevent stones and soil from entering the pipe, a suitable cap or plug shall be provided with which the last pipe laid shall be closed when pipelaying is not actually in progress. The plug will be of the screw-up expanding type or of tapered wood.

Where bends are required, performed bends of the desired radiis shall be used. Hot bending on site is not permitted.

<u>Additional general installation details for HDPE duct for telemetry cables</u>

The line and level of the duct formation shall be kept as straight as possible. Bends will be required for duct formations to be routed around corners at intersecting roads. (For safety reasons manholes shall usually be planned and located away from intersections).

The configuration of the duct formation shall be as shown on drawings.

All ducts shall be located in accordance with applicable roads and municipal Standards. In the absence of relevant Standards, the Engineer must be consulted to ensure compliance with the appropriate standard which may vary depending upon the nature of the undertaking.

Ducts shall be watertight between manholes. Installation methods shall prevent sand and soil from entering the ducts.

At manhole, the bond between the outside surface of the duct and the wall shall be watertight.

Ducts shall be terminated flush to manhole inside walls. Edges shall be bevelled off.

Ducts entering manholes, shall be plugged and watertight. The plugging mechanism or material shall be readily removable to allow for future cable installation.

Ducts shall leave a manhole in a standard formation and enter the subsequent manhole with each duct in the same relative location.

At location between manholes where the duct formation must be modified due to obstructions the formation shall be altered to minimise the movement of each duct.

The separation either longitudinal or perpendicular, to other services, should be minimum 150mm. Where such is not possible a separating/retaining layer of 50 mm of concrete is required.

The Engineer shall have the authority to change the construction method to HDPE in concrete or steel ducts, should the circumstances indicate such a requirement.

If two ducts are to be laid, they shall be supported by spacers so that the formation will maintain the standard spacing between ducts throughout the length of the installation. Sand, to the appropriate highway specification, shall be placed to fill all spaces between ducts, and compacted.

The duct formation shall be covered with 200 mm of sand. This is to be followed by approximately 200 mm of suitable backfill and a plastic warning tape. Warning tape shall be 70mm wide, yellow PVC, durably marked with the text 'WARNING - TELEMETRY CABLE' at no more than 50 cm intervals. Backfill and compaction shall follow.

HDPE tubes shall have minimum 2" inside diameter and minimum 5mm thickness with manholes maximum 100 meters apart.

3.8.5 Jointing

Jointing of HPDE can be one of the following systems:

a) Electro-fusion Fittings and Saddles

Electro-fusion can be used for all polyethylene pipes irrespective of size and pressure rating as long as pipe and fitting are manufactured from polyethylene resin of the same class and series. It is possible to use fittings with higher pressure rating than pipe, but the opposite is strictly forbidden.

- All fittings shall be injection moulded from recognised top quality PE 100 or PE 80 resin.
- All fittings must conform with the requirements of the related standard EN, BS, ..
- All fittings must be packed in such a way to allow instant use on site without additional cleaning.
- Each protective package must clearly indicate its contents.
- The heating coils contained in each individual fitting and saddle should be so designed that only one complete process cycle is necessary to fully electro-fuse the fitting to the adjoining pipe or pipes.
- No heating coil may be exposed and is to be fully imbedded into the body of the fitting for protection purposes during assembly.
- The pipe fixation device shall be an integral part of the fitting body in the sizes up to and including nominal diameter 63 mm.
- An individual magnetic card containing a magnetic strip and an appropriate barcode for data transfer purposes must be supplied with each fitting.
- All fittings must have moulded-in identification and product information.
- Process voltage of all fittings must not exceed a maximum of 40 volts.
- Insulated contacts for the terminal pins are to be provided.
- Terminal pin size shall be 4 mm in diameter.
- A limited path style fusion indicator acting for each fusion zone as visual recognition of completed fusion cycle should be incorporated in the body of the fitting.
- The design of the indicators must prevent the escape of fusion melt.
- All couplers in the sizes up to and including nominal diameter 160 mm must have an easily removable center stop not requiring tools for removal.
- All internal or externally threaded transition adaptors in the nominal sizes up to and including 2" must be designed with an integral polyethylene collar form PE 100 or PE 80 not relying on rubber or synthetic seals.
- Threaded adaptor bodies may be from brass or stainless steel and should be of the modular principle not being supplied moulded into an electro-fusion fitting socket.
- Electro-fusion machines used in the electro-fusion process must be supplied by the same manufacturer of fittings. It strictly forbidden to fuse one manufacturer fitting with another manufacturer machine.

Additional Requirements for Electro-fusion Saddles

- All saddles up to nominal diameter 250 mm should be designed with two separate halves having a single hinge type attachment and are to be correctly processed without specialized external spring-loaded tooling.
- The top half of the saddle shall be equipped with an outlet which can accept various other system components such as tapping tees, adopters, valve tees, stop-off attachments etc., that are simultaneously fused together with the saddle to mains joint in one operation.
- Each branch outlet is to be equipped with an integral clamping device.
- The branch spigot of tapping tees must be long enough to allow a second joint if necessary.
- All pipe saddles sizes above nominal diameter 63 x 20 mm are to allow a 360° rotation of the branch outlet.
- Safe tapping into a main must be possible under the defined allowable maximum water pressure according the respective pipe series and ambient temperature.
- The tapping saddle cutter is to be designed to seal-off the central passage in the uppermost position.

b) <u>Butt-fusion</u>:

Butt-fusion jointing is a thermofusion welding process which invloves the simultaneous heating of the annular end sufaces of two components to be joined until a melt state is attained on each contact surface. The two surfaces are then brought together under controlled pressure for a specified cooling time and a homogeneous weld is formed upon cooling.

The resultant joint is end thrust resistant and has comparable performance under pressure to the unwelded pipe.

In the fabrication and installation of a butt-welded polyethylene system, it is essential that all items which are to be butt-welded are made from compatible material.

The compatibility is dependent upon the process of manufacture, density amd melt flow index.

It is also important that proper butt-welding machines are used to make welds and that these are maintained in good condition as welding pressures and temperatures are critical to achieving satisfactory welds.

c) <u>Compression Fittings</u>

All fittings must be manufactured of pure virgin compounded PP ensuring the best performance as to mechanical properties and flexibilities.

- All fittings must be Push-fit type: to assemble, the installer must just cut the pipe square and clean (no need to chamfering), loosen the nut, push the pipe all the way through the stroke and close the nut. The fittings should be easily disassembled without the need for a special tool.
- All fittings must have a floating split clamp ring to compensate thermal and mechanical stress on the pipe. (Ring must be made of acetalic resin or C-PVC).
- All fittings must have a heavy-duty thrust ring to ensure axial compression of the gasket on ovalized, undersized and scratched pipes.
- All fittings must have a double lip gasket. giving the gasket a broader contact surface with the pipe, allowing a tighter grip and a higher resistance in case of vacuum or suction. Also, permitting higher protection against pipe pullout (Gasket must me made from EPDM or NBR Rubber).

- All female offtakes must be reinforcing with metal rings (Rings must be made of stainless steel).
- All fittings must have an easy traceability of the production batch. The production date must appear on the fitting's body and/or nut.

<u>Certificates and Approvals:</u>

All fittings must pass the testing requirements of ISO 3458/3459/3501/3503. At the time of submission, Manufacturers of fittings must hold valid certificates of conformity in respect to the following:

Toxicological requirements:

- WRc * Low sensitivity to bacteria migration
- DVGW * Low sensitivity to chlorine absorption
- KIWA * Alimentary compatibility as ATA test for color, odor, taste and toxic components in concentrations - BRL-K533

Ageing Test requirement:

- DVGW * 95° C - 1,000 hours - 0.5 x Nominal Pressure (PN)

Pullout Test requirement:

- WRc * For sizes up to 63 mm Diam.
- UNI9562 * for sizes greater than 63mm Diam.

Pressure test requirement:

- IIP * 3 x Nominal Pressure (PN) - 1 hour - 20°C Water Temperature

<u>Clamp Saddles</u>

All clamp saddles must be manufactured of pure virgin compounded PP ensuring the best performance as to mechanical properties and flexibility.

- Clamp saddles could be used on distribution lines of 63mm and below, for section rated at PN16 bars or less.
- All saddle off-takes must be reinforced with metal stiffeners.
- All saddles must have a feature to prevent bolt's rotation during assembly.
- All saddles over 40 mm and outlets ½" to 2" must have flat gasket to ensure added flexibility on ovalized, undersized or scratched pipes and to prevent gasket's pulling-out in case of water hammer.
- All bolts and nuts should be from stainless steel (series 400).

3.8.6 Testing

Testing instructions and requirements for HPDE gravity pipelines shall be as specified in Subsection 217.2.6 except that the leakage under test shall not exceed 0.08 litre/m2 of internal wall pipe area/hour. Testing instructions and requirements for HPDE pressure pipelines shall be as specified in Subsection 217.3.10 (b) for A.C. pressure pipes, except that the Hydrostatic pressure test can commence 24 hours after the completion of filling if permitted by the Engineer. Manufacturer's recommended procedure of testing should be submitted to the Engineer who could accept to take it into consideration or not.

3.8.7 Methods of Measurement and Payment

HPDE pipes shall be classified for payment according to type, diameter and class and shall be measured in linear meters of completed pipeline in place, along the crown of the pipeline, as follows:

- In gravity flow lines: between internal surfaces of manholes or chambers.
- In pressure flow lines: between stations.

The length measured for payment shall include the length of all fittings, valves and specials installed in the line.

Payment for HPDE pipes and for fittings; specials etc. include:

- Supply, hauling, handling, unloading and staking of pipes and fittings including all necessary HPDE joints and jointing materials for pipes and all HPDE joints and jointing materials for fittings, specials, valves, etc.

- Removal from stacks; hauling and stringing alongside trench; laying and jointing of pipes and fittings, at any depth of trench; connections to manholes and/or chambers and final cleaning and flushing of pipeline. The unit rates for this item, for each type, class and diameter of pipe and fitting, shall be the same for all depths of trench in which the pipes and fittings are to be installed.

- Testing of completed pipeline
  - For gravity pipelines: the cost of testing shall be included in the unit rates for pipes and shall not be paid for separately.
  - For pressure pipelines: the cost of testing shall be paid for under a separate item in the Bill of Quantities, by linear meters of pipe tested.

Only pipes, fittings, junctions, bends etc. actually laid in trench and tested and accepted by the Engineer can be measured for payment under the above items, and no allowance whatsoever will be made for any breakage, loss, waste, etc.

Excavation and backfill, special beddings, surrounds and manholes and chambers shall be paid for under separate items in the Bill of Quantities, unless otherwise stated.

3.9 WATER SERVICE CONNECTIONS

3.9.1 Scope

Service connections shall consist of pipes and fittings of small diameters which distribute water from the mains to the consumers.

The nature of these connections shall vary according to the main pipes material.

For DI mains, service connections shall include the following:
- Tapping collars
- Ferrules (Self-sealing fittings for vertical under pressure tappings)
- Stop valves
- Pipes and fittings

and shall end up with:
- House connection accessories

For HDPE mains, the tapping collars and ferrules shall be replaced with saddles and tapping tees respectively. The remaining components (stop valves, pipes and fittings and house connection accessories) shall be identical to those used for DI mains.

3.9.2 Ductile Iron Mains

3.9.2.1 *Tapping Collars*

Tapping collars shall be used for connecting DI mains to service lines. They shall be made from coated ductile iron with anti-corrosive bolts and shall have large threaded boss on which ferrules shall be vertically mounted.

Elastomer gaskets of appropriate shapes shall ensure the seal between the mains and tapping collar.

3.9.2.1.1.1 Ferrules (Self-sealing fittings for vertical under pressure tappings)

They shall be mounted on large threaded boss tapping collars for connecting mains to service lines.

They shall consist of:

- a body, ductile iron, threaded at its lower part, and screwed on under pressure tapping collars. A polyurethane gasket shall allow to obtain the required orientation of the fitting once the fitting is completely screwed to the collar.
- an ABS float valve (Acrylonitrèle - Butadiene - Styrene)
- a ductile iron seat coated with elastomer and screwed inside the body.
- a ductile iron cap fitted with a polyurethane gasket
- an internal threaded outlet on which a nipple for polyethylene or PVC pipe shall be mounted. No need for nipple if stop valves are directly connected to ferrules.

3.9.2.1.2 HDPE mains

3.9.2.1.2.1 Saddles

HDPE mains shall be connected to the service lines through electrofusion saddles, which are made from HDPE and consist of:

- An upper semi-cylindrical piece having a small cylindrical neck incorporated at the center of its convex face; a tapping tee shall be vertically mounted on this upper part through the above-mentioned neck.
  The seal between the upper part of the saddle and the main pipe shall be effected through electrofusion. To this effect, this upper part shall include two ports used to connect the electrofusion machine to the saddle. Two limited path fusion indicators shall also be present to indicate the point beyond which no more sealing is necessary. One of these ports shall be located on the semicylindrical surface of the upper saddle part and the other on the saddle

neck to seal the saddle to the main and the tapping tee to the neck, respectively.

- A lower semi-cylindrical part that shall be attached to the upper one via two pin connectors from one side, the other side being joined together by the means of a hook, formed through appropriate fashioning of the upper and lower saddle ends. This lower part is used to fix the upper one in place prior to sealing this latter to the main through electrofusion.

3.9.2.1.2.2 Tapping Tees

They shall be mounted on the above-mentioned saddles for connecting HDPE mains to service lines.

They shall be made from HDPE and shall consist of:

- A lower cylindrical branch to be inserted in the saddle neck specified above.
- An upper threaded branch that could be closed with a screw cap of the same material (HDPE).
- An outlet branch that could be joined to the service pipe via a coupler, or could be directly connected to the stop valve.
- An O-ring sealed screw cap made from HDPE.

The seal between the tapping tee and the saddle shall be effected through electrofusion as above. The saddle neck shall also be equipped with two pin connectors to be tightened after inserting the tapping tee and orienting it in the right direction, and prior to sealing it to the neck.

As for the coupler connecting the outlet tee branch to the service pipe, it shall be sealed to these through electrofusion as well but shall include four pin connectors for better control before sealing, as well as two limited path fusion indicators.

3.9.2.1.3 Stop Valves

Stop valves shall be equipped with two push-in fittings for connecting standard polyethylene or PVC pipes (this could be applied either for DI or HDPE mains) or they shall be equipped at one end with a threaded nose for direct connection to tapping collars or ferrules installed on the DI mains, and on the other end with a push-in fitting for standard polyethylene or PVC pipe in accordance with NFT 54-003, NFT 54072, ISO 161-1, ISO 3607 or any equivalent.

Stop valves shall consist of :

- a ductile iron body coated with powder epoxy or copper alloy, drilled for automatic draining of service line (after closing of the ferrule).
- a rotary inverted plug, copper alloy, ¼ turn, fitted at its upper part with an operating cap.
- a ductile iron base coated with powder epoxy and screwed to the body lower part. The base and the body shall be of the same material.
- a stainless steel spring supported by the screwed base and pushes the inverted plug against the body.

Stop valves shall be protected by complete systems of surface boxes for operation from the surface. These boxes shall consist of a lower protective hood which shall contain the valve and isolate it from the surrounding soil. The hood shall be surmounted by a PVC extension tube which shall house the spindle used to operate the stop valve (Each stop valve shall be equipped with such a spindle). Finally, the extension tube shall be topped by a surface box made of ductile iron, the cover of which shall be flush with the sidewalk surface and the entire assembly (stop valve, spindle, hood, tube, surface box) located outside the property line.

The stop valve shall be at least 60cm beneath the road surface.

3.9.2.1.4 Service Pipes

Service pipes shall be from HDPE. For further information, refer to section 217.8.

3.9.2.1.5 Test Pressure

Service connection fittings shall undergo a double hydrostatic test:

1. a mechanical strength test, in opened position, under the maximum allowable pressure increased by 50%:
2. a seal test, in closed position, under the maximum allowable pressure increased by 10%:

Test certificate from factory or from approved laboratory shall be submitted with the equipment.

3.9.2.1.6 House Connection Accessories

House connection accessories for each consumer shall consist of a ball valve followed by a water meter and then a pollution check valve including all necessary fittings.

House connection accessories shall be protected by adequate water meter boxes. These boxes shall have generally three sizes: first size for individual consumers, second size for three subscribers and a third size for five subscribers. In these two latter cases, a collector linked to the downstream end of the service line shall distribute water to each house connection.

For pricing purposes, this collector shall be considered an integral part of the water meter box(es) it is supplying.

Water meter boxes shall be watertight, and equipped each with a lock to prevent unauthorized access. These locks shall be identical for a given number of boxes. This number may vary according to the Engineer's request. In addition, a sight glass shall be installed on each meter box cover to provide a proper reading of the water meter measurements without having to open the meter box.

For each group of similar locks, shall be provided a corresponding set of 5 identical keys.

The boxes shall be located inside the concerned property, and shall be provided by the Contractor. Their exact location shall be approved by the Engineer.

3.9.2.1.7 In Situ Testing and Method of Payment

Service lines shall be from HDPE, equipped where required with a ferrule mounted on the tapping collar installed on the main (for DI mains) or with a tapping tee on a tapping saddle in the case of HDPE mains, a stop valve installed on the service line and a ball valve installed at the end of the service line directly upstream the water meter.

Hydrostatic tests are conducted in two stages on service connections and DI mains at the same time:

1. The main is put under test pressure with ferrules and/or stop valves closed - The network tightness is monitored.
2. Ferrules and stop valves are opened and ball valves closed, the seal of service connections, under the same test pressure as stage 1, is monitored.

The same procedure shall be followed for HDPE mains (use tapping tees in place of ferrules).

Service connection testings shall be paid separately by unit of service connection.

3.10 MICROTUNNELLING SYSTEM

3.10.1 Reinforced Concrete Jacking pipes

3.10.1.1 *Static Strength Calculation*

The static strength calculation must be done for all expected load cases in axial direction of the pipes (jacking force for straight or curve drives) and perpendicular to the pipe axis (pipe weight, ground load, internal and external water pressure, traffic load etc.) based on actual valid rules such as general rules for concrete works (DIN 1045), special rules for pipe design and pipe manufacturing (DIN 4035) and detailed rules for the static strength calculation for the specific system of pipe installation (open trench installation or pipe jacking).

Structural calculations for jacking pipes must be according to worksheet ATV-A161-(Driven pipes, Edition I/90).

3.10.1.2 *Concrete and Reinforcing Steel*

Reinforced concrete pipes, to be manufactured according to DIN 1045 and DIN 4035, using approved steel, aggregates, cement (sulfate resistant if need), admixtures and water.

1. Reinforcing steel must be of weldable quality (BSt 500 P / BSt 500 S or similar), fulfilling all tests after cage welding procedure according to DIN 488.

2. The reinforcing cages have to be produced by automatic welding machine according to the structural strength calculation and pipe design.

3. For pipes of a wall thickness of 120 mm or more, two layers of concentric cages must be foreseen, which should be completely embedded in the concrete.

4. A minimum of 30 mm concrete cover must be secured, using special polymer-concrete spacers with roughened surface securing homogeneous adherence to the concrete.

5. Cage design, rod and coil sizes, spiral spacing and relevant dimensions must be as per ATV-A161.

3.10.1.3 Pipe Design and Geometry

1. Jacking pipes should be spigot/socket type, where the spigot includes an incorporate precast groove, allowing for the installation of a rubber seal joint, whereas the socket must be a steel collar including a prewelded steel water stop.

2. The steel grade of the collar should be corrosion resistant to the soil and water at the installation level. Such resistance to be calculated as per DIN 50929 / P3 considering the soil and water analysis. If the pipes are installed near the sea on coastal areas the collar should be stainless steel.

3. Standard mild construction steel according EN 10025 or steel containing chrome and molybdium, to be selected depending on the corrosion resistance calculations.

4. The thickness of the collar must not be less than 8 mm for mild steel and not less than 6 mm for stainless steel, respecting the corrosion resistance standard, but in any case should be designed to resist the physical forces resulting from the allowed angular deviations.

3.10.1.4 Handling Anchors

Each pipe must include 4 anchors, whose load resistance must be approved, two of which to allow for pipe handling at site and for transport, whereas the other two to be used for lifting and titling the pipes upon production. (DEHA anchors or similar).

3.10.1.5 Pipe Particulars

1. At least each third pipe of the jacked sequence should be a special pipe including three outlet nozzles to allow for external surface lubrication during pipe jacking. These nozzles to be precast during production.

2. Special pipes of long-sockets to be foreseen, as per design, to allow for the use of intermediary jacking stations.

3. As a compression absorber, each pipe, must include at the socket side a wooden ring of a thickness of 20 mm.

3.10.1.6 *Joint seals*

1. For the pipe joint sealing a slip-ring seal made of elastomer rubber of dense structure for permanent sealing has to be used. The seal compression should be of a minimum of 25%.

2. The pipe joint design, (spigot groove, rubber seal and steel collar) shall be designed to resist the internal and external hydrostatic pressures at the installation zone, but in any case should resist an internal pressure of at least 1 bar and an external pressure of at least 2.0 bars.

3. Joint of pipes used for storm water, do not need any internal treatment.

4. Joints of pipes for clear water transport, (eventual potable use), must be sealed with approved polyurethane base mastic, as recommended by the manufacturer.

3.10.1.7 *Internal Pipe Lining for Sewage Pipes*

1. The reinforced concrete pipes used for sewage shall be produced with 360° - Lining to prevent from corrosion due to the sewage and gas inside the tunnel.

2. The lining must cover the full pipe length, where the joint zone must also be sealed using thermoplastic hot air extrusion welding, applied by an automatic (satellite) device.

3. Minor repairs and patching the outlet nozzles, could be carried out by manual hot air thermowelding, using the welding rods as recommended by the manufacturer of the liner.

4. A joint strip of the same lining material has to be welded to both sides of the joint (recess joint system). This strip must be of a thickness of at least 3mm.

5. The lining to be of HDPE with minimum thickness of 2.0 mm.

6. The lining must be of the stud type securing resistant adherence (embedment) into the concrete resisting an external pressure of at least 2.0 bar.

3.10.1.8 *System Pipe Length*

Jacking pipes to be of a length of 3 meters. Shorter pipes could be used to allow for curved drives, as per ATV 161, as well as for length compensations at the connections to manholes and others.

3.10.1.9 *Pipe Manufacturing*

The pipes shall be manufactured according to the above mentioned standards in best quality, using special pipe molds with hydraulic shrinkable internal cores and expandable external molds.

The pipes should be kept for at least 4 hours inside the pipe molds to get high quality concrete and smooth pipe surface. During the first 10 hours after pouring the concrete curing shall be carried out by covering the pipes completely to conserve the humidity and avoid fast drying.

After production, the pipes should be sprayed with water for 2 days securing high surface concrete strength.

3.10.1.10 Microtunneling System and Machines

1. The tunneling machine and relevant logistics must be an integral system supplied by the same manufacturer, where the steering and guiding system are to be operated from the computerized, above ground, control room.

   The cutting wheel, its tools, and relevant selection of rock cutting and / or clay handling - etc must be adequately selected considering the soil condition, water table and ground cover.

2. The control plc / ddc system must control all the equipment, as well as their components, where a selectable manual / auto mode is allowed.

3. The computer, and display monitor, must sense and process the mechanical and hydraulic components, as well as the laser beamer, but not limited to:

   3.1. Cutting wheel, torque and rpm, both variable and controllable.

   3.2. Steering cylinders: course control and pressure indication.

   3.3. Roll and yawe display, and limiting levels control.

   3.4. Pitch and level sensing and control.

   3.5. Driven length indication.

   3.6. Main jacking cylinders pressure and speed control.

   3.7. Intermediary jacking station, pressure and course control.

   3.8. Lubrication and slurry pressure control.

   3.9. Laser magnitude and intensity control.

   3.10. Oil level and temperature control.

   3.11. Slurry flow and pressure at both supply and return lines (valid for slurry system).

CIVIL WORKS

4 CIVIL WORKS

4.1 GENERAL

4.1.1 Scope of Section

This section covers formwork, reinforcement, concrete and joints for the concrete required in the Permanent Works.

Formwork constitutes formwork, falsework and void formers required for the placing of concrete.

Reinforcement constitutes plain and deformed bar reinforcement and steel fabric to be cast into concrete but does not include prestressing tendons or any other embedded steel.

Concrete constitutes concrete and mortar other than special concretes and mortars specified in other sections of the Specification.

A list of applicable international standards is included under Sub-Section 4.7 of this specification.

4.1.2 Submissions to the Engineer

The Contractor shall submit to the Engineer all documents etc. as required by the relevant clauses of the Conditions of Contract. With regard concrete works, the submissions are in particular two copies of each of the following:

- shop drawings, details and calculations
- reinforcement detail drawings
- bar bending schedules.

4.2 FORMWORK

4.2.1 Definitions

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

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

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

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

4.2.2 Construction of Formwork and Falsework

The design, provision and maintenance of all falsework shall be the responsibility of the Contractor and shall be in accordance with BS 5268 and BS 5975. When requested, he shall provide a design analysis for particular parts of the work and erection shall not commence until he has received the written permission of the Engineer. Notwithstanding any approval given or implied or comments made, design shall remain the responsibility of the Contractor.

Whether or not a design analysis has been requested, before construction begins the Contractor shall submit to the Engineer drawings showing details of the proposed formwork and falsework including void formers where required.

Formwork and falsework shall be so constructed that they will support the loads imposed on them by the fresh concrete together with additional loads imposed by vibrating equipment and by construction traffic, so that after the concrete has hardened the formed faces shall be in the positions shown on the Drawings within the tolerances set out in Sub-Section 4.2.5.3.

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

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

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

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

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

Formwork shall be provided for concrete surfaces at slopes of 30° to the horizontal or steeper. Surfaces at slopes less than 20° may be formed by screeding. Surfaces at slopes between 20° and 30° shall generally be formed unless the Contractor can demonstrate to the satisfaction of the Engineer that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration.

Horizontal or inclined formwork to the upper surface of concrete shall be adequately secured against uplift due to the pressure of fresh concrete. Formwork to voids within the body of the concrete shall also be tied down or otherwise secured against floating.

The internal and external angles on concrete surfaces shall be formed with fillets and chamfers of 25 x 25 mm unless otherwise shown on the Drawings. Tops of lifts shall have a 20 x 20 mm grout check set true to line, to present a neat joint when the next lift is placed.

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

Removable tapered plugs shall be used against the formwork when casting in all metal ties through the concrete where the surface finishes is Class F3 or higher.

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

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

Shear keys shall be provided in all vertical battered or sloping contraction or construction joints of the size and shape indicated on the Drawings.

Where precast concrete elements are specified for use as permanent formwork, or proposed by the Contractor and agreed by the Engineer, they shall comply with the requirements of Sub-Section 4.5 of the Specification. Such elements shall be set true to line and level within the tolerances prescribed for the appropriate class of finish in Sub-Section 4.2.5.1 and fixed so that they cannot move when concrete is placed against them.

4.2.3 Preparation of Formwork

Before any reinforcement is placed into position within formwork, the latter shall be thoroughly cleaned and then dressed with a release agent. The agent shall be either suitable oil incorporating a wetting agent, an emulsion of water suspended in oil or low viscosity oil containing chemical agents. The Contractor shall not use an emulsion of oil suspended in water nor any release agent which causes staining or discoloration of the concrete, air holes on the concrete surface, or retards the set of the concrete.

To avoid colour differences on adjacent concrete surfaces, only one type of release agent shall be used in any one section of the Works.

In cases where it is necessary to fix reinforcement before placing formwork, all surface preparation of formwork shall be carried out before it is placed into position. The Contractor shall not allow reinforcement or prestressing tendons to be contaminated with formwork release agent.

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

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

4.2.4 Removal of Formwork

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

Formwork may be removed when the concrete has attained the strength set out in the following table, where 'C' is the characteristic strength used for design purposes for a given class of concrete, provided that the attained strength is determined by making test cubes and curing them under the same conditions as the concrete to which they refer.

Position of Formwork	Strength to be Attained
Vertical or near vertical faces of reinforced walls, beams and columns	0.3 C
Underside of arches, beams and slabs (formwork only)	0.5 C
Supports to underside of arches, beams and slabs	1.0 C
Arched layings in tunnels and underground works	3 N/mm2

Alternatively the stripping times required to achieve the strengths in the table above for the anticipated range of ambient temperatures shall be agreed in advance by the Contractor and Engineer for each class of concrete.

Compliance with these requirements shall not relieve the Contractor of his obligation to delay removal of formwork until the removal can be completed without damage to the concrete. The Contractor will be held responsible for and shall make good at his cost all injury and damage arising from the premature stripping of formwork.

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

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

4.2.5 Formed Surface Finishes

4.2.5.1 Classes of Finish

The surface finish to be achieved on formed concrete surfaces shall be as shown on the Drawings and defined hereunder. The selection of materials for the formwork, the design of the formwork and its fixing shall be such as to achieve the required surface finish without any subsequent remedial work.

Class F1 Finish: This finish is for surfaces against which backfill or further concrete will be placed. Unless specifically directed otherwise, formwork may be sawn boards, sheet metal or any other suitable material which will prevent the loss of fine material from the concrete being placed.

Class F2 Finish: This finish is for surfaces which are permanently exposed to view. Forms to provide a Class F2 finish shall be faced with wrought tongued and grooved boards with square edges arranged in a uniform pattern and close jointed or with suitable sheet material. The thickness of boards or sheets shall be such that there shall be no visible deflection under the pressure exerted by the concrete placed against them. Joints between boards or panels shall be horizontal and vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting, but fins, surface discolouration and other minor defects shall be remedied by methods agreed by the Engineer.

Class F3 Finish: This finish is for surfaces which will be in contact with flowing water, for tunnel laying, for reservoirs, and for surfaces prominently exposed to view where good appearance is of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be faced with plywood complying with BS 1088 or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surface. All joints between panels shall be vertical and horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced wrought boarding or standard steel panels will not be permitted for Class F3 finish. The Contractor shall ensure that the surface is protected from rust marks, spillages and stains of all kinds.

Class F4 Finish: This finish is similar to that required for F3 but is used in places where a first class alignment and a particularly dense surface free from air holes and other defects is required, suitable for the application of decorative finishes and at locations which will be in contact with water flowing at high velocities and/or through significant curvatures.

The Contractor's attention is drawn to the fact that this finish requires careful selection of materials and the highest quality of workmanship and supervision at all stages. A proprietary formwork laying membrane may be appropriate to aid the achievement of this class of finish.

4.2.5.2 Curved Surfaces

For curved surfaces where F2, F3 or F4 finishes are called for the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

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

4.2.5.3 Tolerances

All parts of formed concrete surfaces shall be within the tolerances set out in the following table:

Class of Finish	Tolerances in mm (see Note 1)

Class of Finish	Tolerances in mm (see Note 1)		
	A	B	C
F1	10	10	+ 25 to - 10
F2	5	10	+ 15 to - 10
F3	2	5	+ 10 to - 10
F4	Nil (see Note 2)	2	+ 5 to - 5

Notes:

1. The tolerances A, B and C given in the table are defined as follows:
   - 'A' is an abrupt irregularity in the surface due to misaligned formwork or defects in the face of the formwork;
   - 'B' is a gradual deviation from a plane surface as indicated by a straightedge 3 m long. In the case of curved surfaces the straightedge shall be replaced by a correctly shaped template;
   - 'C' is the amount by which the whole or part of a concrete face is displaced from the correct position shown on the Drawings.
2. Abrupt irregularities are not permitted in an F4 finish. Any residual irregularities which remain after removal of formwork shall be removed by grinding to achieve a transition of 1 in 50 between the surfaces adjacent to the irregularity.
3. Where a surface lies in the vertical plane, the maximum deviation from true vertically shall not be greater than 2mm per meter vertical height.

In cases where the Drawings call for tolerances other than those given in the table above, the Drawings shall have precedence.

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

4.2.6 Remedial Work to Defective Surfaces

4.2.6.1 Minor Defects

a. General

This clause covers the remedial work required to repair defects of a non-structural nature. The repair of defects of a structural nature such as honeycombing extending to reinforcement, lack of bond on construction surfaces, shrinkages, cracks etc are covered in Sub-Section 4.2.6.2.

Prior to undertaking permanent work, the Contractor shall submit details of all proposed methods of repairing surface blemishes and shall, where required by the Engineer, carry out trials on test panels to prove the adequacy of the proposed methods and competence of the workmen.

Immediately after the removal of the shuttering, the Contractor shall inspect the concrete and shall report any defects to the Engineer. All repair work on such defects and the timing of such repairs shall be agreed by the Engineer prior to the work being done. The repair work shall be carried out by skilled workmen only, and shall be completed to the satisfaction of the Engineer.

Generally where repairs are required, they shall be carried out immediately after forms have been stripped. Proprietary bonding agents acceptable to the Engineer shall be used where repairs are made on concrete which is older than 7 days.

No plastering of surfaces will be permitted unless specifically stated or ordered. If surfaces are not true to shape due to inaccurate formwork or poor placing or any other cause whatsoever, the Engineer may order the removal of the whole of the section and its reconstruction.

b. Repairs

Surface defects such as small areas of honeycombing, cavities produced by form ties, large isolated blow holes, broken corner edges, etc. shall be repaired with mortar consisting of cement and sand in the same ratio as that of the concrete being repaired. The materials used shall be of the same type and from the same source as those used in the production of the concrete and if necessary a pigment shall be added to the mortar in order to obtain a colour match with the concrete.

Surfaces to be repaired shall be thoroughly cleaned of loose particles and laitance before applying the mortar.

All repaired surfaces shall be cured as specified for that structure or as agreed by the Engineer.

Where the concrete has been damaged by adhesion of the concrete to the formwork panel, the cracked and loose concrete shall be removed or where lifting of the fresh concrete at construction joints has occurred, the crack shall be scraped out immediately on both sides of the wall to a depth of at least 50 mm. The cavities so formed shall thereafter be repaired as described above.

Surface irregularities which are outside the limits of tolerance A set out in the table in Sub-Section 4.2.5.3 shall be ground down in the manner and to the extent instructed by the Engineer.

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

c. Rubbing of Surface

If the finish of exposed formed surfaces does not comply with the requirements for uniformity of texture, appearance and colour, the Contractor shall rub down the exposed surfaces of the entire structure or any part thereof as specified below.

The surface shall be saturated with water for at least one hour. Initial rubbing shall be carried out with a medium coarse carborundum stone, using a small amount of mortar, consisting of cement and sand in the same ratio as that of the concrete being rubbed down, on the face. Rubbing shall be continued until all form marks, projections and irregularities are removed and a uniform surface is obtained. The final rubbing shall be carried out with a fine carborundum stone and water. This rubbing shall continue until the entire surface is of a smooth, even texture and is uniform in colour. Thereafter the surface shall be washed with a brush to remove surplus paste and powder.

Where the concrete surfaces formed by sliding formwork require treatment in order to achieve the surface finish specified for the member, the concrete shall, as soon as the surfaces are exposed under the formwork, be floated with rubber-lined floats to the desired finish.

4.2.6.2 Major Defects

a. General

Concrete damaged by improper curing, traffic or any other cause or any concrete which is honeycombed or has interstices or is not homogeneous or which is not true to dimensions, or the surface finish defects fall outside those covered by Sub-Section 4.2.6.1 may be classed as defective work. Such defective work shall be removed and the Contractor shall replace it with acceptable concrete of specified strength without any additional payment.

If on stripping any formwork the concrete surface is found to be defective in any way, the Contractor shall submit to the Engineer his proposal for remedying the defects and shall make no attempt to remedy such defects prior to the Engineer's inspection and the receipt of the Engineer's agreement to his proposal.

In assessing the Contractor's proposals for remedying any defects the Engineer may request further investigation into the integrity of the concrete. Such investigations shall be carried out by the Contractor at no additional payment. On completion of his assessment the Engineer shall either accept or reject the Contractor's proposal. In the case of the latter the work referred to shall deemed to be not acceptable and shall be removed together with any subsequent permanent works that may have been placed and such removal is necessary to effect the reconstruction of the defective work.

Defects other than those mentioned below shall be dealt with as agreed by the Engineer.

b. Honeycombed and Porous Concrete

In all structures, honeycombed and porous concrete shall be cut out fully to sound concrete or as otherwise agreed by the Engineer, but the depth of cut out shall not be less than 100 mm or 25 mm clear distance behind reinforcement whichever is the greater.

On exposed surfaces, the perimeter of the repair shall be neatly defined by disc cuts not less than 25 mm deep. The cavity shall have roughened sides at least 75 mm in depth for the full perimeter and the sides of the cavity shall be splayed back to form a dovetail.

After cleaning out with water and compressed air, a thin layer of cement grout or a proprietary bonding agent approved by the Engineer shall be brushed on the concrete surfaces in the cavity and it shall then be filled immediately with concrete of the same class as the main body but with aggregate larger than 20 mm nominal size removed, or as otherwise directed by the Engineer. A form shall be used against the cavity, provided with a lip to enable concrete to be placed. The form shall be filled to a point above the top edge of the cavity.

The concrete shall contain the minimum quantity of water to reduce shrinkage as much as possible and shall be thoroughly vibrated into place. Afterwards the lip of concrete shall be broken off and the surface made good. If instructed by the Engineer, suitable shrinkage reducing agents or other additives shall be used.

When required by the Engineer, the Contractor shall drill and grout in injection pipes for subsequent grouting of any remaining voids.

Where acceptable to the Engineer, honeycombed concrete may be grouted with an laying grout of suitable viscosity for penetrating all voids.

Where repairs are to be made with concrete, they shall be carried out as soon as possible to achieve the best bond between the repair and the parent concrete. If repairs are delayed longer than 7 days after concreting a suitable wet to dry laying bonding agent shall be used. All laying materials shall be used strictly in accordance with the manufacturer's instructions.

4.2.6.3 <u>Cracked Concrete</u>

Surface cracks having a width equal or greater than 2 mm shall be pressure grouted using appropriate chemical or laying grouts applied strictly in accordance with the manufacturer's instructions.

4.3 REINFORCEMENT

4.3.1 Materials

In general the reinforcement used in the permanent works shall be either Grade 425, deformed high yield steel bars or Grade 250, plain round mild steel bars to BS 4449. Other types of reinforcement may be required in certain areas as shown on the drawings or agreed with the Engineer. All reinforcement shall comply with the appropriate British Standards, which include the following:

- BS 4449 for hot rolled plain bar and high yield deformed bar
- BS 4482 for hard drawn mild steel wire
- BS 4483 for steel mesh fabric

All reinforcement for use in the Permanent Works shall be tested for compliance with the appropriate British Standard in a laboratory acceptable to the Engineer and two copies of each test certificate shall be supplied to the Engineer. The frequency of testing shall be as set out in the British Standard.

In addition to the testing requirements described above, the Contractor shall carry out additional tests as instructed by the Engineer.

Any reinforcement which does not comply with the Specification shall be removed from Site.

All mechanical couplers used shall be subject to the approval of the Engineer.

For all mechanical couplers proposed the Contractor shall submit to the Engineer test certificates from a recognised testing authority certifying that the tensile and other properties of the couplers comply with the appropriate British Standards or equivalent standards as approved by the Engineer.

4.3.2 Storage of Reinforcement

Reinforcement shall be stored on Site either in racks or on a hard impermeable base so that it remains straight and free from contamination.

Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. All reinforcement which has become corroded or pitted to an extent which, in the opinion of the Engineer, will affect its properties shall be removed from Site.

4.3.3 Cutting and Bending Reinforcement

The Contractor shall cut reinforcement to length and bend it to the shape shown on the schedules within the dimensional tolerances given in BS 8666. Bars shall be bent cold by the application of slow steady pressure. No flame cutting of high yield bars shall be permitted, except where approved by the Engineer. Hooks or right angle bends shall be formed where called for by the schedules and to the dimensions and tolerances specified in BS 8666. At temperatures below 5°C the rate of bending shall be reduced if necessary to prevent fracture of the steel.

After bending, bars shall be securely tied together in bundles or groups and legibly labelled as set out in BS 8666.

Reinforcement shall be thoroughly cleaned and all dirt, scale, loose rust, oil and other contaminants removed before it is placed in the Permanent Works.

4.3.4 Fixing Reinforcement

Reinforcement shall be securely fixed in position within a dimensional tolerance of 20 mm in any direction parallel to a concrete face and within a tolerance of 5 mm at right angles to a face, provided that the cover is not thereby decreased below the minimum shown on the Drawings.

Unless otherwise agreed by the Engineer, all intersecting bars shall either be tied together with 1.6 mm diameter soft annealed iron wire and the ends of the wire turned into the body of the concrete, or shall be secured with a wire clip of a type agreed by the Engineer.

Spacer blocks shall be used for ensuring that the correct cover is maintained on the reinforcement. Blocks shall be as small as practicable and of a shape agreed by the Engineer. They shall be made from dense concrete of the same materials as the member in which they are located, but using 10 mm aggregate and cured in accordance with Sub-Section 4.4. They shall have 1.6 mm diameter soft annealed iron wire embedded in them to facilitate their fixing to the reinforcement.

Alternatively another type of spacer block may be used subject to the Engineer's agreement.

Reinforcement shall be rigidly fixed so that no movement can occur during concrete placing. The Contractor shall provide for all stools and other fixing materials/bars required for the support of the reinforcement. Any fixings made to the formwork shall not be within the space to be occupied by the concrete being currently placed.

On no account shall reinforcing steel be used as a means of support for shuttering or scaffolding and the steel shall be kept entirely free from strain while concrete is being placed.

No splices shall be made in the reinforcement except where shown on the Working Drawings or agreed by the Engineer.

Reinforcement shall not be welded except where required by the Contract or agreed by the Engineer. If welding is employed, the procedures shall be as set out in BS 2640 for gas welding or BS 7123 for metal arc welding. Full strength butt welds shall only be used for steel complying with BS 4449, and if used on high yield deformed bars complying with BS 4449 the permissible stresses in the vicinity of the weld shall be reduced to those applicable to plain bars complying with that specification.

The quality and strength of welding will be assessed by destructive laboratory testing of samples selected by the Engineer.

Mechanical splices shall not be used unless the Engineer agrees otherwise.

The Contractor shall ensure that reinforcement left exposed in the Permanent Works shall not suffer distortion, displacement or other damage. When it is necessary to bend protruding reinforcement aside temporarily, the internal radius of the bend shall not be less than four times the bar diameter for plain bars or six times the bar diameter for high yield bars. Such bends shall be carefully straightened before concrete placing continues, without leaving residual kinks or damaging the concrete round them.

High tensile bars shall not be bent after placing in the Works.

Before concrete is placed in any section of the Permanent Works which includes reinforcement, the reinforcement shall be completely clean and free from all contamination including concrete which may have been deposited on it from previous operations.

In members that are formed with sliding formwork, spacer "ladders" for the placing and fixing of the wall reinforcement shall be used at spacing agreed with the Engineer. The ties shall be spaced at multiples of the horizontal spacing of the horizontal bar spacing in the wall, and be used to secure the horizontal reinforcement. The laps in the horizontal reinforcement shall be staggered to ensure that no part of two laps in any four consecutive layers lie in the same vertical plane.

Where holes are to be drilled subsequently, the Contractor shall ensure that the reinforcement is placed clear of the corridor required for drilling and shall mark the location of the hole by attaching a suitable former to the shutter.

4.3.5 Cover to Reinforcement

The concrete cover to reinforcement shall be equal to or greater than the cover stated in the general notes accompanying the Drawings, or indicated on the Drawings but shall not be less than 10 mm greater than the nominal maximum size of the aggregate.

When directed, the Contractor shall measure the cover to all reinforcement with a cover meter as soon as the formwork has been stripped and submit the record of this survey to the Engineer as soon as practical.

Where cover meters show cover less than specified above the work shall be rectified to the satisfaction of the Engineer.

The Contractor shall, in addition, provide on site two portable electronic cover meters for the sole use of the Engineer. The Contractor shall recalibrate these cover meters weekly on a test section of the concrete containing the full range of reinforcement used on site set at known depths. The cover meters shall be capable of accurately measuring covers 25 mm greater than the greatest minimum cover specified.

Precast concrete members with inadequate cover shall be rejected and removed from Site.

4.4 CONCRETE

All aspects of concrete to be provided for the Permanent Works shall be in accordance with EN 206 and BS 8110.

4.4.1 Definitions

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

Non-structural concrete is composed of materials complying with the specification which is used only for filling voids and for similar purposes.

No fines concrete is composed of cement and of aggregates sized between 40 mm and 12 mm only.

Shotcrete (sprayed concrete) is an intimate mixture of cement, aggregates, water and (if applicable) additives, shot into place by means of compressed air through a spray nozzle.

Rebound is defined as the constituents of shotcrete that rebound from the surfaces during the application of shotcrete.

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

A free surface is a horizontal or nearly horizontal surface produced by screeding or trowelling to the level and finish required.

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

Water:cement ratio is the ratio of the weight of the free water in the mix to the weight of cement content in the mix. Free water is the water in the mix excluding water absorbed by the aggregate.

Characteristic strength means the specified 28 day cube strength (150 mm cubes) below which not more than 5% of the test results may be expected to fail.

4.4.2 Materials for Concrete

4.4.2.1 General

The Contractor shall submit to the Engineer full details of all materials which he proposes to use for making concrete not less than 30 days before he proposes to commence batching of Trial Mixes specified in Sub-Section 4.4.3 and shall provide samples of the proposed materials as directed by the Engineer. No concrete shall be placed in the Permanent Works until the

Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or replaced by other materials without the consent of the Engineer.

The Contractor shall ensure that the sources of supply are sufficient to meet the quantities and rates of supply required to comply with the Contractor's programme.

In the event that any source of supply has to be changed for any reason, the tests and trial mixes shall be repeated.

4.4.2.2 Requirements for Cements

The term 'cement' means Portland Cement (Pc) or, subject to the prior approval of the Engineer, a combination of Pc and ground granulated blast furnace slag (g.g.b.s) in accordance with BS 6699 or pulverized fuel ashes (p.f.a.) in accordance with BS 3892, unless otherwise stated.

Ordinary Portland Cement used in the works shall comply with the requirements of EN 197 and shall come from a single source of supply.

Admixtures shall only be used on the written approval of the Engineer.

Should low alkali Portland Cement be called for, the cement shall not contain more than 0.6% by weight of alkali measured as sodium and potassium oxides and expressed as the "equivalent sodium oxide content".

If approved by the Engineer for use in water retaining structures, the target mean proportion of g.g.b.s. shall not exceed 50% and the target mean proportion of p.f.a. shall not exceed 35%. This applies to blended cement and combinations made at the mixer.

4.4.2.3 Transporting, Storing and Testing of Cement

Bulk cement shall be transported to the Site in watertight containers built and equipped for the purpose, and shall be stored on Site in weatherproof silos.

Bagged cement shall be transported to Site in vehicles provided with effective means of ensuring that it is protected from weather. Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level and shall be so constructed that no moisture rises through it. Each delivery of cement in bags shall be stacked together in one place; the height of the stack shall at no time exceed 3 metres. The bags shall be closely stacked so as to reduce air circulation and shall not be stacked against an outside wall. Different types of cement in bags shall be clearly distinguished by visible markings and shall be stored in separate stacks. Cement from broken bags shall not be used in the Permanent Works.

The Contractor shall store at the Site sufficient cement so that construction of the Works is not delayed and at least sufficient for the programmed requirements for the succeeding three weeks. In arranging his storage facilities he shall take into account all factors which might cause delays in the supply of cement such as the manufacturer's capacity, time for transport to the Site, holidays, weather conditions and breakdowns. Cement shall be used in the same chronological order as that in which it is delivered to Site.

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

All cement used in the Permanent Works shall be tested by the manufacturer or the Contractor at the laboratory on Site or at another laboratory acceptable to the Engineer. The tests shall be in accordance with BS 4550 and EN 196, and the Contractor shall supply two copies of each test certificate to the Engineer. The requirements for acceptance of cement are as follows:

Specific surface		:	not less than 225 m^2/kg
Chemical composition		:	within the limits set out in BS EN 197
Minimum mortar cube strengths		:	23 N/mm2 after 3 days
			41 N/mm2 after 28 days
Setting time:	initial	:	not less than 45 minutes
	final	:	not more than 10 hours
Soundness		:	expansion not more than 10 mm
Heat of hydration (if required)		:	not more than 250 kJ/kg at 7 days
			not more than 290 kJ/kg at 28 days

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

Cement which is stored on Site for longer than two months shall be retested in a laboratory acceptable to the Engineer at the rate of one set of tests for every 200 tonnes, and at monthly intervals thereafter.

Cement which does not comply with the Specification shall not be used in the Permanent Works.

The temperature of the cement shall at no time be permitted to exceed 50°C.

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

4.4.2.4 Aggregates for Concrete

The Contractor is free to obtain aggregates from any source.
Aggregates for concrete shall conform to the requirements for fine and coarse aggregates in BS 882 and EN 12620. Fine and coarse aggregates shall separately conform to the requirements set out below.

a. General Requirements
Aggregate shall be clean, hard, durable and frost resistant and shall not contain iron pyrites, iron oxides (other than magnetite), mica, shale, coal or other laminar, soft or porous materials.

b. Gradings:
Fine aggregate shall conform to BS 882 Table 4, Zones C or M. In order to achieve an acceptable grading it may be necessary to blend materials from more than one source. Coarse aggregates shall be supplied in the nominal sizes specified and shall be graded in accordance with BS 882 for single sized aggregates. A coarse aggregate shall be predominantly angular, rounded or irregular as defined in BS 812: Part 1.

c. Chlorides:
The chloride content shall not exceed 0.03% by weight expressed as chloride ion when tested in accordance with BS 812 subject to the further restriction on total chloride content hereunder.

d. Sulphates:
The sulphate content shall not exceed 0.4 per cent by weight expressed as SO3 when tested in accordance with BS 812: Part 118 subject to the further restriction on total sulphate hereunder.

e. Total Chloride and Sulphate Content:
The total chloride content arising from all ingredients in a mix including cement, water and admixtures shall not exceed the following limits, expressed as chloride ion and as a percentage of the weight of cement in the mix:

- for prestressed concrete, steam cured concrete or concrete containing sulphate resisting or supersulphated cement: 0.05%;
- for any other reinforced concrete 0.3% in 95% of all test results providing no result is more than 0.5%.

The total sulphate content expressed as SO3 of all the ingredients in a mix including cement, water and admixtures shall not exceed 4.0% of the weight of cement in the mix.

f. Soundness:

After testing using the procedure set out in BS 812: Part 121, aggregates shall not show a weight loss of more than 18 per cent.

g. Alkali Reactive Minerals:

No part of the aggregates shall contain any mineral known to have a potential to cause alkali silica, alkali silicate, alkali carbonate or any other damaging chemical reaction between alkalis and aggregates. The minerals present should be determined by ASTM C294 on a range of samples selected to include every mineral type present in the aggregate as a whole irrespective of the proportion of the mineral. The reactivity of the minerals shall be assessed by ASTM Test Designation C289 and BS 812: Part 106.

If during the course of the test it is concluded that the presence of a potentially reactive mineral cannot be discounted and that an unequivocal identification of a potentially reactive mineral is not possible, alternative tests shall be carried out such as to provide the required identification.

If the presence of a potentially reactive material cannot be discounted then either

- a low alkali Portland cement shall be used, or
- the reactive alkali of the mix as assessed in accordance with BS EN 206 or BS 5328: Part 4 and expressed as sodium oxide equivalent, (Na2O)e, shall not exceed 3.0 kg/m3.

h. Flakiness:

Flakiness Index of coarse aggregates when tested in accordance with BS 812 shall be as set out hereunder and not as given in BS 882 Table 1:

- for nominal 40 mm aggregate and above: not more than 40;
- for nominal 20 mm aggregate and below: not more than 35.

i. Water Absorption:

The coarse aggregate shall not have a water absorption of more than 2.5 per cent and fine aggregates shall have an absorption of not more than 3% when tested as set out in BS 812 or BS EN 1097: Part 6.

j. Organic Impurities:

Fine aggregate shall be tested as set out in BS 1377: Part 3 and rejected if the percentage of organic matter exceeds 1 per cent.

k. Shrinkage:

Aggregates for structural concrete shall have an intrinsic shrinkage value such that shrinkage of the resultant concrete shall not be greater than 0.05% when tested in accordance with BRE Digest No. 35, Second Series (***Building Research Station, Garston, Watford WD2 7JR. England***), Shrinkage of Natural Aggregates in Concrete.

l. Thermal Properties:

Coarse aggregates used for water retaining structures shall have a low coefficient of thermal expansion.

4.4.2.5 Aggregates for Mortar

Aggregates for mortar shall conform to BS 1200.

4.4.2.6 Aggregates for Pavement Concrete

Aggregates for pavement concrete shall comply with the requirements of this Section.

4.4.2.7 Testing Aggregate

a. Acceptance Testing

The Contractor shall deliver to the Engineer samples containing not less than 50 kg of any aggregate which he proposes to use in the Permanent Works and shall supply such further samples as the Engineer may require. Each sample shall be clearly labelled to show its origin and shall be accompanied by all the information called for in BS 882 and EN 12620.

Tests to determine compliance of the aggregates with all the requirements of Sub-Sections 4.4.2.4, 4.4.2.5 or 4.4.2.6 shall be carried out by the Contractor in a laboratory acceptable to the Engineer. If the tested materials fail to comply with the Specification, further tests shall be made in the presence of the Contractor and the Engineer and acceptability of the material shall be based on such tests.

The acceptance tests carried out by the Contractor shall generally be on three representative samples of fine and coarse aggregates taken in the presence of the Engineer. Total numbers of tests required for acceptance are as follows:

Test	Fine Aggregates	Coarse Aggregates
Water absorption	-	3 *
Flakiness Index	-	3 *

Test	Fine Aggregates	Coarse Aggregates
Shell content determination	-	3 *
Test for shell content (where required)	-	1
10% fines test or aggregate Impact Value	–	3 *
Gradings	3 *	3 on each nominal size
Chloride content	3 *	3 *
Sulphate content	3 *	3 *
Soundness	-	3 *
Petrographic examination	as required (minimum 3)	as required (minimum 3)
Clay, silt and dust determination	3	3
Organic impurities	3	3

* One test on each sample

If at any time a significant physical or chemical change in the nature of the coarse or fine aggregate occurs, or a new source of aggregate is used, the Engineer may direct that some or all of the acceptance testing is repeated.

b. <u>Routine Testing</u>

The Contractor shall carry out routine testing of aggregates for compliance with the Specification during the period in which concrete is being produced for the Permanent Works. The tests set out below shall be performed on aggregates from each separate source on the basis of one set of tests for each 250 tonnes of fine aggregate or more than 500 tonnes of coarse aggregate, provided also that the aggregates are of uniform quality. If the aggregate from any source is variable, the frequency of testing shall be as instructed by the Engineer.

- Grading: BS 812 or EN 933: Part 2
- Silt and clay content: BS 812 or EN 932
- Moisture content: BS 812 or EN 109 : Part 5

<u>Check on organic impurities</u>: A 350 cc graduated bottle filled to the 120 cc mark with the aggregate sample, and a 3 percent solution of sodium hydroxide in water added to bring the total volume of aggregate plus liquid after shaking to 200 cc. The bottle is stoppered and allowed to stand for 24 hours. If after 24 hours the colour of the solution is no darker than pale brown the aggregate tested may be deemed satisfactory.

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

Moisture content: As frequently as may be required in order to control the water content of the concrete as required by the Specification.

Chloride content: As frequently as may be required to ensure that the proportion of chlorides in the aggregates does not exceed the limit stated in the Specification.

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

4.4.2.8 Delivery and Storage of Aggregates

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

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

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

4.4.2.9 Water for Concrete and Mortar

Water for mixing or curing concrete or mortar shall not contain more than the following concentrations of impurities:

	max ppm
Sum of sulphates, alkali carbonates and bicarbonates	1000
Chlorides	500
Suspended solids	2000
Other dissolved solid	2000

At the commencement of the Works the Contractor shall send a sample of the water proposed for concrete and mortar to an accredited laboratory capable of carrying out the full analysis of potable water in accordance with either the "Analysis of Raw, Potable and Waste Waters" published by Her Majesty's Stationery Office (HMSO) or "The Standard Method of Examination of Water and Waste Waters" published by the American Water Works Association (AWWA). The results of the analysis shall be submitted to the Engineer. The sample of water sent for analysis shall be taken in the presence of the Engineer. If the water selected comes from a reliable potable water source the Contractor shall obtain a copy of a recent analysis from the chemist of the Water Authority. If the Engineer considers this satisfactory the tests required above need not be carried out.

The water shall be retested at intervals of one month initially until sufficient results are available to determine the suitability of the source. The frequency of testing may then be reduced.

If the source of water is changed it shall be tested as above. If the water contains in excess of 80 per cent of the maximum concentration of any of impurities given above it shall be retested at intervals of not more than two months or as directed by the Engineer.

4.4.2.10 Admixtures

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

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

i. The typical dosage and the detrimental effects of an excess or deficiency in the dosage.

ii. The chemical names of the main active ingredients in the admixture.

iii. Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a percentage by weight of admixture.

iv. Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage, and if so, the extent to which it does so.

v. Long and short term effects of the admixture on concrete including the effects on different types of cement and aggregates.

vi. Storage life.

vii. Safety precautions required in handling.

viii. Compatibility with other additives.

ix. Compliance with Standards.

The chloride ion content of any admixture shall not exceed 2% by weight of the admixture nor 0.03% by weight of the cement in the mix.
Admixtures shall not be mixed together without the consent of the Engineer.
Admixtures shall comply with BS EN 480 and shall not have any adverse effect on the properties of the concrete.

4.4.3 Design of Concrete Mixes

4.4.3.1 Classes of Concrete

Concrete classes are shown on the Drawings in the style: A/B
where: A = 28 days characteristic strength (N/mm^2)
B = maximum aggregate size
The grading may be followed by the suffices:
NF = No Fines
NS = Non-Structural
Concrete classes are shown alternatively by designation of anticipated usage. The grades of concrete mix that shall be used in the works are set out in the table in Sub-Section 4.4.3.2 .

4.4.3.2 Design of Proposed Mixes

The Contractor shall design the mixes which he proposes to use in the Permanent Works to achieve homogenous durable concrete which will have the required strength, and other criteria specified and which will achieve acceptable workability and resistance to segregation during handling and placing. The proposed mixes shall also comply with the following requirements:

i. The aggregate portion shall be well graded from the nominal maximum size of stone down to 150 micron size.
ii. The cement contents shall not be less than that shown in the table below.
iii. The maximum cement content will not exceed 400 kg/m3.
iv. The water:cement ratio shall be the minimum consistent with adequate workability but in any case not greater than that shown in the table below.
v. The workability shall be consistent with ease of placing and proper compaction having regard to the presence of reinforcement and embedded items, and the proposed method of placing.
vi. The Contractor shall take into account the requirement for temperature control of massive concrete elements or units. Massive elements are defined by a reference

thickness tr = 2A/C, where A is the cross sectional area of the element and C its circumference. Elements are considered massive if tr exceeds 0.5 m.

vii. The "required compressive strength" of cubes crushed on site at 28 days shall be determined by adding to the control strength a figure equivalent to 1.65 x the standard deviation of the cube results (for a permitted 5% failure rate). Until such time as sufficient cubes or at least 40 cubes sampled in a period of not less than 6 days have been tested to enable the standard deviation to be determined statistically, the concrete mix shall be designed so that the average cube strength is greater than the control strength by at least 12 N/mm2. A value not less that 6 N/mm2 may be employed if data of the plant, the materials and the operatives are available from previous use to justify this margin until such time as specific information is available from the site operations.

Where the maximum size aggregate is 40 mm or less, the control strength shall be the characteristic strength. Where the maximum size aggregate is 75 mm the control strength shall be the characteristic strength multiplied by the factors defined in Sub-Section 4.4.3.3.

viii. The drying shrinkage determined in accordance with BS 1881 or EN 12390 shall not be greater than 0.05%.

ix. Plastic shrinkage shall be limited such that cracking does not occur along reinforcement with minimum cover.

x. For water retaining structures and reservoirs, the minimum cement content shall be 325 kg/m3. A maximum water/cement ratio of 0.55 shall be used except when Portland pulverized-fuel ash cement or a combination of ordinary Portland cement and p.f.a. is used, in which case the water/cement ratio shall be 0.50. The 28-day characteristic cube strength shall not be less than 35 N/mm2, and the concrete shall be classed as Class 35/20. Plasticizers may be used to reduce water:cement ratios.

Where cements containing p.f.a. are used, the maximum permissible cement content may be increased to 450 kg/m3.

xi. For tunnel laying, where pumping of the concrete is approved by the Engineer, the concrete mix to be pumped shall be so designed that ¬

- Slump will not exceed 125 mm;
- Graded aggregate and suitable admixtures be used, wherever necessary, with a view to improving the pumpability of the mix; and
- Its shrinkage capacity shall not be excessively higher than that of ordinary concrete mixes.

Class	Characteristic Strength (N/mm^2)	MSA (mm)	Min Cement Content (kg/m^3)	Maximum Water: Cement Ratio	Anticipated Usage
15/40	15	40			Fill Concrete
20/20	20	20	270	0.65	Blinding
25/20	25	20	280	0.60	Non water-retaining structures
35/20	35	20	325	0.55	Water retaining structures (without p.f.a.)
40/20	40	20	350	0.50	Precast concrete

NS : Non Structural Concrete as Specified in Sub-Section 4.4.17

NF : No Fines Concrete as Specified in Sub-Section 4.4.17

The Contractor shall submit to the Engineer full details of all the mixes he proposes to use not less than 30 days prior to the production of trial mixes. The details to be submitted shall include as a minimum the following:

(i) aggregate source
(ii) proportions of aggregate sizes
(iii) cement content, including extender
(iv) aggregate: cement and water: cement ratios
(v) batch quantities
(vi) additives
(vii) workability
(viii) flakiness index of aggregates
(ix) estimated standard deviation
(x) target strength
(xi) mixing time.

4.4.3.3 Trial Mixes

Not less than 28 days before the date on which the Contractor proposes to use a mix in the Permanent Works, he shall in the presence of a representative of the Engineer prepare six separate batches to the full capacity of the mixer of the proposed mix on separate days, using the materials, plant and equipment which will be used for the Permanent Works. He shall take sufficient samples from each batch to prepare twelve standard 150 mm test cubes in accordance with EN 12390: Part 1.

If the proposed mixes contain admixtures to improve workability the Contractor shall prepare identical trial mixes omitting the admixture if so instructed by the Engineer in order to determine the effect of the admixture.

If the mix satisfies the requirements of Sub-Section 4.4.3.2 (v) to the satisfaction of the Engineer, the average slump obtained for each class shall be adopted as the target slump for that grade of concrete.

Three of the cubes from each batch of twelve shall be tested for crushing strength at seven days and six more from each batch at 28 days, all in accordance with EN 12390. The remaining three cubes from each batch shall be tested as instructed by the Engineer.

The density of all the cubes shall be determined before the cubes are crushed.

The average value of the crushing strength of the thirty-six cubes tested at 28 days shall not be less than the "required compressive strength" of cubes as defined in Sub-Section 4.4.3.2(vii) for the class of concrete tested.

If the 28 day strength as defined above is less than the required compression strength the mix shall be adjusted in order to comply. If adjustment of aggregate proportions does not increase the strength the water cement ratio shall be reduced. An increase in cementitious content will not normally be acceptable.

In order to save time and expense, initial trials on any mix may be carried out using cubes tested at 7 days where a relationship between 7 day and 28 day strengths has been agreed between the Contractor and the Engineer. The final results of the trials would nevertheless still have to be confirmed by 28 day cube results.

The Contractor shall carry out tests to determine the drying shrinkage of the concrete.

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

If required by the Engineer, the Contractor shall place not less than one cubic metre of any trial mix into formwork prepared to simulate conditions which will apply during construction of the Permanent Works, including reinforcement if appropriate, and using the plant and equipment which he proposes to use for the Permanent Works.

The timing for the removal of formwork shall be in accordance with Sub-Section 4.2.4 and the concrete surfaces inspected jointly by the Contractor and the Engineer.

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

If the properties of the concrete or of the constituent materials vary during concrete production, the Engineer may require further trial mixes to be made.

The Contractor shall arrange for supplying concrete, making, transporting, curing and testing test cubes and recording the test results which shall be submitted to the Engineer in accordance with Sub-Section 4.4.15 for both trial mixes and quality control of concrete production unless stated otherwise.

4.4.3.4 Quality Control of Concrete Production

For each class of concrete in production at each plant for use in the Permanent Works, samples of concrete shall be taken at the point of mixing or of deposition as instructed by the Engineer and in the presence of a representative of the Engineer, all in accordance with the sampling procedures described in EN 12390.

Samples shall be taken on the basis of one for each 100 m3 of concrete placed but in any case not less than one sample per day or one sample for each pour of more than 10 m3 concrete placed, whichever is the more frequent, for each class of concrete produced.

The slump of each sample carried out in accordance with EN 12390 shall be determined at the time of sampling. The slump of each batch of concrete shall similarly be determined.

The concrete shall be deemed to comply with the workability requirements if the slump is within ± 20% of the target slump established from the trial mixes.

Six test cubes shall be cast from each sample and cured as set out in EN 12390: Part 2. Additional cubes as instructed by the Engineer shall be made for testing at ages more than 28 days.

Three cubes shall be tested at 7 days and three at 28 days. The average strength of the three cubes crushed at 28 days shall be referred to as one test result.

Concrete shall be deemed to comply with the strength specified if:

i. no more than 3 test results from any set of 40 consecutive test results fall below the specified control strength;

ii. the average of any 6 successive test results for the same class of concrete is not less than the specified control strength plus 3 N/mm2;

iii. no single cube result is less than the specified control strength minus 3 N/mm^2 for that class of concrete.

4.4.3.5 Failure to Comply with Requirements

The Contractor shall undertake such action as the Engineer may consider appropriate to remedy concrete which fails to comply with the Specification. Such action may include but is not necessarily confined to the following:

i. adjusting the mix proportions until the concrete again complies with the Specification;

ii. cutting test cores from the failed concrete and testing in accordance with BS 1881;

iii. full scale load tests or sonic investigations;

iv. carrying out additional works to overcome the effect of the failed concrete;

v. removing the failed concrete;

vi. increasing the frequency of sampling until control is again established.

4.4.4 Mixing Concrete

4.4.4.1 <u>Equipment</u>

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

4.4.4.2 <u>Batching of Materials for Concrete</u>

Unless otherwise authorised by the Engineer, the quantities of material for each batch of concrete shall be measured separately by weight. The batching plant shall be suitable for weighing out, for any particular batch of concrete, the aggregate, cement and water in quantities up to half the weight of cement if required and any approved admixtures. Apparatus shall be included to record automatically, within an accuracy of plus or minus one per cent, the weight of cement used in the production of each mix of concrete.

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

The bins for storage of concrete constituents in the batching plant shall be of a self-cleaning type and shall be drawn down until they are practically empty at least three times per week. Aggregate of nominal size 40 mm and larger shall be deposited in the storage bins in a way to avoid separation. Those bins used for storing sand shall be fitted with drainage outlets to prevent the build up of free water in the bottom of the bins. The weighing hoppers shall be constructed so as to permit the convenient removal of overweight material in excess of the prescribed tolerances. The equipment for cement handling shall be constructed so as to minimise the release of dust during operation.

The quantity of water to be added to each batch shall be automatically adjusted to compensate for the variation in moisture content of the coarse and fine sands. The sand bins shall be covered. The readings of percentage moisture content shall be integrated with the weight of sand to give the quantity of water contained in the sand. This quantity shall be automatically fed into a water meter, clearly visible to the batching plant operator, which has been preset with the total quantity of water required for each class of mix. The water meter shall also be linked with the control valve feeding water into the mixer so that when the total quantity of water has been introduced into the mixer the control valve is automatically closed. The water supply circuit shall be fitted with safety devices to prevent spillage or leakage of extra water into the mixer.

Provision for the dispensing of approved admixtures shall include means for obtaining uniform dispersion into the concrete. Admixtures in liquid form shall be discharged into the mixing water and admixtures in powder form shall be discharged concurrently with the cement.

The constituents of each batch shall be weighed within an accuracy of plus or minus one per cent for cement and water and concrete admixture, plus or minus two per cent for fine aggregates and coarse aggregates up to and including 40 mm in size, and plus or minus three per cent for coarse aggregate of larger size.

Convenient facilities shall be provided for readily obtaining representative samples of cement, admixtures, sand and each class of coarse aggregate between the supply bins and the mixers.

The facilities shall also include means for obtaining representative samples of concrete at the point of discharge of each mixer.

The Contractor shall provide standard test weights, at least equivalent to the maximum working load used on the most heavily loaded scale, and other auxiliary equipment required for checking the satisfactory operation of each scale or other measuring device. Tests of the weighing mechanisms shall be carried out in the presence and to the approval of the Engineer. The Contractor shall furnish the Engineer with copies in duplicate of the complete results of the tests and shall make such adjustments, repairs or replacements as the Engineer may consider necessary to ensure satisfactory performance.

The plant shall be arranged in a way which will permit the inspection and checking of all operations by one person. The box containing the levers and/or weights of the weighing scales of the batching plant shall be locked and the keys shall be kept by the Engineer's Representative.

At intervals decided by the Engineer, but which will normally be not less frequently than once per day, the Contractor shall carry out tests by a method agreed by the Engineer to determine the free moisture content of the aggregates. Based on these tests, adjustments shall be made to the quantity of water added to the mix to maintain the approved water/cement ratio.

The Contractor shall prepare a mix content record for each mix showing show the following information:

- class of concrete and mix designation
- quantities of cements, fine aggregates, coarse aggregates, water and additives in each mix
- the location to which the mix is to be sent
- the truck or skip number used to move the concrete

- the numbers of mixes in each truck or skip.

One copy of the record for each truck or skip load shall be delivered to the location where the concrete is to be placed and handed to the Engineers Representative.
A second copy of the record shall be delivered to the Engineer daily on the day following the date of mixing.

4.4.4.3 Mixing Procedures

Concrete mixing machines shall be capable of producing a uniform distribution of the ingredients throughout the mass.
The mixing operation shall be under the control of a suitably experienced supervisor. Automatic operations shall not be interfered with by operators. The sequence of filling a mixer with the concrete ingredients shall be subject to the agreement of the Engineer and, unless otherwise authorised, the same sequence of filling shall be followed throughout the work. The quantity of mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.
The period of mixing shall be measured from the time when all the materials except the full amount of water are in the drum until the commencement of discharge. An automatic timing device shall be used to set the duration of mixing, which shall not be less than the values given in the following table:

Mixer Capacity	Mixing Time
1.5 m^3 or less	1.5 minutes
Exceeding 1.5 m^3 but not exceeding 2.5 m^3	2.0 minutes
Exceeding 2.5 m^3 but not exceeding 3.5 m^3	2.5 minutes
Exceeding 3.5 m^3	Time to be agreed by the Engineer

In addition, mixing shall continue for at least one minute after all the water required has been admitted.
The nominal drum or pan capacity of the mixer shall not be exceeded. The speed of rotation of a mixer shall be that recommended by the manufacturer of the machine. Each mixer shall be equipped with an automatic recorder of the number of batches mixed.
After the concrete has been mixed no subsequent addition of water shall be made in the course of concreting.
Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed.

4.4.5 Transport of Concrete

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

Should the Contractor wish to pump concrete to any section of the Works, then he shall satisfy the Engineer regarding his proposals, which shall include the provision of such spare items of plant necessary to avoid delays due to mechanical breakdown. If the Contractor wishes to vary the agreed design mix proportions in order to permit concrete to be placed by pumping, then details of his revised mix design shall be submitted to the Engineer and trial mixes prepared in accordance with this Specification. Precautions shall be taken to avoid depositing water or grout in the Works during starting-up operations or in flushing or clearing of the pipeline. The concrete shall pass through the pipeline in not more than 20 minutes.

The time elapsing between mixing and placing a batch of concrete shall be as short as practicable and in any case no longer than will permit completion of placing and compaction before the onset of initial set. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the Permanent Works.

4.4.6 Placing of Concrete

4.4.6.1 Consent for Placing

Concrete shall not be placed in any part of the Permanent Works until the Engineer's consent has been given in writing, and the Contractor shall give the Engineer at least 18 hours notice of his intention to place concrete.

When all preparatory work for a proposed pour has been completed, the Contractor shall request the Engineer's written consent to commence concrete placing at a specified time not less than three hours after making the request.

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

4.4.6.2 Preparation of Surfaces to Receive Concrete

Existing concrete surfaces shall be prepared as set out in Sub-Section 5.12. Before deposition of further concrete they shall be clean, hard and sound and if required by the Engineer shall be wet but without any freestanding water.

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

If so instructed by the Engineer, surfaces against which concrete is to be placed shall receive a prior coating of mortar complying with Sub-Section 5.16. or microcrete mixed in the proportions similar to those of the fines portion in the concrete to be placed. The mortar or microcrete shall be kept ahead of the concrete and shall be well worked into all parts of the excavated surfaces and shall be not less than 5 mm thick.

If any fissures have been cleaned out, they shall be filled with the mortar or with concrete as instructed by the Engineer.

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

4.4.6.3 *Placing Procedures*

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

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

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

Placing of concrete in continuous walls of water retaining structures shall commence at convenient points on the perimeter of the wall and shall proceed in both directions simultaneously until the ends of the lift unite at intermediate points between the commencement points such that fresh concrete from one direction meets fresh concrete from the other direction. The Contractor's plant and organisation on Site shall be sufficient to ensure that a lift of 500 mm in compacted thickness can be poured for the full circumference of the structure in a continuous operation not exceeding 10 hours in duration.

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

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

During periods when wind is liable to accelerate the drying of exposed concrete surfaces, covers shall be provided for all fresh concrete surfaces which are not being worked on. Water shall not be added to concrete for any reason.

When concrete is discharged above its place of final deposition, segregation shall be prevented by the use of chutes, downpipes, trunking, baffles or other appropriate devices. Unless otherwise agreed by the Engineer concrete shall not be allowed to fall freely through a height greater than 1.2 metres.

When placing concrete round galleries and other places of difficult access, the Contractor shall take particular care to ensure that the equipment used and the method of its operation is such that the concrete is placed without segregation. Special care shall also be taken during vibration of the concrete to ensure that all irregularities in the rock surfaces are completely filled. Placing equipment shall only be operated by experienced workmen.

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

When it is necessary to place concrete under water the Contractor shall submit to the Engineer his proposals, which shall conform to the recommendations of BS 8004, for the method and equipment to be employed. The concrete shall be deposited either by bottom-discharging watertight containers or through funnel-shaped tremies which are kept continuously full with concrete up to a level above the water and which shall have the discharging bottom fitted with a trapdoor and immersed in the concrete in order to reduce to a minimum the contact of the concrete with the water. Special care shall be taken to avoid segregation.

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

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

4.4.6.4 Interruptions to Placing

The face from which placing of concrete is to commence shall be selected so that if an emergency occurs which prevents the layer being completed, the construction joint will be formed in a structurally favourable position.

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

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

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

4.4.6.5 Heights of Concrete Lifts

Concrete in the Permanent Works shall generally be placed in lifts not exceeding 2.5 metres but the Engineer may authorise or instruct different heights to be used according to the section of concrete being placed.

Approval will only be given for placing concrete in lifts exceeding 2.5 m in height where the Contractor demonstrates to the satisfaction of the Engineer that his plant and organisation on Site are sufficient to ensure a continuous uninterrupted pour in accordance with the Specification.

4.4.6.6 Placing Sequence

Unless otherwise approved by the Engineer, concrete shall be cast in one operation between external faces of concrete and joints shown on the Drawings. The sequence of construction shall be such that the effects of shrinkage and thermal contraction are minimised.

The Contractor shall submit a detailed concreting programme to the Engineer for his approval at least one month ahead of concreting.

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

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

4.4.7 Compaction of Concrete

4.4.7.1 General Requirements

The Contractor shall thoroughly compact all concrete immediately after it has been placed in position. In general, the concrete shall be placed in layers not exceeding 0.5 metre in depth after compaction. Unless otherwise authorised by the Engineer, compaction shall be accomplished with the aid of approved immersion vibrators, together if necessary with rods, shovels and the like. Particular care shall be taken to fill all voids and to work the concrete against rock and existing concrete surfaces, round any reinforcement and embedded fixtures and into the corners of the formwork.

If the Contractor does not wish to use immersion vibrators for any portion of the Permanent Works, he shall submit his proposals for alternative vibrators or compaction equipment and shall await the Engineer's approval of the equipment before commencing to concrete the portion concerned.

Concrete shall not be subject to disturbance by vibration within 4 hours to 24 hours after compaction.

4.4.7.2 Vibration Equipment

Vibrators shall be of a type and size capable of fully compacting the concrete being placed.

Vibrators shall operate at a frequency of between 7 000 and 10 000 cycles per minute or to the Engineer's approval.

For concretes containing aggregates of size 75 mm, the vibrators used shall be of at least 100 mm diameter and generally requiring two workmen to operate, but smaller vibrators shall also be available for use in places where access is restricted and adjacent to intricate formwork, waterstops, instruments, pipes, ducts, embedded steelwork, etc.

The number of vibrators in use on each pour shall collectively be capable of achieving the specified compaction at a rate of at least 20% in excess of the average placing rate. In addition standby vibrators of a similar size shall be available for immediate use on each pour. The numbers of such standby vibrators shall be not less than one quarter of the number actually in use as specified above, or a minimum of one where less than four vibrators are actually in use. The pour shall not commence until the specified number of standby vibrators are available at the pour.

Where compressed air vibrators are used the Contractor shall ensure that the air pressure at the pour shall not fall below the operating pressure recommended by the manufacturers of the vibrators and where electrical vibrators are used the Contractor shall likewise ensure that the voltage does not fall below that recommended by the manufacturer for correct operation of equipment.

The length of the vibrating element of immersion vibrators shall be sufficient to penetrate through the layer of concrete being placed and re-vibrate the upper portion of the underlying layer of concrete.

4.4.7.3 Method of Vibration

Only workmen skilled and experienced in the use of vibrators shall be employed on this type of work.

In compacting large volumes of concrete compaction of the unvibrated heap of concrete shall commence with the vibrators being inserted into the leading face of the heap to form a toe in order to retain the remainder of the heap during compaction. Vibration shall then continue by gradually working towards the previously vibrated concrete. The slope of the face after completion of vibration shall be not steeper than 25° to the horizontal and succeeding buckets shall be discharged partly on top of this face.

Immersion vibrators shall be inserted vertically to penetrate into the layer underneath at regular intervals which shall not exceed the distance from the element over which vibration is visibly effective, and in any case shall not exceed 600 mm. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

Vibration shall not be applied by way of reinforcement nor shall vibrators be allowed to touch formwork or reinforcement or other embedded items as far as is practicable.

Vibration shall be continued at each point until the concrete ceases to contract, a thin layer of mortar has appeared on the surface and air bubbles have ceased to appear. The period of vibration necessary shall be determined carefully by trial in the presence of the Engineer. Vibration shall be continued for this period at each point before any further concrete is superimposed.

4.4.8 Curing of Concrete

4.4.8.1 General

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

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

The above objectives are covered in Sub-Sections 5.8.2. and 5.8.3., but nothing shall prevent both objectives being achieved by a single method where circumstances permit.

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

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

4.4.8.2 Loss of Moisture

The Contractor shall keep the exposed surfaces continuously wet by means of a water spray or by covering with a water absorbent material which is kept wet.

Water used for curing shall be of the same quality as that used for mixing as stated in Sub-Section 5.2.9.

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

If the use of the foregoing methods is inappropriate, surfaces which will not have further concrete bonded to them and which are not to receive an application of a finish may, subject to the approval of the Engineer, be cured by the application of an approved curing compound. Curing compounds shall contain a fugitive dye to enable the extent of the spread to be seen easily.

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

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

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

4.4.8.3 Limitation of Differential and Peak Temperatures

The Contractor shall limit the development of heat in concrete after placing to such that the temperature gradient at any point within the pour shall not exceed 25°C per linear metre and the absolute temperature at any point shall not exceed 50°C.

In order to achieve this control, the Contractor shall use means appropriate to the circumstances as accepted by the Engineer which may include:

i. limiting concrete temperatures at placing as set out in Sub-Section 5.10.3;

ii. use of low heat cement or p.f.a, subject to the agreement of the Engineer;

iii. insulation of exposed concrete surfaces by insulating blankets. Such blankets shall have a thermal conductivity C value less than 1.0 W/m2/°C;

iv. leaving formwork in place during the curing period (steel forms shall be suitably insulated on the outside);

v. preventing rapid dissipation of heat from surfaces by shielding from wind;

vi. avoiding the use of water sprays when such use would cause rapid cooling of the surfaces and using curing compounds instead;

vii. shielding concrete surfaces from clear night skies, together with the use of heaters where appropriate.

Where instructed by the Engineer, the Contractor shall demonstrate the control of temperature by the installation of appropriate temperature measuring devices at selected locations to monitor the development of temperature profiles.

4.4.9 Protection of Fresh Concrete

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

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

Concrete placed in the Permanent Works shall not be subjected to any structural loading until it has attained at least its required control strength as defined in Sub-Section 5.3.2 (vii).

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

4.4.10 Concrete in Hot or Cold Weather

4.4.10.1 General

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

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

4.4.10.2 Concrete Placing in Cold Weather

Provided the ambient air temperature does not fall below 10°C, no special precautions need be taken to protect concrete from the effects of cold weather.

If the ambient air temperature is in the range 0°C to 10°C and freezing conditions are confined to ground frosts during the night, the Contractor shall take precautions as approved by the Engineer so as to ensure that concrete is placed and compacted at a temperature of not less than 5°C and that it is subsequently covered and protected from cold winds and frosts so that its temperature will not fall below 5°C for at least 3 days.

4.4.10.3 Concrete Placing in Hot Weather

During hot weather the Contractor shall take all measures necessary to limit the temperature of concrete at the time of placing in the Permanent Works and to ensure that the concrete does not lose any moisture during transporting and placing. The concrete temperature at the time of placing shall not exceed 25°C unless the Contractor can demonstrate that a higher temperature, not exceeding 30°C, allows the subsequent temperature to be controlled as specified in Sub-Section 5.8.3.

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

i. shielding aggregates from direct sunshine;

ii. sun shields on mixing plants and transporting equipment;

iii. Cooling the mixing water – if ice is used for this purpose it shall be in flake form (lump ice shall not be allowed to enter the tank supplying the mixer drum), and no ice shall be present in the concrete when the concrete is discharged from the point of mixing;

iv. covering skips closely with polythene sheet so that the latter is in contact with the concrete;

v. painting all equipment and sun shields white.

Areas in which concrete is to be placed shall be shielded from direct sunshine and rock or concrete surfaces shall be thoroughly wetted if instructed by the Engineer to reduce absorption of water from the concrete placed on or against them. Concrete shall not be placed against formwork that is hotter that 30°C.

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

4.4.11 Finishes on Free Surfaces

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

4.4.11.1 U1 Finish

All surfaces on which no higher class of finish is called for on the Drawings or instructed by the Engineer shall be given a U1 finish.

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

4.4.11.2 U2 Finish

The surface shall first be treated as a Class U1 finish and after the concrete has hardened sufficiently, it shall be floated by hand or machine sufficient only to produce a uniform surface free from screed marks.

4.4.11.3 U3 Finish

The surface shall be floated as for a U2 finish but to the tolerance stated below. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, it shall be teel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

4.4.11.4 U4 Finish

The requirement is similar to a U3 finish but the permissible tolerances are smaller.

4.4.11.5 Tolerances

The permissible tolerances on free surfaces shall not exceed the values given in the following table:

Class of Finish	Tolerances in mm (see Note)		
	A	B	C
U1	not applicable	10	+ 15 to - 10
U2	Nil	7	+ 10 to - 7
U3	Nil	5	+ 7 to - 5
U4	Nil	2	+ 5 to - 2

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

- "A' is the maximum allowable value of any sudden change of level in the surface;
- "B" is the maximum allowable value of any gradual irregularity of the surface, as indicated by the gap between the surface and a three metre long straightedge or correctly shaped template placed on the surface;
- "C" is the maximum allowable value of the difference in level or position between a straightedge or correctly shaped template placed on the surface and the specified level or position of that surface.

Where dimensional tolerances are given on the Drawings or elsewhere in the Specification they shall take precedence over those given in the table above.

4.4.12 Construction Joints

Whenever concrete is to be bonded to other concrete which has hardened, the surface of contact between the sections shall be deemed a construction joint.

Where construction joints are shown on the Contractor's Working Drawings, the Contractor shall form such joints in those positions. Any change in the location of joints or additional joints which the Contractor requires to make for the purpose of construction shall be subject to the agreement of the Engineer and details shall be submitted with the Programme of Works required by the Conditions of Contract. The exact location of all construction joints shall be submitted to the Engineer at least four weeks prior to the start of construction of the relevant part of the Works. Construction joints shall be in vertical or horizontal planes except in sloping slabs where they shall be normal to the exposed surface or elsewhere where the Drawings require a different arrangement.

Construction joints shall be so arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing, and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints.

Feather edges of concrete at joints shall be avoided and any feather edges which may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal or near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 2% from the horizontal.

Stub columns, stub walls or kickers on footings shall be cast integrally with the base concrete or footing and not afterwards, even when a different class of concrete is to be used in subsequent pours.

The surface of the fresh concrete in horizontal or near horizontal joints shall be thoroughly cleaned and roughened by means of wire brushing after the initial set but prior to the final set, or by means of high pressure water and air jets when the concrete is hard enough to withstand the treatment without the leaching of cement. The surface of vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

Where concrete has become too hard for the above treatment to be successful, the surface whether formed or free is to be thoroughly scabbled by mechanical means or wet sand blasted and then washed with clean water. The indentations produced by scabbling shall be not less than 10 mm deep and shall not extend closer than 40 mm to a finished face.

Construction joints where curing has ceased and which have dried out shall be kept continuously wet for 48 hours where the surface has dried out for longer than 7 days, and for 24 hours where it has dried out for less than 7 days, before placing the next concrete in addition to being washed shortly before concreting. Shortly before concreting is commenced the surface shall be thoroughly cleaned of all loose concrete, shavings, dust and extraneous material by washing by high pressure water jets, and standing water shall be blown off with clean compressed air. Any standing water in or on the construction joint surface shall be mopped up or blown away by means of compressed air jets. Shutters shall be provided with properly formed windows at the level of the previous pour to permit the proper cleaning of the surfaces before concreting recommences.

If instructed by the Engineer, the surface of the concrete shall be thoroughly brushed with a thin layer of mortar complying with Sub-Section 5.16 and having the same or greater strength as that of the concrete, or microcrete mixed in proportions similar to those of the fines portion in the concrete to be placed all as set out in Sub-Section 5.6.2, immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete may be placed in position on or against a construction joint until the joint has been inspected and passed by the Engineer.

Construction joints between lifts in mass concrete structures shall incorporate a shear key, generally formed by a 0.25 m high upstand extending the full width of the block between joints, and the central third of the length.

Vertical or inclined construction joints of any kind shall not be permitted in the walls of water retaining structures except where instructed or specifically approved by the Engineer.

The formwork to walls or columns shall be overfilled with concrete when pouring and poorer material such as scum, laitance and porous concrete which collects at the top shall then be removed by striking off level with the top of the formwork within four hours after the concrete is placed.

4.4.13 Expansion and Contraction Joints

4.4.13.1 General

Expansion and contraction joints are discontinuities in concrete designed to allow for thermal or other movements in the concrete.

Expansion joints are formed with a gap between the concrete faces to permit subsequent expansion of the concrete. Contraction joints are formed to permit initial contraction of the concrete and may include provision for subsequent filling.

Expansion and contraction joints shall be formed in the positions and in accordance with the details shown on the Drawings or elsewhere in the Specification.

4.4.13.2 Compressible Joint Filler

Compressible joint filler shall consist of sheets or strips of the following materials complying with the requirements of the relevant specifications listed:

i. Bitumen impregnated fibre board and bitumen impregnated cork board – US Federal Specification HH-F-341F or AASHTO Specification M213

ii. Resin impregnated cork board – US Federal Specification HH-F-341E

iii. Flexible foams of expanded polyethylene, polyurethane, PVC or polypropylene – AASHTO Specification M153

iv. Rigid foams of expanded polyethylene polyurethane or polystyrene – BS 4840 or BS 3837.

Other compressible joint filler materials may be used if approved by the Engineer after submission of full specifications and information by the Contractor.

4.4.13.3 Sealants

Thermoplastic hot-poured sealants shall comply with the requirements of US Federal Specification SS-S-1410B, BS 2499 or AASHTO Specification M173. The sealants shall be of the rubberised bituminous type containing a minimum of 20% natural or synthetic rubber.

Thermoplastic cold-applied sealants shall comply with the requirements of US Federal Specification SS-S-156. The sealant shall be of the rubberised bituminous type containing a minimum of 20% natural or synthetic rubber.

Thermosetting chemically cured sealants shall comply with the requirements of US Federal Specification SS-S-195B, American National Standards Institute Specification ANSI A 116.1 (formerly ASA A 116.1 and USASI A 116.1) or BS 4254. The final IRHD (International Rubber Hardness Degree) of the sealant shall be 20 ± 5.

Other sealants may be used if approved by the Engineer after submission of full specifications and information by the Contractor.

Where the type of sealant is not specified on the Drawings, the selection of the type of sealant to be used in any application shall be generally in accordance with BS 6213 and subject to the approval of the Engineer to ensure that its properties are suitable for the application.

4.4.13.4 Construction Joints in Water Retaining Structures

Waterstop not less than 150 mm wide shall be built into all construction joints in external walls and construction. Construction joints shall only be formed at positions approved by the Supervisor.

4.4.13.5 Watertightness of Structures

The Contractor shall be responsible for the watertightness of structures and any remedial measures necessary. Where detailed on the Drawings the surfaces of concrete shall be coated with a waterproof coating.

In the event that a structure designed and specified to be water retaining fails to satisfy the watertightness tests, the Contractor shall undertake such remedial works as are necessary and are approved by the Supervisor. In certain situations the Supervisor may permit the provision of an internal waterproofing coating in compliance with the specification. Where such a coating is permitted, it shall be applied to the whole of the internal water retaining face.

4.4.14 Waterproofing Protective Coating Water Retaining Structures

4.4.14.1 Description

This coating shall be a surface-applied material which waterproofs and protects concrete in depth and shall be suitable for use in water retaining structures. It consists of rapid-hardening Portland cement, specially treated quartz sand, and a compound of active chemicals. It is supplied in powder form and needs only to be mixed with water prior to application.

4.4.14.2 Waterproof Coatings

Waterproof coatings shall be applied to the interior walls of water retaining structures or where shown in the drawings or where instructed by the Supervisor.

The system shall be applied in accordance with the manufacturer’s recommendations. Prior to application, the surfaces shall be prepared and all cracks, porous patches and generally defective areas shall be cut-out and made good.

The system shall provide a waterproof coating without impeding the breathing of the structure. Expansion joints shall be formed in the waterproofing system using compatible sealants as recommended by the manufacturer. The system shall be cured for a period of not less than 7 days.

4.4.14.3 Hydrophillic Rubber Sealer

Hydrophillic rubber sealer shall be co-extruded from chloroprene and hydrophillic rubbers into a cellular strip approximately 25 mm x 7 mm thick which expands as it absorbs water. The strip shall incorporate an expansion delay coating to prevent activation during setting of the surrounding concrete.

Hydrophillic rubber sealer could be applied to the perimeter of all pipes to be built into concrete structures to existing concrete walls and slabs at or below water levels which have been demolished and require extension, the strip sealer shall be bonded to the pipe diameter or on to the face of demolished structures on to which new concrete is to be placed so as to be at least l00 mm from the wall surface. Where dowel bars are incorporated in bonding new concrete to old, the sealer shall be placed above the dowel bars on the "wet" side of the structure. Bonding shall be accomplished using proprietary neoprene or epoxy adhesives to ensure the sealer is not disturbed during placement of the concrete.

The application shall be in accordance with the manufacturer's recommendations.

1.1.1.1 Preparation of substrate

All concrete to be treated with this coating must be clean and have an “open” capillary system. Laitance, dirt, grease, etc. should be removed by means of high pressure water jetting, wet sandblasting or wire brushing. Faulty concrete in the form of cracks, honeycombing etc. should be made good. Surfaces must be carefully pre-watered prior to the application of the coating. The concrete surface must be damp but not wet.

1.1.1.2 Mixing

The powder material is mechanically mixed with clean water to a consistency of thick oil paint. Approximate mixing ratio is 0.8 parts water to 2 parts powder (by volume). Materials mixed shall be as can be used within 20 minutes. Mixture should be stirred frequently. If mixture starts to set, no water should be added, the mixture should be stirred to restore workability.

1.1.1.3 Application

The mix is applied by masonry brush or appropriate power spray equipment. When two coats are specified the second coat shall be applied while the first coat is still "green".

1.1.1.4 Post Treatment

The treated surfaces should be kept damp for a period of five days and must be protected against direct sun, wind and frost by covering with polythene sheeting, damp hessian or similar.

4.4.14.4 BITUMINOUS COATING FOR BURIED WALLS

This material shall be applied on the exterior side of the concrete elements buried surfaces. Ground water should be checked previously by the Contractor for chemicals which may have a deleterious effect on the structure or internal finishes.

The Contractor must obtain the previous approval of the Supervisor on the support as well on the type of material proposed.

The bituminous coating for damp-proofing should be cold applied emulsion in two coats (of at least 0.750 kg/m^2 each) and cross applied.

Bitumen primer should be of the same cold bitumen emulsion compound diluated to 50% with water and applied at a minimum rate of 0,400 kg/m^2. The damp-proof bituminous coat shall be applied around 24 hours after the primer application.

4.4.15 Records of Concrete Placing

Records in a form agreed by the Engineer shall be kept by the Contractor of the details of every pour of concrete placed in the Permanent Works. These records shall include class of concrete, location of pour, date of pour, ambient temperature and concrete temperature at time of placing, moisture contents of aggregates, details of mixes, batch numbers, cement batch number, results of all tests undertaken, location of test cube sample points and details of any cores taken.

The Contractor shall supply to the Engineer four copies of these records each week covering work carried out during the preceding week. In addition he shall supply to the Engineer monthly histograms of all 28 day cube strengths together with accumulative and monthly standard deviations and any other information which the Engineer may require concerning the concrete placed in the Permanent Works.

4.4.16 Mortar

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

Mortar shall be composed of fine aggregate complying with Sub-Section 5.2.4 and the type of cement specified. The mix proportions shall be as stated on the Drawings or elsewhere in this Specification or if not stated shall be one part of cement to two parts of fine aggregate by weight.

Small quantities of mortar may be hand mixed but for amounts over 0.5 m^3 a mechanical mixer shall be used.

The water content of the mortar shall be as low as possible consistent with the use for which it is required but in any case the water:cement ratio shall not be more than 0.5.

Mortar which is specified as 'dry pack' shall be mixed with sufficient water for the mix to become cohesive but not plastic when squeezed in the hand. Dry pack mortar shall be rammed into the cavity it is required to fill, using a hand rammer with sufficient force to ensure full compaction.

4.4.17 Concrete for Non Structural Purposes

Non-structural concrete (NS concrete) shall be used only for non-structural purposes where shown on the Drawings or agreed or directed by the Engineer.

NS concrete shall be composed of aggregates complying with all-in aggregate within the grading limits of Table 5 of BS 882, Sub-Section 5.2.4 and the type of cement specified.

The weight of cement mixed with 0.3 m3 of combined or all-in aggregate shall not be less than 50 kg. The mix shall be proportioned by weight or by volume. The maximum aggregate size shall be 40 mm nominal.

The concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted where required.

The concrete shall be compacted by hand or by mechanical vibration.

No Fines concrete (NF concrete) is intended for use where a porous concrete is required and shall only be used where shown on the Drawings or instructed by the Engineer.

The mix shall consist of the cement specified and aggregate complying with this section. The aggregate size shall be 40 mm to 12 mm only or as shown on the Drawings or directed by the Engineer. The weight of cement mixed with 0.3 cubic metre of aggregate shall not be less than 50 kg. The quantity of water shall not exceed that required to produce a smooth cement paste which will coat evenly the whole of the aggregate.

Blinding concrete shall be Class 15/40 or Class 20/20 as indicated on the Drawings.

4.4.18 Shotcrete (Sprayed Concrete)

4.4.18.1 Scope of Work

This clause applies to shotcrete required in any part of the Works including underground works and includes sprayed mortar.

The work under this Section includes all labour, materials, equipment and services required for the execution of shotcrete work under this Contract. Shotcrete shall be applied to unstable or weak rock surfaces along the tunnel according to the temporary support classes shown on the drawings or as directed by the Engineer.

The Contractor shall design the mix, furnish materials, place, cure and test shotcrete as necessary to provide temporary or permanent protection and/or support of excavation surfaces.

The Contractor shall furnish all materials, labour and equipment for preparing test panels, both for trial mixes and during the course of the work, and for testing cores from panels or from in-situ shotcrete.

When the shotcrete is intended to remain as a permanent protection of rock/soil surfaces, the thickness of such laying shall be as specified in the drawings or as directed by the Engineer.

Shotcrete shall be placed with meshes of welded wire fabric, as specified, and may be used in conjunction with rock bolts.

Where applicable, and subject to approval by the Engineer, shotcrete reinforced with welded wire fabric meshes may be replaced by steel fibre shotcrete mix by means of equipment designed for that purpose.

The Contractor shall maintain adequate stockpiles of materials for shotcrete for immediate use. Any damage or delay resulting from shortage of such materials shall be to the Contractor's expense.

4.4.18.2 Submittals

At 30 days from the date of receipt of Notice to Commence, the following submittals shall be sent to the Engineer for approval:

- details, including numbers and type of equipment proposed for mixing, applying and curing the shotcrete;
- manufacturers' certificates giving full details of any proposed admixture, and the Contractor's proposal regarding the use of such admixtures, including certification of harmlessness to operatives;

The selection of method, i.e. dry-mix or wet-mix process is the Contractor's option.

4.4.18.3 Standards

The aspects of shotcrete construction including equipment, crew organisation, preliminary preparation, proportioning, shotcrete placement, and quality control shall conform to the requirements of ACI Manual of Concrete Practice, Part 5, Guide to Shotcrete, reported by the ACI Committee 506 or any other approved guideline or as directed by the Engineer.

4.4.18.4 Materials

Cement, aggregate, water, and admixtures shall comply with Sub-Section 5.2, except as noted below.

a. Aggregate

Aggregate gradation used in shotcrete shall conform to those established by the pre-construction trial mix tests. The gradation shall not be changed without the prior approval of the Engineer. Unless otherwise approved by the Engineer, the percentages of fine and coarse aggregate shall conform to the gradings, measured by weight, shown in the following table. They shall be taken as a guide for mix design purposes, but may be modified, subject to the results of the trial mix tests specified hereinafter.

Shotcrete or mortar made with finer sand will have a higher water requirement and correspondingly increased drying shrinkage.

The following table gives the recommended aggregate grading envelopes for shotcrete.

Sieve Size		Fine Aggregate	Coarse Aggregate	
US Standard Sieve	mm		2.5 – 10 mm	5 – 18 mm
1"	25	–	–	100
¾"	18	–	–	90 – 100
½"	12	–	100	–
3/8"	10	100	85 – 100	20 – 55
No. 4	5	95 – 100	10 – 30	0 – 10
No. 8	2.5	80 – 100	0 – 10	0 – 5
No. 16	1.25	50 – 85	0 – 5	–
No. 30	0.63	25 – 60	–	–
No. 50	0.315	10 – 50	–	–
No. 100	0.160	2 – 10	–	–

The maximum aggregate size fractions of the mix shall depend on the shotcrete thickness and be determined by suitability tests.

No more than 5% of the aggregate, by weight, shall pass the US Standard Sieve No.200 (0.075 mm). In the case of manufactured sand, if the material finer than the No. 200 sieve (0.075 mm) consists of the dust of fracture, essentially free of clay or shale, these limits may be increased to 7%.

Should the nature of the aggregates used during the course of the work change (e.g. source, rock type, shape) from that used in the trial mix tests, the Contractor shall produce new trial mixes, using the new aggregates.

b. <u>Water</u>

Mixing water shall be clean and free from substances which may be injurious to concrete or steel.

c. <u>Admixtures</u>

Admixtures may be used in shotcrete to enhance certain shotcrete properties, for special shotcrete applications, and for certain conditions of shotcrete placement.

Admixtures shall meet the requirements of the Sub-Section 5.10 of this Specification.

The use of admixtures in shotcrete shall be tested prior to large scale use to determine that the advantages expected are obtained.

The use of some rapid set accelerators results in considerable reductions of ultimate shotcrete strength, and they shall be thoroughly evaluated before use. Some of these admixtures are caustic and care shall be exercised in handling them. Only accelerating agents free from chloride shall be used.

d. Reinforcement

Welded wire fabric (mesh) shall conform to the relevant Standard BS 4483 of this Specification. General requirements are described in the Sub-Section 3 of this Specification.

As an alternative to welded wire fabric meshes, the Contractor may propose the use of fibrous reinforcement (steel fibres), containing artificial fibres of size and concentration recommended by the manufacturer for the intended use, or as otherwise approved by the Engineer.

Recommendations of ACI Committee 544 "State of the Art Report on Fiber Reinforced Concrete (ACI-544.I.R.-82) shall be applied for the use of steel fibre reinforced concrete.

4.4.18.5 Batching and Mixing

The correct proportions of sand and cement shall be established by weigh batching and cement shall not be added more than 1 hour before the time of placing the shotcrete.

The sand shall be dampened or dried as required to bring the moisture content to a satisfactory consistent level. Fluctuations in moisture contents shall be minimised.

The water:cement ratio of the fresh shotcrete in place shall be in general between 0.35 and 0.50. The mix will contain sufficient water to meet the required water/cement ratio but less water than will cause sloughing.

The mixing equipment shall be capable of thoroughly mixing the aggregate and cement so that the aggregate particles are thoroughly coated and capable of producing the mix in sufficient quantity to maintain continuity of placing. The Contractor shall demonstrate that the mixing plant he proposes to use is capable of meeting these requirements.

The mixer shall be self cleaning and capable of discharging all material without any carrying-over from one batch to the next. It shall be inspected by the Contractor and thoroughly cleaned at least once a day.

The quantity of any additive used shall be kept to the absolute necessary minimum and shall be fed by the machine direct and in the exact proportion by weight.

The non-lift mixing process shall take at least two minutes and the composition of the mix shall remain unchanged until it is applied.

During handling, the mixed concrete shall be protected against dripping water.

The use of ready mix from transit-mixing plants is allowed for subordinate structural parts only and is subject to explicit approval by the Engineer in writing.

4.4.18.6 *Procedures*

Before commencing application of shotcrete, the Contractor shall submit to the Engineer full details of the plant he proposes to use for the mixing and application of shotcrete and of the arrangements he proposes to make.

Prior to start of spraying concrete operations in any area the Contractor shall, in close cooperation with the Engineer and as part of the initial application establish procedures for the application of shotcrete which will produce the best quality product with the minimum of rebound. Such establishment of procedures shall include minor variations to mixes, if required, and the establishment of acceptable finishes and thicknesses of layer and quantities to be discharged at the nozzle to a unit area of rock or other surfaces, as required by the Engineer.

The Contractor shall develop operating procedures and operations to the satisfaction of the Engineer to give:

- minimum rebound
- no inclusion of rebound in the finished shotcrete
- as smooth a finished surface as possible
- no hollow area in the shotcrete
- a minimum of shrinkage cracks, and
- good adherence of the shotcrete to rock or other surface.

The Contractor shall make available all and any equipment, machinery, etc., meeting the requirements of continuous spraying procedure, particularly with respect to the workmanlike construction of the thick shotcrete layings, if any, with a structural function.

The Contractor shall advise the Engineer of the brand names and type, number and capacity of the spraying machines he proposes to use, together with all other equipment required to carry out the spraying operations. All equipment shall require approval by the Engineer. The spraying method shall be indicated.

All equipment required to prepare, mix and place shotcrete shall be kept clean and maintained in good operating conditions at all times during the performance of the works.

The shotcrete machine shall have an adequate placing capacity to ensure minimum delays to excavation and other operations. The equipment shall be such that the rapid hardening additive can be mixed satisfactorily and immediately before placing.

The air supply shall have sufficient capacity to meet the requirement for the size of nozzle and the working conditions. The water supply shall be pressurised to overcome the air pressure at the nozzle to ensure that the water is intimately mixed with the other materials.

The Contractor shall ensure that the air compressor he intends to employ is of sufficient capacity to maintain continuity of placing. The compressor shall maintain a supply of clean dry air adequate to maintain sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing any rebound if required.

The quality of the shotcrete as placed depends on the experience and reliability of the operators as well as on the correct nozzle spacing and spray angle. Only trained and tested operators with appropriate experience shall be employed for shotcrete operations. The Contractor shall satisfy the Engineer that the personnel are capable of doing work of a high standard prior to any shotcrete work being undertaken in the Works. For this purpose each nozzleman and back-up team shall carry out a series of trial applications in the presence of the Engineer to demonstrate their ability in applying shotcrete on vertical and overhead surfaces. Test panels as described in Sub-Section 5.18.5 shall be made by each operator. No operator will be approved unless the 28 day crushing strength of all tests exceed the design requirements.

If, in the opinion of the Engineer, operation of spraying equipment becomes unsatisfactory, the Contractor shall make all necessary repairs or replacement of the equipment. The Engineer may direct that spraying ceases until the Engineer's instructions are complied with, and the Contractor shall have no grounds for any additional payments or extension of time on this account.

In all areas where excavation is proceeding, the Contractor shall ensure that sufficient equipment is available to apply shotcrete at any face.

4.4.18.7 Mix Design

The mix design shall be carried out by the Contractor and details submitted to the Engineer for approval. The proportions shall be developed in accordance with the recommendation of ACI 211.1 and ACI 214 for obtaining specified compressive strengths. Aggregate content corrections shall be done in the case of wet-mix process. Shotcrete mixes shall not be used in the Works until approved by the Engineer. Mix proportions shall be varied as directed to maintain rebound at a minimum.

Mixes shall be such that the aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced from approved trial mixes. All constituents shall be uniformly dispersed throughout the mix. The use of admixtures in shotcrete shall be tested for compatibility with cement in accordance with ASTM C 1141 prior to large scale use and to determine that the advantages expected are obtained.

Accelerator (e.g. Sigunit of SIKA or approved equal) shall be added to the mix to speed-up the setting rate of the cement. The maximum content of accelerator by weight of cement shall be according to manufacturer’s instructions.

4.4.18.8 Preconstruction Testing

For the purpose of approving mix design, the Contractor shall prepare not less than four test panels for each mix for testing in the presence of the Engineer initially at 30 days before any shotcrete placing is started in the Works, before approval of an additive is given, when the use of new equipment is proposed, and subsequently whenever, in the opinion of the Engineer, shotcrete is being produced which may not meet this Specification.

Preparation and testing shall comply with ASTM C 1140. The Contractor shall furnish all plant, equipment, materials and assistance necessary and carry out all work to obtain representative test panels of shotcrete.

Test panels moulds at least 750 mm square and at least 150 mm thick shall be constructed for each mix designed and for each position required in the works such as downhand, vertical and overhead positions, and for each proposed nozzleman. Panel moulds shall be formed from plywood at least 20 mm thick, be adequately braced and be held rigidly in position. Panels shall be made in the presence of the Engineer.

Separate test panels shall be constructed with and without accelerator. For each important shotcrete section of the Works one test, consisting of three panels, shall be performed.

The test panels shall be positioned alongside the area of placement and at the same angle and shall be sprayed by each proposed nozzleman in rotation so that the tests shall represent the quality of the shotcrete being placed by each nozzleman.

The panels shall be left undisturbed at the point of placing until the final set has taken place. They shall be kept moist and at 21°C ± 5°C until moved to test laboratory.

Test panels and specimens shall be transported by the Contractor to the Site Laboratory immediately after final set has taken place and in such a manner as to prevent their being damaged in any way.

Five drilled cores with a diameter of 100 mm and L/D of at least 1 (L: Length, D: Diameter) shall be obtained from each panel at right angles to the plane of the panel. Cores shall not be taken within 10 cm of the edges of the panel.

Visually grade the reinforced specimens for compliance with grade requirements of ACI 506.2. Determination of grade shall be by computing the mean of a minimum of three test specimens, by excluding the best and worst test result of the five tested specimen. A mean grade of 2.5 or less is acceptable. Individual shotcrete cores with a grade greater than 3 are unacceptable.

Only nozzlemen with a test panel mean core grade less than or equal to 2.5 shall be allowed to place job shotcrete. When the prequalification test panel is rejected, a second panel may be shot. When the nozzleman's second mean core grade is greater than 2.5, the nozzleman shall not be permitted to shoot on the project.

The non-reinforced specimens shall be tested for compliance with the specified physical properties in accordance with ASTM C 42.

After 12 hours five cores from one test panel shall be tested for compression and the average is calculated by deleting the best and worst test result. In the case cores can not be drilled after 12 hours, non-destructive strength tests (impact hammer), as specified further, shall be carried out by the Contractor in the presence of the Engineer.

Five specimens from another test panel shall be core drilled and tested for compression and the average is calculated by deleting the best and worst test result at 24 hours. After 48 hours five specimens from the last test panel shall be core drilled and carefully stored. At 28 days these specimens shall then be tested for compression and the average is calculated by deleting the best and worst test result. The core testing shall be carried out in the Contractor's laboratory.

Core strengths shall be corrected for L/D as described in ASTM C 42. The cores shall be stored, cured and tested in accordance with ASTM Standard Method C 42. All cores shall be suitably labelled to identify them with the panels from which they have been taken, and the location in the Works to which they relate.

The required cylinder compressive strength for each set of five 12-hours cores, by deleting the best and worst test result (5 N/mm²), 24-hours cores (10 N/mm²) as well as 28-day cores (25 N/mm²) shall be satisfied if the mean compressive strength of a test set of three cores (by testing five cores and deleting the best and worst result) shall equal or exceed 1/0,85 (= 118%) of the specified cylinder compressive strength with no individual core with a compressive strength less than the required cylinder compressive strength.

Should any of the cores reveal defects such as a lack of compaction, dry patches, voids or sand pockets, or should the strength test results be unsatisfactory, the Engineer may require further tests or cores to be taken from the remainder of the panel(s) or he may reject the procedure used to make the defective test panel and require that a replacement test panel be made with a modified procedure.

The procedures described above shall determine the optimum proportions to achieve the result desired. Once the mix proportions have been established they shall be monitored.

4.4.18.9 Work Quality Control

One test panel shall be sprayed for every 100 m³ of shotcrete applied, measured in theoretical quantities. Fifteen cores of 100 mm diameter shall be drilled from the panel. Five cores each shall be tested for compressive strength after 1, 7 and 28 days.

Test panels for shotcrete quality control to determine the suitability of admixtures shall be made as specified previously for preconstruction testing and as directed.

The required cylinder compressive strength for each test set of three 12-hours cores (5 N/mm²), 24-hours cores (10 N/mm²) as well as three 28-day cores (25 N/mm²) shall be satisfied if the mean compressive strength of a set of three cores (by testing five cores and deleting the best and worst result) shall equal or exceed 1/0,9 (= 111%) of the specified cylinder compressive strength with no individual core with a compressive strength less than the required cylinder compressive strength.

In the case cores cannot be drilled after 12 hours, non-destructive strength tests (impact hammer), shall be carried out by the Contractor in the presence of the Engineer in order to determine the early compressive strength of shotcrete. The Engineer may also require non-destructive strength tests before 12 hours after shotcrete placement.

Non-destructive strength tests will be carried out by means of dynamic ball impact hammers which shall be supplied by the Contractor, including equipment calibration. Impact hammers shall be suitable also for early strength determination, i.e. approximately 10 N/mm^2 or lower. Testing shall be performed and evaluated in compliance with DIN 2048 or equivalent international standard.

The Contractor shall drill cored holes not less than 25 mm in diameter in places instructed by the Engineer to determine the thickness of shotcrete. Alternatively the Contractor, subject to the agreement of the Engineer, may fix thickness indicators at not more than one metre centres on the surface to which the shotcrete is to be applied. Such indicators shall be easily visible during and after the spraying operation.

When instructed by the Engineer, the Contractor shall drill 100 mm diameter cores in the shotcrete, and these cores shall be tested in a similar manner to those from the test panels.

Test holes in shotcrete surfaces shall be filled by ramming in dry pack concrete of a similar mix to the surrounding concrete which shall be finished flush.

4.4.18.10 Control of Rebound

Under no circumstances shall rebound be worked back into the construction. If it does not fall clear of the work it must be removed. Rebound which has been removed shall not be included in later batches. The quantity and nature of rebound shall be ascertained at the request of the Engineer.

All rebound must be removed from the working area and Site by skip, chute or similar method. The rebound shall not cause any contamination of adjacent structures or completed work.

The basic screening necessary to avoid contamination from the shotcrete process and the means of disposal of the rebound material from the working area shall be provided by the Contractor. The Contractor shall satisfy the Engineer that the measures provided are adequate to provide complete compliance with this clause.

4.4.18.11 *Application*

Shotcrete can be applied by two methods, either the dry mix method or the wet mix method, the choice of which shall be at the discretion of the Contractor.

a. Dry Mix Method

Applying this method, materials are pre-mixed and then fed to the gun. At the same time an accelerator is added to the gun. The material is then carried in suspension by compressed air through a hose to the nozzle. At the nozzle, water is injected into the material in a number of fine streams. As the material passes through the final portion of the nozzle, it is mixed with the water. Mixing continues as the stream of material and water passes between the nozzle and the point of impingement.

b. Wet Mix Method

Applying this method, materials are pre-mixed with water added in the required ratio and then fed to the pumps. Concrete accelerators will be injected in the pressurised air line at the nozzle of the shotcreting hose and then sprayed onto the surface to be sprayed with concrete.

c. General

Shotcrete shall be applied so that it neither sags nor slumps, and each layer shall be not less than 50 mm thick unless otherwise shown on the Drawings.

Formwork or guides shall be fixed rigidly. Reinforcement shall also be fixed rigidly so that no movement occurs during spraying. If shotcrete is applied directly onto the rock, the reinforcing wire mesh has to be fixed to the rock as tightly as possible, in order to reduce the movement of the reinforcement to a minimum.

During starting or stopping the spraying operation, or when the delivery from the nozzle is irregular, the nozzle shall be directed away from the work.

The flow of the material at the nozzle shall be continuous and uniform and the rate of application over any given area shall be uniform. Slugs, sand spots, wet areas or other defects shall be cut out and corrected as specified herein.

When shotcreting is to be performed near existing structures, the Contractor shall ensure that no damage results to the structure and shall protect the surfaces of structures before shotcreting.

The quantities of shotcrete to be discharged at the nozzle shall be determined on the basis of the average thickness of shotcrete shown on the drawings or required by the Engineer and taking due account of rebound. Once procedures for the application of shotcrete are established, subsequent work shall be carried out accordingly.

If reinforcement is to be embedded, shotcrete shall be applied so that voids cannot form under the steel bars.

The water pressure shall be greater than the air pressure in case of the dry shotcreting method to ensure complete wetting of the materials at the nozzle and to give the nozzleman a quick, positive control.

Compressed air and pressure water shall be free from oil and shall not be liable to pressure fluctuations.

In the case of applying the wet shotcreting method the air pressure recommended by the manufacturer's instruction shall be maintained. Shotcrete shall be applied to rock surfaces as soon as possible after excavation and removal of spoil. For inclined surfaces application shall begin at the bottom.

Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for drumminess, to the satisfaction of the Engineer. The Contractor shall repair all drummy, sandy, cracked or spalled areas and any other areas where, in the opinion of the Engineer, the shotcrete is faulty, by removing the shotcrete to a sound area of rock or shotcrete, carrying out surface preparation as specified herein and reshooting that area to the satisfaction of the Engineer.

The working area shall be well illuminated to a minimum lighting intensity of 50 lux. Caplamps attached to safety helmets shall not be accepted as sufficient. Dust pollution shall be minimised by means of pre-damping of materials, additional ventilation, water sprays, and maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by operators.

If at any time the Engineer considers that the environmental conditions of the area where shotcrete is being applied are likely to cause a health hazard or affect the quality of the finished work because of excessive dust or lack of adequate ventilation or lighting, he may order the Contractor to suspend operations on shotcrete work until steps are taken to improve the conditions in the affected area. No additional payment will be made either for the additional measures called for or for any delays resulting from such suspension of works.

Concrete shall not be sprayed when the air temperature is 5°C or less.

Freshly sprayed shotcrete shall be completely protected from drying out for a minimum period of three days after spraying.

4.4.18.12 Filling of Soft Indented or Shattered Areas

Where instructed by the Engineer, the Contractor shall fill soft indented or shattered areas of the rock face with shotcrete. The preceding layer shall be allowed to harden before the following layer is applied.

4.4.18.13 Tolerances on Finished Surfaces

In the case of tunnels the finished surface shall not project beyond the clearance surface indicated on the Drawings.

All surface finishes are to be reasonably uniform in texture and free from blemishes. If any surface shows a lack of compaction or bond, dry patches, voids, sand pockets, sags or slumps, the material shall be removed immediately over an area not less than 300 mm square and resprayed at once.

Finished shotcrete surfaces shall be such as to require no further treatment. If surface finish and roughness do not satisfy the Engineer, or do not meet the requirements of a minimum radius of 300 mm for edges in the shotcrete laying or of a depth/height less than 1/10 of the span of any depression/protusion, then a thin levelling course shall be placed on the fresh shotcrete on the instructions of the Engineer. This thin levelling course shall be included in the unit prices for the respective shotcrete items. Whether or not a smooth finished surface is additionally required will be decided by the Engineer.

4.4.18.14 Water Pressure Relief Holes

Water Pressure relief holes shall be drilled through permanent shotcrete surfaces where shown on the Drawings or if directed by the Engineer. The holes shall be a minimum of 38 mm diameter and be drilled at least 100 mm into rock.

When drain holes have been drilled and instruments have been installed into rock on which shotcrete is to be placed, the Contractor shall take all necessary precautions to prevent such holes from being plugged or instruments from being damaged.

4.4.18.15 Shotcrete Applications – General

Shotcrete whether as a sealing tunnel laying or as an arch with load bearing functions shall show in the entire cross-section a uniform, compact, monolithic (not stratified) texture, free of cracks. Any openings in the rock formation shall be secured against loosening and undue yielding of the rock by the shotcrete layer.

All steel parts such as wire, reinforcing steel, mesh, rock bolts, rock bolt plates and nuts, arched steel rib supports (lattice girders) and the like remaining in the shotcrete shall be covered neatly throughout their entire extent by at least 30 mm of shotcrete.

Any adherent rebound and/or loose or clogged material from previous applications shall carefully be removed before spraying. Any steel inserts shall be fixed in such a way that they will not give rise to laminated cross-sectional separation.

If local conditions permit and economy of work is not prejudiced, the sprayed-on concrete layer as a final tunnel laying may assume any structural functions required.

The Contractor shall be fully responsible for an efficient method and the use of appropriate equipment. This responsibility shall rest with him also in cases where subcontractors may be engaged for this work.

4.4.18.16 Shotcrete Application Above Ground

Spraying concrete above ground shall not be carried out when, in the opinion of the Engineer shotcrete cannot be placed effectively because of adverse weather and wind conditions, unless adequate cover is provided over the working area until the shotcrete has been cured sufficiently to prevent damage.

4.4.18.17 Curing

During a period depending on local conditions and to be agreed upon with the Engineer, the freshly placed shotcrete shall be protected against sunshine, cold, rain, running water, chemical attack, and vibrations until it hardens, and it shall be kept moist for at least 7 days. If shotcreting is carried out under adverse weather conditions or low temperatures, an additional protective application shall be provided.
In case of open air spraying, the surface shall be protected from the direct rays of the sun for the first 3 days.

4.4.19 Concreting Around Pipes

Where pipes pass through or are to be set into concrete work, they shall be well cleaned (to bare metal in the case of ductile iron or steel pipes) and the concrete worked thoroughly into contact with the pipe wall.
The Contractor shall take particular care to ensure that pipes are correctly aligned and that shuttering is carefully cut to the shape of the pipe. No concrete shall be poured until these preparations have been completed to the satisfaction of the Engineer.
Pipes should in all cases preferably be cast into concrete. Openings may be left into which pipes are to be set at a later stage only with the specific approval of the Engineer. If the Engineer approves an opening for this purpose, a square hole to accommodate the pipe shall be left in the concrete exposing part of the reinforcement, and a recessed central key formed in the bottom and sides of the opening. The key shall be not less than 50 mm deep and tapering from 75 mm wide at the surface to 50 mm wide at its base. The dimensions of the hole shall be the minimum necessary to accommodate the largest cross section of the pipe and permit filling of the hole with concrete in accordance with this Specification.
Prior to filling with concrete the surfaces of the existing surrounding concrete shall be roughened, moistened and coated with an approved Laying adhesive to aid adhesion and ensure a sound bond. The pipe shall be then set into position and the hole filled with

concrete. Formwork shall be so arranged that concrete can be poured into the opening from one side and rise up the other side to a level at least 300 mm above the top of the opening. Excess concrete shall then be removed while still green, and all surfaces neatly finished and thereafter kept moist until set by wrapping with wet sacking or some other approved method. Once set the joint between the new and the old concrete shall be hacked back on both sides of the wall to form a V-joint 20 mm deep and caulked with cement caulking with an approved laying mortar admixture.

4.4.20 Grouting of Pockets and Holes, Underpinning of Baseplates, Setting Frames

Pockets and holding-down bolt holes shall be thoroughly cleaned out using compressed air and water jets. Holes drilled by a diamond bit shall be roughened. The pockets and holes shall be filled either with a proprietary non-shrink chloride free grout approved by the Engineer or with grout consisting of cement and clean fresh water mixed in the proportion of two parts by weight of cement to one part by weight of water. The pouring of liquid grout shall cease as soon as each hole is filled, and any excess grout on the surface of the concrete foundation shall be completely removed and the surface dried off before the next operation proceeds.
Where recesses to be filled are of significant dimensions the Engineer may instruct the Contractor to use a mix of one part cement to two parts sand and small stone aggregate to reduce shrinkage.
The space between the top surface of foundation concrete and the underside of baseplates shall be filled either with a proprietary non-shrink chloride free grout approved by the Engineer or with a special mortar made up in the following proportions:

- Portland Cement 50 kg
- Fine aggregate 50 kg
- Additive an additive acceptable to the Engineer to counteract shrinkage in proportions recommended by the manufacturer.

The special mortar shall be mixed with the lowest water/cement ratio which will result in a consistency of mix of sufficient workability to enable maximum compaction to be achieved.
The special mortar shall then be well rammed in horizontally below the baseplate and from one edge only until it is extruded from the other three sides. The mortar which has extruded shall then be rammed back to ensure complete support without voids.
Proprietary grouts shall be used in accordance with manufacturer's instructions. The Contractor shall obtain the approval of the Engineer to use such proprietary grouts not less than four weeks prior to their intended use in the Permanent Works.

Where necessary bolts shall be set directly into position by template. A small annular opening may be provided when holding-down bolts are set into concrete to provide for final adjustment by bending. Manhole frames, step irons and all such metal work are wherever possible to be set directly in place, or else where necessary bedded on a previously prepared bed of concrete or mortar, and the surrounding concrete carefully tamped into contact with the metal work. After the concrete has set and the formwork has been removed, the surface of the concrete shall be neatly finished off by pointing around metal work, and all exposed metal surfaces shall be carefully cleaned and a double coat of black bituminous paint applied unless otherwise indicated on the Drawings or in the Bill of Quantities.

Bolt holes shall be formed in concrete either by setting tapered boxes into position before concrete is placed, or by drilling into the concrete after it has set. The method to be adopted shall be at the discretion of the Engineer.

The position of bolt holes shall be to a maximum tolerance of ± 10 mm, and the Contractor shall be responsible for ensuring that the position and alignment of each hole is such as to provide a satisfactory bolted connection. Care must be taken to ensure that the depth of any hole is not excessive.

4.4.21 Hand Mixed Concrete

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

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

For hand mixed concrete not more than 0.5 m3 shall be mixed at one time. During windy weather efficient precautions shall be taken to prevent cement from being blown away during the process of gauging and mixing.

4.4.22 Concrete Layings in Underground Works

4.4.22.1 Method of Working

The Contractor shall submit to the Engineer full details of the Constructional Plant he proposes to use, the methods of work he proposes to adopt and the programme he proposes to follow in placing concrete layings in underground works. The details to be submitted shall include a statement of the procedure to be followed to ensure that the excavated profile gives the required minimum laying thickness.

The installation of the concrete laying inside the tunnels and shafts is allowed as soon as the trend lines of deformation monitoring suggest that the deformations at any part of the tunnel cross section are and will stay within a limit of maximum 1.00 mm per month.

4.4.22.2 Laying Formwork

Formwork for tunnel layings shall be approved by the Engineer. It shall be rigid and strong and capable of being adjusted accurately to the prescribed alignment.
The formwork shall generally be faced with metal or other approved material for repetitive sections of the work and shall be provided with openings having an area of not less than 0.5 m² at three metre centres horizontally and circumferentially. A series of openings shall be provided in the crown of the formwork. All openings shall be provided with rigid closing pieces secured by a system of positive quick action locks. The closing pieces shall be constructed to close tolerances and shall be maintained to a standard that will ensure on completion a surface free from irregularities and loss of grout.
The formwork shall be grout tight and the Contractor shall pay particular attention to the use of seals built into the shutter to ensure a grout tight joint between the walls and invert of the tunnel and at the construction joints.
Formwork to transitions and other non repetitive sections may be constructed with timber built up of splines, but in accordance with the foregoing requirements for access hatches and grout tightness. The formwork shall be lined with plywood or other suitable materials so that board markings are eliminated.

4.4.22.3 Concrete for Layings

Concrete shall be of the class shown on the Drawings. It shall comply with the relevant clauses of this Section of the Specification and have a workability suitable for placing in accordance with Sub-Section 5.22.5.

4.4.22.4 Preparation of Surfaces

The ground against which concrete is to be placed shall be cleaned to remove all loose material, dirt and debris. Water lying on surfaces shall be removed and water entering the area to be concreted shall be diverted so that it cannot damage the placed concrete. Rock bolts, anchor bars and other fastenings and previously applied shotcrete shall be in a condition satisfactory to the Engineer.

4.4.22.5 Placing Concrete in Layings

Concrete shall be placed so that the space between the formwork and the surrounding ground is completely filled including any voids over the arch of tunnels and other similar places and so that no voids, honeycombing or cold joints are visible on the face of the laying after completion.

Notwithstanding any agreement of the Engineer to the concreting cycle proposed by the Contractor, the period of such cycle shall be extended in the event of damage being caused to the concrete laying due to too early removal of the formwork.

The Contractor shall take such precautions and adopt such methods as will ensure that all voids in the excavations are completely filled with concrete and that the space between the shutter and the rock is completely filled and free from honeycombing particularly at the crown of the arch.

The concrete shall be transported from the mixing plant in suitable vehicles which shall ensure that there is no segregation of materials during transportation. The rate of supply shall be carefully matched to ensure that cold joints do not form in the concrete and that all concrete is placed in its final position within 45 minutes of being mixed.

Concrete for hydraulic tunnel layings shall be pumped into position by a positive displacement reciprocating pump located close to the section being lined and using methods which do not cause segregation or require remixing of the concrete. Pneumatic placers shall not be used. The location of pipework associated with pumping shall be approved by the Engineer.

Concrete in the walls of tunnels shall be placed through the openings in the formwork and compacted with immersion vibrators. The placing shall continue equally in parallel layers in both wall until only the crown of the arch remains to be completed.

Placing of the concrete in the arch shall be either by pumping from the end adjacent to the construction joint and forcing the concrete towards the stopend shutter or by immersing the open end of the supply pipe in the concrete and gradually withdrawing the supply as the concrete advances. The point of discharge when concreting the crown above the springline shall be kept buried sufficiently to allow enough pressure to be built up to completely fill the crown, including areas of overbreak in the crown.

Where the laying thickness is insufficient to use a concrete delivery pipe between the shutter and rock surface, concreting ports shall be provided in the crown shutter at intervals of not more than two metres.

Concrete vibrators shall not be run in circumstances likely to draw concrete away from contact with the rock surface in the crown unless pressure is maintained by the concrete pump while vibrators are run. This requirement is of particular importance at the end of a concreting cycle.

4.4.22.6 Construction Joints

Construction joints shall generally be formed at locations and angles to the line of the tunnel or shaft in a manner approved by the Engineer.

Prior to the concreting of an adjacent section of laying, the surface of the construction joint shall be cleaned of all laitance, loose or defective concrete coatings and foreign material. Cleaning shall be effected by the use of high velocity air water jets and/or sandblasting followed by thorough washing or other means approved by the Engineer.

Before deposition of further concrete, the surface of the existing concrete shall be clean, hard and sound and if required by the Engineer shall be wet without any freestanding water.

If not otherwise indicated on the Drawings or instructed by the Engineer, construction joints shall be sealed with hydrophylic waterstops, placed in a half-depth indentation preformed in the previous end stop shutter, in accordance with Sub-Section 4.4.13.4. A polysulphide sealant shall be provided in a cleanly preformed indentation at the inner surface of construction joints in concrete laying to tunnels and shafts.

4.4.22.7 Location of Embedded Steelwork

Where concrete layings are to be constructed in areas in which steelwork is cast in, careful note shall be made of the exact locations of all steelwork. This information is required so that holes can be drilled for post-laying grouting to ensure complete filling of the spaces between the excavated surface or rock support layers and the final laying.

The above record will be required whether or not sleeves are provided for grouting.

4.4.22.8 Grouting Concrete Layings

Not sooner than 28 days after placing the concrete, the interface between the concrete and the surrounding ground shall be grouted .

4.4.23 Sliding Formwork

Prior to fabrication or bringing the assembly and auxiliary equipment to the Site, the Contractor shall submit drawings of the complete sliding formwork assembly to the Engineer for acceptance. The drawings shall show full details of the forms, jacking frames, access ladders, hanging platforms, safety rails and curing skirts, as well as details of the jacks and jack layouts.

The Contractor shall be required to submit to the Engineer, before sliding commences, an instruction manual wherein the sliding technique, jacking procedure, methods of keeping the formwork level, procedure to be adopted to prevent bonding of the concrete to the forms and method to release the forms in the event of bonding, the instrumentation and monitoring of the slide, correcting for verticality, twisting and levelness, etc. are described in detail.

The formwork panels shall be inclined to give a small taper, the forms being slightly wider at the bottom than at the top. The taper shall be designed to produce the specified concrete thickness at mid-lift level of the form.

The spacing of the jacks with their jack rods must be so designed that the dead load of the sliding formwork assembly, the frictional load and the mass of materials, personnel and equipment are evenly distributed and within the design capacity of the jacks used.

Concrete sections with dimensions smaller than 200 mm shall not be formed with sliding formwork, unless approved by the Engineer.

During the entire duration of the sliding operations a competent person on the Contractor's staff, who is fully acquainted with the sliding technique and the Contractor's methods of construction shall be in attendance on the sliding platform and in control of the sliding operations.

The Contractor shall give the Engineer 24 hours notice of his intention to commence with a slide. Permission to commence with the slide shall not be given by the Engineer before the sliding formwork assembly is fully operative and the complete stock of all materials required for the slide as well as back-up equipment are on Site.

The Contractor shall ensure that the rate of sliding is such that the concrete at the bottom of the formwork has obtained sufficient strength to support itself and all loads that may be imposed upon it at the time, and that the concrete does not adhere to the sides of the forms.

The sliding operations shall be continuous, without any interruptions, until the full height of the structure is reached. The rate of sliding shall be agreed with the Engineer.

Concrete shall be cast in uniform layers along the formwork so that the top surface of the concrete does not differ by more than 150 mm at any part of the formwork. In addition, the level of the concrete shall never be more than 300 mm below the top of the sliding panel. The working platform must be kept clean and no concrete which has partially dried out may be swept into the formwork.

When the sliding operations are delayed for more than 45 minutes, the Contractor shall prevent adhesion of the setting concrete to the formwork panels by easing the forms or by moving them slightly every 10 minutes, or alternatively, where reversible jacks are used, by lowering the forms by 10 mm to 25 mm. Wherever interruptions occur emergency construction joints shall be formed and treated in accordance with Sub-Section 4.4.12 and, where appropriate, Sub-Section 5.22.6 Before concreting is restarted, the form shall be adjusted to fit snugly into the hardened concrete so as to avoid steps forming on the exposed concrete surface. When sliding is recommenced, care shall be exercised to prevent the fresh concrete from being lifted off from the old concrete.

4.4.24 Water Tightness Test for Concrete Water Tanks

4.4.24.1 *General*

Water tanks testing shall be done according to the method specified below.
The testing of tanks or water containment structures shall confirm to the following standards, as applicable to the project and as modified herein:

i. Reinforced concrete water retaining structures-ACI 350 IR and as specified herein.

ii. Wire wound pre-stressed concrete tanks AWWA D110 or ACI 344 R-W.

iii. Pre-stressed tendon tanks- ACI 344 R-T.

iv. Steel tanks AWWA D100.

If water tanks are not above ground, perform water tightness tests prior to placing backfill around the water tank in order to permit observations and detection of leakage points. Walls may be backfilled prior to testing only when approved in writing by the Engineer. The request to backfill prior to testing shall include a description of the method proposed to detect leakage points after the backfill is in place. Approval place backfill prior testing shall not relive the Contractor of the responsibility for conducting water tightness tests.

a. Inspection:
Inspect the water tank for potential leakage paths such as cracks, voids, etc and repair such paths in compliance with the provisions specified herein.

b. Preparation:
Thoroughly clean the water tank to be tested of dirt, mud and construction debris prior to initiating water tightness tests. The walls, floors and sumps shall be flushed with water to provide a clean surface, ready for testing.
Inlet and outlet pipes not required being operational for the tests might be temporarily sealed or bullheaded prior to testing.
Confirm adequacy of seals around gates and valves and reset or seal as approved by the Engineer. Estimates of gate or valve leakage will not be allowed as adjustments to the measured tank or structure leakage.

c. Conditions for Testing-Concrete Water Tanks:
Do not begin initial filling of concrete water tank until all concrete elements of the water tank have attained the designed compressive strength of the concrete (28 days), nor less than 14 days after all concrete walls or base slabs have been placed.

d. Reports:

Submit to the Engineer water tightness test results for the water tank tested. The report should include the test date, the operating level, level records, test duration, temperature, attendees, and other related information.

Notify the Engineer of the scheduling of tests three working days prior to the tests. The Engineer should attend and monitor any water tightness testing performed on the water tank.

4.4.24.2 Water Tightness Test

Water tightness test shall be carried out before any internal painting or external isolation of water tank walls.

a. Filling the Water Tanks with Water

The water tank shall be slowly filled with potable water keeping the level in the tank at a maximum height rate of 1.2 metres per 24 hours until the maximum operating level is reached.

If the water tank is divided into two compartments, the water tank shall be slowly filled with potable water keeping the level in both sections of the water tank at the same height. Filling of the water tank shall be done at a maximum rate of 1.2 metres per 24 hours up to the maximum operating level.

If there is any leakage during the test period (24 hours), the tank shall be emptied and the leakage shall be repaired before continuing.

b. Procedure

i. Filling of reinforced concrete water tanks shall not exceed a rate of 1.2m in 24 hours.

ii. Fill unlined (fair face) or partially lined (plastered) concrete water tanks to the maximum operating water surface level and maintain the water at that level for 24 hours.

iii. Measure the drop in water level over the next 72 hours to determine the water volume loss for comparison with the allowable leakage limits (72 hours to minimize water absorption by the concrete during testing process).

iv. Measure and record loss of water volume should be at 24 hours intervals. The loss of volume is usually determined by measuring the drop in water surface elevation, and computing the change volume of the contained water. Measure water surface level at not less than locations at 180° apart and preferably at four locations 90 degrees apart. Record water temperature 450 mm below the water surface when taking the first and last sets of measurements.

v. If all records for the loss of water volume over the 72 hours does not exceed the allowable leakage limits, the leakage should be considered acceptable.

vi. If the leakage (loss of waster volume) in any of the three days exceeds the maximum allowable leakage limits, the leakage test should be extended to a total of five days.

vii. If at the end of the five days the average daily leakage (average loss of volume) does not exceed the maximum allowable limits, the test should be considered acceptable.

viii. If the leakage of the water volume exceeds the maximum allowable leakage limits, leakage should be considered excessive and the tank should be emptied and repaired.

c. Acceptance

The following conditions shall be considered as NOT meeting the criteria for acceptance regardless of the actual loss of water volume from the water tank:

i. Ground water leakage into the water tank through floors, walls, or wall-floor joints.

ii. Water tank which exhibit flowing water from joints, cracks or from beneath the foundation (except for under-drain systems).

iii. Lined concrete water tanks or pre-stressed concrete water tanks on which moisture can be picked up by a dry hand from the exterior surface of the walls.

iv. Damp spots on the exterior wall surfaces of the water tank appears.

The water tightness of concrete tanks should be considered acceptable when loss of water volume is within the allowable leakage limits listed bellow:

i. For unlined (fair face) tanks with a sidewater depth of 7.5 m or less, loss of volume not exceeding 0.10% in 24 hours.

ii. For tanks with lined (plastered) walls and a sidewater depth 9.0 m or less, loss of volume not exceeding 0.06% in 24 hours. Steel diaphragms in concrete walls shall be considered the same as a wall liner.

iii. For completely lined tanks (walls and ceiling), loss of volume not exceeding 0.025% in 24 hours.

d. Open Water Tanks

During the test period, the ambient evaporation of water shall be measured at a location near the water tank in an evaporation pan or by other approved means. Evaporation for local areas measured shall be considered.

If the drop in the tank water surface in a 24 hours period exceeds the normal evaporation of water by 0.1% of the filled total volume, the leakage shall be considered excessive and shall be repaired before continuing.

e. Repairs and Retesting

A water tank failing the water tightness test and not exhibiting visible leakage may be retested after an additional stabilization period of 7 days. Tanks failing this second test shall be repaired prior to further testing.

Water tanks which fail the water tightness test, and water tanks showing visible leakage, shall be repaired in compliance with the provisions specified herein.

Repair and retesting of tanks shall be accomplished at no additional cost to the Employer.

The Contractor shall make all necessary repairs if the tank fails the water tightness test or is otherwise defective. The method of repair shall be subject to prior approval by the Engineer.

1. Minor Concrete Repair:

   The most common repair method for small areas of honeycombed concrete (rock pockets) and other defective concrete is removal and replacement with non-shrink aggregate grout (which may include pea gravel aggregate) bonded to the concrete with an laying bonding agent. The minimum strength of material used in the repair shall equal or exceed that specified for the concrete.

   Defective tie hole patches shall be removed and the holes repacked or laying injected.

2. Laying Injection Grouting:

   - Walls:

     Damp or wet spots on a wall resulting from leakage through the wall shall be repaired with a high-pressure laying injection grouting system or other method acceptable to the Engineer. When laying grouting is to be performed, a low-viscosity, two-component, water-insensitive, nontoxic laying-resin system with an in-line metering and mixing system shall be used. The pumps shall be capable of producing minimum injection pressure of 100 psi (680 kPa). Injection pressure shall be limited to 300 psi (2.1 Mpa) to ensure complete penetration of the defect without damaging the structure. Laying shall reach a minimum compressive strength of 6,000 psi (40 MPa) in 24 hours in accordance with the requirements of ASTM D695.

An applicator with successful past experience in water structures shall be present on the job at all times while repairs are being made. Work shall be guaranteed against failure of the laying bond in the repair areas for a minimum period of one year.

Any exposed defect receiving laying repair shall first be cleaned of dirt, laitance, and other material that might prevent proper bonding. A suitable temporary seal shall then be applied to the surface of the defect to prevent the escape of the laying. Entry ports shall be spaced along the seal at intervals not grater than the thickness of the cracked element. The laying shall be injected into the crack at the lowest port first, with sufficient pressure to advance the laying to an adjacent port, using a small nozzle held tightly against the port. The operation shall continue until laying material begins to extrude from the adjacent port. The original port shall be sealed and the injection shall be repeated in one continuous operation until the crack has been injected with laying for its entire length. All ports, including adjacent locations where laying seepage occurs, shall be sealed as necessary to prevent drips and runouts. On completion of the injection of the crack, the grout shall be allowed to cure for sufficient time to allow the removal of the temporary seal without any draining or running out of the adhesive laying material from the crack. The surface of the crack shall then be finished with the adjacent surfaces and shall show no indentations or evidence of port filling.

- Floors, Piping and Valves:

  Generally the loss of water through the tank floor, piping, and valves is difficult to determine separately. The total water loss shall not exceed the criteria set forth in Sub-Section 5.24.2-c If the loss of water exceeds the criteria, the tank floor shall be inspected for point sources of leakage with the tank full or empty.

  Water loss through floor joints or shrinkage cracks shall be located and the defective sections removed and replaced, or repaired by laying injection grouting as specified earlier or by other means acceptable to the Engineer. Any potential point sources of leakage found shall be repaired and the water tightness test repeated.

4.4.24.3 Measurements

Unless otherwise provided for by specific items in the Bill of Quantities, water tank testing shall not be measured for separate payment but shall be deemed to be subsidiary works, the cost of which is to be included within the other prices for concrete works.

4.5 PRECAST CONCRETE

4.5.1 Formwork

Moulds shall be so constructed that they do not suffer distortion or dimensional changes during use and are tight against loss of cement or fines from the concrete.
Moulds shall be set up on firm foundations so that no settlement occurs under the weight of the fresh concrete.
Moulds shall be constructed so that units may be removed from them without sustaining any damage.
Release agents used for demoulding shall not stain the concrete or affect its properties in any way.

4.5.2 Reinforcement

Reinforcement in precast units shall comply with the requirements of Sub-Section 4. When preformed cages are used the cages shall be made up on jigs to ensure dimensional accuracy and shall be carefully supported within the mould in such a way that they cannot move when concrete is placed. Reinforcement complying with BS 4449 may be tack welded where bars cross to provide rigidity in the cage but cold worked steel bars shall not be welded.
The concrete cover to reinforcement shall be equal to or greater than the cover stated in the general notes accompanying the Drawings or indicated on the Drawings. Precast members with inadequate cover shall be rejected and removed from Site.
Bars shall be spaced so that the minimum clear distance between them is the maximum nominal aggregate size plus five millimetres but in any case not less than the diameter of the bars.
Bars may be placed in pairs provided that there are no laps in the paired lengths.

4.5.3 Casting of Units

Concrete for precast units shall comply with Sub-Section 4, using the class of concrete specified on the Drawings. The concrete in each unit shall be placed in one operation.
The area in which units are cast shall be adequately protected from the weather so that the process is not affected by rain, freezing conditions, sun or drying winds.

4.5.4 Curing Precast Units

Requirements for curing shall be generally as set out in Sub-Section 4.

The Contractor shall ensure that units do not suffer any loss of moisture or sudden changes of temperature for at least four days after casting. If a water spray is permitted for curing, the water shall be at a temperature within 5°C of the temperature of the unit being cured.
If the Contractor proposes curing at elevated temperatures, the method shall be subject to the agreement of the Engineer and shall include means whereby units are heated and subsequently cooled evenly without any sudden changes of temperature.

4.5.5 Dimensional Tolerances

Units shall be accurately formed to the dimensions shown on the Drawings and within the tolerances set out in BS 8110 unless closer tolerances are called for elsewhere in the Contract.

4.5.6 Surface Finish

The formed faces of precast units shall be finished to Class F3 as set out in Sub-Section 3 unless another class of finish is specified on the Drawings.
Free faces shall be finished to Class U2 unless another class of finish is specified elsewhere.
In cases where a special finish is required a trial panel shall be constructed by the Contractor which after approval by the Engineer shall be kept available for inspection at the place of casting and production units shall thereafter match the approved pattern.
Surfaces of precast units against which concrete is to be placed shall have an exposed aggregate finish.

4.5.7 Handling and Storage of Units

Precast units shall be handled in a manner which will not cause damage of any kind and shall be stored on a hard, impermeable base. Precast units shall be handled and stored so that no stresses shall be induced in excess of those which they will incur in their final positions in the Permanent Works unless they have been designed to resist such stresses.
Units shall be provided with adequate lifting holes or loops, placed in the locations shown on the Drawings or agreed by the Engineer and they shall be lifted only by such holes or loops. Units are to be indelibly marked to indicate the final orientation. Where it is not possible to provide holes or loops, suitable sling positions shall be indicated in paint on the units.
Units shall be marked indelibly with the reference number and date of casting and shall be stacked on suitable packers which will not damage the concrete or stain the surfaces. Reference numbers shall correspond with those shown on placing plans and shall be clearly visible after the unit has been fixed in place. Not more than two packers shall be placed under each unit and these shall be located either at the positions of the permanent support points or in positions such that the induced stresses in the unit will be a minimum.

4.5.8 Purchased Units

If the Contractor proposes to purchase precast units from a supplier, he shall ensure that such units comply with the requirements of the Specification and shall carry out any tests which the Engineer may require to check compliance. The Contractor shall provide free facilities for the Engineer to inspect the manufacturer's premises.
Units shall not be obtained from any supplier who refuses free access by the Engineer to the factory to inspect and test materials and workmanship.

4.5.9 Testing Units

Precast units shall be capable of safely sustaining the loads which they have been designed to carry. If instructed by the Engineer, the Contractor shall subject units selected by the Engineer to load tests simulating the working conditions. Details of such tests shall be agreed between the Engineer and the Contractor.
In the case of units subject to bending loads the test piece shall be supported at full span and a loading equivalent to 125% of the sum of the live and dead loads which were assumed in the design shall be maintained for one hour without the appearance of any signs of distress. The recovery one hour after the removal of load shall be not less than 75% of the full load deflection.
If the unit fails to meet the above requirements, further tests shall be carried out on two more units. If either of these fail the whole batch of units will be rejected.
If the Engineer so requires, a test to destruction shall also be carried out which on units subject to bending shall be as follows:

i. The unit shall be supported at full span and a load applied in increments instructed by the Engineer up to 95% of the designed ultimate load. This load shall be held for 15 minutes without failure of the unit. The deflection at the end of this period shall be not more than 1/40th of the span. The load shall then be further increased until failure occurs.

ii. If the unit fails to sustain the required load for the prescribed period or if the deflection exceeds the specified amount, the Engineer may order two further tests, and if either of these fail, the batch of units which they represent may be rejected.

4.6 CONCRETE ANCILLARIES

Concrete inserts for the support of cabling, pipework etc. shall be formed from proprietary units approved by the Engineer and formed from hot dip galvanised steel.

4.7 STANDARDS

The following international standards are applicable for Works covered by this Section of the Specification.

BS 1088	Marine Plywood
BS 1200	Specification for Building Sands from Natural Sources
BS 1370	Specification for Low Heat Portland Cement
BS 1377	Methods of Test for Soils for Civil Engineering Purposes
BS 146	Specification for Blastfurnace Cements with Strength Properties Outside the Scope of BS EN 197-1
BS 1881	Testing Concrete
BS 2499	Hot-applied Joint Sealant Systems for Concrete Pavements
BS 2640	Specification for Class II Oxy-acetylene Welding of Carbon Steel Pipework for Carrying Fluids
BS 3837	Expanded Polystyrene Boards
BS 3892	Pulverized Fuel Ash
BS 4027	Specification for Sulfate-resisting Portland Cement
BS 4254	Specification for Two-part Polysulphide-based Sealants
BS 4449	Specification for Carbon Steel Bars for the Reinforcement of Concrete
BS 4482	Specification for Cold Reduced Steel Wire for the Reinforcement of Concrete
BS 4483	Steel Fabric for the Reinforcement of Concrete
BS 4550	Methods of Testing Cement
BS 4840	Rigid Polyurethane (PUR) Foam in Slab Form
BS 4887	Mortar Admixtures
BS 5075	Concrete Admixtures
BS 5224	Specification for Masonry Cement
BS 5268	Structural Use of Timber
BS 5328	Specification of Concrete
BS 5975	Code of Practice for Falsework
BS 6213	Selection of Construction Sealants
BS 6699	Specification for Ground Granulated Blastfurnace Slag for Use with Portland Cement
BS 7123	Specification for Metal Arc Welding of Steel for Concrete Reinforcement
BS 7973	Spacers and Chairs for Steel Reinforcement and their Specification
BS 7979	Specification for Limestone Fines for Use with Portland Cement
BS 8004	Code of Practice for Foundations
BS 8007	Code of Practice for Design of Concrete Structures for Retaining Aqueous Liquids
BS 8110	Structural Use of Concrete

BS 812	Testing Aggregates
BS 8666	Specification for Scheduling, Dimensioning, Bending and Cutting of Steel Reinforcement for Concrete
BS 882	Specification for Aggregates from Natural Sources for Concrete
EN 1008	Mixing Water for Concrete
EN 1097	Tests for Mechanical and Physical Properties of Aggregates
EN 12350	Testing Fresh Concrete
EN 12390	Testing Hardened Concrete
EN 12620	Aggregates for Concrete
EN 196	Methods of Testing Cement
EN 197	Cement
EN 206	Concrete – Specification, Performance, Production and Conformity
EN 480	Admixtures for Concrete, Mortar and Grout – Test Methods
EN 932	Tests for General Properties of Aggregates
EN 933	Tests for Geometrical Properties of Aggregates
EN 934	Admixtures for Concrete, Mortar and Grout
EN 998	Specification for Mortar for Masonry

marking of the corrected or revised items.

a. *Insertions, Supplements*

Insertions or supplements shall be accompanied by a new respective "Table of Contents" page, where the latter shall be handled as described above under replacements.

Revisions and supplements requested by the Engineer shall be made by the Contractor at the Site as far as possible, and shall be submitted in each case to the Engineer for checking and revision as stated above.

Before the Taking-Over Certificate can be issued, the revised copies of the Operation and Maintenance Manual shall be submitted together with the specified number of complete sets of drawings of the Works as completed. The Works shall not be considered complete for purposes of taking-over under the terms of the Conditions of Contract until the above documents have been supplied by the Contractor.

ed on the pump so as to be easily readable. The reading shall be directly in metres of water. The gauges shall be the oil filled type and shall be provided with an isolating cock. Each pump shall have the required provisions for the installation of the necessary sensors to supply the operating data for the instrumentation and control system.

All drainage pipe work for gland bowls and air release cocks shall be chromium plated copper tubing to BS 2871 and fed to a common collecting tundish mounted on the pump/motor bedplate.

d. Documentation and Tools

The Contractor shall submit three complete copies of the following documentation with each pump and motor set:

i) Operating and maintenance instructions

ii) Works manuals

iii) Spare parts and price lists

iv) Circuit diagram.

The Contractor shall provide a complete and comprehensive set of tools with each pump and motor set, including special tools, as required for the following:

- routine maintenance of the pump/motor set
- carrying out a complete overhaul of the pump/motor set.

METAL WORKS

5 METAL WORKS

5.1 GENERAL

5.1.1 Scope

The work required under this Chapter includes doors and windows in buildings, gratings, hand-railings and miscellaneous non-structural metalwork and shall be in accordance with British Standards.

The Contractor shall supply all the metal, ironmongery, paints and auxiliary materials required, shall manufacture the metalwork and shall install them in the required positions and paint them - all in accordance with the Drawings and the Specification, or as directed by the Engineer.

Alternatively, the Contractor shall supply and install standard factory-made elements, approved by the Engineer. Such elements shall also meet all requirements of this Division.

Steel for doors, windows and other metalwork shall be new, first-grade quality mild steel, without mill defects, cracks, grooves or rough surfaces and shall comply with all requirements specified on the Drawings and/or in the Particular Specification.

Hardware, metal fittings and accessories

These elements shall comply with standards and be of first grade quality and approved manufacture. They shall be carefully installed, all notches having the required sizes and depths so as not to impair the solidity of rolled sections.

5.1.2 Metalwork

All shapes, bars and plates shall be cut, drilled, bent and otherwise worked to the exact lines and dimensions shown on the Drawings. All burrs resulting from cutting and drilling shall be neatly removed. Where cutting is done by oxyacetylene torch, cut surfaces shall be clean and smooth.

Hinges and locks shall be secured by means of metal-screws for any eventual unmaking. Other accessories may be welded. Unless otherwise specified, bolts, casement bolts, locks, etc, shall be mortised. Hinges shall be solid and of quantity corresponding to door leaves size and weight. They shall have the exact required sizes and allow an easy setting and replacement. Locking devices such as locks, buttons, crutch handles, bolts, etc.. shall immobilize totally the door leaves in closed positions.

Metal fittings are integral parts of each door or hatch even when not explicitly stated in the work description.

The Contractor shall take on site all dimensions deemed necessary for metalwork and remain wholly responsible for their good adaptation to the concrete and masonry works in the building.

Jointings shall be notched and angles mitred. Electric welding shall be as continuous as possible along the joint after filing the metal elements.

After soldering, burrs and slags shall be trimmed completely. Holes shall be drilled by means of an electric drill fitted with a bit having a smaller diameter than the hole, then with another having the same diameter as the hole.

Distances between holes shall be as follows:

- Distance between hole edge and section edge ≥ hole diameter
- Distance between axes of two consecutive holes ≥ 3 × hole diameter
- Axes of aligned holes : a size margin equal to one tenth the hole diameter
- Irregularities in distance between holes $\leq \frac{1}{10} \times$ hole diameter.

The Contractor shall supply and install any material whether specified or not on the Drawings, but necessary for the good execution of the works.

<u>Surface finishing</u>

Surface finishing of works shall be in strict accordance with the General Technical Specification and shall include the protection of materials and the surface treatment.

Exposed surfaces shall have no unevenness, burrs, or metal run-out. Salient angles and projecting parts shall be rounded off. Welds shall be carefully ground. Screws shall be inserted and then painted. Accessible bolts shall be covered. Element showing appearance or assembly defects shall be rejected. It is expressly forbidden to cover and hide these defects.

Protection of metals against corrosion

No metal part shall be accepted on site unless previously protected against corrosion. Elements shall be in-factory protected according to relevant applicable standards. Unprotected iron parts shall be painted after removal of calamine, rust, and oil, with a rust proof zinc chromate paint, 60 microns thick, compatible with the top coat specified in the relevant Section (or eventually with two coats of red lead). Immediately after installation, any painted surface showing imperfections due to impacts or handling shall be wire brushed and repainted.

Contact between differents metals

All measures shall be taken to avoid electrolytic corrosion caused by the contact between metal parts and accessories (screws, bolts, washers, etc ...) of various natures.

Greasing

Upon the completion of works, the Contractor shall grease all mobile metal fittings such as hinges, locks, etc ...

5.1.3 Workmanship

5.1.3.1 Manufacture

Details and profiles shown on the Drawings constitute the basic Drawings. Works shall be solid, rigid and have a perfect finish. The components shall be one-piece. Connections shall be right-angled in such a manner as to resist, without deformation nor rupture, mechanical tests and the efforts imparted to them.

Jointings shall be notched and angles mitred so that sections join at right angles without overlapping. Welding shall be continuous along the joint after bevelling the metal. Holes shall be drilled by means of a drill fitted with a bit having the same diameter of the hole. Elements shall be cleaned of all slag and burrs.

5.1.3.2 Assembly

Metalworks shall be fixed to their support (concrete and masonry works, partitions) by welded inserted plates, holdfasts, screws and expansion bolts or any other approved system. The use of a stud gun SPIT is prohibited. Anchor bolts shall only be used in concrete works or hollow blocks masonry; only traditional anchoring means are permitted for other surfaces.

Anchors shall be screwed, bolted or welded on locks. Their section, shape, length and number are conditional upon the element sizes and installation conditions.

Fixing devices proposed by the Contractor shall be shown on shop Drawings. Fixing devices shall be placed close to hinges in order to diminish stresses.

All welding shall be done by the shielded electric-arc method by experienced welders, to the highest standards of workmanship and to the satisfaction of the Engineer. Electrodes for steel welding shall be of a kind and class approved by the Engineer. All surfaces of parts to be welded shall be well cleaned of dirt, rust, slag, and paint. All slag and splatter adhering to metal shall also be removed.

5.1.3.3 Installation

Prior to installation, the Contractor shall wedge and adjust the different elements so as to ensure perfect plumb, alignment and levelling.

He shall ensure all required sealings and caulkings for fixing the works. He shall set out all his works and verify the location of openings left in the structure.

5.1.3.4 Tolerances

a) Tolerance on setting out

Maximal variation between the real position of each axis of metalwork and each axis of an opening in a wall shall not exceed 1 cm.

b) Tolerance on installation

Rectitude and plumb errors in door frames, stiles, and posts shall not entail a deviation exceeding 2 mm, provided that stiles and posts be parallel to ± 2 mm in all points and planes.

Rectitude and levelling errors in crosspieces shall not exceed 2 mm for the first meter and 1 mm for each additional meter with a maximum of 4 mm.

c) Tolerances on leaves play

The play between leaves and the finished ground shall vary between 5 and 10 mm regardless of the opening position.

d) Sealing

Air and watertightness between the structure and the metalworks shall be ensured by stable and 10 year guaranteed sealants. They shall be easily replaced. The unit rates of metalwork shall include the cost of all sealants.

5.1.3.5 Handling and storage

Unloading and handling of elements shall be done without causing any permanent deformation or defect that might impair the good functioning of mobile parts, or their resistance to corrosion.

Elements shall be stored in dry premises on appropriate horizontal and vertical devices avoiding any deformation whatsoever.

5.1.3.6 Samples and mock-ups

Samples of hardware to be used shall be as shown on Drawings.

Prior to any serial manufacture, a mock-up of each type of work shall be submitted for approval, namely:

- Ventilation grilles
- Handrails
- Guard-rails
- Protection bars
- Etc ...

The Contractor shall submit to the satisfaction of the Employer all varnish samples.

5.1.3.7 Locks

Locks shall be supplied with 3 keys bearing each a permanent label indicating the premises they are intended for. The loss of a key on the day of taking over entails the changing of the relevant lock at the cost of the Contractor. Prior to installation, all types of locks shall be submitted to the Employer for approval. The outside locks shall be resistant to atmospheric conditions.

5.1.3.8 Sections, painted wrought iron

Hatches, balustrades, guard-rails, angle-irons for antennas, handrails, stiles, posts and crosspieces, rungs, ladders, etc, ... shall be made of sectional irons, flats, pipes, etc ... and have the dimensions shown on the Drawings. Works shall be carried out according to the above-mentioned specifications. Paint shall be consistent with the specifications mentioned in the relevant Section.

5.1.3.9 Ladders

Ladders shall be of galvanized tubes or sections to the dimensions shown on the Drawings. They shall be painted according to the relevant Section.

Ladders shall be fixed to the upper platform and to the floor taking into account all works to be performed under other Sections (ex: waterproofing works, ...) as well as all above-mentioned conditions. Where specified, ladders shall be fitted with safety hoops.

5.1.3.10 Metal shutters

Rolling shutters with fastened metal blades shall be of cold-rolled and galvanized steel, with a minimum thickness of 7/10 mm, with lateral bolting of each blade. The steel curtain should withstand without deformation a load of 400 kg/m^2.

Scroll axes, gears, winches, etc ... shall be of stainless metals or metals that are especially treated against rust by galvanization or any other approved process.

Guide bars shall be hot-rolled and galvanized channel irons of 30 mm minimum depth and embedded in the masonry or the concrete.

Operation shall be by winch and built-in crank, with a lock system constituted of six-turn brass lock with 35 cm cylinder. The scroll axis shall be fitted with springs that balance the curtain at any height.

The shutter case shall be of galvanized sections and 7/10 mm sheets with all necessary reinforcement to ensure a perfect rigidity and easy dismantling and maintenance. Components shall be galvanized, coated with an epoxy primer and painted, as specified in the relevant Section.

5.1.3.11 Glazing

All sheet glass shall be of approved manufacture, and samples shall be submitted to the Engineer for approval prior to ordering. Labels shall remain on the glass until final clean-up. Putty shall be of the best quality available and shall be suitable for wood or steel sash glazing as required.

Glass, except where glazing beads are provided shall be back-puttied and face-puttied. In wood sash, the glass shall be secured with metal glazer's points; in steel sash, with metal clips. where glazing beads are provided, the glass shall be bedded.

The sizes of panes indicated on the Drawings are approximate, and the final sizes of panes shall be taken from the actual frames.

Putty shall be neatly and cleanly run in straight lines even with edges of sash members, with corners carefully made. Glazing beads shall be carefully removed and re-set, using every precaution to avoid marking or defacing.

Glass louvre blades shall be accurately cut to the sizes required and to the widths specified by the manufacturer of the blade holder. The edges of the blades shall be cut perfectly straight and then ground to produce a smooth slightly rounded edge and the blade firmly secured in the clips of the louvre holder.

Prior to final inspection, all broken, cracked, or imperfect glass shall be removed and replaced. All glass shall be washed, cleaned, and polished on both sides prior to final inspection.

5.1.4 Miscellaneous metalwork

Miscellaneous metalwork shall comprise grating, handrailing, hatches and other metal parts as shown on the Drawings or directed in the Particular Specification. The work shall be carried out to the exact details shown on the Drawings, to the highest standards of workmanship and to the satisfaction of the Engineer.

5.1.5 Methods of measurement and payment

Metalwork shall be measured either by number, according to type, size, etc. or by square meter, or by kilogram, all as shown on the Drawings and/or as specified. Each unit rate shall include for the manufacture, supply, transport, handling, fixing, glazing ironmongery, painting, and anodizing, and for all materials, equipment and labour necessary for the completion and installation of all metalwork item in accordance with the Drawings and the Specification and to the Engineer's satisfaction.

ELECTROMECHANICAL

6 ELECTROMECHANICAL

6.1 GENERAL

6.1.1 General Requirements

The Contractor shall carry out all work in a skilled and workmanlike manner in compliance with modern methods of engineering. All design, calculations, materials, Plant, manufacture and testing shall conform to the latest applicable standards.

In addition, the Contractor shall conform to all applicable regulations regarding the execution of construction and installation work, and shall follow all related instructions issued by the Engineer or by the competent Authorities under the applicable law.

The Contractor shall prepare the detailed design, construction and installation drawings as well as calculations, material specifications, operating and maintenance instructions etc. as detailed in the Particular Mechanical and Electrical Specifications.

The Contractor shall manufacture, supply, install, test and commission the Plant complete in every respect with all necessary accessories for reliable continuous operation, even if not all details are expressly stated in the Specifications.

These Specifications include the performance of all work and the provision of all materials, permanent and temporary equipment, tools, accessories for transport to the Site, including loading, unloading, if necessary reloading in the port of arrival, intermediate storage, protection of the Plant from the effects of the weather, cleaning, drying, complete installation, painting, testing and commissioning of all Plant and accessories of the Plant.

The Contractor shall make available competent and experienced staff for the training and assistance of the Employer's operating staff during commissioning and trial run operation and for a period after completion of the trial run operation as detailed in the Particular Specifications.

6.1.2 Standards

Although European or International Electro-technical Commission (IEC) standards for workmanship, materials and Plant have been selected generally in these Specifications as a basis of reference, other standards and recommendations of standard international organisations will be acceptable provided they ensure equal or higher quality than those specified, and provided furthermore that the Contractor submits in advance for approval complete copies of the detailed standards which he proposes to use.

Except where modified by this Specification, Plant and materials shall be in accordance with European and IEC Standards. If relevant European and IEC Standards are not available in any specific case then relevant National Standards may be proposed by the Contractor for approval by the Engineer.

When European or IEC or National Standards are referred to, the edition of any such standard shall be that current at the time of issue of Tender Documents, including all Amendments thereto issued up to that date. A list of National Standards for Plant not complying with the above which the Contractor proposes to be used in the manufacture and construction of the Plant shall be submitted by the Contractor in his Tender.

If requested by the Engineer the Contractor shall supply at his own expense three copies in English and one in the original language of any National Standards which are approved by the Engineer and are applicable to the Contract.

6.1.3 Time Schedule

The Programme shall give the details of the following individual activities:

- design work
- shop work
- procurement
- transport to the Site
- preparations on the Site
- erection and commissioning
- trial operation
- removal of erection equipment and clearing of Site.

The Contractor shall be responsible for ensuring that the information on the Plant necessary to finally and completely define the associated civil works is provided in sufficient time and detail to enable the civil work execution drawings to be produced to meet his programme for this section of the work.

6.2 TECHNICAL DOCUMENTS

6.2.1 General

The documents which shall be delivered by the Contractor to the Engineer have been listed in Appendix B: Required Documents for Electrical and Mechanical Plant Installation , however the Engineer reserves the right to request from the Contractor additional documents as may be required for the proper understanding and definition of constructional, operational, coordination or other matters.

All documents to be supplied shall be submitted in accordance with the agreed programme so that any comment and change requested by the Engineer can be taken into account before starting of the manufacture in the workshop and/or erection or installation at Site.

If the Contractor fails to submit such documents, then the later execution of changes requested by the Engineer and the resulting additional cost and/or delays shall be the Contractor's responsibility. The Contractor shall not be released from his responsibility and guarantee after drawings and computations have been approved by the Engineer.

The preparation of drawings, computations or other technical documents shall not be sublet by the Contractor without the written authorisation of the Engineer. In such a case the Contractor shall be fully responsible for such drawings, computations and other technical documents as if they were done by himself.

On drawings, catalogue sheets or pamphlets of standard Plant submitted to the Engineer the applicable types, paragraphs, data, etc., shall either be marked distinctively or the non-applicable parts shall be crossed out. Documents not marked in such a manner will not be accepted or approved by the Engineer.

If required for proper understanding of the documents, additional descriptions/ explanations shall be given on these documents or on separate sheets. All symbols, marks, abbreviations, etc., appearing on any document shall clearly be explained by a legend on the same document or on an attached sheet.

Each device appearing on any document (drawing, diagram, list etc.) shall be clearly designated. The abbreviation mark used for an individual device shall be identical throughout the complete documentation in order to avoid any confusion. All documents shall have a uniform title block as agreed by the Engineer, irrespective of the origin of the document, provided with an approved identification number.

Revised technical documents replacing previously submitted documents shall be marked accordingly. The revised part in the Document itself shall be marked clearly. Documents are to be supplied either "FOR APPROVAL" (A) or "FOR INFORMATION " (I), respectively.

Any comment given by the Engineer on an "I" type drawing shall have the same effect as if it were given on an "A" type drawing.

6.2.2 Drawings

6.2.2.1 Arrangement Drawings

All arrangement drawings shall be drawn to scale. The General Arrangement Drawings shall show the physical arrangement of Plant (machines, complete switchgear, control panels, instrument cubicles etc.), civil constructions (buildings, rooms, foundations, ducts etc.) and reserved areas (for pipes, cables, lines etc.) in relation to each other.

The Arrangement or Layout Drawings of electrical and instrumentation and control equipment shall indicate the location of all apparatus wherever used, i.e. in or on machines, control boards, switchboards, cubicles, control desks and panels etc. The apparatus shall be denominated with the same standardised abbreviations as used in all other documents.

6.2.2.2 Dimension Drawings

The Dimension or Outline Drawings shall show all elements and the main dimensions of individual components where necessary with plan, section, side and top views. Wherever reasonably possible such dimensions can be shown on the Arrangement Drawings.

6.2.2.3 Design Drawings

The Design Drawings shall include the shop drawings, assembly drawings, erection and installation drawings, piping diagrams and piping arrangement drawings etc, showing the dimensions, design and data of all apparatus and Plant to be furnished under this Contract.

6.2.3 Diagrams

For electrical diagrams general reference is made to IEC 60113-1.

6.2.3.1 Single Line Diagrams

This is a simplified diagram of the essential electrical Plant and their interconnections. Each circuit shall be represented by a single line only. It shall contain all required technical information of the Plant represented, e.g. voltage, capacity, short circuit level, ratios, voltage variations, positive and zero sequence impedances, measuring transformer and protection relay indices, interlockings, type of switch drive, code designation, etc.

Single line diagrams of individual main components and switchboards shall additionally show the control, indicating, measuring, metering, protection, automatic, and other auxiliary electric devices (including rheostats, hygrostats, cable end boxes etc.), separated for each individual installation site and location as applicable:

a) Local

Switchboard control compartment, switch compartment, cable termination compartment, etc.

b) Remote

monitoring/control room (in control panel, control desk)

unit control panel

separate energy meter cubicle.

The applied recommended setting of adjustable devices (protection and control elements, time relays etc.) shall also be indicated.

6.2.3.2 Circuit Diagrams

The Circuit Diagrams shall show the power circuits in all phases with the main apparatus as well as the pilot circuits (measuring and control circuits). It shall show in full the functioning of part or all installations, Plant or circuits with all required technical information.

The control part shall be subdivided into separately drawn "current paths", each showing all its components regardless of their actual physical location. The individual circuits are to be drawn in a straight line sequence, avoiding line crossings. The current paths (to be designated by numbers) shall be drawn starting from two horizontal lines which represent the control voltage source. All devices belonging to the Plant or forming part of the Plant or control devices shall appear between these two lines.

Contact developments of the installed switches, contactors, relays and other apparatus which appear in the diagram shall be shown below the respective contactor coil, indicating by means of numbers (and, if not on the same diagram sheet, also the diagram sheet No.), the current path in which the corresponding contact has been used.

Interconnections to other circuit diagrams shall be clearly marked by means of dotted line separations and the corresponding functional designation.

The power circuit portion of the installation shall be drawn at the left side of the drawing.

Circuit diagrams shall also contain all terminals and their correct designations. Terminals grouped together to terminal blocks of switchboards, distributors, etc. shall be shown on the circuit diagrams in one fictitious horizontal line surrounded by demarcation lines. If for any reason the current paths of circuit diagrams must be separated, the corresponding counter terminal has to be indicated by all means.

The representation of electrical Plant and control circuits shall not be terminated at the limits of the scope of supply, but has to be extended beyond this limit by all switchgear, protective, measuring and monitoring equipment required for full comprehension of the whole circuit. All terminals and functions of Plant to be supplied by others shall be taken over as well.

Standard Circuit Diagrams are patterns of circuit diagrams which have been standardised with regard to scope, arrangement, representation and allocation of Plant with the aim of simplification and easy surveillance of electrical circuitry.

6.2.3.3 Terminal Diagrams

Terminal Diagrams shall be prepared for any type of terminal box, marshalling rack, control cubicle, switchboard etc., and shall show the terminals (properly numbered) and the internal and/or external conductors (wires or cables) connected to them.

The terminal diagram of each individual switchboard, terminal box, panel etc., shall include, but not be limited to, the following information:

- terminal No. of terminal board with targets (terminal No. and current path) of incoming and outgoing cables and wires
- cable designation
- type of cable
- number and cross sections of conductors

- assignment of conductors
- number of spare conductors
- approximate length of cable and its destination.

6.2.3.4 Protection Coordination Diagrams

Protection Coordination Diagrams shall show in a graphical manner separately for each power supply circuit the following:

- a simplified single line diagram of the circuit with technical data of all instrument transformers and relays
- coordinated tripping curves of related protection devices
- setting of the protection devices.

6.2.4 Material or Plant Specifications

6.2.4.1 General

Material or Plant Specifications shall be prepared for all principal Plant and installations. They shall describe the performance (design, construction, material, dimensions, corrosion protection etc.) of the Plant and include a parts list detailing the manufacturer, type and all technical data, in order to provide:

- full information on the Plant, completing and updating the information required for and provided in the Tender Schedules by the general information and technical data of the actual specific manufacture;
- proof of compliance with all the requirements of the Specification.

The technical data provided for electrical Plant shall include as a minimum the following:

i. maximum and minimum permissible ambient conditions (temperatures, humidity)
ii. rated current and rated output/capacity
iii. rated current and rated output/capacity under specified severest site conditions
iv. rated voltage and ratio or regulation/setting range
v. maximum service voltage (according to IEC)
vi. power frequency and impulse withstand voltages
vii. short time (1 second) current rating and design fault currents as maximum dynamic (subtransient), peak and breaking current
viii. ratio, burden and accuracy of measuring transformers and transducers

ix. type and code No. of protection relays and of instantaneous or thermal releases directly attached to circuit breakers and contactors

x. power requirements for each voltage level (AC/DC).

6.2.4.2 *Motor Specifications*

The Motor Specifications shall include the thermal motor characteristic both for cold and hot condition, the start-up characteristic when running with the driven machine, and all data required for selection of the appropriate motor protection relay (both for cold and hot condition) and for locked rotor protection. Construction type, class of protection and insulation shall also be given.

6.2.4.3 *Cable Specifications*

The General Cable Specifications shall include the calculation of the derating factors for the individual modes of installation at applicable ambient temperatures and grouping of cables, and in addition for each cross section:

i. the rated current carrying capacity

ii. the maximum short circuit capacity

iii. the voltage drop

iv. type, insulation serving, armouring and sheathing of cable

v. type, description and catalogue/pamphlet of cable termination.

vi. Separate specification(s) shall be prepared for cable trays, conduits, supporting structures and other accessories.

6.2.4.4 *Measurement and Control Apparatus*

The accuracy of performance with respect to variable ambient conditions and the power supply requirements shall be included in the data provided by the Contractor.

6.2.5 *Lists and Schedules*

The Tender Schedules which are required to be submitted with the Tender shall include detailed information on the Plant and equipment proposed to be supplied as well as the lists of spares, tools etc. These Tender Schedules shall be completed in full as part of the Tender and may be accompanied by additional material if considered to be necessary or relevant.

At the time of Tender the Employer may require the submission of additional information if in his opinion the information submitted on the Tender Schedules is insufficient to describe the Plant and equipment being proposed.

No Plant or equipment which deviates from that described in the Tender Schedules shall be subsequently provided without the specific written approval of the Engineer. The selection of Plant or equipment which corresponds with that described in the Tender Schedules shall still be subject to the prior approval of the Engineer.

6.2.6 Calculations

When specified or requested by the Engineer, design calculations, diagrams and operating data etc. shall be submitted to the Engineer including all the formulae, standards, test results, basic assumptions etc. used for these calculations. Submission of only the results of the calculation shall not be accepted.

6.2.6.1 Short Circuit Calculations

The short circuit calculations shall be performed in accordance with the VDE Standard 0102: Part 1. Wherever applicable the following maximum values for Plant layout and maximum and minimum values for protection system layout shall be calculated for the individual Plant components:

i) initial symmetrical short circuit capacity S"K (3) and current J"K (3)

ii) symmetrical breaking capacity SA (3) and current JA (3)

iii) peak asymmetrical short circuit current JS (3)

iv) sustained short circuit current JK (rms) (3).

Also the following values shall be calculated for solidly or partially earthed network systems:

v) maximum single pole short circuit current J"K (1)

vi) maximum earth fault current JE as determined by the earthing resistance RE

vii) maximum contact voltage as determined by the values as stated above.

The impedance values of the network elements shall uniformly be calculated by taking one of the following reference values as basis:

- reference voltage, impedance expressed in Ohm/phase
- reference power, impedance expressed in p.u.
- no reference, impedance expressed in %/MVA.

For impedance values of network elements, the design figures as stipulated in the Technical Schedules shall be taken as the basis. If tolerances are agreed upon, then the permissible minus tolerance is to be applied. The variations of transformer impedance values caused by the position of the tap changer is to be considered in case this variation exceeds -5 % of that value as stated for the middle position.

The contribution of motors for determination of the total values of S''K(3) and SA(3) shall be as follows:

a) In MV systems: in accordance with VDE 0102, considering a further 30% spare capacity in excess of the actually planned total motor power.

b) In LV systems: for determination of SK'' (3) – six times (6 x) the transformer rating of the pertinent switchboard;

for determination of S_A (3) – the individual contribution of motors rated 50 kW and above is to be calculated as defined in VDE 0102.

Since in AC power systems the initial symmetrical short circuit current J''K resulting from the short-circuit capacity S''K will decay according to its DC component and the ratio of J''K/JK, this current is to be converted into a mean value of equal effect for a given duration according to the following formula:

$$J_K \, mean \; (3) \; = \; J''_{K(3)} \, V \, m \; + \; n$$

The values of m and n shall be taken from the graphs contained in VDE 0103 / DIN 57103.

This figure is to be marked out for comparison in all such cases in which the current carrying capacity for a certain duration has been stipulated as a design figure of electrical components.

6.2.6.2 <u>Earthing Network Calculations</u>

The Earthing Network Calculation shall determine, on the basis of the short circuit currents, the relevant design criteria for the layout of the Plant's earthing network and the potential gradient control system, such as:

- earthing resistance
- earth electrodes or conductors (number and dimensions)

- mesh network and other means for potential gradient control for different locations (mesh widths and dimensioning)
- maximum contact and step voltages.

6.2.6.3 Load Evaluations

The load evaluations shall demonstrate for each voltage level (AC and DC), and for each individual distribution board/MCC, the following data:

i) rated capacity of all consumers;

ii) maximum number of identical consumers which can operate simultaneously;

iii) total electric demand in kVA and the power factor at nominal service of the driven machine, subdivided into

- start-up
- rated service
- shut-down
- stand still.

The maximum load on one of the MV or LV auxiliary supply transformers shall be determined with due consideration of the most unfavourable condition when feeding, especially in case of emergency, several main and subdistribution boards.

6.2.6.4 Selection of LV Breakers and Minimum Cable Cross Sections

Information shall be required to prove the correct application of LV breakers, and where required of s.c. current limiting devices.

The minimum size of cable connections shall be calculated applying the maximum admissible temperatures and ratings (continuous and s.c. conditions).

The results shall be presented in the form of a table which shall include at least the following:

i) the maximum initial symmetrical s.c. current upstream and downstream of the switchgear (breaker/fuse)

ii) the breaker setting range

iii) the let-through current

iv) the resulting minimum cable cross section

v) the applicable standard cross section.

6.2.6.5 <u>Water Hammer Calculations</u>

Pipelines shall be protected from the effects of water hammer during pump start-up, pump shut-down and in the event of power failure or operation of isolating valves.

The Contractor shall carry out his own independent complete water hammer analysis of the pipeline system associated with each pump station, and shall submit his detailed results for the written approval of the Engineer before commencing the manufacture or supply of any components of the system.

In the event that pressure vessels are found to be required and are approved by the Engineer, they shall be sized to protect the pipelines from any positive pressures likely to damage the pipe and to limit negative pressures to less than - 5.0 m under the conditions of the worst case of total power failure whilst all pumps are operating.

The Contractor shall provide all necessary pipework, valves, level controls and fittings associated with the provisions for protection against water hammer.

6.2.7 Operation and Maintenance Manuals

Five printed/plotted and bound copies of all Operation and Maintenance Manuals are to be provided, including all relevant brochures, pamphlets etc. from the manufacturers, together with three full copies of the electronic versions of all files.

6.2.7.1 <u>Contents</u>

The Operation and Maintenance Manuals shall contain the following information in sufficient detail to enable the Employer to maintain, dismantle, reassemble, adjust and operate the Plant with all its systems, components and installations:

i) Table of Contents

ii) List of Illustrations

iii) Introduction:

The introduction shall contain:

- a brief general description of the Plant items
- a brief description of the operation and use of the Plant items
- definitions of technical terms used.

iv) Detailed Description:

The detailed description shall contain a complete and accurate description of the Plant, all components and ancillaries, their assembling and dismantling. An accurate list stating clearances, tolerances, temperatures, fits etc. shall be included.

v) Operating Principles and Characteristics:

The principles and characteristics shall include a brief summary of the technical operating principles of the Plant, including diagrams, circuit diagrams, sequence diagrams, piping, etc.

vi) Operating Instructions:

The operating instructions shall be accurate and easy to understand, and shall contain the detailed sequence of individual manipulations required for operation. The information shall be presented in such a manner that the contents of this section can be used for instructing personnel in the operation of the Plant. Tables, lists and graphic presentations should be used whenever possible for making the description readily understandable. An appropriate trouble-shooting list shall be included in this section.

vii) Testing and Adjustment:

The entire testing and adjustment procedure required for the Plant after overhauls and during operation shall be described.

viii) Maintenance Instructions:

This section shall be divided into five sub-sections:

a. Preventive maintenance, indicating the inspections required at regular intervals, the inspection procedures, the routine cleaning and lubricating operations, the regular safety checks and similar steps. The maintenance instructions shall include a tabular (or in other approved form) summary of the required activities sorted according to:

- daily, weekly, monthly
- quarterly, yearly

or other cycles as applicable.

This sub-section shall provide the maintenance engineer with a brief and yet fully comprehensive information including all references to the applicable detailed service and maintenance instructions.

b. Repair and adjustment, describing the inspections, fitting and dismantling of parts, and fault tracing, as well as repair and adjustment procedures.

c. Spare part lists, containing all the necessary data for ordering spare parts. These lists shall include all spare parts, both those to be supplied and those not to be supplied under the present Contract. The prices for spare parts shall be indicated in the list.

d. Tool lists, containing all necessary data for identification of tools to be delivered under the present Contract.

e. List of suppliers and alternative suppliers and their addresses/contact details.

ix) As-built drawings.

6.2.7.2 *Revisions and Supplements*

The completeness of the manuals shall be checked during installation, testing, commissioning and trial operation jointly by the Contractor and Engineer.

If it becomes evident during the installation, trial operation and guarantee period of the Plant that the Operation and Maintenance Manuals are inadequate or incorrect, the Contractor shall supply immediately the necessary supplements and corrections. This shall be handled in the following manner:

b. *Deletions*

One sheet of errata, printed on pink paper, shall be issued indicating the pages and date of issue of those pages which are to be deleted and are no longer valid.

c. *Correction, Revisions, Replacements*

New sheet or sheets shall be issued to replace the wrong pages. Whenever a new sheet is added to the instruction manuals, this sheet shall be given the new date of issue and a revision symbol, and an indication "Substituted for ... " and a marking of the corrected or revised items.

d. *Insertions, Supplements*

Insertions or supplements shall be accompanied by a new respective "Table of Contents" page, where the latter shall be handled as described above under replacements.

Revisions and supplements requested by the Engineer shall be made by the Contractor at the Site as far as possible, and shall be submitted in each case to the Engineer for checking and revision as stated above.

Before the Taking-Over Certificate can be issued, the revised copies of the Operation and Maintenance Manual shall be submitted together with the specified number of complete sets of drawings of the Works as completed. The Works shall not be considered complete for purposes of taking-over under the terms of the Conditions of Contract until the above documents have been supplied by the Contractor.

6.3 DESIGN AND MANUFACTURE

6.3.1 General Design and Construction Requirements

6.3.1.1 General

The following directions, information and technical requirements for layout, design and erection shall be observed as far as they are applicable to the Plant to be provided.

Wherever the Plant is proposed at Bid stage which deviates from these Specifications, the data called for in the Tender Schedules shall be furnished and a summary shall be given of and the reasons for each and every such deviation in the Schedule provided for this purpose in the Bidding Forms in Section 5 (if any). Failure to accomplish this may cause either the elimination of the Bid or the complete rejection of the proposed Plant during the Contract, especially when a major deviation is involved.

Any changes of the design of any part of the Plant which may become necessary after signing the Contract have to be submitted in writing to the Engineer for approval, being sufficiently substantiated and justified.

No additional payment will be made for any such changes to the design of the Plant unless the change affects a fundamental aspect or characteristic which defines the nature of the Plant and becomes necessary solely due to a change in the basic design of the Works under the Contract made by the Engineer after award of Contract.

The Plant shall be designed, manufactured, arranged and installed to provide functional design and neat appearance. All parts of the Plant shall be arranged to facilitate surveillance, maintenance and operation. All control sequences shall be simple and rational.

The parts of the Plant shall be designed and arranged so that they can be easily inspected, cleaned, erected and dismantled without involving large scale dismantling of other parts of the Plant. The Plant shall be designed and manufactured in accordance with the latest recognised rules of workmanship and modern engineering practice, and the regulations, standards and guidelines listed in these Specifications shall be observed.

All parts of the Plant shall be suitable in every respect for continuous operation at maximum output under the climatic conditions and operating conditions prevailing at the Site.

Special attention shall be given to Plant of which parts are delivered by different manufacturers. Problems arising in this conjunction shall be solved by the Contractor and be defined in writing.

For individual items of the Plant, materials and design are to be selected which are best suited for the operating conditions to which the parts in question will be subjected. Only such design and types of Plant shall be provided which has confirmed its reliability in long term continuous operation.

All live, moving and rotating parts shall be adequately secured in order to avoid danger to the operating staff. All electrical components shall be electrically earthed.

Manufacturers shall take appropriate measures to prevent the ingress of dust into any Plant (such as bearings, relays, control and measuring equipment, etc.) which may be endangered thereby.

Suitable lifting eyes and backing-out bolts shall be provided where required or where they will be useful for erection and dismantling.

Pockets and depressions likely to hold water shall be avoided, and if not avoidable they shall be properly drained.

Parts of the Plant principally intended for standby purposes shall be protected from corrosion by careful choice of material and, if necessary, by additional means. These measures should not reduce the continuous standby readiness of such Plant.

All design details and layout matters shall be discussed in periodic meetings with the Engineer. The first design discussion between the Contractor and the Engineer shall take place within 28 calendar days after Contract award. Further design meetings shall take place as agreed between the participants until the design work is completed.

6.3.1.2 Allowable Stresses

The layout of the parts of items of Plant shall fundamentally consider the most severe conditions to which they will be subjected during testing and operation.

The stresses which occur in a section of a part when subjected to the most severe operating conditions or test pressures shall not exceed 70 % of the yield point of the material of the respective part.

If different stress values are given elsewhere in the General Mechanical and Electrical Specification or in the Particular Specifications or in the relevant standards and regulations, then the most stringent values of these shall be applicable.

When complicated steel castings or welded parts are exposed to a pressure test, the maximum allowable stress limit of 70 % of the yield point may be exceeded locally in limited zones if these zones are small in extent and do not endanger the strength of the part. To check these stresses in the critical zones the Engineer may require strain gauges to be mounted during pressure tests.

In the design of the Plant, the maximum stresses due to normal operating conditions shall not exceed one third of the yield point or one fifth of the ultimate strength of the material, with the exception of safety elements which are designed to fail in the event of destructive overload thus preventing damage to other parts of the Plant.

Increased size or thickness, by at least 1 mm, is required for parts subject to corrosion or erosion and for parts mainly designed for rigidity.

The dimensions of the parts which are exposed to repetitive and alternating stresses as well as to impacts and vibrations shall take into account the safety measures approved in practice.

The calculations performed by the Contractor when dimensioning the main parts of the Plant shall be submitted to the Engineer at any time at the Engineer's request.

6.3.1.3 Standardisation of Plant

As a general principle and wherever reasonably practicable measures shall be taken to standardise parts of the Plant throughout the Plant in order to facilitate keeping stocks, maintenance, replacement, interchangeability, etc. This requirement shall especially be applicable to small mechanical and electrical Plant such as the following:

- small/medium size valves
- pressure gauges

- small/medium size flow meters
- terminals and terminal racks
- indicating instruments and meters
- auxiliary relays
- contactors, fuses, circuit breakers
- motor protection switches
- control devices
- lights, bulbs, plugs, sockets.

All instrument scales shall be written in English and in the international SI System of units.

6.3.1.4 *Quality of Materials and Plant*

No welding, burning, filling or plugging of defective castings or any other components shall be permitted without the Engineer's agreement in writing.

Any steel castings which have been repaired by welding with the consent of the Engineer shall be subjected (after the final heat treatment) to whatever crack detection, radiographic and/or gamma ray examination or any other tests which the Engineer may require. The cost of these and other additional tests shall be borne by the Contractor.

6.3.1.5 *Noise*

The noise level caused by the installed Plant shall not exceed 70 dB(A) at any place more than 1 metre from operating Plant.

6.3.1.6 *Identification Plates*

a. *General*
The identification plates shall be protected during erection and especially during painting. Damaged or illegible identification plates shall be replaced by new ones. The identification plates shall be of non-corroding, non-disintegrating material (except manufacturer's nameplates of small standardised components) and shall be inscribed in English.
The inscription may be printed, stenciled, or handwritten, but in any case shall be waterproof, oil-proof and wear resistant.

b. *Manufacturer's Nameplates*
The following data shall be shown in accordance with the relevant standards:
Manufacturer's name and address
Plant item's serial number and date of manufacture
Main design data.

As a general rule, standardised components, such as small or medium sized electric motors, transformers, instruments, etc., may be delivered with the manufacturer's standard nameplate.

6.3.1.7 *Colour Code*

The colour code system for electrical and mechanical Plant shall be as agreed by the Engineer.

The colouring of pipelines, moving parts etc. shall be according to internationally recognised standards such as DIN 2403 or equivalent. Pipes shall be entirely painted in the colour given for the marking of pipes according to DIN 2403, unless otherwise directed by the Engineer.

6.3.2 Workmanship

6.3.2.1 *Finished Surfaces*

Where the finish is not indicated or specified, the type of finish shall be that type which is most suitable for the surface to which it applies and shall be consistent with the class of fit required.

Surfaces to be machine finished shall be indicated on the shop drawings by symbols. Compliance with the specified surface shall be determined by the sense of feel and by visual inspection of the work compared to applicable "Standard Roughness Specimens", or with roughness feeler gauge instruments. Both "Standard Roughness Specimens" and feeler gauge instruments shall be procured by the Contractor at the request of the Engineer.

6.3.2.2 *Unfinished Surfaces*

As far as practicable all work shall be laid out to secure proper matching of adjoining unfinished surfaces. Where there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined to secure proper alignment.

Unfinished surfaces shall be true to the lines and dimensions shown on the drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts shall be filled in a manner approved by the Engineer.

6.3.2.3 *Protection of Machined Surfaces*

Machine finished surfaces shall be thoroughly cleaned of foreign matter. Finished surfaces of large parts and other surfaces shall be protected with wooden pads or other suitable means.

Unassembled pins or bolts shall be oiled or greased and wrapped with moisture resistant paper or protected by other approved means.

6.3.2.4 Roundings, Chamfers, Edges

The edges of surfaces to be painted shall be rounded (minimum radius 2 mm) or chamfered accordingly. This requirement must be stated in all shop drawings for the relevant parts.

6.3.3 Corrosion Protection

6.3.3.1 Scope of Work

The Contractor's services shall cover the procurement of all materials, and the preparation and application of the painting and other protective coats as specified, and all costs therefor shall be included in the Contract Price.

6.3.3.2 Painting Materials

The Contractor shall provide a complete, reliable coating system. Coating materials shall be standard products of a paint manufacturer with proven experience in the field of corrosion protection of the type of Plant to be supplied.

The Contractor shall submit for the Engineer's approval full details of the preparation, type of materials, methods and sequences he proposes to use to comply with the requirements for the protection of the structures, machinery and Plant.

With regard to materials, the Contractor shall submit full details including the source of the basic raw materials, volatile matter content, nature of solvent, number of components, type of coat, coverage, time interval between coats and number of coats, compatibility of each coat with the previous coat, toxic properties, physical properties, shelf life, resistance against chemical attack, resistance against ozone and UV radiation, compatibility with drinking water standards, etc.

The Contractor shall describe in detail the treatment he proposes to apply in order to give adequate protection during transport, site storage, building and concreting and subsequent erection.

The different coats of primer and subsequent coats shall be each of different shades of colour where practicable.

All pigment, paints and primers shall be delivered to Site in sealed containers packed by the manufacturer. The manufacturer's instructions for preparation and application of all painting and protective coats shall be strictly observed.

6.3.3.3 Painting Systems

Appendix A "Paint Systems" to this Section indicates painting materials considered suitable for the various parts of the Works.

Details of the manufacturer and identification of the any product proposed by the Contractor as an equivalent shall be included in the Bid and shall remain subject to the approval of the Engineer.

6.3.3.4 Surface Preparation

The term "preparation", as used below, includes any cleaning, smoothing or similar operations that shall be required to ensure that the material to be painted attains a suitable condition.

To be ready for painting, a surface should be clean, dry and sound. The surface to be coated shall be free from any deleterious material liable to impair good paint adhesion or attack the coat.

For removing rust and mill scale on structural steel, piping and other steel surfaces, those parts suitable for sandblasting shall be sandblasted to a grade specified or required in accordance with SIS 05.59.00 (Sveriges Standdardiserings Kommission) or the American SSPC-SP standard. This applies particularly to parts which will be in contact with water, exposed to heavy condensation and humidity or subjected to high temperature.

For health reasons, sandblasting with quartz sand shall be avoided. All parts of the Plant shall be sandblasted at the shop unless otherwise specified or approved by the Engineer. The sandblasted surfaces shall receive a shop coat with a primer compatible with the paint system to be used.

Parts which cannot be sandblasted shall be cleaned of rust by power tool cleaning to the highest degree possible. Hand or power tool cleaned parts of minor importance and not exposed to water or humidity may be coated with a quick drying rust proof primer formulated on a combination of synthetic resins (ready mixed paint).

6.3.3.5 Execution of Painting

The Contractor shall supply full details regarding the extent to which the sandblasting and subsequent painting shall be performed in his workshop, on the Site or in situ after installation.

Unless otherwise required by the Technical Specifications, painting shall be done in accordance with DIN 55928 (Protective Coatings for Steel Structures) or other equivalent standard approved by the Engineer.

Painting operations shall only be carried out in dry weather and shall be interrupted in case of rain, fog or condensation. Preventative measures shall be taken to avoid the contamination of any painting works by dust or other contaminating matter.

Each coat shall be free from pores, runs, pinholes, and sags. Each coat shall be allowed to dry or to harden before the succeeding coat is applied. Where pore-free coats are specified, it shall be compulsory for the Contractor to prove this quality with adequate instruments.

Care shall be taken to maintain full paint thickness at all corners and edges and special attention shall be paid to the application of protective coatings over welds, mitre joints, etc.

The first coat shall be applied (manual application by brush) immediately after sandblasting and shall be finished within six hours to avoid new corrosion.

Shop coats shall be checked for good quality and, where necessary, before proceeding with the painting or coating operations at the Site the Contractor shall clean and repair all shop coats which are defective or damaged.

Oil and grease shall be removed before mechanical cleaning is started. Clean cloths and clean fluids shall be used to avoid leaving a film of greasy residue on the surfaces being cleaned. Any required wash treatment shall be done in accordance with the paint manufacturer's instructions.

The Contractor shall take into account that damage to paintwork during shipment, storage and erection is practically unavoidable and the application of all protective treatment should be programmed accordingly. It is essential that, before any coat of paint is applied, the surface shall be prepared as described above so that it is clean and free from all deleterious matter and completely dry.

Temporary or permanent welding shall not be permitted on areas where the welding will damage paint or other protective coatings, unless the areas of coatings which would be damaged thereby are accessible for repairing and inspection. Material which has been painted shall be handled with care and protected as necessary to preserve the coating in good condition.

6.3.3.6 Quality Control

The first and each successive coat shall not be applied without prior inspection, approval and certification. The minimum dry film thicknesses specified or recommended by the manufacturers shall be observed. If considered necessary, arrangements shall be made to check the thicknesses and if they have not been met the costs of this and the repair must be borne by the Contractor.

Upon completion of each coat, the painter shall make a detailed inspection of the painting finish and shall remove from adjoining work all spattering of paint material. He shall make good all damage that can be caused by such cleaning operations.

A detailed inspection of all painting work shall likewise be made, and all abraded, stained, or otherwise disfigured portions shall be touched up satisfactorily or refinished as required to produce a first-class job throughout and to leave the entire work in a clean and acceptable condition.

6.3.3.7 Warranty

The general guarantee periods required under the Conditions of Contract shall not apply to paint work. The guarantee period for all painting shall be 5 years, starting from the issue of the Taking-Over Certificate for the whole of the Works. This painting guarantee period shall be effective regardless of any other guarantee periods for the Works or parts of the Works under the Contract, or any Defects Liability Certificate issued prior to the elapse of the painting guarantee period.

The Contractor shall carry out painting repair work at no charge to the Employer if the painting quality guarantee is not met.

At the end of the painting guarantee period the anticorrosive protection of the painted or galvanised surfaces shall not have a degree of rusting higher than RE 1 on the European scale of degree of rusting for anticorrosive paints as defined by the corrosion committee of the Royal Swedish Academy of Engineering Sciences, Stockholm.

6.3.3.8 Galvanising

Steel described as galvanised shall be hot dipped galvanised in accordance with BS 729 or ISO 1459, 1460 and 1461. The coating of zinc shall not be less than specified in these standards.

6.3.4 Welding

All welding shall be carried out using a metal-arc process complying with BS 5135 by operators approved in accordance with BS 4871: Part 1, working to approved welding procedures meeting the requirements of BS 4870 : Part 1.

6.4 MECHANICAL PLANT, PIPEWORK AND STEEL STRUCTURES

6.4.1 General

All mechanical Plant, pipework and steel structures associated with any mechanical or electrical installation shall be of an approved, reliable design providing the highest possible degree of uniformity and interchangeability.

The design and arrangement of Plant and installations shall facilitate erection, testing, operation and maintenance, and all Plant shall be pre-assembled in the manufacturers premises to the utmost extent practicable.

6.4.2 Pump Sets

6.4.2.1 <u>General Requirements</u>

The scope of work shall include the design, manufacture, factory works witness testing (by representatives of the Engineer and/or the Employer), delivery, storage, installation, site testing, commissioning and maintenance as specified of the pump units and motors at Site.

Unless otherwise stipulated in the Particular Mechanical and Electrical Specifications, pump units shall be centrifugal single or multi stage horizontal end suction type.

Wherever practical all pump units should be of the same manufacture and design according to DIN 2460, 24255, 24295, 42005, and 57100/100. Pumps shall normally be supplied complete with motor, gearbox, bearings, couplings, pressure and vacuum gauges.

For the requirements for the electric motors and the motor control centre, which includes the starters, circuit breakers, and all control components required for the operation of the pumps, reference is to be made to Sub-Section 6.5. The Contractor shall be wholly responsible for ensuring that the electrical equipment is at all times fully coordinated with the final selection of the pumps.

Low maintenance costs, reliability and trouble-free operation will be the prime consideration when selecting pumps. Pumps shall be quiet in operation and free from vibration. Preference will be given to pumps with lower speeds in operation.

Unless otherwise specified pump casings shall be of the best quality cast iron, capable of withstanding all pressures that may be produced during normal operations or during pressure surges, and the pumps shall be mounted on base plates or suction stools manufactured of steel. Vibration isolation pads shall be provided between the pumps and their steel base plates in accordance with the recommendations of the pump manufacturer. The pumps shall be accurately aligned and located by dowels or machined spigots. Holes shall be provided in the base plates or stools for foundation bolts.

The pump shafts shall be of adequate size to avoid the possibility of fatigue failure and shall be shock and corrosion resistant. The pump shafts and elements shall be adequately designed to assume a rigid support of the impeller and to rotate without whip, vibration or undue deflection at all operating speeds and under all operating conditions.

Exposed shafting drive pulleys and belts are to be completely protected by galvanised steel guards, securely fixed and supported. The guards shall be of approved design and manufacture. Approved guards shall be fitted over all moving parts.

The coupling between the pump and motor shall be of the flexible pin and rubber or other approved type.

The impellers shall be designed to give non-overloading characteristics within the range of duties stated.

Where pumps work in parallel, curves for solo and parallel operating shall be submitted. These curves shall also incorporate the system curve.

Non-corrodible metal and rating plates shall be screwed or riveted to each pump or motor casing. These shall be stamped or deeply engraved in such a way that the lettering will not be obliterated. Rating plates shall include all information required by BS 2613 or BS 4999 or equivalent ISO standard, in addition to the pump make, impeller size, head and output at normal duty speed, serial number, pump curve number, power and current.

6.4.2.2 Centrifugal Pumps

a. Characteristics

The Tender Schedules shall include full information regarding the proposed pump unit and complete original characteristic curves showing flow and head, power consumption, efficiency and net positive suction head (NPSH).

Each pump shall be designed to give a continuous falling head/quantity characteristic to allow stable parallel operation. The net positive suction head (NPSH) required shall be compatible with that available to enable the pump to operate without cavitation over the full range of flow.

The Contractor shall ensure that the pump motors provided will be of sufficient power to drive the centrifugal pumps without overloading under all specified conditions of operation.

The pumps shall operate satisfactorily over the full range of feasible static lifts, and the Contractor shall make his own assessment of all frictional losses under all conditions of operation. The NPSH required for the pumps when pumping singly or in any combination as specified shall satisfy the NPSH available, and the appropriate calculations are to be submitted with the Tender. It shall be the Contractor's responsibility to correct any deviation in the NPSH of pumps.

Characteristics and system curves for the pumps against the various static heads shall be submitted with the Tender, presented to a reasonably large scale, for review. After award of Contract the same curves shall be formally submitted for the approval of the Engineer. When subsequently tested through their complete range of operational heads at the manufacturer's works the pumps shall give results which conform to the submitted and approved curves.

Pumps shall be quiet in operation and free from excessive vibration, shall be designed for continuous duty and shall have stable operating curves in accordance with the requirements of these Specifications. In cases of dispute concerning vibration reference should be made to US Hydraulic Institute Standards, 12th Edition (Hydraulic Institute 1969, centrifugal pumps handling clean liquids) for acceptable field vibration limits.

Rotating parts of pumps shall be statically balanced during manufacturing and dynamically balanced after assembly. Any excessive vibration detected after installation and during the Defects Liability Period shall be eliminated by the Contractor.

Pumps shall be lined internally with a Fluiglide flaked glass coat or similar and shall be coated externally with the standard pump manufacturer's coating. All lining/coating systems shall be submitted for the approval of the Engineer.

b. General Arrangement

Unless otherwise indicated on the Drawings or instructed by the Engineer centrifugal single stage horizontal split casing or end suction type pumps shall normally be mounted with the shaft in a horizontal arrangement directly coupled by a flexible coupling to the drive motor. The coupling is to be protected by a coupling guard. Wherever practicable each pump and motor set shall be mounted on a common stiff and robust base plate of mild steel or other approved material, extending beneath the pump and motor, of sufficient strength and rigidity. The pump/motor units shall be located on fully supported mechanical mounting pads complete with all necessary foundation belts and fixings, and there shall be sufficient space for full grouting access to all constructed compartments.

If any minor departures from the specified arrangements are proposed, the modifications shall be shown on drawings submitted with the Tender which shall include clear marking for attention to the proposed alterations.

c. Pump Unit Construction

Unless otherwise specified the pump components shall be manufactured in the following materials:

- pump casing austenitic cast iron to BS EN 13835
- impeller aluminium bronze to BS EN 1982
- shaft and gland sleeves stainless steel to BS 970 (Grade 316S29)

The impellers shall be of robust construction and machined where possible with the water passages and blades filled and scraped to produce smooth surfaces, well finished, free from holes and imperfections. Impellers shall be securely fitted to the spindle and in such manner that they cannot loosen or become detached when the pump is in operation or when it rotates in the opposite direction by reversed motor connection. The impellers shall be designed to give a non-overloading characteristics over the range of duties specified, and unless otherwise specified the peripheral speed of the impeller blades shall not exceed 25 m/s at the specified duty.

Impeller diameters chosen for each specified pumping duty shall not be the maximum for the particular casing but shall be at least 5 % less than the maximum diameter that can be fitted into the casing. Renewable impeller wear rings shall be fitted. For quietness and good performance the impeller eye velocities shall be kept to a practical minimum.

The pump shaft shall be fitted with sleeves where it passes through the gland and water passages. The sleeves shall extend up to the impeller boss, and shall be secured by keys and locked to prevent lateral movement.

Glands shall be of split construction to facilitate dismantling. Prefabricated soft packing shall be used or other method of sealing subject to the approval of the Engineer. Sealing/cooling water for the gland shall be taken from the pump casing through a minimum 19 mm diameter galvanised steel pipe to be drained away suitably.

Unless otherwise specified or approved by the Engineer, acceptable tolerances for manufacture shall not exceed the following:

- shaft diameter running through stuffing box: 0.05 mm
- shaft run-out on stuffing box face and at the impeller: 0.05 mm full indicator movement
- dynamic shaft deflection at stuffing box face 0.05 mm.

All bolts, nuts, studs, screws, washers etc. shall be stainless steel or cadmium plated steel.

Unless otherwise specified each pump shall be fitted with two bourdon pressure gauges connected to the suction and discharge sides of the unit, and placed on the pump so as to be easily readable. The reading shall be directly in metres of water. The gauges shall be the oil filled type and shall be provided with an isolating cock. Each pump shall have the required provisions for the installation of the necessary sensors to supply the operating data for the instrumentation and control system.

All drainage pipe work for gland bowls and air release cocks shall be chromium plated copper tubing to BS 2871 and fed to a common collecting tundish mounted on the pump/motor bedplate.

d. Documentation and Tools

The Contractor shall submit three complete copies of the following documentation with each pump and motor set:

i) Operating and maintenance instructions
ii) Works manuals
iii) Spare parts and price lists
iv) Circuit diagram.

The Contractor shall provide a complete and comprehensive set of tools with each pump and motor set, including special tools, as required for the following:

- routine maintenance of the pump/motor set
- carrying out a complete overhaul of the pump/motor set.

6.4.2.3 Pump Casings

Casings shall be designed in such a way that the withdrawal of the impeller and drive end cover assembly can be effected without disturbing the pump casings.

Hand holes shall be provided, close to the eye of the impeller and near the delivery branch on the volute, to facilitate inspection and the clearance of blockages. The covers to the hand holes are to be bolted and shaped internally to match the internal contours of the casing, and renewable internal wear plates shall be fitted or the casing shall be arranged for replaceable suction and gland plates.

Casings shall have sufficient metal thickness in the volute where not protected by wearing plates to compensate for corrosive and abrasive action of the raw water including any suspended matter and solids content as applicable.

Casings shall have recesses manufactured for top and bottom wearing rings shaped in such a way that, after fitting the rings, a smooth internal profile is obtained and the casing is continuously protected by renewable parts from the inlet to the impeller vane tips.

6.4.2.4 <u>Pump Impellers</u>

Impellers shall be smooth, well-finished, free from blow holes and imperfections, statically and dynamically balanced.

The impellers must be of the self clearing unshakable type and whenever possible of the non-shrouded type. Impeller shrouds shall have rudimentary vanes designed to keep grit, solids and foreign matter away from the eye and neck bush.

The impellers shall be securely fitted to pump spindles in such manner that they do not loosen or become detached when the pump is in operation, or when the impeller is rotated in the wrong direction by reversed flow or reversed motor connections.

The impellers shall be provided with means to prevent abrasive matter reaching the glands, and in the case of fully shrouded impellers to prevent the collecting of matter between the outer shroud and the pump casing.

The stainless steel pump spindles shall be fitted with renewable stainless steel, nickel chrome or bronze sleeves to protect the spindles against wear over the distance it passes through the stuffing box.

6.4.3 Water Hammer Protection

6.4.3.1 <u>General</u>

Where not shown on the drawings, the arrangement of the equipment in each pump station shall be proposed by the contractor.

The pump station hydraulic dimensions and data given in the Drawings and the Bill of Quantities are to be considered for tendering purposes only. The final dimensions shall be confirmed on the basis of the Contractor's surge calculations.

The Contractor shall submit a water hammer analysis and the resulting calculation of the dimensions of any protection measures required for each pump station. The format of these submissions and calculations shall be as agreed in advance by the Engineer, and shall be subject to the checking and approval of the Engineer.

6.4.3.2 Hydraulic Calculations

a. Steady State

Based on the design and the actual data, all states during normal operation of the Plant shall be calculated. The result shall be presented as a Q-H diagram of all parallel working pump sets and as a graph of the internal pressure in the transmission pipe, depending on the distance to the pump set for the significant static states.

b. Dynamic Analyses

Based on the steady state calculation, the following situations shall be analysed:

- switching on and off the pumps during normal operation;
- shut-down of all pumps caused by electrical power failure while at maximum flow rate;
- closure of the transmission pipe while at maximum flow rate.

The design requirement is that the internal pressure of the pumping facilities and pipe shall not increase above the rated pressure of the equipment, and the pressure shall not drop to a value at which the flow cavitates following the formation of vapour under negative (vacuum) pressure conditions.

Through these analyses the proposed equipment of the pump sets and transmission pipe shall be optimised, making additional measures such as a surge vessel wherever possible unnecessary, by the determination of the following:

- operating time of the valves at the discharge side of the pump set;
- characteristics of the non-return valve at the discharge side of the pump sets and at the supply reservoir inflow;
- moment of inertia of the pump units;
- operating times of the valves in the transmission pipe.

The basic assumptions and the execution of the analyses and calculations must be reproducible, and the results shall be summarised in both tabular and graphical form accompanied by an overall evaluation and recommendations.

c. Determination of Additional Protection Measures

In the event that the internal pressure of the pumping facilities and pipe cannot be maintained below the rated pressure of the equipment, or the pressure cannot be prevented from dropping to a cavitating value, then additional measures shall be necessary. The calculations shall then include the reproducible derivation of full details (types, dimensions and characteristics) of the optimum additional measures, such as the following:

- volume of surge vessel;
- dimensions of surge pipe and characteristics of the non-return valve;
- locations of the level switch at the surge vessel for alarm indication.

The final results shall show clearly that the surge control requirements have been met satisfactorily

6.4.3.3 *Surge Pipe*

A welded steel pipe according to this specification, shall be installed. The pipe starts with a flange connection at common suction pipe, it ends at the common discharge pipe.

The statical calculation and the water tightness shall be suitable for the shut-off head of the pump and an internal pressure of 16 bar minimum.

A non-return valve and two butterfly valves all with flange connections to PN 16 shall be installed in the pipe. These valves shall comply with the requirements of the Technical Specification.

Corrosion protection shall comply with this Specification.

6.4.3.4 *Surge Vessel*

a. Design Features

Unless otherwise specified a surge vessel shall be a vertical bladder type, floor standing, cylindrical, steel welded vessel designed with four feet, transport eyes, manhole, water level indicator, pressure gauge, fitted with a three-way cock and water connection at the center of the bottom, an air connection at the center of the top, and connections for the water level switches. All flanges in the vessel construction are to be in accordance with DIN 2533.The test pressure shall be 30 % higher than the maximum operating pressure. The vessel shall also be provided with an insulation layer not less than 50 mm thick in accordance with the manufacturer's recommendations in order to ensure continuous full functionality without excessive deterioration of any of the components of the vessel under the climatic conditions which can be expected in the Project area. The surge vessel will be connected to the common discharge pipe by a welded steel pipe via a butterfly valve and dismantling piece. Within the vessel a float-operated valve closes this pipe connection if the water level within the vessel falls to the preset level point, thereby avoiding the outflow of air.

b. Functions

The proper function of the surge vessel depends on a correct water level value, which will be measured by two level switches installed at the upper and the lower operating water levels.

If the water level falls to the lower operating level switch an alarm will be initiated. If the level rises to the upper operating level switch the compressor set will be switched on for a predetermined time, and if the water level does not fall below the upper operating level switch after this predetermined time an alarm will be initiated. The measurement data from each surge vessel shall also be provided for the instrumentation and control system.

6.4.4 Valves and Accessories

6.4.4.1 <u>General</u>

The Contractor shall furnish all valves and other accessories for pipework installations as specified in the Particular Specifications and as shown on the Drawings. All valves and other accessories shall be of the sizes specified and, as far as possible, all valves of the same type shall be from the same manufacturer.

Valves of diameter ≤ 50 mm are to be screwed with a bronze body and trim. Valves of diameter ≥ 50 mm are to be flanged with a ductile iron body. Valves of a diameter larger than DN 150 installed in horizontal pipe runs shall be provided with their own support and shall not be supported by the pipework alone.

All valves and accessories shall be designed for a minimum working pressure of 16 bar, unless otherwise specified, and test pressures shall be 1.5 times the working pressures.

The Contractor shall submit shop drawings to the Engineer for approval which shall include the following:

- list and schedules of materials
- details of joints (and adaptors if necessary)
- names of manufacturers
- sizes, details, materials and thickness of all items.

6.4.4.2 <u>Valve Actuators</u>

Valve actuators to be provided for valves shall comprise electrical 3-phase motors with integrated gear rated as follows unless otherwise specified:

- service voltage 380 Volt · 10%, 50 Hz
- control voltage 110 Volt (AC)
- protection class IP 68

The motor capacity is to be designed to open the valve from the final closed position while the maximum operating pressure is effective at one side of the valve. The operating time shall be taken to be 60 seconds unless otherwise stipulated in the Particular Specifications. The actuator shall accept a valve positioning control of between 4 mA and 20 mA.

For modulation duty actuators, a position indicator signal shall be provided to transmit the valve position status to the instrumentation and control system. The modulating actuator shall be suitable for up to 1200 starts per hour to IEC34 S4 – intermittent duty.

The actuator shall give valve open and valve closed signals and two limit switches each with a floating change-over contact are to be installed for the messages "valve open" and "valve closed". The torque shall be monitored for both directions of the motor by adjustable limit signallers, each with a floating change-over contact for the message "over torque while opening" and "over torque while closing". An additional floating contact is to be provided for the flashing message "valve in motion".

A clutch shall be provided to engage the handwheel manual operation and to prevent the handwheel from turning under power operation.

The mounting of the actuator to the valve or pedestal shall be in accordance with the requirements of ISO 5210/5211.

The motor shall have class F insulation but shall be designed for a class B temperature rise. In-built thermal protection and anti-condensation heaters shall be provided.

Each actuator shall be provided with over-current, reverse phase rotation, and under-voltage protection, and shall indicate the following:

- power supply failed
- control supply failed
- local–off–remote switch not in remote position, motor tripped on overload.

Labels shall be provided in English and Arabic languages and shall be secured by round-headed stainless steel screws. Adhesive labels are unacceptable.

6.4.4.3 *Coupling Guards*

All moving parts of machinery, including shafts, couplings, collars, projecting key heads, gear wheels, rope/belt drives etc., shall be completely guarded to provide full protection. All set screws on revolving shafts shall be countersunk or suitably protected. The guards shall be of approved design and shall be fitted, where necessary, with inspection doors/openings. All guards shall be arranged so that they can be removed without disturbing the parts of the gears and Plant which they protect.

6.4.5 Pipework and Fittings

All pipework shall be designed for the nominal pressure rating shown on the Drawings or instructed by the Engineer or specified in the Particular Specifications, and shall be furnished complete with flanges, joints, expansion joints, gaskets, packing, valves, drains, vents, pipe suspensions, supports etc.

Pipework crossing over joints of civil structures providing an allowance for differential movement or settlement shall be provided with flexible joints to allow for vertical, horizontal, and angular deviations.

6.4.6 Compressor Sets and Fans

6.4.6.1 Compressor Sets

The following components shall be provided and assembled in a single compressor unit ready for operation:

- compressor
- squirrel cage 3-phase motor
- base plate with vibration dampers
- flexible coupling or V-belt with guard
- galvanised steel anchor and connecting bolts, nuts and washers
- pressure gauge (diameter 60 mm) with valve and connecting fittings
- air inlet filter
- isolation valve
- safety valve (spring loaded)
- non-return valve
- protection measures and final coating
- miscellaneous materials for start-up (grease, oil etc.)

The capacity of the compressor is stated as the volume of air intake per minute under standard conditions (20°C, 1,033 mm Hg).

The motor must be able to start against the working pressure. The equipment shall be designed for an internal pressure which is 2.0 bar higher than the working pressure.

6.4.6.2 Ventilation and Air Conditioning

a. Ventilation Fans

Unless otherwise specified ventilation units shall be of heavy duty type, suitable for continuous operation in an ambient temperature of up to 50°C on 220 Volt single phase, or 380 Volt 3-

phase, 50 Hz electrical supply. The equipment shall comprise sufficient units to provide a minimum of ten air changes per hour for pump rooms, 15 changes per hour for switchrooms, ten changes per hour for toilets, or else as otherwise stipulated in the Particular Mechanical and Electrical Specifications.

Ventilation equipment, comprising extraction fans manufactured in external grade aluminium, shall be provided in Plant rooms including pump stations at the locations shown on the Drawings. The extraction fans shall terminate outside the buildings with a heavy duty weatherproof cowl with air operated shutters and birdguard. All fittings shall be non-rusting, and access panels shall be made of stainless steel and be of the captive type.

Ventilation units for chemical buildings and drum/bottle store rooms shall comply in general with the above requirements and shall be wall mounted at a low level of 150 mm above floor level. When high and low level chlorine or chemical sensor alarms are activated, the fans shall provide thirty air changes per hour. Manual control shall also be provided. When any door of a chlorine/chemical room or drum/bottle store is opened, a single fan shall be switched on by a door switch, and this fan shall stop when all doors are closed.

The noise level, measured at a distance of 1 metre, shall not in general exceed 70 dB(A).

b. Louvres

Louvres shall be of the required size for operation in accordance with the following criteria:

i) Air Intake Louvres shall be of the sand-trap type and shall be constructed in anodised aluminium. The louvre blades shall be constructed from 1.5 mm thick aluminium and the casing from 2 mm thick aluminium. The size of the louvre shall be such that the face velocity does not exceed 0.5 m/s and at this velocity the louvres shall be capable of removing at least 85 % of a typical wind-blown sand and dust mixture from the incoming air flow. The sand and dust collected by the louvres shall be discharged continuously by gravity to the exterior of the building. The design of the louvres shall be such that the pressure loss across the louvres shall not exceed 25 N/mm2 when operating at a face velocity of 0.5 m/s.

ii) Where required under the Particular Mechanical and Electrical Specifications, panel filters shall be fitted on the downstream side of the louvres which shall be capable of handling the required volume at an efficiency of not less than 85 % based on tests in accordance with BS 2831 with test dust No 2.

iii) Filters shall be washable and complete with holding frame sufficiently robust to ensure no distortion in operation. All filters shall be installed with edge seals which shall prevent the air bypassing the filters. The seals shall remain effective even though the cells are periodically removed and refitted. The air velocity through the filters shall be such that the clean resistance of 60 N/m2 is not exceeded and the filter fabric shall not be carried over into the system.

c. Air Conditioning Units

Wall mounted air conditioning units shall be air cooled split units as detailed in the Particular Specifications and supplied by an approved local air conditioning contractor.

The units with heaters shall be provided complete with slide-out chassis and frame, suitable for installation in the positions shown on the Drawings. All units installed in walls shall be provided with a separate anodised aluminium wallbox for building into the wall, in order to give passage and support to the unit.

The units shall be rated for continuous operation in the prevailing climatic conditions, and the materials of construction, particularly the heat exchanger, shall be subject to the approval of the Engineer.

Fresh air and recirculated air shall be passed through a filter, the filter being arranged for easy removal from the unit for cleaning and replacement.

Air conditioning/heating is required to maintain a dry-bulb temperature of 23°C with a summer external design temperature of 50°C and a winter external design temperature of 5°C, at any value of relative humidity between 10% and 100%.

The Contractor shall estimate and propose the size and number of units required for each location, and calculations shall be submitted with the Tender to substantiate the proposed equipment which shall include the heating and cooling loads with the cooling load based on a recirculation of one third of the inside air. Air conditioning shall be mandatory for spaces such as offices, and instrumentation and control rooms.

Each air conditioning unit shall be provided with a manually adjustable thermostatic air temperature control and such other controls as are necessary to achieve the following modes of operation:

- fan only (speed 1, speed 2)
- cooling / heating (fan speed 1, fan speed 2)
- recirculation of air from the room through the unit
- recirculation of air from the room through the unit with partial exhaust air flow
- recirculation of air from the room through the unit with partial fresh air intake.

Each unit shall also include an automatic delay timer in the compressor control circuit to prevent the compressor restarting under load in the event of an interruption in the power supply.

Motors shall be of the squirrel cage, continuously rated type, protected to IP 54, and shall be rated at 20 % above the calculated power required for the location. The motor starters shall be housed in the associated motor control panel.

All fans shall be provided with local isolators. The isolators shall be weatherproof but shall not be fused.

The refrigerant used in the units shall be of a type which does not affect atmospheric ozone.

6.4.7 Lifting Appliances

6.4.7.1 General Requirements

The lifting capacity of cranes shall be as detailed in the Particular Specifications and as indicated on the Drawings.

Ball or roller bearings shall be used on all motions, and the load hook shall revolve on a ball swivel. All gears shall be machine-cut, and runway wheels for gantry cranes shall be machined and be of the double flanged type.

A load chain collection box shall be incorporated on all gantry cranes and pulley block units. A reliable braking and locking arrangement shall be incorporated.

All runway beams shall be designed to BS 2853 and fabricated in accordance with BS 449. End stops shall be provided to all runway beams.

Manually operated lifting equipment shall have hoisting gear with which one person can readily lift the maximum load. Each item of lifting equipment shall include a double leg chain sling and a double ended rope sling.

All items of equipment shall be have corrosion protection in accordance with the Technical Specification.

6.4.7.2 Gantry Crane

The gantry crane shall be provided complete with tracks, track support beams electrical runway bus bar system, and all accessories including slings for installation on the support columns in the structure. The whole crane (trolley, bridge, beams and electrical equipment) shall be supplied by the same manufacturer and shall have a single assembly serial number in addition to the individual equipment serial numbers.

The gantry tracks and track support beams shall be jointed and fixed to the concrete support columns. Fish plates shall be supplied for jointing sections of runway, with the number of joints kept to a minimum, and the joints shall be executed such that the carriage rides smoothly over the joints. Suitably designed end stops shall be provided to prevent the carriage (or hook, when hanging vertically) from touching the wall.

The crane shall consist of end carriages and bridge unit delivered as separate sections and bolted together during erection on site. All components shall be obtained from the same manufacturer who shall certify his design.

The crane shall be of a double girder or single girder travelling type as detailed in the Particular Specifications and shall have a geared travelling trolley. The trolley shall run on bridge rails which shall be accurately aligned, designed to accommodate double flanged wheels, and securely fixed to the bridge girders. All wheel treads and flanges shall be machined to the correct profile to suit the runway.

Three motions (vertical, longitudinal and transverse) shall be provided on the crane and shall be such that the operation is speedy without impairing safety in working, and each motion shall have two speeds (high and low). All three motions wheels shall be equipped with heavy duty roller bearings, and a reliable braking and locking arrangement shall be incorporated.

A separate rail with hangers and rollers, as approved, by the Engineer for the feeding cable to the crane, shall be installed with the cable.

Operation of the crane shall be by means of pushbuttons on a hand-held control pendant connected to the crane with reinforced cable or separate steel rope. The control pendant shall extend to within 600 mm of the lowest operating floor everywhere over the area within which the operator may walk while operating the crane.

The load steel rope or chain with the hook shall be such that the hook will reach the lowest floor or duct level, with a limit-switch in both directions for this motion also.

The crane shall bear a permanent inscription readily legible from floor level stating the safe working load expressed in kilograms. The crane shall also bear the manufacturer's name, serial number and the year of manufacturer.

An extending portable aluminium ladder in addition to the fixed ladder structure shall be provided at each end for access to the crane for maintenance.

The electrical panel shall contain all the overload protection devices, under-voltage relay etc. for the three motions.

The overhead crane shall be equipped with all the electrical motors, cables, wires, control box, electrical panels, steel ropes, channels, rails etc., and the Contractor shall supply all accessories and ancillary equipment necessary to make the bring the crane unit into perfect operating condition.

6.4.7.3 Detailed Description-Pulley Blocks

Manually operated travelling pulley blocks shall be provided complete with runway beam or lifting frame and all accessories where specified or shown on the Drawings. Where used with a runway beam, the block shall be arranged to run on the lower flange of the beam.

The block shall be of the spur-geared, close haul type, and the hoisting gear shall be such that one person is capable of easily raising the maximum load. The hoisting and lowering chain and the operating chain for the longitudinal motion of the trolley shall both extend to within 600 mm of the operating floor, and the load chain shall be capable of reaching the ground level, everywhere within the operating area.

The block shall be provided complete with geared travelling trolley and shall be capable of easy removal from the trolley without the need to dismantle.

6.4.7.4 Testing and Safety

All lifting equipment shall be tested at the manufacturer's works and at Site following the completion of the installation in accordance with the Particular Specifications. The Contractor shall supply all necessary equipment for testing at Site. The safe working load shall be clearly marked in large print on the units in Arabic and English following completion of installation and final painting, for which appropriate stencils shall be supplied.

Safety notices shall be provided, and the wording of the notices shall be subject to the approval of the Employer.

6.4.8 Lubrication

Efficient means of lubrication, suitable for use under Site conditions, shall be provided for all moving parts.

Self-lubricating types of bearings shall be given preference, unless otherwise specified or where this is not practicable. All bearings shall be mounted in dustproof housings. Bases of bearing supports shall be machined and shall rest on machined surfaces.

The contamination of the air, water and soil by lubricants shall by all means be avoided by applying an appropriate design and layout of the Plant in conformity with the latest recognised standards for modern engineering practice.

The number of different lubricants used in the items of Plant under the Contract shall be limited to a minimum in order to facilitate keeping stocks and maintenance.

All proposed different types of oils, lubricants, etc., shall be stated in the Tender and shall be subject to the written approval of the Engineer.

Unless otherwise stated in the Particular Specifications, the first oil or grease filling for bearings, including the necessary quantity for flushing and for the first oil change, shall be supplied and shall be included in the Contract Price.

Reference must also be made to the quantity of lubricants required to be kept in stock for the time of operation of the Plant, and the respective quantities together with the respective costs shall be quoted in the information provided to the Engineer.

6.4.9 Mechanical Instruments

All mechanical parts of instruments shall be suitably protected against shock and vibration, heat, humidity and splash water, etc.

Pressures gauges shall be provided with a damping liquid, e.g., glycerine, to compensate vibrations. Pressure gauges without damping means are not permitted, unless approved by the Engineer.

6.4.10 Embedded Parts

Embedded parts shall be amply designed to guarantee strength and resistance against corrosion. Unless otherwise specified or shown on the Drawings the minimum thickness shall be 10 mm. All parts shall be equipped with fixing bolts in sufficient number and size to be fixed by welding to the baseplates which shall be built into the civil works.

The fixing bolts shall have a minimum diameter of 12 mm unless otherwise indicated, shall be fitted with threads and be equipped with adjusting nuts to facilitate adjustment. They shall be arranged such that the parts to be embedded in the second stage concrete will be firmly fixed. All fastening struts and embedded parts of regular steel shall be covered by at least 50 mm of well compacted concrete.

6.5 ELECTRICAL PLANT

6.5.1 General requirements

The Contractor will be entirely responsible for all mechanical, electrical and building work required for the installation of the electrical Plant and equipment, including the handling, erection, adjustment, commissioning, testing and maintenance of all electrical equipment and materials supplied under the Contract.

The electrical items of Plant and any electrical or mechanical installation to be provided under this Contract shall fulfil the requirements of this section, unless specified otherwise in the Particular Specifications.

The installation and the equipment shall be designed and manufactured in accordance with the best modern practice and shall be arranged for ease of inspection, cleaning and repair. The prime design considerations shall be safety, achievement of a high degree of reliability under normal conditions and under any abnormal conditions that could reasonably be anticipated, and the keeping of maintenance costs to a minimum. Adjusting and cleaning and the exchange of "worn" parts is to be made as easy as possible with due regard to safety. Components of the same type shall be uniform and interchangeable, and any component that may require removal shall be provided with adequate withdrawal space.

All equipment and apparatus shall operate safely and satisfactorily under the ambient and other conditions prevailing on Site, and the equipment shall be derated or uprated as necessary for the stated site conditions.

Particular care shall be taken to prevent excessive stresses produced by expansion or contraction due to temperature changes. Outdoor installations shall be protected against solar radiation by means of adequate covers, where required.

Where corrosion may be expected from contact with water or from any other cause, the Contractor is to supply materials which are resistant to corrosion. All Plant and equipment shall operate without undue vibration and excessive noise.

Once full details on the proposed materials have been submitted by the Contractor and approved by the Engineer, substitutions shall not be made without the written consent of the Engineer.

Unless otherwise agreed, ratings of main electrical Plant (infeeds, bus-ties) as selected or proposed by the Contractor, whether originally specified or not, shall generally include a safety margin of not less than 10 % over that required for the worst condition likely to be met in service. The approval of the Engineer shall be required for such basic characteristics, for which the Contractor shall submit all relevant information such as consumer lists, short circuit calculations, derating factors, etc.

Short circuit calculations shall be elaborated by the Contractor to demonstrate that every electrical component can withstand the maximum stresses under fault conditions, for fault levels and durations obtained under the worst conditions (e.g. upon failure of the corresponding main protection device and a time delayed fault clearing by the back-up protection device).

The Contractor shall ensure that all the supplied Plant is insensitive to any signals emitted by wireless communication equipment.

6.5.2 Standards and Regulations

The electrical installation shall be in accordance with the provisions of the IEE Wiring Rules 16th Edition (BS 7671), or an equivalent international standard subject to the written approval of the Engineer.

In addition, the electrical equipment and the installation shall comply with all requirements and regulations of the local responsible Electricity Supply Authority.

6.5.3 Colour Code

6.5.3.1 <u>Electrical Phases</u>

The phases, neutral and earth of the electrical supply shall be denoted by the colour-coding given in the following table, and any phase designation plates, busbar identification system, coloured cables, coloured insulators or protective relay phase identification shall be consistent with this colour code:

Line	Preferred	Alternative
1st phase	Red	Red
2nd phase	Yellow	White
3rd phase	Blue	Blue
neutral	Black	Black
earth	Green/yellow striped	Green

6.5.3.2 *Paint Colours for Electrical Equipment*

Unless otherwise stipulated in the Particular Specifications or agreed in writing by the Engineer, the required colour for electrical cabinets and panels shall be ‘electric orange'.

Steel trunking used above laboratory benches or in Plant areas shall also be ‘electric orange'. Steel skirting trunking used in office areas shall be grey, the shade to be approved by the Employer.

Motors shall be painted to match the items of mechanical Plant they drive, however the covers over shaft-mounted cooling fans shall be red.

Unless otherwise specified, the manufacturer's painting systems shall be used to the maximum possible extent but shall in all cases be subject to the approval of the Engineer. Final coats of paint shall, if required, be colour matched to adjacent Plant or installations.

6.5.4 Electric Motors

6.5.4.1 *General*

Electric motors shall comply with BS 4999 or similar approved standards, and shall have moisture resistant windings. Terminals, terminal leads, winding tails and associated equipment shall be suitable for connection to supply systems having the short circuit MVA and clearance times determined by the protective devices. Terminals shall be of the stud type, insulated from the frame and of a minimum size of 6 mm brass or 4 mm stainless steel or phosphor bronze.

Motors of the same type and size shall be fully interchangeable and shall comply, except where so approved in writing by the Engineer, with the standard motor dimensions given in BS 4999: Part 141. All motors shall be fitted with approved types of lifting hooks or eye bolts.

Unless otherwise specified or agreed motors shall be squirrel-cage AC induction motors and shall be direct coupled to the driven Plant through couplings as detailed in this section or in the Particular Specifications.

Terminal boxes shall be totally enclosed, designed to exclude the ingress of moisture and dust. All joints between a terminal box and its cover, between box and motor and all detachable gland plates shall be flanged with gaskets of neoprene or similar material. Flanged joints on terminal box covers shall not be situated directly above the motor terminals. Each terminal box shall be fitted with a detachable gland plate, to be drilled as required. For all cable entries, the cable glands shall project inside the terminal box at least 5 mm for machines up to 8 kW and at least 9 mm for machines above 8 kW.

Motors shall undergo routine tests in the manufacturer's works, and the results of type tests shall be made available if required by the Engineer.

6.5.4.2 Drive Motor

Unless otherwise stipulated in the Particular Mechanical and Electrical Specifications, each pump unit shall be equipped with an electric totally enclosed fan cooled (TEFC) motor of a design to match the pump, of double squirrel cage type to limit the starting current, and shall be supplied with vacuum circuit breaker. It shall be horizontal foot mounted, of construction type B3 according to DIN 42950, and shall be protected against the ingress of splashed water according to IEC IP 54, or equivalent international standard.

The Particular Specifications shall stipulate for each pump motor set the nominal supply voltage and the insulation class.

The electric motor shall be provided with a terminal box of adequate size for the supply cables. The motor shall be continuously rated at least 25% above the power adsorbed by the pump at the duty point, or to cover the complete pump curve whichever is greater, and shall be provided with an inside thermal protection (thermistor bimetal type) to protect the winding against overheating.

The stator windings shall use a modern synthetic resin insulation system based on mica glass tape continuously wound on the coils to give a void free homogeneous structure. The end windings shall be securely braced to prevent harmful movement arising from electromagnetic and mechanical forces. The rotor bars shall be securely keyed into the rotor, and the rotor shall be shrunk and keyed onto the shaft.

Resistance temperature detectors per phase shall be installed in pockets within the stator windings to monitor winding temperatures. The detectors shall be supplied complete with temperature indicator, alarm and trips as required for the instrumentation and control system associated with the pump and motor sets.

The stator connections shall be led out to a terminal box which shall be manufactured of splinter-proof steel plate, provided with moisture seals to meet IP55 enclosure requirements, and sealed off from the internal motor space.

6.5.4.3 Rating

AC motors shall be capable of operating continuously under rated output conditions at any frequency between 95 % and 105 % of the rated frequency and with any voltage variation between 90 % and 110 % of the nominal supply voltage (assuming rated frequency). Due consideration shall be taken of such possible supply variations when selecting motors for various duties. Motors shall also be capable of withstanding an occasional excess current at a level of 150 % of the rated current for 2 minutes (BS 4999: Part 101, Clause 18.2).

The motors shall also be capable of maintaining stable operation when running at 70 % nominal voltage for a period of 10 seconds. The pull-up torque for continuously loaded 3 phase induction motors shall be at least the value (expressed as a per unit value of the rated torque) given in Tables 1 or 2, as applicable, of BS 4999 : Part 101.

DC motors shall be capable of operating continuously under rated output conditions at any voltage between 90 % and 110 % of the nominal voltage, with a fixed brush setting for all loads. Unless otherwise approved, the speed drop between no load and full load shall not exceed 10 % of the no load speed.

6.5.4.4 Starting

Whether or not there may be specific starting current restraints imposed by the Electrical Supply Authority to minimise disturbances to the Electrical Supply Authority network and other consumers connected thereto, AC motors shall be designed for direct-on-line starting unless otherwise agreed by the Engineer. They shall be capable of being switched on without damage to an infinite busbar at 110 % of the nominal voltage with an inherent residual voltage of 100 %, even in phase opposition. For starting the motors from the individual main and auxiliary busbars, a momentary voltage drop of 20 % referred to nominal voltage should be taken into consideration. With 85 % of the nominal voltage applied to the motor terminals, each motor shall be capable of accelerating its associated load to full speed with a minimum marginal (accelerating) torque throughout the run up period of 5 % of full load torque.

Unless the nature of the process requires a more stringent duty, all motors shall be able to withstand two cold starts in succession and one start from hot conditions, in accordance with the requirements of Clause 5 of BS 4999: Part 112. Motors for frequent automatic starting shall have an adequate rating. Full details of the frequency of starts permitted in compliance with the proposed motor design shall be included in the Tender Schedules.

6.5.4.5 Windings and Insulation Class

The stator winding shall be suitably braced to withstand the forces due to direct-on-line starting and transfer conditions. The winding envelopment and tails shall be non-hygroscopic. The stator winding shall withstand the maximum fault current for the period determined by the associated protective devices.

The rotor winding, where applicable, shall be designed to give trouble-free continuous service including repeated direct-on-line starting. The rotor shall be subjected to a 120 % overspeed test for 2 minutes without showing any winding dislocation.

Motors shall be insulated in accordance with BS 2757, or similar approved standard, for Class B temperature rise. Class F insulation materials shall be used. The insulation shall be suitable for operation in damp locations, for occasional contact with corrosive gases and vapours, and for considerable fluctuations in temperature.

6.5.4.6 Ventilation and Type of Enclosure

Unless otherwise specified, all motors shall be of the totally enclosed fan-cooled type, with protection class IP 44 according to BS 4999: Part 105.

They shall have a closed internal cooling air circuit recooled by an external cooling air circuit drawn from the opposite side from the driving end, in accordance with the cooling classification IC41 in BS 4999: Part 106.

Where motors are installed outdoors, a weather-proof design shall be chosen. A hole shall be provided at the lowest point of the casing for draining condensed moisture. Any motors to be installed above reservoirs or tanks, and all motors of rating greater than 75 kW, shall be equipped with automatically controlled heating elements for protection against internal condensation of moisture during stand-still periods. Such AC heaters shall be suitably fixed inside the motor casing, and the leads shall be led to a separate terminal box.

Motors installed outdoors and directly subjected to solar radiation shall be provided with sun shields and shall be rated such as not to exceed a maximum metal temperature of 85°C.

Vertical motors shall be provided with a top cover to prevent the ingress of dirt, etc.

6.5.4.7 Bearings

As far as possible self lubricating ball and roller bearings with solid races shall be provided for all motors, and vertical motors shall have thrust bearings to the approval of the Engineer. All motors with ratings of 11 kW and above shall be equipped with lubricators permitting greasing while the motor is running and preventing over lubrication. Additionally, the bearings shall be fitted with grease nipples permitting the use of a universal grease gun.

For the transport of motors equipped with ball or roller bearings, special bearing inserts shall be provided to prevent transport damage.

6.5.4.8 Shafts and Couplings

The motors shall be provided with a free shaft extension of cylindrical shape with key, keyway and coupling to the load as described in this section or in the Particular Specifications. A coupling guard shall be provided.

6.5.4.9 Brushgear and Commutators

Brushgear for DC motors shall be designed to ensure constant brush pressure. Carbon brushes shall be provided which will withstand at least 6 months of operation without replacement. Each brush shall be independently adjustable but should be designed not to require adjustment throughout its life. A design of brushgear which permits the brush holder to touch the commutator as the brushes wear, or which passes current through the pressure fingers, will not be accepted.

A sufficient number of brushes, not less than two per pole, shall be fitted to ensure that vibrations do not affect the commutation.

The minimum safe wearing margin of commutators shall not be less than 20 % the total thickness of the commutator bars, and the minimum safe diameter shall be clearly marked on the commutator bar.

6.5.4.10 Terminal Boxes and Earthing

The terminal leads, terminals, terminal boxes and associated equipment shall be suitable for terminating the respective type of cables as specified in this section and in the Particular Specifications.

The terminal boxes shall be of ample size to enable connections to be made in a satisfactory manner. Supports shall be provided at terminal boxes as required for proper guidance and fixing of the incoming cable.

The terminal boxes with the cables installed shall be suitable for connection to supply systems with the short circuit current and the fault clearance time determined by the motor protective devices.

A permanently attached connection diagram shall be mounted inside the terminal box cover. If motors are provided for only one direction of rotation, this shall be clearly indicated.

Terminal boxes shall be totally enclosed and designed to prevent the ingress of moisture and dust. All joints shall be flanged with gaskets of neoprene or similar material. For motors above 1 kW the terminal box shall be sealed from the internal air circuit of the motor.

Depending on the size, the terminal box of LV motors shall be fitted either with an approved cable sealing-end or with a gland plate drilled as required and provided with suitable fittings for cable fixing and sealing. Such openings shall be temporarily plugged or sealed during transportation.

For earthing purposes each motor shall have adequately sized bolts with washers at the lower part of the frame. In addition, each terminal box shall contain one earthing screw, and a stud connection shall be provided from the inside to the outside of the terminal box.

6.5.4.11 Measuring and Monitoring

Motors with a rating greater than 50 kW shall be provided with slot temperature detection devices (resistance thermometers) embedded in each phase of the stator winding, the leads of which shall be brought out to a terminal box separate from the main terminal box.

From these sensors, at least one "winding temperature high" contact shall be derived either thermostatically or electronically to give separately an alarm and to trip the associated motor starter.

Hour-meters shall be installed if maintenance work such as regreasing, oil change etc. depends on the operation time of the motors.

6.5.4.12 Noise Level and Vibrations

Under all operating conditions, the noise level of motors shall not exceed the figures tabulated in Appendix D of BS 4999: Part 109 when measured in accordance with the methods described therein.

In order to prevent undue and harmful vibrations, all motors shall be statically and dynamically balanced, and vibration measured after installation according to the methods in BS 4999: Part 142 shall be within the levels tabulated in Tables 1 or 2 therein, depending on the height of the shaft. In the event that the tabulated levels are exceeded then the motor shall be suspended or mounted on rubber or other elastic supports and the tests repeated to establish whether the vibration arises from the motor itself or from the combination of motor and base, and an appropriate remedy proposed for the Engineer's approval.

6.5.4.13 Tests

Each motor shall be factory tested and shall undergo a test at Site. The following tests shall be performed and the Contractor shall be entirely responsible for the proper preparation for, conduct and supervision of, and reporting on these tests as specified:

a. Workshop Tests

For motors produced as the manufacturer's standard model, and for which model type tests have previously been performed, the Duplicate Tests in accordance with Table 1 of BS 4999: Part 143 shall be performed.

For motors produced to the manufacturer's standard pattern, but for which model no type tests have previously been performed, the Basic Tests in accordance with Table 1 of BS 4999: Part 143 shall be performed.

For non-standard motors produced to meet any special constraints and specifications applicable to this particular Contract (e.g. limited starting current), whether to a pattern for which type tests have previously been performed or not, the Basic Tests in accordance with Table 1 of BS 4999: Part 143 shall be performed.

Type Test Certificates for the Basic or Duplicate Tests shall be submitted to the Engineer before the motors are despatched from the manufacturer's works, and in the case of Duplicate Tests are called for on standard motors, the Engineer reserves the right to request submission of the Basic Test Certificates for motors of the same size and rating tested previously.

b. Site Tests

The tests to be performed at site shall include, but not be limited to, the following:

- measurement of winding resistances
- recording of direction of rotation
- phase rotation checks at motor terminals
- no-load current measurements
- measurement of motor vibrations (on motors rated 15 kW or more)
- measurement of noise level (on motors rated 15 kW or more)
- measurement of starting time (on motors rated 15 kW or more)
- measurements of steady-state load current.

6.5.5 MV and LV Switchgear, Cubicles and Panels

6.5.5.1 General Design and Construction Features

Control panels and switchboards shall be constructed to comply with BS 5486 (IEC 60439). The degree of protection of each enclosure, as defined in BS EN 60947-1 (IEC 60144), shall be as stated in the Particular Specifications.

In the case of indoor switchboards, the degree of protection in accordance with BS EN 60947-1 (IEC 60144) shall be a minimum of IP54. For switchboards to be installed outdoors the minimum degree of protection shall be IP 55, and, if necessary, sun shields shall be provided.

Each control panel and switchboard shall be made of substantial folded and welded 2 mm minimum thick cold rolled mild steel sheets and channel or angle iron sections to form a rigid, robust, free standing, floor-mounted, dust and vermin proof structure.

Unless wall mounting is specified, back access control panels or switchboards shall be provided with one or more heavy gauge sheet steel back cover plates firmly attached to the board in such a way as to be easily removable to give access to the interior of the board.

The front of the control panel or switchboard shall be completely enclosed by means of rigid, flush type sheet steel doors gasketed with suitable non-perishable materials to form a firm seal, mounted on substantial hinges and held firmly closed by means of chromium plated tee type handle locks. All door handles, hinges, or nuts and bolts which protrude from the surface of any panel shall be either of stainless steel or cadmium plated.

Each control panel or switchboard shall be jig constructed. The construction in general must be mechanically adequate with regard to stresses arising from the passage of through fault currents at the specified fault levels. Each complete section of a board or panel shall be of ample strength to withstand all stresses incidental to shipping and installation, and shall be supplied complete with lifting lugs and eye bolts, and with all required base frames, anchors, fixing materials, etc.

Switchboards shall be divided into compartments each containing only one major circuit breaker, starter or similar unit in order to limit the effect of any electrical failure, and be equipped such that the safety of any maintenance staff working on the equipment is assured. To this end the supplies to each compartment must be through isolators, and either it must be impossible to open the door of the compartment until it is totally isolated from all supplies, or else all terminals which are live when the door is open shall be shrouded to prevent accidental contact.

A copper earthing bar shall be firmly attached to the metalwork of the panel and shall be rated to carry the asymmetrical fault currents. All earthing conductors of the incoming and outgoing circuits shall be firmly connected to the earthing bar by means of non-corrosive fasteners. Clearances between live parts and to earth shall be in accordance with the relevant standards.

Busbars shall be completely screened from any other compartments by removable bolted covers, which shall under no circumstances be of the quick release/fastening type. Provision shall be made for expansion and contraction of the busbars resulting from temperature variations.

Adequate space shall be provided for the entry and termination of all busbar trunkings and cables. Undrilled removable gland plates shall be provided. A separate cable compartment shall be provided at the top and/or bottom of the board, and bottom entry gland plates shall be no less than 300 mm above floor level.

Control and operating components such as switches, circuit breakers, starters, relays etc., shall be mounted in tiers in recessed sheet steel enclosures behind the front door of the panel. At least 10 % spare space shall be allowed for the possible future addition of equipment. Wherever the correct operation of instruments and relays makes it necessary, adequate vibration and shock absorbers shall be installed. Control panels and switchboards shall be readily capable of expedient and economic extensions at either end.

Electrical equipment shall be secured by means of bolts, set screws or welded studs and nuts. Self tapping screws shall not be used for any purpose whatsoever.

All switchgear, busbars and connections shall be capable of withstanding all electrical, mechanical and thermal stresses to which they may be subjected under normal or fault conditions.

Indicating lights are to be led, and both the lamp holder and the lamp shall be selected with a view to the ready availability and easy physical installation of replacement lamps.

The correct phase rotation and colour markings shall be employed throughout the equipment.

6.5.5.2 Painting and Protective Coatings

a. Cleaning of Surfaces

All metal surfaces shall be thoroughly cleaned of all mill scale, rust and dirt. Any traces of grease or oil shall then be removed by a suitable degreasing agent, and any traces of soluble salts and corrosive airborne contaminants shall be thoroughly washed off prior to painting or galvanising.

b. Painting

Unless otherwise specified, all exterior metal surfaces shall be painted. Rotating bright steel parts, copper alloy or chromium plated knobs need not be painted.

After cleaning of surfaces is completed one coat of adequate thickness of zinc chromate or similar primer shall be applied.

Two finishing coats of good quality high gloss enamel paint, compatible with the primer, shall then be applied to form a coating of not less than 100 microns thickness.

The make and quality of primer and paint shall be to the approval of the Engineer. Colour finishes shall conform to BS 381C (or equivalent) and shall be to the approval of the Engineer.

Handling of factory finished painted equipment by the Contractor shall be done with utmost care to prevent damage to the surface during installation, and the Contractor shall provide suitable protection after installation to prevent damage during the Contract period. Damage to factory finished surfaces during installation shall be made good by the Contractor at his own expense and to the satisfaction of the Engineer.

The requirements of BS 5378, or an equivalent approved standard, shall be adhered to.

c. Galvanising

Galvanising shall be applied by the hot dip process applying at least 610 g/m2 and 0.1 mm minimum thickness. Articles to be galvanised shall be thoroughly cleaned mechanically and chemically prior to galvanising, and the zinc coating shall be smooth and continuous.

Welding of steel after galvanising will not be permitted.

6.5.5.3 *Internal Wiring*

The rated continuous current of the proposed equipment shall be included in the Tender Schedules to be submitted with the Tender, and shall be suitable for the loads specified without the need for any form of forced cooling or deliberate natural ventilation. The rating shall be obtained with the equipment mounted in its housing, as in service, without exceeding the limits of temperature rises expected in BS 5486 (IEC 60439).

Busbars shall be hard drawn high conductivity copper, and the current density shall be that allowed by BS 159 (or equivalent) with due regard to ambient air temperature.

Busbars shall be adequately rated for the normal current carrying capacity as detailed, and shall be designed to be adequately braced and supported to withstand the short circuit stresses imposed by faults of the specified fault levels during the time taken by the incoming circuit breaker or fuses to clear such faults.

Busbars shall be coloured red, yellow, blue for phases and black for neutral and shall be arranged as follows:

- Red–Yellow–Blue–Black: from left to right for vertical bars
- Red–Yellow–Blue–Black: from top to bottom for horizontal bars
- Red–Yellow–Blue–Black: from front to back for both vertical and horizontal bars.

Connections from the busbars to panel units shall be by means of fully insulated, adequately rated conductors firmly bolted to the busbars and secured to the appropriate terminals of the panel units using crimped-on terminal lugs (unless solid flat conductors are used).

All joints and tees in busbars shall be made with cadmium plated high tensile bolts, spring washers, etc. in accordance with BS 4395.

At all points where connections or joints occur, the busbars and connecting pieces shall be tinned or silver plated.

All power wiring in control panels shall be colour coded with the appropriate phase colours.

All instrument and control panel wiring shall be carried out in a minimum size of 1.5 mm2 cross-section copper, preferably colour coded PVC wire, 600 Volt grade. Wires connected to the secondaries of current transformers shall have a 4 mm2 cross-section.

Each end of every wire shall be permanently marked with wire numbers by means of cable ferrules in black lettering on a yellow base, preferably of PVC or similar material.

Switchboard accessories or auxiliaries such as current transformers, voltage transformers etc., shall be effectively earthed to the earthing bar. Hinged panels shall be earthed by braided copper leads with lugs at each end.

Current transformer circuits shall include an accessible pair of double stud type terminals at which the CTs may be temporarily shorted (whilst in service) for the purpose of reversing or modifying the secondary path. Current transformer circuits whose only terminations are screws will not be accepted unless provisions acceptable to the Engineer are made for shorting.

Termination of all wiring shall be done by using suitable compression crimp lugs or crimp sleeves. The wiring shall be done in a neat and orderly manner, with looms being secured by suitable approved strapping material or within covered plastic wire channels.

The marking of wiring shall conform to BS 5486 (IEC 60391) and shall correlate with the appropriate schematic and wiring diagram.

Terminal strips and blocks shall be made of melamine or similar material and shall comply with BS 1322 or equivalent. In the case of circuits driven by current transformers, terminal strips shall be of the "double stud" type as detailed above.

The minimum size of terminal shall be capable of accepting wire sizes of up to 6 mm2, and at each terminal block assembly at least 10 % spare terminals shall be allocated for future use.

6.5.5.4 *Identification Plates and Labels*

Identification plates and labels shall be affixed to all electrical equipment such as switchboards, panels, circuit breakers, isolators, starters, fuses, relays, switches, controllers, etc. Labels shall be mounted in label-slots or shall be secured using round head, metal threaded screws set into saddle nuts, unless otherwise approved by the Engineer. Self tapping screws will not be accepted.

A main designation label shall be fitted in the centre of each complete switchboard on the main structure above the manufacturer's name plate. It shall indicate the name of the board and from where its supply originates. Designation labels shall be fitted back and front on the structure of all individual switch panels and on the front of withdrawable circuit breaker carriages.

Identification plates and labels shall correlate with the corresponding schematic and wiring diagrams. Label descriptions shall be in English and Arabic.

All labels shall be made of composite sandwich type plastic material of the following colours:

- identification labels Black–White–Black
- danger labels Red–White–Red

Letters and numbers shall be in block capitals and in the following sizes:

- Main Boards Designation 25 mm high
- Individual Panel Designation 12 mm high
- Component Labels 6 mm high.

Embossed plastic strip type labels are not acceptable.

Where panels are equipped with voltage or current transformers, the panel shall be fitted with an etched or engraved metal plate in a conspicuous place showing all the relevant data of such transformers.

Labels for control fuses shall indicate function and fuse rating.

6.5.5.5 *Motor Control Centre*

a. Construction

Where required under the Particular Mechanical and Electrical Specifications, each motor starter, together with circuit breakers and other control components, shall be housed in a suitable factory-built cubicle type assembly, the motor control centre, complying with IEC 60439-1:1990, with a smooth well finished front surface. Each starter panel shall enclose all related devices, and no devices related to the starter shall be installed outside the starter enclosure, unless otherwise specified.

The motor control centre shall be manufactured to a high standard from steel sheet (minimum thickness 2 mm), adequately braced to give a rigid structure, with sufficient removable eye bolts for lifting. Access to the cubicle compartment for all normal routine maintenance shall be from the front by robustly hinged lockable doors, maximum 800 mm wide, secured with cam type fasteners and cylinder locks with removable key, and stops shall be provided to prevent doors touching adjacent cubicles. Additional access shall be by means of bolted panels. The base plate shall be of non-magnetic material to avoid electric heating.

All bolts, nuts, screws, hinges, handles etc. shall be made of galvanised or stainless steel, cadmium-plated steel, or chrome-plated steel as appropriate.

Components shall be mounted such as to prevent mechanical shocks transmitted from large components to small components and thereby adversely affecting their proper functions, and shall be arranged to give adequate accessibility for maintenance and removal with the minimum disturbance to the wiring. Plug-in connectors shall be used wherever possible.

Substantial mechanical interlocks shall be provided between the door and the circuit breaker such that the door cannot be opened unless the circuit breaker is in the "Off" position and all live parts which can be accidentally touched have been disconnected.

All cables and piping shall be made through glands in a plate covering the base of the cubicles. All the wiring, instruments, devices and all parts of the panel shall be facing the front of the panels for ease of maintenance access. The internal wiring of all cubicles shall be completed before delivery. Busbar assemblies including the conductors connecting the busbars to each outgoing unit shall be arranged to withstand a short circuit at any point.

b. Operating Mode of Primary Pump Set Protection

For the protection of pumps the following shall be monitored as a minimum by the control equipment, subject to the specific requirements of the Particular Mechanical and Electrical Specifications:

- low water level/pressure in the pump intake sump/suction side and dry run protection
- Low/high pressure at the discharge side of the pump.

Unless otherwise specified these signals shall switch off the pump after a predetermined time delay, independent of the selected operating mode, and simultaneously an alarm will be given at the appropriate local and/or remote control points. After the fault has been eliminated the pump shall not restart automatically, but must be restarted by means of a reset pushbutton at the local and/or remote control panel to be pressed by the operator.

An emergency pushbutton switch will be installed close to each pump. Once operated, a key shall be necessary to permit the emergency switch to be reset.

c. Selection of Pump Operating Mode

Unless otherwise specified the sequence of pump switching at the control panels in pump stations will permit selecting manually between the units and an automatic setting. If

"Automatic" is selected, the control device automatically selects the duty pumps to equalise the running time of the pump units.

A selector switch will also be installed for each pump set with the positions:

- Manual
- Off
- Automatic

In the position "Manual", the pushbuttons "On" and "Off" located at the same control panel will be effective. In the position "Off" the pump is switched off and interlocked.

If automatic operation is selected, the pumps will be switched on and off according to the signals received from the water level in the receiving reservoir or tank.

6.5.5.6 Tests

The tests to be performed at the manufacturer's works shall be in accordance with the applicable standards.

The tests to be performed at Site shall include, but not be limited to, the following:

- visual inspection
- Megger test (to include Plant and internal wiring but excluding electronic equipment)
- functional tests of controls, interlocks, measurements
- setting of protection relays (adjustment by means of special testing equipment and operational checks)
- HV test as required by the applicable standards.

6.5.5.7 Low Voltage Distribution Board up to 630A

a. General

The low voltage switchboards shall comply with the IEC 439-1 standard. The degree of protection, in compliance with the IEC 529 standard, shall be as follows:

- IP 30.5 with front plate
- IP 40.7 with door
- IP 43.7 with door + joint and canopy
- IP 55

The low voltage switchboards shall:

i) have a rated insulation voltage of 1000 V and a rated operating voltage of up to 1000 V;

ii) be suitable for IT, TT or TN earthing systems;

iii) withstand a short-time rated current of 25 kA rms for 1 second;

iv) have a rated current up to 630 A;

v) be designed for a LV distribution at frequency of 50 – 60 Hz.

b. Construction and Operation

The low voltage switchboard enclosures and front plates shall be made of electro-steel zinc plates with a rust-proof coating of high temperature polymerized lining powder.

The low voltage switchboards shall allow simple, dependable installation of the busbars and switchgear, as well as their connections, by means of specific brackets and protective screens for each function:

- the switchboards, except for IP55 switchboards, may be combined and house a lateral duct for the bars, cables or terminals;
- the external housing of switchboards, except for IP55 switchboards, may be removed in order to facilitate intervention.

The construction system shall offer a complete functional assembly of factory-built components for installing the breaking, protection, measurement and monitoring and control gear.

A busbar may be installed at any height in the switchboard to facilitate the connection of devices and modifications.

Insulated current distribution blocks shall be used to supply a row of similar or not similar modular devices, with phase balancing at any time. Spare locations shall be pre-equipped for supplying additional modular devices.

c. Protection and Safety

Protective front escutcheon with cut-outs for operating handles shall be systematically installed.

Internal protections shall prevent accidental direct contact with the live parts including the upstream terminals of the feeder devices.

6.5.5.8 Low Voltage Distribution Board up to 2000A

a. General

The withdrawable modular switchboards shall comply with the IEC 439, NF EN 60439-1, and VDE 0660 part 500. The degree of protection, in compliance with the IEC 529 standard, shall be IP 32/54 for standard models.

The withdrawable modular switchboards may be used to make LV switchboards up to 1000 V, and shall have a rated insulation voltage of 1000 V AC. These modular switchboards shall comply with the IEC 68.2.30 for "hot, humid climate" and with 68.2.11 for "salt mist tests", and shall be suitable for IT, TT or TN earthing systems.

The withdrawable modular switchboards shall have a permissible short-circuit current for 1 second of:

- 50 kA rms or 105 kA peak for standard constructions;
- 70 kA rms or 154 kA peak for constructions on request.

The withdrawable modular switchboards shall allow full front access, permitting assembly back to back or against a wall, and interchangeable feeders.

b. Construction and Operation

The withdrawable modular switchboards may have a 3-pole + neutral + earth distribution. Racking in or racking out of the feeder drawers shall allow safe, quick intervention with the installation still energized. It shall be possible to modify the current rating or type of drawer, with no downtime.

The total withdraw capability of the upstream or downstream power and control circuits shall be:

- for feeders with ratings < 125A, a single power (3 or 3-P) and control block (maximum 26);
- for feeders with ratings · 125A, 3 or 4 power connection terminals (400 A) and a separate control output block (maximum 26).

The cubicles shall be designed to house 1/24 module type modular equipment, the smallest drawer being 2/24.

c. Installation

Electrical continuity of the horizontal busbar shall be ensured by splicing.

The switchboards may be anchored to the floor, in which case the floor must be flat and level and a trough or false-floor must be provided.

d. Protection and safety

A cover shall be provided to close off the upstream power cables. Operating safety shall be ensured by individual separation of equipment.

A self centering control supply block with 1 or 3 two-pole outlets shall be provided.

The withdrawable modular switchboards may be used in all areas which require safety of people and equipment.

A locking latch with padlock shall be used to lock the drawer in the "racked out" position.

6.5.5.9 <u>Low Voltage Distribution Board up to 3200A</u>

a. General

The low voltage switchboards shall comply with the IEC 439-1 standard. The degree of protection, in compliance with the IEC 529 standard, shall be:

- IP 20.7: cubicle with door or front plate support frame
- IP 30.7 with door
- IP 31.7 with door + joint
- IP 54.7 with door and sealing kit
- IP 55.

The low voltage switchboards shall have a rated insulation voltage of 1000 V and a rated operating voltage of 1000 V. The switchboards shall be suitable for in IT, TT or TN earthing systems, and shall have a permissible short-circuit current of 85 kA rms for 1 second.

The low voltage switchboards shall have a rated current up to 3200 A, and shall be designed for a LV distribution at frequency of 50 – 60 Hz.

b. Construction and Operation

The low voltage switchboard enclosures and front plates shall be made of electro-steel zinc plates with a rust-proof coating of high temperature polymerized lining powder.

The low voltage switchboards shall allow simple, dependable installation of the busbars and switchgear, as well as their connections, by means of specific brackets and protective screens for each function:

- the switchboards, except for IP55 switchboards, may be combined and house lateral ducts for the bars, cables or terminals;
- the external housing of switchboards, except for IP55 switchboards, may be removed in order to facilitate intervention.

The switchboard panels shall be removable. The construction system shall offer a complete functional assembly of factory-built components for installation of the fixed or withdrawable breaking and protection gear and the measurement and monitoring and control devices in the cubicle.

A busbar may be installed at any height in the switchboard, with full front access, to facilitate the connection of devices and modifications.

Insulated current distribution blocks shall be used for suppling a row of similar or not similar modular devices or a row of devices from 100 to 250 A, and spare locations shall be pre-fitted to supply additional modular or other devices up to 250A.

c. Protection and safety

Operating safety shall be achieved by means of:

- upstream and downstream separation of the incoming device on the busbar;
- busbar separation;
- screens to limit the risk of spreading faults between each of the functional units.

Internal protections shall prevent accidental direct contact with the live parts up to the upstream terminals of the feeder devices.

6.5.6 Switches, Fuses and Circuit Breakers

6.5.6.1 <u>General</u>

Switches, fuses, switch and fuse combinations and circuit breakers shall comply with the relevant approved standards, and full details of the standards whose requirements the proposed equipment meets shall be included in the Tender Schedules submitted with the Tender.

6.5.6.2 Circuit Breakers

Circuit breakers shall comply with BS EN 60947-2 (IEC 60157) or similar approved standard. Circuit breakers shall be of the fully magnetic or temperature compensated thermal, inverse time delay type, unless otherwise approved by the Engineer. The circuit breakers shall trip according to their inverse characteristic at not more than 125 % of their rated load current and instantaneously on short circuit.

The breakers shall be capable of carrying their rated load current continuously without exceeding their specified temperature rise, and also of carrying their rated short circuit current for the time taken for the breaker to trip without damage.

The current rating of every breaker shall be clearly and indelibly marked on the breaker, such marking to be visible without the need to remove the panel facia. Adhesive labels are not acceptable for this purpose.

Moving contacts of triple-pole breakers shall have their mechanisms ganged together internally and the poles shall open and close simultaneously when the operating handle or tripping mechanism operates.

The breaker shall be designed such that it is not possible to hold the contacts closed under overload or short circuit conditions.

Where miniature circuit breakers are offered because they can provide the requisite fault ratings, these shall be single-pole or triple-pole with adequate current ratings. The operating and the overload mechanisms shall be sealed. The mechanism shall provide positive closing, contact roll and wipe, trip-free action with follow through on opening. The contacts shall be of anti-welding silver tungsten tips fixed on high conductivity copper backings.

Where circuit breakers of the requisite fault current rating are not manufactured, those used should be of the highest rating obtainable and backup HRC fuses installed to protect each bank of such circuit breakers, all to the approval of the Engineer.

6.5.6.3 Air circulators up to 6000A

a. General

The circuit breakers shall comply with IEC947.2 or corresponding approved standards (such as VDE 0660, BS 4752, UTE C63120). Subject to the approval of the Engineer an optional version may comply with the UL / ANSI / JIS standard.

The breaking capacity performance certificates shall be available for category B to the above mentioned standards. The test shall be carried out with a breaking performance during operation (Ics) and admissible short time withstand (Icw) equal to the ultimate breaking capacity (Icu).

All circuit breakers can be reverse fed without reduction in performance. The circuit breakers shall have a rated operational voltage of 690V AC and a rated insulation voltage of 1000V AC (at 50 – 60Hz).

All circuit breakers shall be fully tropicalized (T2) as standard, and shall comply with the isolating function requirements of IEC 947-2 section 7.1.2.

b. Construction

The air circuit breaker shall have one size from 800 to 3200A.

The required safety clearance around the air circuit breaker may be cancelled by adding protective covers. Type tests shall be achieved with the minimum safety clearance.

All air circuit breakers shall be designed to be easily maintained, and in order to reduce maintenance the electrical endurance characteristics shall be very high. Up to 2000A, the circuit breaker shall offer an electrical endurance without servicing or maintenance (CO at Un = 690V) equal to the mechanical endurance.

The circuit breakers shall be available in fixed or drawout models and in 3-pole or 4-pole versions. On the 4-pole version the neutral pole shall have the same current rating as the other poles from 800A up to 4000A, and N/2 from 5000A up to 6300A.

All air circuit breaker main contacts shall be encased in a reinforced polyester casing and offer double insulation for the operators on the breaker front face. The circuit breaker also shall offer total insulation of the control part with respect to the power part.

c. Operating mechanism

The operating mechanism shall be of the OCO stored energy spring type with a closing time of less than or equal to 80 ms. Two types of spring charging may be accepted:

- hand-charged spring, where the springs are wound only by hand;
- motor-charged spring, where the springs are automatically charged by an electric motor (the maximum time to charge the springs shall not exceed 4 seconds, and it must also be possible to charge the springs manually).

d. Main contacts

i) General

Contacts shall be designed to be maintenance-free in normal usage. The main contacts shall be equipped with an indicator in order to allow its wear level to be checked without measurements nor specific tools.

ii) Indicators

A mechanical indicator shall be provided on the front face of the air circuit breaker which is linked to the main contact assembly in such a manner as to positively indicate the contact status. It shall only be possible for "OFF" to be indicated when all contacts are parted and isolated by the required distance.

iii) Arc Chutes

Arc chutes shall be common on the whole range and removable on site to allow inspection of the arc chutes and the main contacts.

e. Drawout mechanism

i) General

The drawout operation shall be possible through a closed door. Three positions of the moving part shall be possible:

- connected position - all auxiliary and main circuits engaged;
- test position - all auxiliary circuits engaged all main circuits disconnected;
- isolated position - all circuits disconnected.

ii) Safety Requirements

A door interlock shall be provided so that it shall not be possible to open the door until the air circuit breaker moving part is in the disconnected position.

Insulated safety shutters shall be provided over the incoming and outgoing main circuits and over the auxiliary circuits. An interlocking shall be provided to prevent insertion of a circuit breaker having a rating higher than the current rating of the fixed part, into that fixed part.

The racking handle shall be stowed on the air circuit breaker in such a manner as to be accessible without defeating the door interlocking.

The safety perimeter shall be reduced to zero for the drawout version above and to the sides of the ACB.

f. Electrical auxiliaries

All electrical auxiliaries including the motor spring charging mechanism shall be field adaptable without adjustment or the necessity for any special tool (except a screwdriver). They shall be fitted into a compartment which under normally loaded conditions has no metalwork energized from the main poles exposed with it. Any adaptation carried out thus shall not increase the breaker volume.

It shall be possible to connect all auxiliary wiring from the front face of the air circuit breaker, this wiring shall be taken through a set of disconnecting contacts so that all auxiliary wiring is automatically disconnected in the isolated position.

g. Mechanical indicators

Mechanical indication on the front of the air circuit breaker shall be provided to indicate the following :

- main contacts closed "ON"
- main contacts open "OFF"
- springs charged
- springs discharged
- circuit breaker in "connected" position (drawout only)
- circuit breaker in "test" position (drawout only)

- circuit breaker in "disconnected" position (drawout only)

All indicators must be clearly visible.

i) General requirements

The overcurrent relay shall be a solid state type, micro-processor based and use digital programming techniques for highest protection accuracy and be integrated as part of the circuit breaker, as follows:

- the sensors and the wiring shall be integrated within the case;
- the overcurrent relay shall be self powered;
- the current sensors shall be located within the case of the circuit breaker.

The overcurrent relay shall have a wide adjustment range to allow flexibility of setting on site.

The trip unit shall measure the true RMS value of any waveform of current.

The control unit shall be equipped with a push-to-reset mechanical indicator, for anti-pumping function.

The control unit may communicate with other equipment on a communication BUS.

ii) Characteristics

Long time protection (LT):

- adjustable (in steps of 4%) from 0.4 to 1.0 times the sensor rating (In);
- time delay adjustable from 15 to 480 seconds (at 1.5 times the long time setting).

Short time protection (ST):

- adjustable (in steps of 4%) from 0.4 to 15 times the long time protection setting (Ir);
- time delay adjustable from instantaneous to 0.4 seconds;
- time inverse characteristic (I2t) may be switched in order to improve discrimination.

Instantaneous (INST) shall be adjustable from 2 times the rated current for sensor ratings up to:

- at least 20 times the rated current for sensor ratings up to 2000 A.
- at least 10 times the rated current for sensor ratings above 2000 A.

iii) Control Functions

In order to optimize the operation, maintenance and monitoring of the breaker in complete safety, the following control items shall be supplied as standard as an integral part of the control unit:

- local overcurrent LED indication with 2 levels – LED steady or flashing – on the front face and one volt-free output contact shall indicate as a pre-trip alarm;
- two NO and two NC output contacts plus one CO fault trip contact (SDE) shall be available.

iv) Thermal Memory

The control unit shall optimize the protection of the equipment or the circuit conductors in the event of repeated overloads or faults by using thermal integration to memorize temperature rises.

v) Safety

Internal overheating of the control unit shall be signalled by a self monitoring alarm.

vi) Options

Without increasing the volume it shall be possible to combine the following functions into the circuit breaker control unit:

- load monitoring and control;
- two adjustable settings with output contacts (these settings to be related to the long time protection setting);
- zone selective interlocking for the short time and earth fault protection;
- earth fault protection;
- remote indication of one particular fault as selected by a switch on front face;
- fault trip indication – indicating the element (long time, short time/instantaneous, earth fault protection if supplied) that has caused the circuit breaker to trip, indicated locally by a LED.

vii) Measurement

A digital display ammeter shall indicate the RMS value of the circuit breaker phase currents with a switch on the front face for selection. The highest value of phase current shall be stored and displayed on demand.

A bar graph shall display the load indication of each phase.

viii) Communication

The data or action needed for the control and indication functions shall be available on a BUS via a specific modular system, including:

- circuit breaker state
- control unit settings
- cause of circuit breaker trip
- circuit breaker operation.

6.5.6.4 Switches and Isolators

Air break switches and isolators shall comply with BS EN 60947-3 (IEC 60408) or similar approved standard. Switches and isolators shall be rated for the normal current carrying capacity and shall be capable of withstanding the specified through fault currents without sustaining any damage.

Where specified it shall be possible to "padlock" any isolator or switch in the "Off" position.

Unless otherwise specified, all switches and isolators shall be of the "fault make – load break" type.

6.5.6.5 *Fuses*

Fuses shall comply with BS 88 (IEC 60269) and shall be of the high rupturing capacity (HRC) type. HRC fuses above 200 A rating shall be of the bolted type.

6.5.6.6 *Switch Fuse Units*

The fuses supplied shall be to BS 88 (IEC 60269) type HRC. Switch fuse units shall have a padlocking device for the "Off" position and shall employ self-cleaning contacts and a quick-making/quick-breaking action to switch the specified rated currents.

Where these units are 3-phase, they should be such that the rupture of any one fuse causes all three phases to be disconnected.

Preconnected fuses up to 63 A rated current shall be inserted into lever-operated fuse isolators such that no special tool is required for their replacement. Devices shall be provided to indicate blowing of the fuse locally and remotely respectively.

6.5.6.7 *Motor Protecting Devices*

a. General

For the protection of motors the following shall be monitored as a minimum by the control equipment, subject to the specific requirements of the Particular Mechanical and Electrical Specifications:

- overcurrent (3 phases)
- thermal overload (3 phases)
- winding temperature (3 phases)
- phase monitoring (3 phases)
- over and under voltage
- earth fault (3 phases)

Unless otherwise specified these signals shall switch off the pump independent of the selected operating mode, and simultaneously an alarm will be given at the appropriate local and/or remote control points. After the fault has been eliminated the pump shall not restart automatically, but must be restarted by means of a reset pushbutton at the local and/or remote control panel to be pressed by the operator.

Normally the main (running) contactor rating shall be 125 %, and the delta (bridging) contactor rating shall be 100 %, of the maximum current rating of the motor at its nominal rated voltage.

b. Motor Monitoring Protection Unit (MMPU)

Depending on the details of the specified instrumentation and control systems and equipment, motors of power rating 50 kW and above shall normally be provided with a microprocessor based MMPU (motor monitoring protection unit), installed in the motor starter. The MMPU shall measure the voltage, current and temperatures, and processes the measured values and performs arithmetical and logical operations in order to display the required information and to activate the necessary alarms and trips caused by failures and faults. The MMPU shall have low power consumption, the adaptability of self-supervision, fault diagnosis by means of data recording, flexible construction and a selection of relay characteristics.

Whether or not the information is transmitted to a remote monitoring/control point, it shall normally be possible to operate and set the device by pushbutton on the front of the device, and all the measurements, messages, instructions etc. shall be shown on a local alphanumeric back-lighted display with two lines and 32 characters. The unit shall also have a free selectable parameter setting of 4 output relay functions (alarm / tripping).

The MMPU shall have the following features:

i) Protection Functions

All protection functions are equipped with warning (connected to separate alarm horn) and tripping element.

- Voltage based protection:
  - 3 phase under voltage protection
  - 3 phase over voltage protection
  - phase loss protection
  - phase sequence protection.
- Current based protection:
  - overload protection (thermal capacity according to I2.t characteristics) with adjustable current / tripping characteristics
  - thermal overload pre-alarm
  - load increase alarm
  - 2-stage undercurrent protection
  - high set overcurrent protection
  - low set overcurrent protection
  - 2-stage current unbalance protection
  - short-circuit protection
  - excess starting time protection
  - 2-stage earth fault protection
  - excess number of starts protection.
- RTD / thermistor based protection:

- temperature supervision: three sensors inserted in the motor windings, one on the motor bearing (drive end), and one on the load bearing (pump).

ii) Measured Data

- Phase and line voltage (phase to phase, phase to neutral, for all phases)
- Phase current
- Earth fault current (for all phases)
- Power (kW), power VA
- Power factor
- Thermistor channel resistance (ohm.· C).

iii) Calculated Data

- Motor load – percentage FLC
- Thermal capacity used
- Time to trip
- Time to start
- Unbalance current.

iv) Logical Input Status

- Motor available indication
- Individual status of all input contacts.

v) Statistical Data

- Motor hours run
- Number of motor starts
- Last start time
- Last peak starting
- Number of motor trips.

vi) Fault Data

- Last fault
- Last alarm
- Phase currents time of trip
- Earth fault at time of trip
- Phase volts at time of trip.

vii) Indications

- Motor running
- Motor stopped
- Watchdog unit self supervision for software and hardware.

6.5.7 Starters

6.5.7.1 General

Unless otherwise specified, all starters shall comply with BS EN 60947-4 (IEC 60292) and shall provide the following:

- a triple-pole instantaneous overcurrent device for short circuit protection;
- a triple-pole overload device, either directly or current transformer operated, having a characteristic closely aligned to the thermal characteristics of the associated motor;
- inherent under-voltage protection;
- single phasing protection on all three phases.

For motors above 60 kW the overload shall have a characteristic and setting taken in conjunction with the associated motor starting time and current such as to permit starting of the motor when hot or cold without danger of tripping on starting currents, and also to permit the selection of close protection for the running condition and stalled condition when either hot or cold. If necessary, protection against stalling should be provided by means of a separate relay. A single-pole instantaneous earth fault element shall be provided which shall be stable for all switching operations including motor starting currents with maximum asymmetry. These requirements would normally be satisfied by the provision of a composite overload/protection relay from a recognised manufacturer type 'P & B Golds' or equivalent. Composite starter/breaker units which combine the functions of circuit breaker and starter may be acceptable provided they meet the requirements for both.

Overload releases shall be temperature compensated up to 70°C ambient temperature. The overload protection shall be set at not more than 100 % of rated full load current, and a notice shall be fixed in a prominent position prohibiting increased settings.

Any special protective devices such as winding temperature or gland seal protection recommended and fitted by the motor/pumpset manufacturer shall be incorporated in the starter control and protection circuits. Such provisions shall be included in the Contract Price.

Contactors shall be in accordance with BS EN 60947-4 (IEC 60158) and shall be of minimum AC 3 rating and shall have a guaranteed mechanical life of one million operations at a utilisation category 99.5 % AC3/AC2 + 0.5 % AC4/AC2. Contactors shall have 220 Volt AC, 50 Hz replaceable operating coils.

When closed, the contactors shall withstand the system fault current at their respective locations.

An overload "reset" pushbutton shall be fitted to each motor starter.

Block type contactors may be used for all motor control applications not exceeding 150 kW. No block contactor having a continuous thermal rating of less than 35 A shall be used for motor starting.

All DC contactors shall be of heavy duty clapper type with combined rolling and wiping contact action and shall be fitted with arc shields and magnetic blow out coils, or de-ionising arc chutes.

Where specified, motors shall have one current transformer operated ammeter of industrial grade in accordance with BS 89 (IEC 6051-2) and shall be suitable for 1.0 A current transformer secondaries. The ammeter shall have a red line at full load current and a compressed overload scale.

6.5.7.2 Motor Starters

Unless otherwise specified starters of 30 kW and above shall be of soft start design, as required suitable for the squirrel cage induction motor. Each motor starter shall comprise the following:

- automatic circuit breaker (50 kA rated short circuit breaking capacity)
- starting, bridging, and running contactors as required
- starting auto transformer with 70 % tapping
- all controls for the pump sets as specified
- all alarm indication lamps for the pump set as specified
- resettable audible and visual alarm system for all faults.

The main, step, and star contactors shall be selected in accordance with required utilisation category. The starter shall be rated to stand a minimum of four starts per hour at an ambient temperature of 50・ C.

The motor shall incorporate the following protection relays:

- Thermal overload protection relay, with a suitable adjustable range, shall be installed between the running contactor and the motor (with or without current-TFs, depending on the situation). The overload range shall be approximately from 80 % to 120 % of the nominal current rating of the motor.
- Dry running protection relay, the sensor installed on the suction side of the pump.
- Power monitor relay installed with a sealable transparent cover shall trip in case of:
  - incorrect phase sequence
  - over-voltage
  - under-voltage
  - phase failure,

with an adjustable trip time delay for over-voltage and under-voltage up to 10 seconds.

- Thermistor motor protection relay, with PTC resistor sensors in the motor starter windings, to protect the windings from over-heating.
- Thermistor protection relay to prohibit starting the motor when the Auto transformer is overheated and to protect the Auto transformer.

Separate current transformers shall be provided for protection and instrumentation duties. The rate burden shall be as needed by the instrumentation and/or protection, but not less than 10 VA. Fuses and links shall be grouped where appropriate according to these functions, and shall be clearly marked both on panels and the associated wiring diagrams.

The Auto transformer shall have the following design features:

- air cooled
- the core and coil shall be twice impregnated under vacuum in high temperature grade
- satisfies the requirements of IEC 60292 - 4 for an ambient temperature of 50・C
- 4 starts per hour
- 3 phases
- PTC resistor sensors to protect the transformer windings from over-heating
- insulation class F.

The starter shall be fully assembled by the manufacturer. Where modifications such as additions of extra protection devices or indicators are required, such modifications shall be performed in a similar manner by the original equipment manufacturer and full details of the modifications and the circuit diagrams shall be provided.

All power circuits in the shall be protected by moulded-case circuit breaker (MCCB) with an adjustable thermal magnetic trip unit, and the short-circuit breaking capacity shall be not less than 50 kA unless otherwise specified and shall comply with IEC 60157-1, 60292, and 60947.

The control circuit shall be protected by miniature circuit breakers (MCB) with current limiting feature, and IC not less than 6 kA in accordance with IEC 15701 P1.

The following CV ratings shall be applicable to the starter contactors:

- main contactor 125 % of full motor rating
- delta contactor 100 % of full motor rating
- star contactor 80 % of full motor rating.

Starters of more than 50 kW shall be Auto-transformer starter type suitable for the specified pump motor characteristics. They shall be housed in floor mounted steel cubicles of 2 mm thick steel plate to IEC and IP54 protection, referred to as motor control centre. Starters of greater than 50 kW shall include the following components as a minimum:

- main incoming circuit breaker incorporating magnetic and adjustable thermal overload protection
- starting, bridging and running contactors or circuit breakers
- phase failure relay
- high motor winding temperature trip relay
- three ammeters and three current transformers

- voltammeter with a voltage range from zero to an appropriate maximum, with phase-to-phase and phase-to-neutral selector switch set
- control fuses or MCBs for protection of control circuits and protection relays
- illuminated pushbuttons
- indication lamps for R-S-T phases with red-yellow-blue colours
- visual and audible alarm, and reset systems

All switching circuit breakers shall have a rupturing capacity of not less than 50 kA. .

Each starter of power rating 50 kW and above shall be furnished with a door-mounted motor monitoring and protection device (MMPU), which shall monitor as a minimum the following:

- motor current
- motor winding and starter transformer winding temperature
- motor and pump bearing temperature
- number of starts
- running hours
- trips, overloads etc.,

as well as any other functions specified above. Where a starter is supplied without installation on site, all wiring needs for this device to go out of the starter shall be terminated on a comprehensive full wire labelled terminal bar, with complete identification and wiring to other integral control devices installed on the pump and motor in conjunction with MMPU.

Each starter of power rating 200 kW and above shall have at least one PTC thermal sensor embedded in the Auto transformer's coil.

Complete circuit diagrams shall be provided together with service instructions and a spare parts list for all components used in the starter panel, inserted into a transparent plastic case inside a pocket on the rear of the panel door.

The manufacturer shall conduct the required tests on each starter in accordance with IEC 60439-1:1990 (clauses: 8.1.2 and 8.3), and the required tests shall include but not be limited to the following:

- visual inspection
- mechanical inspection
- operation test
- HV test (2.5 kV for 1 minute)
- insulation (Megger) test
- primary injection test
- secondary injection test (for measuring instruments and protection).

The manufacturer shall submit the test report (certificate) for each panel showing that the starters were completely tested and that the setting of the relays were adjusted.

6.5.7.3 *Electronic Soft Starter*

a. Assembly

The Auto transformer shall be fixed such that its longitudinal axis is parallel to the rear plate of the panel.

The starter shall be well ventilated, such as by suitable long-life industrial metallic fans if necessary, to maintain the inside temperature of the panel within the operational limits.

Protection category of the starter enclosure in accordance with IEC 60529-10/91 shall be at least IP54.

The starter assembly shall be designed to withstand any external fault. In the event of any internal arcing fault on a functional unit, the damage should be confined to that unit such that the busbars and all other functional units remain fit for service. The conductors connecting the busbars to the outgoing unit may however be damaged by the internal arcing fault.

b. Wiring

The maximum ampere loading for the power interconnectors between main, step, and star contactors shall not be rated more than 2.5 Amp/mm2, and a larger cable or busbar cross-section shall be installed in case the computed cross-section is not available.

All input interconnectors for the main, step (bridging) and star contactors in starters of power rating of 200 kW and above shall be insulated copper busbars. For starters of power rating less than 200 kW, the input and output interconnectors for the contactors (main, step and star) shall be PVC-insulated copper cables.

Starter panel enclosures with a height less than 1600 mm shall be provided with an empty metal base, at least 300 mm high, with covered sides, in which nothing shall be installed. An additional empty space not less than 300 mm high shall be left above this base to allow room subsequently to install any connection bar or terminal L-bar cables to the panel and for the outgoing cables to the motor.

Free standing starter panel enclosures with a height of 1800 mm and above shall be mounted on a 100 mm steel plinth.

c. Performance Characteristics

Unless otherwise specified the electronic soft starter shall have the following characteristics:

- Main supply as specified
- Designed for an ambient temperature of 50°C
- Set point facility (progressive Vge) to limit start-up current and torque (M · I2)
- Ramp characteristic for start-up to preset rated value (same for stopping sequence)
- Power supply monitoring and protection (on both input and output of the starter)
- Two selectable levels of start-up current and torque
- Current limitation on start-up (by potentiometer – partial resettable load current)

- Start voltage selectable between 0 % and 65 %
- Current rise adjustable, time range adjustable from 1 second to 60 seconds
- Automatic and manual restart facility
- Acceleration end relay
- Run indication (acceleration), start-up complete indication
- Soft down capability up to stand still
- Connection/disconnection of line contactor under no load if supplied with bypass contactor
- Energy saving continuously controlling the load when motor is partially loaded (when supplied without bypass contactor)
- Controlled acceleration and deceleration of pump motor without feed back devices
- Start fault detection protection
- Temperature (overheating) fault protection for internal and motor protection
- Controlled soft start and controlled acceleration
- Motor stop control in case of failure (internal and external)
- Over-voltage and under-voltage protection
- Motor stop after a preset time (via delay timer) if the discharge control valve does not close as scheduled, and starts only when the discharge control valve is fully closed
- Emergency stay pushbutton
- By pass contactor (rated for AC3 duty) to short out the soft starter after completion of motor starting, and to go out when stopping the motor for any reason which stopping shall nevertheless be through the starter
- Thermal overload suitable for the motor rating
- Proper main circuit breaker with adjustable magnetic and thermal protection
- Sufficient I/O connection points to wire the starter to a remote status or telemetry control.

Wherever applicable the protections and functions listed above shall be provided with indication lamps on the starter cubicle front door.

d. Installation and Commissioning

The Contractor shall supply, install, commission, test and put into operation completely each soft starter. Prior to the commencement of fabrication and in any case before supply of the starter, the Contractor shall submit complete documentation and information including drawings and circuit diagrams to the Engineer for approval.

The Contractor shall completely commission and bring the soft starter into operation, and shall make any necessary repairs or rectify any faults including procuring all the necessary materials and actions should the soft starter fail or abruptly cease to function in an acceptable manner during any time within the Defects Liability Period within 48 hours of recall after malfunctioning of the soft starter, otherwise the Employer shall will perform the repair or rectification all associated costs thereof shall be to the account of the Contractor.

6.5.8 Switchboard/MCC Auxiliary Equipment

6.5.8.1 Anti-condensation Heaters

Each individual enclosure accommodating electrical Plant which is liable to suffer from internal condensation due to atmospheric or load variations shall be fitted with heating devices suitable for electrical operation at the specified standard AC voltage, being of sufficient capacity to raise the internal temperature by about 5°C above the ambient temperature.

Heaters in motors and similar equipment shall be switched on automatically upon opening of the motor starter, and vice versa. Heaters in switchgear/MCC cubicles, control cubicles, panels, desks etc. shall be controlled automatically by adjustable hygrostats (setting range about 50 - 100% relative humidity).

The electrical apparatus so protected shall be of such design that the maximum permitted temperature is not exceeded if the heaters are energised while the apparatus is in operation.

Heaters shall be equipped with a suitable terminal box. All Plant, whether fitted with a heating device or not, shall be provided with suitable drainage and be free from pockets in which moisture can collect.

6.5.8.2 Current Transformers

Current transformers shall be of the air insulated bar primary type and shall comply with BS 3938 (IEC 60185) and shall be suitable for operation under the specified fault conditions.

All current transformers shall have 1.0 A secondary windings and a minimum rating of 15 VA, unless specified otherwise.

The following current transformer types shall be used for individual applications unless otherwise specified:

Type of Application Class of CT

"Pilot wire" feeder protection X

Extreme inverse time overcurrent protection (e.g. transformers) 10P15

Inverse definite minimum time overcurrent and earth fault protection 10P10

"Frame leakage" protection 10P10

Measuring (e.g. ammeters, power factor) Class 3

Metering (e.g. maximum demand kVA and kWh) Class 0.5

All protection current transformers shall be of the low reactance type and the output shall be such that satisfactory operation is ensured when used with overcurrent and earth fault relays with inverse and definite minimum time lag characteristics.

6.5.8.3 Indication and Measuring Instruments

All indicating instruments mounted on control panels shall be of the flush mounted type, with matt black finish, industrial grade to BS 89 and BS 5685: Parts 1, 3 and 4 or other approved equivalent standard. The marking and lettering of faces and other displays shall be black on a white background. Full load current or normal voltage shall, where applicable, be marked with a red line on the scale.

The scaling of voltmeters shall be from 0 % to 120 % of the corresponding nominal system voltage.

Ammeters shall be scaled to suit the circuit loading and on motor circuits shall have a suppressed overload scale.

6.5.8.4 Polyphase Meters

Where required, polyphase meters shall be provided which comply with BS 5685 or similar approved standard.

The meters shall have a precision accuracy over a wide load range. The meters shall be of a compact design and be protected against corrosion by using electroplated assemblies. The meters shall have totally encapsulated coils to give a high impulse level protection and have magnetic support bearing to assure long life and accuracy.

Meters shall be housed in cases with a degree of protection IP 50, and shall be suitable for surface or flush mounting. The registers shall be of the large jumping figure cyclometer type, and the units of the register dials shall be clearly marked in the appropriate units. The maximum demand indicator shall be of the Merz pattern with a 312 mm scale to give an accurate reading of the average demand over the integration period which shall be 30 minutes, unless otherwise specified. The integration period shall be controlled by an internal synchronous time switch, but terminals shall be provided so that the integration period may be controlled from an external time switch.

The meter shall have a rating plate which shall be fixed to the housing and shall be visible without removing the front cover. The information on the rating plate shall comprise the following:

- class of meter
- type of supply
- pulse value (if required)
- DC supply (if required)
- revolutions / unit
- CT ratio
- VT ratio
- integration period
- meter No.
- meter type.

6.5.8.5 Protection Relays

All protection relays shall comply with the requirements of BS 142 or similar approved standard. The normal range of ambient temperature over which the relays shall comply with the requirements of the above standard during operation shall be - 10°C to + 55°C, unless otherwise specified.

The relays shall have dust-tight cases, glass fronted where necessary, and shall be designed such that when the case is opened with reasonable care dust shall not thereby be projected onto the relay mechanism. The degree of protection of the case shall be IP 52.

The relays shall be of approved type construction and finish and shall be arranged such that replacements can be effected quickly and with the minimum amount of labour. Relay equipment incorporating electronic devices shall be arranged to jack in, and there shall be positive means for locating them in the service position.

The contacts of all relays shall be capable of making the maximum current which can occur in the circuit which they have to control. They shall also be capable of breaking such currents unless provision is made for breaking the currents on contacts elsewhere in the circuits. Relays shall not be affected by mechanical shock or vibration or by external magnetic fields. The contacts shall be of approved material and shall be capable of repeated operation without deterioration.

All metal bases and frames of relays shall be earthed except where the latter must be insulated for special requirements.

All relays which are connected to complete either the tripping circuit of a circuit breaker or the coil circuit of any auxiliary tripping relay shall be provided with approved indicators which, wherever possible, shall be of the mechanically operated type. Indicators shall also be provided on such additional relay elements as will enable the type or phase of the fault condition to be identified.

Each indicator, whether of the electrically operated or mechanically operated type, shall be capable of being reset without opening the relay case and it shall not be possible to operate the relay when resetting the operation indicator. Each indicator shall be designed such that it cannot move before the relay has completed its operation. Indicators shall be clearly visible from the front when operated, and concealed at all other times. It shall not be possible to operate any relay by hand without opening the case.

Overcurrent relays shall be of the triple-pole type and shall be of the definite minimum and inverse time limit pattern with separately adjustable time and current settings. The time of operation when carrying a current of ten times the setting current shall be continuously variable from 0.15 to 3.00 seconds, and the current setting range shall be variable between 50 % and 200 % in six equal intervals of 25 %. The time current characteristics shall be as specified in BS 142 or similar approved standard.

Where specified in the Particular Specifications, each element of the overcurrent relay shall be provided with a high setting instantaneous element (HSIE) having a current setting range of between 4 and 16 times the setting of the inverse time element.

Where single-pole earth fault relays are specified, they shall have the same characteristics as the overcurrent relays except that the current setting range shall be 20 % to 80 % with suitable intermediate tappings.

All relays shall have 5.0 A rating unless otherwise indicated in the Particular Specifications or on the Drawings, and shall be suitable for operation in conjunction with the respective current transformers.

All relays shall be suitably marked with the following information:

- function of relay (e.g. Neutral / Earth / Fault)
- phase colour of the current supply
- characteristic curve, where appropriate
- rated current and/or voltage of the relay coils
- rated making capacity of tripping contacts.

The first three if these listed information items shall be visible from the front without removing the cover.

Auxiliary tripping relays shall have a simple attracted armature type of element, which shall incorporate cut-off contacts which shall interrupt the operating circuit instantaneously when the relay has operated and latched in to reduce relay burden and possible heating effect. These relays shall be of the hand resetting type.

Details of the protection system and the required relays will be stipulated in the Particular Specifications.

6.5.9 Remote Control Equipment and Motor Isolators

6.5.9.1 Remote Control Principles

Where remote control of motors is required the circuitry must be so arranged that:

- operational control is effectively confined to one station at a time;
- maintenance workers at the motor are effectively protected from inadvertent operation by some other person;
- stop controls shall be operable whenever the motor runs.

6.5.9.2 Motor Isolators

Where the starter is installed remote from the drive it controls, and unless otherwise stipulated, a weatherproof isolator shall be installed adjacent to the motor. The isolator shall be lockable and shall provide full isolation for the drive.

6.5.10 Control Stations/Pushbutton Stations

Control stations shall be fully enclosed (IP55) unless otherwise stipulated and shall be suitable for installation under prevailing Plant conditions as described in the Particular Specifications.

All control stations shall have at least one threaded 20 mm conduit/cable entry hole. A terminal strip of sufficient size shall be provided inside for the cable termination and shall be large enough to accept conductors of a maximum size of 4 mm2.
"Emergency stop" pushbuttons shall be mushroom headed, red in colour, and complete with latching mechanism which after being pushed to activate must be rotated 90° for release. Except where the circuit requires more, each emergency stop pushbutton shall have one normally closed contact.
"Stop" pushbuttons shall be red in colour, with one or more normally closed contacts.
"Start", "Reverse", "Forward", "On" etc. pushbuttons shall be green in colour and shall have one normally open and one normally closed contact.

All pushbuttons with functions other than the above shall be black in colour and shall have one normally open and one normally closed contact.
"On/Off", "Auto-Off-Manual" etc. switches shall be black in colour, and for each position shall have one spare contact which closes when that position is selected, and shall be lockable in the "Off" position.

6.5.11 Electric Cables

6.5.11.1 General

The Contractor shall supply and install all the power and control cables required for the operation of the Plant. The Contractor shall select the most suitable cable routes and raceways ensuring a minimum of interference with other installations.

Unless sizes are specified, the Contractor shall select cable sizes to suit the Plant, and this shall be reflected in the information provided in the Tender Schedules submitted with the Tender, taking into account the load, length of cable run, voltage drop, fault level and characteristics of the protective MCB or fuse on the particular circuit. All cable sizes shall be subject to the approval of the Engineer.

The arrangement of the cables and all methods of laying shall be planned to provide an orderly formation, free from unnecessary bends and crossings, which will permit the removal of any one cable without undue disturbance of adjacent cables. The standard of workmanship shall be to the approval of the Engineer.

Care shall be taken to avoid the formation of magnetic circuits around single core cables, or around any cables likely to carry unbalanced currents.

All cables shall be identified below the gland at each end and at approved positions by means of labels engraved or stamped with the cable number or feeder name, size of cable and number of cores. The labels shall be securely fastened in a permanent manner and shall be made of material able to resist corrosion, damp and mechanical damage.

Every cable shall be securely supported not more than 1.0 metre from its termination, and, where vertical runs pass through floors, immediately above the floor. The type of installation used for the support system shall be to an approved method.

6.5.11.2 Types of Cables

a. General

Unless specified otherwise in the Particular Specifications, only cables with copper conductors will be acceptable, and in respect of cables to 380 V / 220 V motors cables not exceeding 16 mm2 shall be 4-core or 7-core. Three or six cores, as appropriate, shall be used for power, and the fourth or seventh core respectively for the earth. Joints in cables are unacceptable except with the prior written approval of the Engineer.

The cores of all cables shall be identified by means of a colour code or permanently legible numbers.

Unless otherwise specified, and for power distribution cables up to 16 mm2, earth conductors may be provided by the use of a spare core in the cable. Where cable conductors exceed 16 mm2, a separate insulated copper wire with not less than half the cross sectional area of the conductor size shall be run with the cable and connected between earth terminals. The minimum size of insulated copper wire shall be 16 mm2.

b. 380 Volt Power, Control and Alarm Cables

All cables intended for operation at 380 Volt shall be 600 V / 1000 V cable complying with BS 6346 or equivalent standard approved by the Engineer.

The cables shall incorporate stranded copper conductors and XLPE or PVC insulation (as indicated on the Drawings) and shall be either drawn into conduit or trunking, or else armoured and PVC sheathed cables (steel wire armour in the case of multi-core cable, aluminium armour in the case of single core cable) as indicated in the Particular Specifications or on the Drawings.

Multi-conductor cables shall be number-coded and/or colour-coded or identified by other suitable means. The colour-coding or other identification system shall be shown on the circuit/connection diagrams.

Multicore control cables with more than 7 cores shall have approximately 20 % spare cores for future use.

c. Low Voltage Signal and Instrument Cables

Cables used to transmit signals from instruments, transducers or other apparatus such as float switches or ultrasonic sensors shall be suitable for the voltage, frequency and environment under which they will be required to operate. Where appropriate, the cables shall incorporate a screen and the Contractor shall make recommendations on the earthing/bonding procedures to be applied to the cables and apparatus. The cables shall be manufactured and tested to BS 5308 or other suitable and approved standard.

Where instrumentation cables are to be run outside a building, especially where they are to be buried in soil, a steel wire armour layer shall be incorporated in the construction immediately under the outer sheath.

6.5.11.3 Ratings

Unless sizes are specified, cables shall be selected by the Contractor with due consideration to the continuous current carrying capacity, the voltage drop, the short circuit capacity and the type of protection afforded by the protective circuit breakers or fuses in the selection. In addition, the Contractor must take into consideration the ambient temperature, location and method of installation.

Where cables are not manufactured to BS 6346 but are made to another approved standard, current ratings shall be determined in accordance with a recognised code of practice, e.g. IEE Wiring Regulations, 16th Edition.

Cables shall be sized so as to limit the maximum voltage drop at equipment terminals during full load operation to that laid down in the Regulations, that laid down in the standards, or to 5 % of the nominal system voltage, whichever is the lowest.

Motor feeder cables shall in addition be sized for maximum voltage drop during motor starting of 20 % of the nominal system voltage.

6.5.11.4 *Cable Terminations*

The following types of cable terminations shall be used:

- PVC/PVC/SWA/PVC or XLPE/PVC/SWA/PVC cables shall be terminated in armour grip type mechanical glands complete with neoprene shrouds;
- flexible cable terminations shall consist of a suitable mechanical gland complete with shroud.

Instrument and signal cables shall, where the apparatus to which it is connected so requires, be terminated on proprietary male/female plug connectors which shall in all cases be suitable for the conditions pertinent to the location of the connector and which shall incorporate a mechanical cable grip and seal to the approval of the Engineer. Where a special connector is not required, the cable shall be terminated through a suitable mechanical gland complete with shroud.

The tails of all cables shall be of sufficient length to facilitate disconnecting and testing, and for 3-phase power cables to allow any two tails of any cable to be interchanged (for phase reversal).

On all power, control, alarm and indication circuits copper conductors shall be terminated with suitable tinned and annealed copper crimp lugs. A hexagon type crimping tool and compatible lugs shall be used for all stranded conductors of 35 mm2 and larger.

Cables (or cores) carrying currents generated by a current transformer shall be terminated on "double stud" type terminals in order that the CT may be shorted in the event that wiring changes are required either at the time of commissioning or at a future date.

6.5.11.5 *Tests*

Cables shall be tested at the manufacturer's works in accordance with the routine tests described under the applicable standards.

Testing on site after installation shall include, but not be limited to, the following:

- Power cables measurement of insulation resistance (Megger test)

- Power cables measurement of voltage drop on motor feeders rated 100 kW or higher
- Control cables measurement of voltage drop of critical lengths.

6.5.12 Cable Trenches, Markers, Pipes, Tunnels, Ducts and Racks

6.5.12.1 General

All cabling shall be protected, as far as is practicable, by being run in tunnels, ducts, trenches, or on cable racks. The use of conduit for protection shall be avoided, although this does not apply to insulated conductors run in conduit for lighting and small power installations. Unless otherwise directed by the Engineer, all cables shall enter buildings below ground level.

6.5.12.2 Cable Trenches

Cables in main cable runs in excavated ground shall be buried at depths as prescribed, but minimum depths shall not be less than 600 mm for cables up to 1000 V or 1000 mm for cables of higher voltage.

Once trenching is completed, the bottom of each trench shall be cleaned of all stones, steel cuttings, bricks or any other sharp or large objects which could damage the cable, where after the cables shall be laid on an 80 mm deep bed of sieved soil. The mesh size of the sieve shall not exceed 6 mm.

Covering of the cables shall not be commenced until the cables in the trenches have been inspected and approved by the Engineer. If so specified in the Particular Specifications, protective covers shall then be placed over the cables consisting of precast concrete slabs, at least 30 mm thick and a minimum of 200 mm wide, as approved by the Engineer. The width shall be increased if necessary to adequately protect the cable or group of cables, so as to provide an overlap of not less than 50 mm on each side of the outside cables. The trench will then be backfilled in layers of 150 to 200 mm of soil thoroughly cleaned of all large or sharp objects and each layer of soil properly compacted.

For high voltage cables, or if specified in the Particular Specifications, the Contractor shall lay at approximately 300 mm below ground level along the entire length of the trench a cable marking tape of yellow colour bearing warning signs and the inscription "DANGER - CABLE" in English and Arabic languages.

The trench routes shall be clearly designated with concrete cable route markers at each turning point and in any event not further than 25 metre apart. A "turning point" is considered to be any point in the cable route which deviates from a straight line.

The rates for laying cables in cable trenches shall allow for all this work, including the supply and delivery to site of the precast concrete slabs and cable route markers, and the provision of suitable mesh sieves and hand rammers.

Unless otherwise approved, auxiliary cables shall not be laid under the same covers as power cables.

6.5.12.3 *Cable Markers*

Cable markers shall be made of concrete, approximate size 500 x 200 x 50 mm, buried on end 200 mm deep. The words "MV CABLE" shall be set into the marker on both sides. Markers shall be to the approval of the Engineer.

6.5.12.4 *Cable Pipes*

Cables laid into buildings, across roads, in concrete or through foundations shall be run in hard PVC plastic pipes. Unless otherwise specified, cable pipes shall be Class 4 PVC pipe. Cable pipes shall be buried at depths as prescribed, but the minimum depth shall be as for cables buried directly in trenches, unless otherwise shown on the Drawings or directed by the Engineer.

The cross sectional area of the pipes shall be utilised to not more than 50 %. Cable pipes shall, if so stipulated in the Particular Specifications or on the Drawings, terminate in concrete manholes before entering buildings. Manholes and pull pits shall be provided where required to facilitate cable installation.

Where pipe ducts have been provided through brickwork, masonry, or other solid construction, suitable local protection against mechanical damage shall be provided by the Contractor. The Contractor shall be responsible for sealing the openings around the cables, after the cables are laid, to provide a seal which is fire proof and water proof.

No cables shall be directly built into civil structures.

Cables on brick walls or similar civil structures can be laid in galvanised steel conduits or, if indoors, in prefabricated installation channels made of galvanised sheet metal or plastic.

Fire partitions shall be provided when cables are passing through different fire zones.

6.5.12.5 *Cables in Tunnels*

Trays and racks in tunnels used for access shall be installed on one side only and shall not impede any access way or operating area.

The details of the installation and fixing of signal cables laid within the concrete lined hydraulic tunnel shall in accordance with the Particular Specifications.

6.5.12.6 <u>Cable Ducts</u>

Cable ducts shall be of sufficient size to provide protection from mechanical damage and shall be self draining into a waste water reticulation system.

Cable ducts into substations, monitoring/control rooms and switch rooms shall be covered with chequer plating suitably reinforced.

Cable ducts in all other locations shall be backfilled with sand with a maximum particle size of 2.5 mm, covered with a minimum of 50 mm weak mix concrete screed, and the joint with the edge of the screed shall be ruled.

Where necessary, cables shall be laid on side mounted trays in ducts 1.0 m wide by 1.0 m deep.

6.5.12.7 <u>Cable Racks</u>

Cable racks and supporting brackets shall be of substantial design and shall allow a 25 % spare capacity.

Cable racks shall be installed vertically, and may be mounted as follows:

- Directly upon structural steelwork or masonry, for which any drilling or welding of structural steelwork may only be carried out with the prior written approval of the Engineer;
- Directly on the side wall of the tunnel used for access as shown on the Drawings;
- On the floor in the form of single or double sided stands.

Racks and brackets shall be constructed of galvanised mild steel or other non-corrosive material, and may be either purpose made from standard sections or a pre-formed package system of metal frame construction. All sections shall have sufficient mechanical strength so that distortion is prevented.

Ladders and trays shall be capable of supporting an increase of 25% in cable weights, and the design shall include a factor of safety to guard against permanent distortion when the ladders and trays support erection staff during cable installation. The inside radius of bends in cable trays measured from the centre of the axis of the bend shall not be less than 450 mm and in every case be suitable for the cable supported.

In chemically-endangered areas all racks, supports etc. shall be of hot-dip galvanised steel elements painted with suitable lining-resin paint or provided with a sintered coat of suitable material for protection against such chemical environment.

Painting and lining coating shall only be carried out on cable racks which are completely installed, but before actual cable installation.

Galvanised ladder type cable racking shall be used for supporting all cables of 50 mm2, triple-core and larger, and the cable shall be clamped by means of proprietary galvanised clamps designed for the racking.

Galvanised perforated cable trays shall be used for supporting all cables of 35 mm2 and smaller. The tray shall be securely fixed on galvanised stand-off supports, and the cables shall be secured to the tray by means of strapping at approved intervals. Not more than three cables may be secured by a single strap.

Power cables up to 16 mm2 and control cables on racks may be run double banked. Cables above this size shall be run in single layers and clamped singly.

Single cable runs shall be clamped to suitable flat bars welded to steelwork and shall be fixed by means of galvanised or approved plastic strapping. The strapping of all cables, including all cable saddle supports shall be done in a manner so that no sagging occurs on a horizontal run after the installation is completed. Cable dropouts to equipment shall be provided with substantial angle iron supports.

PVC cables run overhead or outside shall be run so as to avoid direct sunlight as far as possible.

Care shall be exercised by the Contractor to ensure that cable trays or supports do not obstruct access to areas where maintenance or other work activities are likely to be performed, or the flow of light from light fittings.

Although the clamping of cables to structural steelwork is not permissible, individual cables may be saddled directly onto existing concrete and steel structures in accordance with acceptable and approved practices. Cable saddles shall be approved by the Engineer and shall be fixed at intervals on vertical and horizontal runs not exceeding those laid down in the Wiring Regulations (BS 7671).

6.5.13 Alarm Scheme

Unless indicated otherwise in the Particular Specifications or on the Drawings, the alarm scheme shall be based on the following principles or provide the following features:

i) The alarm scheme shall be operated by a secure DC supply, preferably 12 Volt unless a different voltage is specified or is needed for some other DC function and can be made common with the alarm supply, and shall be supplied complete with suitably rated battery and charger.

ii) Alarm information shall not be lost in the event of an AC mains power failure.

iii) A DC buzzer shall be included, which is audible over a distance of 10 metres.

iv) Except with the Engineer's approval, the alarm scheme shall utilise easily replaceable incandescent bulbs for indication rather than light emitting diodes.

v) The following switches shall be incorporates:

- Accept (silence/audible alarm) pushbutton
- Reset pushbutton
- Lamp Test pushbutton.

vi) Separate amber or red alarm indicator lamps shall be provided for each of the various alarm conditions it is required to signal.

vii) Upon initiation, the relevant alarm lamp shall flash and the buzzer shall operate until the Accept pushbutton is depressed, which action shall silence the buzzer and change the alarm lamp status to steadily lit. The alarm lamp shall stay lit until the operator has had a chance to log the alarm and tackle its cause, whereafter he will press the Reset button. The flashing of the lamp and operation of the buzzer shall occur even if a previous alarm condition has been acknowledged but not yet been reset.

viii) If any alarm condition is still present, operation of the Reset pushbutton shall not permit the cancellation of that alarm.

ix) An AC hooter and indicator lamp shall operate in the event of a failure on the DC supply to the alarm scheme, and a pushbutton shall be provided to silence the hooter.

x) Repeat contacts shall be provided (1 NO and 1 NC for each of the following alarms) for remote signaling to indicate separately:

- group alarm condition
- alarm power failure.

The alarm scheme shall be mounted in a wall mounting panel, be equipped with a gland plate and all the equipment needed for providing the above features, and shall have hinged doors or removable covers to permit access to the terminations and internal equipment.

6.5.14 Battery Charger and Batteries

6.5.14.1 Charger

The battery charger shall be designed to charge the connected battery according to a charging regime suited to the type of battery, and shall be manufactured in accordance with a recognised standard.

Unless otherwise specified, the charger shall be designed to operate from a 220 Volt AC single-phase supply which may vary to ± 10 % from nominal. The charger control circuits shall be designed such that the output voltage or output current, as applicable, is automatically controlled within 3 % of the designed or specified level against a supply variation of ± 10 % and a load variation of between 0 % and 100 %. A manual control facility shall be provided to set the floating voltage or charging rate.

The charger shall be capable of charging the connected battery from fully discharged to at least 80 % of the battery capacity within 16 hours.

The battery charger shall include the following features:

i) "On/Off" switch for the AC supply input

ii) lamp to indicate "Mains On"

iii) Suitably scaled moving coil instruments to indicate:

- battery voltage
- charger current
- battery current (bi-directional)

iv) AC input fuse

v) DC output fuses in both positive and negative poles

vi) alarm contact to signal low battery volts

vii) alarm contact to signal any fault condition in the charger.

The internal wiring of the charger shall be ferruled and ferrule numbers must only change where the circuit is interrupted. The charger shall be housed in a cubicle suitable for installation in an outdoor protection panel. The charger shall be fitted with a rating plate which shall be securely riveted to the outside of the unit, and two cable gland holes shall allow entry and exit for the AC and DC cables. The positions of the AC input and DC output terminals shall be clearly labelled.

6.5.14.2 Batteries

The batteries shall be of the "NICAD" nickel cadmium Alkaline type or similar approved, and unless otherwise stipulated in the Particular Specifications or agreed by the Engineer shall be designed to supply a 12 Volt (nominal) alarm scheme. The cells shall be housed in plastic containers, shall be supplied with a suitable wooden stand and shall be interconnected by bolted links. The batteries shall be supplied complete with a protective box, cell test voltmeter and record (log) book. The Ampere-Hour rating of the batteries shall normally be selected by the Contractor to operate his equipment under worst case conditions for a period of 24 hours, or as specified in the Particular Specifications.

The preparation of electrolyte for the batteries and the charging cycles performed to initialise the batteries shall in both cases be strictly in accordance with the battery manufacturer's recommendations, and the Contractor shall deliver to the Engineer within a week of filling the batteries a signed statement that the recommended procedures have been followed, clearly stating the date(s) and by whom the steps were taken. The Contractor shall in addition make an entry in the battery log book to record the date and procedure followed in initializing the cells.

6.5.14.3 UPS equipment

Pump stations will be equipped with (UPS) to cover the time period between the main network power break and the generator unit taking off in case of the failure of the generator unit to start the UPS unit shall supply continuous power for 15 minutes.

Every UPS unit consists of a charger and batteries with inverter working as stand-by sources for power that provides continuous supply for the connected equipment in case of general supply break.

The group consists of two metal enclosures each having a screen showing the necessary information.

The operation modes of the UPS unit are as follows:

i) Mode 1

The main power supply is on. Loads are supplied by the converter while the batteries are being charged.

ii) Mode 2

In case of network power failure, the loads are supplied from the batteries through the UPS continuously without making any disturbance in the load supply.

iii) Mode 3

In case of the load or any defect in the converter circuit, the supply will be instantly through the main, by static by-pass switch.

When the failure is removed, the unit will instantaneously return to the previous position without any disturbance in supply.

The charger shall be equipped with special switches for trickle charge position and for boost charge position, and suitable for (1U, 1W) charging according to DIN 41773 (voltage stability ± 1%, current stability ± 2%) for a gradual ± 10% change in the supply voltage, a ± 4% change in the frequency and load change from 0% to 100%. The charger is also to be equipped with a suitable manual switch for the primary charging of the batteries.

The converter elements must be of silicon THYRISTOR type.

The charger shall be equipped with the following meters:

- Voltmeter: for the batteries
- Ampere meter: for the charger current

for measuring the load current

- Frequency meter

All necessary operating switches and automatic protection switches and fault indicators shall be included.

The batteries must be maintenance-free lead-acid type.

All components of the unit (including materials and paint systems(shall be alkaline resistant.

The principal operating characteristics of the UPS system are as follows:

Work principle:	double conversion, true, on line
Power:	5 kVA
Input voltage 3-phase:	380 V / 220 V ± 20%
Input frequency:	50 Hz ± 5%
Output voltage:	380 V / 220 V ± 1%
Output frequency:	50 Hz ± 1%
Wave form:	sine, distortion less than 3%
Overload:	50% for one minute
Time of discharge:	15 minutes
Ventilating system:	coactive
Operating humidity:	30% – 80%
Noise:	less than 40 dB
Battery type:	lead-acid, maintenance-free
Battery endurance:	10 years
Operating periods:	15 minutes discharge 30 minutes charging time 15 minutes discharge

6.5.15 Lighting and Small Power Distribution

6.5.15.1 *LV Distribution Boards*

The lighting and small power distribution boards shall be either surface (wall) mounted, or of the architrave type, suitable for flush mounting in the wall.

Access to the distribution board shall be from the front by means of a double or single leaf door, depending on the size of the cabinet. The door shall be flush fitting and shall be provided with rust resisting, robust hinges and door handles of the padlocking type. In the case of surface mounted boards, top entry of conduits shall be avoided.

Suitable gaskets shall be fitted to the board to ensure sealing of the door(s) to achieve the standard of protection specified. Foam rubber is not regarded as suitable. Key catches shall be fitted to ensure proper sealing of the gaskets.

The boards shall be cleaned and painted in accordance with this specification.

Each board shall be equipped with copper busbars continuously rated for the full load of the incoming supply plus 20 %, and one external/internal earthing bolt, firmly attached to the metal work of the boards, which is firmly connected to an adequately rated earthing bar to which all earthing conductors shall be firmly connected.

13 Amp and 15 Amp socket outlets shall be protected by earth leakage units with a 30 mA sensitivity. Welding socket outlets shall be protected by earth leakage units with a 300 mA sensitivity.

Contactors shall comply with BS EN 60947-4 or IEC 60158, and shall be of minimum AC 3 rating for the safe switching of the number of mercury vapour or HP sodium lamps as prescribed.

All switches and switch/fuse units shall conform to BS EN 60947-3 or IEC 60408 and shall be of the quick break, dust proof type.

Equipment shall be mounted on a rigid folded and a welded minimum 1.2 mm thick mild steel chassis, and isolator, circuit breaker and switch toggles shall project through slots in a removable panel.

A minimum of 20 % spare ways per phase shall be provided, complete with blanking plates in the front panel, on all lighting and small power distribution boards.

Each board, and the terminals of all outgoing circuits, shall be labelled in an approved manner to correspond with the labelling of the units on the panel of the distribution board.

A durable circuit chart listing the incoming isolator, all MCBs, E/L units, contactors etc. shall be secured inside the front door.

6.5.15.2 Light Fittings

The types of light fittings required are as stated in the Particular Specifications. Light fittings and lamps shall be supplied, installed, checked, connected, lamped and tested by the Contractor who shall, however, place no order for them until patterns have been approved by the Engineer.

6.5.15.3 and Fingerplates

All switches and fingerplates in final subcircuits are to be AC rocker type mounted in metal or PVC boxes as specified, holding the requisite number of switches, and must be adequately rated for the load they control.

6.5.15.4 Time Switches

A time switch shall consist of a 225 Volt AC, 50 Hz single-phase synchronous motor with a battery powered or mechanical spring reserve of 12 hours. It shall incorporate contacts suitable for making and breaking a current of 16 A resistive or 3 A inductive at 250 Volt AC.

Time switches shall be of modern design, small in size, lightweight suitable for dinrail, flush or direct surface mounting. They shall also be easy to programme with a minimum time setting of 15 minutes and a complete cycle time of 24 hours.

6.5.15.5 Socket Outlets

The types of socket outlet required are stated in the Particular Specifications. These are to be supplied complete with metal or PVC boxes (for surface or flush installation respectively). Unless otherwise specified, they shall be 13 Amp or 15 Amp, switched, 3-pin, to an approved standard (as detailed in the Tender Schedules and subsequently approved by the Engineer). A maximum of five socket outlets may be fed on a 30 Amp ring circuit, given that a twin socket outlet may be counted as a single unit. All socket outlets are to be mounted in the conventional flush wall-mounted single or twin configuration at a mounting height of 300 mm above finished floor level unless otherwise specified or directed by the Engineer.

6.5.15.6 Trunking

The type of trunking required is stated in the Particular Specifications in terms of material, dimensions, number of compartments, and method of installation.

In all cases however, corners, elbows, or changes in direction shall be of rigid construction, i.e. corner pieces shall be welded, not cut on site.

Perforated copper earth strap shall be used to provide earth continuity across all joins and to the Distribution Board. Trunking shall in all cases be rigidly fixed to its supporting surface (wall or slab), and trunking covers shall be installed free from distortion with an adequate number of screws or clips to ensure this.

6.5.15.7 *Conduit and Conduit Fittings*

In all surface installations, rigid screwed metal conduit shall be used (BE indoor, galvanised outdoor) and be secured by means of stand-off saddles at intervals not exceeding 1.2 metres. Outdoor installations shall be completely weatherproof and shall be to the approval of the Engineer.

On long conduit runs and at concrete and structural steel expansion joints, suitable conduit expansion joints and earth bonding conductors shall be provided. Flexible conduit and couplings shall be to the approval of the Engineer.

PVC conduits may be used in all installations cast in concrete, and chased into plastered brickwork or masonry. A minimum of two steel boxes are to be used for securing fluorescent fittings however, and proprietary adaptors used to convert to PVC conduit.

Where joints occur between steel and PVC conduit, a female steel coupling shall be screwed onto the steel end, a PVC proprietary adaptor coupling screwed into that, and the other end shall then be glued over the PVC conduit.

Conduits which are not being wired under this Contract (e.g. telephone conduits) shall be fitted with a draw wire.

6.5.15.8 *Welding Socket Outlets*

Welding socket outlets shall be metal clad and shuttered. Unless otherwise specified, they shall be of the 4-pin type (3-phase + earth) for 380 Volt, 3-phase, 50 Hz, 3-wire, of a rating as specified, and their installation shall comply with BS 7671 (IEE Wiring Rules, 16th Edition).

The welding sockets shall be equipped with one 3-pole gang operated fault make load break isolator which is fully interlocked with the connected plug, such that the plug cannot be inserted or removed when the isolator is "On". Alternatively sockets having a rotary type interlocked switch with dust-tight and weatherproof spindle may be acceptable.

The housing of the welding socket shall be of a type and material to suite the site conditions as mentioned in the Particular Specifications. No preference shall be given towards any construction and therefore full details of performance data of the offered sockets are to be submitted with the Tender. The welding sockets shall be provided with an adequately sized conduit or cable entry hole.

Earth leakage protection shall be provided for all circuit breakers feeding welding socket outlets (300 mA instantaneous).

6.5.16 Other Equipment in Switchrooms

All electrical switchrooms shall be provided with notices prohibiting unauthorised interference with electrical apparatus and giving directions for first aid for electric shock etc.

In addition each electrical room shall be provided with a CO2 type fire extinguisher and a glass framed single line diagram of the reticulation system.

6.5.17 Earthing System

The earthing of all electrical equipment shall be consistent with BS 7430, shall comply with the requirements of BS 7671 (IEE Wiring Rules, 16th Edition), and shall be to the approval of the Electrical Supply Authority and the Engineer.

The earthing shall comply with the requirements of the Wiring Rules without taking account of any sensitive earth leakage units which are specified, and the earth loop impedance tests shall be carried out at all socket outlets to ensure compliance.

All metalwork associated with the electrical Plant such as switchgear, motors, conduit and cable sheaths and cable racking shall be connected directly to earth, but not to an Electrical Supply Authority earth connection unless so required by the Electrical Supply Authority. A continuous metallic conducting path shall be formed using copper conductors to bond the metalwork to the earthing system, and to ensure electrical continuity to an earth bar in the main switchboard.

The earthing bar in the main switchboard shall be connected to earth electrodes which shall consist of a network of horizontal conductors with vertically buried rods connected to the horizontal conductors of suitable cross section. Rods shall have a diameter of not less than 16 mm and a length not less than 2 metres. In addition, one earth rod is to be driven as close as possible to the main board using 16 mm2 bare conductor.

Where driven rod earthing electrodes may not be practical, copper earth mats and/or copper conductor earthing in the main cable trenches shall be provided and connected up to the earthing bar in the main switchboard.

All steelwork, racking, roof, gutters, down pipes, water pipes, waste pipes, etc., shall be effectively bonded to the main earthing network.

The earthing system shall be designed to have a resistance to the general mass of earth of not greater than 3 ohms, and this shall be measured by the Contractor in the presence of the Engineer separately for each building and for all interconnected systems.

Where potential corrosion hazards exist, for example from saline laden air, industrial fumes, spillage of corrosive liquids etc., all earthing conductors shall be PVC covered. The colour of the PVC cover shall be standard green/yellow or green.

The sole use of wire armouring of cables for earth continuity purposes is not permitted. A separate bare copper conductor not less than half the cable core size (minimum 16 mm2) shall be employed or, for cables up to and including 16 mm2, an extra core in the cable may be used for earthing (if included in a multicore cable it may be black, with green markings at terminations).

Socket outlets shall be earthed to the earth bars of the distribution boards via an earth conductor.

6.5.18 Outdoor Distribution Feeder Pillars

Outdoor distribution feeder pillars shall be non-corrodible and shall be fully weatherproofed and suitable for outdoor installation. Each pillar shall be complete with mounting frame and two front doors, arranged to open through an angle of 180°. The doors shall be fitted with an approved hasp and staple to accept a standard padlock.

The general layout of the feeder pillar shall be at the discretion of the Contractor, but drawings shall have to be submitted to the Engineer for approval before manufacture is commenced. Each pillar shall be provided with rear and front entry and shall be suitably ventilated and vermin-proofed. Gland plates shall be easily removable and shall also be vermin-proof.

Pillars shall be finished in white baked enamel inside and grey baked enamel externally. The internal wiring of the outdoor distribution feeder pillars shall be in accordance with the requirements of this Specification.

The outdoor distribution feeder pillar shall be provided with an earth terminal stud fixed onto the mounting frame. The mounting frame shall be firmly bolted to a concrete plinth of suitable size. Cables shall enter the pillar from below ground level.

Where the feeder pillar is required to house a current transformer compartment for the Electrical Supply Authority metering, or any busbars, fuses or switchgear for the Electrical Supply Authority, the respective compartments shall include provision for sealing by the Electrical Supply Authority. The exact method is to be approved by the Engineer, but it is envisaged that a method involving holes drilled through the heads of screws and adjacent posts/tabs may be acceptable and will permit the Electrical Supply Authority to prevent unauthorized access using wire and lead crimp seals.

6.5.19 Low Voltage Power Factor Correction Equipment

6.5.19.1 General

This Sub-Clause specifies the capacitor type power factor correction equipment for use in electrical power systems rated 600 Volts and less.

The system shall consist of one or more power factor correction units installed in a dedicated enclosure, IP 43, for indoor installation, which shall achieve a power factor correction of at least 0.95 and shall be an integral part of low voltage panel board. The system shall include a separately mounted current transformer sensing current in the power circuit being corrected, and providing input to the system controls. The capacitor shall be of the dry type and shall be capable of withstanding twice its rated voltage for 10 seconds at the rated frequency. The capacitor shall also withstand 3 kV for 10 seconds, and capacitor losses shall be less than 0.5 W/kVAR.

The material and equipment to be provided by the manufacturer shall be essentially standard cataloged products. Standard catalogue items and IEC (or NEMA) sizes, ratings, capacities and voltages shall be given preference. The products and the manufacturer shall be registered as being acceptable to the Employer.

All access panels to the electrical equipment shall be provided with appropriate warning labels.

6.5.19.2 Reference Standards

The design, manufacture and installation of this equipment as a part of the low voltage panel shall be in accordance with one or more of relevant publications of the following standards, subject to the approval of the Engineer:

- International Electro-technical Commission (IEC)
- Institute of Electrical Engineers (TEE)
- National Electrical Manufacturing Association (NEMA)

6.5.19.3 , Warranty and Product Quality

For the products specified the Contractor shall submit for the approval of the Engineer data on the features, components, ratings and performance. This information shall include a dimensioned plan and elevation views of the enclosure and details of control panels, showing access and working space requirements.

The Contractor shall full technical data on the effect of the actual sizes of the motors and generators under this Contract on the capacitors.

The Contractor shall submit three complete original sets of operation and maintenance manuals. Each set shall include:

- lists of spare parts for 3 years of operation and replacement, to be stored at the site for ready access;
- detailed operating instructions covering both normal and abnormal conditions;
- detailed installation/construction manuals.

In case of any proposed deviation or alternatives, the Contractor shall provide sufficient data to allow evaluation of proposed alternatives with his Tender.

The Contractor shall furnish extra materials suitable for interconnection, commissioning and operation matching all products installed and identified with labels describing contents.

6.5.19.4 Configuration

The basic types of power factor correction equipment used to incorporate the capacitor cells may include automatic systems which include integrally mounted, factory wired major components.

Individual capacitors (rated at 440 – 470 V) shall be self-healing utilizing dry polypropylene films as a dielectric with vacuum deposited conductors on the polypropylene as an electrode. Each 3-phase capacitor shall be furnished with an approved pressure sensitive interrupter. The interrupter shall disconnect all 3 phases at the same time to maintain a balanced circuit.

The capacitors shall be contained in hermetically sealed metal containers to prevent atmospheric contaminants from shortening the useful life. The nominal design life of individual capacitor cells shall be 10 years, and they are to be covered by a 5-year warranty from the manufacturer.

The dielectric material shall be low loss, less than 0.5 Watts per kVAR. Multiple fused capacitor banks shall have dry metallized dielectric of the self-healing type. To reduce line transients on system no stage shall switch more than 120 kVAR and no capacitor cell shall exceed 50 kVAR.

The dry cell encapsulation medium shall be a thermoplastic material which allows out-gassing to engage the pressure interrupter.

The terminal bushings shall withstand 10 kVAC to ground and be rated at 30 kV or greater.

All capacitor cells shall have threaded terminals for wire connection, and multiple contactors shall connect capacitor banks selectively to the output circuit. The contactors shall be 660 V rated category AC 6b with dampling resistors for the repetitive high-inrush-switching duty presented by the capacitor loading, and shall be of the fast opening and closing type. The contactors shall help to achieve a reduction in the transient starting current from 200 to 100 times (maximum) the nominal current.

Solid-state microprocessor-based controls (power factor regulator) shall be provided to switch the banks on and off (on a flexible step basis) to suit the amount of power factor correction needed as load conditions change in the distribution system served, and which shall be suitable for harmonic applications.

Discharge resistors shall be provided to discharge safely and automatically the stored energy in the capacitors. The discharge shall be within 1 minute after disconnection from the supply. Resistor shall be chosen to ensure 20 years minimum life.

A potential transformer is required for the under-voltage relay which interrupts the capacitor switching for a power supply interruption longer than 15 ms.

"Advance" and "Retard" pushbuttons on the control panel shall permit manual sequencing of the capacitor switching, together with an "On-Off" switch. Buttons will permit the target power factor range to be adjusted from 0.75 to 1.0 PF inductive, and the step combination as well as the delay between steps to be adjust or selected.

A current transformer shall measure the overall current of loads and capacitors mounted on the incoming of the main switchgear and interconnected to the control switching.

Air-core type inductors with the coil mechanically braced to withstand short-circuit current (SCC) shall be installed in the capacitor circuit to be used to limit switching surges within the contactor ratings.

Indicator LED lights shall indicate the energized capacitor banks.

A power factor meter will be provided, together with blown fuse indicators with 3 "push-to-test" blown fuse pilot lights (one per phase) mounted on the door to indicate a blown fuse condition.

The circuit breaker magnetic characteristics shall be Curve "D" and in accordance with IEC recommendations for switching and protecting capacitors by circuit breakers.

HRC fuses are to be provided to provide for major fault protection, with line fuses being provided on all 3 phases of each switched stage and fixed bank. The line fuses shall be current limiting, recognized Class T type or equivalent, with minimum interrupting ratings of 200 000 A. For fuses of 30 A and above, the fuses shall be designed for capacitor applications and shall be rated not less than 200% capacitor current rating.

Necessary filters of system harmonics elimination shall be provided.

Alarms will be provided for:

- low power factor
- overload
- over-current
- under-voltage
- over-voltage
- over temperature.

6.5.19.5 <u>Fault Current Considerations</u>

Air-Core Type inductors and power buswork in the power factor correction units shall withstand the mechanical forces that occur when the prospected short circuit currents flow.

These currents shall be limited by the appropriate protective means, and the bracing of these components shall withstand the peak asymmetrical symmetrical short-circuit current (S.C.C.) of the system.

The switching device should be over sized (as mentioned below) to exceed the capacitor nominal current as follows:

Moulded Case Breakers 150%.

The wire sizes shall match the switching devices rating.

Performance Requirements

The controls shall continuously sense the power factor on the circuit being corrected and when it differs from the target settings for more than 10seconds, system shall bring the corrected circuit power factor closer to the target setting.

The supply cables and the control and protection devices of selected capacitor bank ratings shall be oversized to at least (1.3 x1.15 =1,5) times their current rating (other than installation derating requirements)

Only one capacitor bank shall be switched at a time.

The construction of the system should give excellent withstanding capability to current transients resulting from frequent switching of the stages of a multistage capacitor bank.

6.5.19.6 *Execution*

a. Inspection

Examine conditions under which centralized automatic power factor capacitor assemblies are to be installed. Notify Engineer in writing of conditions detrimental to proper completion of the work. Do not proceed with work until unsatisfactory conditions have been corrected.

b. Installation

Install centralized automatic power factor capacitor assemblies as indicated in accordance with manufacturer's written instruction, requirements of applicable standards, and with recognized industry practices to ensure that installation complies with requirements and serves intended function.

Coordinate as necessary to interface installation of centralized automatic power factor capacitor assemblies with other work.

Mount the switchboard assembly on flush steel aligning channels elevated above floor level by a concrete pad.

Ensure that centralized automatic power factor capacitor assemblies are shipped in sections which can be fitted through the available structures and openings available.

Bond together the centralized automatic power factor capacitor assemblies structure, sections and all conduits terminating at the same with a 120 mm2bare copper earth (ground) cable, and connect to the switchboard earth(ground) bus and to the earthing (grounding) grid as required. Provide conduits terminating at centralized automatic power factor capacitor assemblies with earthing (grounding) Wedges of the required size.

Tighten electrical connectors and terminals, including screws and bolts, in accordance with equipment manufacturer's published torque tightening values for equipment connectors.

Provide 6.35 mm minimum thick x 60 cm wide insulation material (on ground) in front of centralized automatic power factor capacitor assemblies and rear of freestanding equipment and extend 30 cm beyond ends.

Provide protective covering during construction. match original finish. Provide control fuses, with five spare fuses for each rating.

c. Field Quality Control

Upon completion of installation of equipment and after circuitry has been energized, test equipment to demonstrate compliance with requirements When possible, field-correct malfunctioning units, then retest to demonstrate compliance.

Prior to energization of switchboards and centralized automatic power factor capacitor assemblies:

- Perform insulating resistance test on each pole, phase-to-phase and phase-toearth for one (1) minute. Minimum test voltage to be 1000 Volts D.C. with a minimum resistance of 100 megohms.
- Check centralized automatic power factor capacitor assemblies for continuity and for short circuits.
- Notify Engineer of any abnormalities.

After assemblies are energized, demonstrate functioning in accordance with manufacturers requirements.

d. Maintenance

All maintenance and inspection on the capacitor assembly shall be done with the system disconnect device in the open position.

Maintenance and inspections (before handing over of the installation) should be limited to 15 minutes or less so not to affect utility billing.

An annual inspection of the capacitor cell (before the handing over of the installation) shall be done to identify failing capacitor cells (a bulged cover is the symptom to watch for).

6.6 INSTRUMENTATION AND CONTROL EQUIPMENT

6.6.1 Design Criteria

6.6.1.1 *General*

All components shall be of an approved and reliable design, providing the highest degree of uniformity and interchangeability and facilitating maintenance and repair of the components. All components shall be suitable for continuous operation under site conditions.

The equipment shall be pre-assembled to the maximum extent possible in the manufacturer's works, including shop welding of thermometer wells and other connections, wiring of boards and desks, internal wiring and installation of devices etc. Fragile instruments shall be removed for transportation to Site.

Materials for instrumentation and control equipment, including piping materials which are exposed to the measured media, shall be selected accordingly. All components shall also be compatible with other electrical, electronic and mechanical equipment. Shielded cables shall be provided for the control and supervisory equipment where required.

All instrumentation and control functions shall be shown on the piping and instrumentation diagrams and the symbols to be used shall be in accordance with ISO standard. The identification system (tag numbers) shall be in accordance with the Plant identification system and is subject to approval by the Engineer. All measurements and alarms shall be listed in a measuring list of a standard form, which shall be subject to the approval of the Engineer. For remote controls, a schedule of interlocks shall be provided, and the features of automatic controls shall be shown in block diagrams.

6.6.1.2 *Sizes of Indicators, Recorders, etc.*

The meters, instruments and recorders shall be of standard size, to be selected to guarantee unique appearance of switchgears, control panels, control desks, etc. The front glasses shall be of the anti-glare type, and the scales shall be 90· or 240· type.

The indicating instruments and recorders shall have the following or similar sizes:

- Indicators on local control panels, MV and LV switchgears:

72 x 72 mm or 144 x 72 mm

- Indicators on vertical sections of control desks in control / monitoring rooms and on rectifier or converter panels:

96 x 48 mm or 96 x 96 mm

- Indicators on horizontal parts of control desks in control / monitoring rooms:

48 x 48 mm

- Indicators on control panels in control / monitoring rooms:

72 x 72 mm or 144 x 72 mm or 144 x 144 mm

or when incorporated in mimic diagrams: 96 x 48 mm

- Recorders:

line and 6-point recorders 144 x 144 mm

12-point recorders: 288 x 288 mm

- Pressure gauges and other dial type instruments (local):

60 mm diameter (preferably)

The control switches, adjusters, etc., on the panels and desks shall harmonise with the utilised indicator sizes.

6.6.1.3 Special Local Conditions

If the prevailing local conditions require special measures, the following shall be observed for the I&C equipment:

i) Local indicators shall be of stainless steel.

ii) Copper pipes shall be protected with an external plastic sheath.

iii) External bolts and screws shall be of non-corrosive material.

iv) Secondary shut-off valves, balancing and drain/blow-off valves shall be of the non-corrosive type.

v) Metallic instrument piping shall be protected with corrosion protecting painting, or shall be of non-corrosive materials.

vi) I&C equipment exposed to the sun shall be protected against direct solar radiation by means of protection casings, sun shields etc.

vii) Multi-core I&C cables installed outside buildings shall be completely protected by means of closed cable trays, flexible conduits etc., and the individual cables from the terminal boxes to the instruments shall be protected as far as practicable.

6.6.2 Tests

The individual components and pre-erected assemblies shall undergo functional and routine tests at the manufacturer's works. The ready mounted control and supervisory system shall undergo functional tests on Site prior to commissioning of the Plant.

Calibration tests shall be made on all important pressure gauges and other instruments as required by the Engineer.

6.6.3 Measuring Systems

6.6.3.1 General

Only electric measuring signals of from 0 mA to 20 mA or from 4 mA to 20 mA shall be transmitted to the control room. The output signal of transmitters shall be from 4 mA to 20 mA and linear over the whole measuring range. The binary sensors shall be fused separately and supplied with 24 Volt DC, unless otherwise specified.

The components shall quickly respond to any changes of the measured magnitudes. Measuring ranges of indicators, transducers etc. shall be selected in such a way that wherever possible the rated value of the measured magnitude covers approximately 75% of the range.

All local instruments shall, as far as practicable, be mounted vibration free to allow good reading, and damping elements shall be used wherever necessary.

All local indicating instruments and test connections shall be included in the respective equipment as integrated parts. The scope of local indicating instruments and test connections shall enable the operator to properly survey the equipment, and shall also allow to adequately carryout all acceptance and other tests.

Corresponding systems shall be grouped together in local panels.

6.6.3.2 Flow Measurements

The design and performance of the flowmeters shall be in accordance with the applicable standards.

The design and arrangement of tapping points, piping and valves shall be in accordance with VDI/VDE rules 3512.

Beginning at a rate of flow of no more than 5 % of the measuring range, all flow transmitters shall measure correctly. The error limit shall be ± 1 % for a rate of flow higher than 10 %, whereby the error of the primary elements is not included in this accuracy. The root extraction of flow measurement shall be effected electrically within the transmitter.

The arrangement of the throttling device, and the straight lengths upstream and downstream from the throttling device, shall be in accordance with the applicable standards and the manufacturer recommendations. Bends shall be at a sufficient distance upstream from the throttling device, particularly when large orifice ratios are used.

6.6.3.3 *Temperature Measurements*

All wells for capillary type thermometers, resistance temperature sensors and thermo-couples shall be of the weld-in type. Wells for thermometers and temperature sensors of the screw-in type shall be restricted to measuring points for lubrication oil and to such measuring points where welding is not suitable, e.g. at cast-iron parts. Shop-welded thermometer wells shall be covered by screw caps for protection during transportation and erection.

The temperature sensors shall be selected in such a way as to minimise the number of different spare inserts.

Temperatures to be recorded shall be measured by means of resistance thermometers or thermocouples which can directly be connected to the recorders. The use of dial-type contact thermometers shall be restricted to bearing metal, cooling water and oil temperature measuring. In all other cases, thermocouples or resistance thermometers and electric contact modules (monitors) shall be used. Glass thermometers or similar will not be accepted as contact thermometers.

Resistance thermometers shall generally be of type Pt 100 or Ni 1000. Double resistance thermometers (with two resistors in one insert) should be avoided.

Resistance thermometers and thermocouples shall be equipped with water-proof connection heads. Thermometer arrangements shall be such that the temperature of the connection heads does not exceed 80· C, and the measuring inserts shall be easily exchangeable.

6.6.3.4 *Pressure Measurements*

The design and arrangement of tapping points, piping and valves shall be in accordance with VDI/VDE rules 3512. In general, all pressure gauges, transmitters and pressure contacts shall easily be accessible for maintenance and supervision.

Pressure gauges shall be shock-proof and vibration-proof (preferably by filling with glycerine), and shall be equipped with toothed wheels and toothed segments of the machined type. All casings shall be dust proof and watertight and be made of stainless steel.

The error for pressure transmitters shall not exceed ± 0.5 %. Higher than rated pressure shall not deteriorate the pressure gauge or affect its calibration. The pressure gauge shall be equipped with a radial connecting stud, to allow the mounting on a gauge holder.

Pressure gauges with potentiometers will not be accepted for use as a pressure transmitter.

The scales shall have a diameter of 150 mm with black letters and figures on a white ground. The calibration shall be in "bar". The adjustment of the pointer shall be possible by means of an adjustment device without removing the pointer from its axle.

The high and low pressure connections of differential pressure gauges shall be marked accordingly.

Each gauge, pressure switch and transmitter for absolute or differential pressure shall be equipped with a pressure gauge isolating valve including a test connection of the screwed type M20 x 1.5 mm such that the device can be removed without any disturbance of the Plant operation.

Pressure gauges and transmitters for pressures of 10 bar and above shall not be directly mounted on the pressure tapping point but shall be mounted apart from the tapping point on gauge holders or gauge boards. Whenever possible pressure gauges and transmitters shall be combined in groups on racks or consoles.

Pressure gauges for high pressures shall be equipped with a relieve valve for safety reasons in case of leaks (with a rubber reverse flow check).

In case of flowing substances, the measuring point shall be selected in locations of undisturbed flow.

If the pressure is pulsating, the devices concerned shall be connected via flexible tubes or other pulse-absorbing means.

6.6.3.5 Level Measurements

Liquid level measurements in reservoirs and tanks with atmos¬pheric pressure shall be made by means of pressure transmitter of mercuryless-type, by displacement-type transmitters or by float-disc transmitters.

The measurement errors shall not exceed ± 1.0 % of the total measuring range unless othewise specified.

Level switches shall be of the externally mounted float or displacer operated type. The switch shall be of packless construction, and there shall be a minimum of moving parts.

6.6.3.6 Electrical Measurements

All electrical measuring instruments shall be of flush mounted design, dust-proof and moisture-proof. AC ammeters and voltmeters shall have a moving iron system of not less than 1.5 accuracy class for connection to the secondary side of instrument transformers. DC measuring instruments shall have a moving coil system of the same accuracy. Wattmeters shall have an electro-dynamic measuring mechanism or alternatively a moving coil mechanism if fed by transmitters. Wattmeters shall be suitable for unbalanced systems.

All indicating instruments shall generally withstand without damage a continuous overload of 20 % referred to the rated output value of the corresponding instrument transformers. Ammeters shall not be damaged by fault currents within the rating and fault duration time of the associated switchgear via the primaries of their corresponding instrument transformers.

All instruments and apparatus shall be capable of carrying their full load currents without undue heating. All instruments and apparatus shall be rear connected, and the enclosures shall be earthed. Means shall be provided for zero adjustment of instruments without dismantling.

All voltage circuits to instruments shall be protected by fuses in the unearthed phases of the circuit, installed as close as practicable to the instrument transformer terminals, or, where instruments are direct-connected, as close as practicable to the main connection. All power factor indicators shall have the star point of their current coils brought out to a separate terminal which shall be connected to the star point of the current transformer secondary windings.

When more than one measured value is indicated on the same instrument, a measuring point selector switch shall be provided next to the instrument and shall be engraved with a legend specifying each selected measuring point.

All instruments shall be of the flush mounting type and shall be fitted with non-reflecting glass and shall comply in every respect with the requirements of IEC Publication 6051. Except for instruments employed for Plant performance tests, all instruments shall have an accuracy class of 1.5.

Scales shall be arranged in such a way that the normal working indication is between 50 % and 75 % of full scale reading permitting an accurate reading. Ct connected ammeters provided for indication of motor currents shall be provided with suppressed overload scales of two times full scale. The dials of such ammeters shall include a red mark to indicate the full load current of the motor.

Where directly connected ammeters are provided for indication of motor currents they shall be supplied with overload scales indicating up to six times full load current. The dials of such ammeters shall include a red mark to indicate the full load current of the motor.

Instrument scales shall be submitted for prior approval by the Engineer. All instruments mounted on the same panel or similar panels shall be of same style and appearance.

Transmitter connected ammeters (for example those in mosaic-type control desks) shall have 90· or 240· circular scales calibrated from 0 % to 120 %. The rated motor current shall correspond to 100 % scale indication.

Energy meters shall be of the induction disc type with limits of error according to IEC 60170. The casings shall be dust-proof and moisture-proof and shall fit into the boards to permit reading without opening the corresponding front door. Disc and cyclometers of the drum-type shall be clearly visible through a window in the casing, and the cyclometer shall be able to record for a minimum of 2,500 hours. Meters shall be suitable for unbalanced systems.

6.6.3.7 *__Position Measurements__*

Position transmitters shall be of the inductive or capacitive type. Position transmitters of the potentiometer type will not be accepted.

6.6.3.8 *Recorders*

All recorders shall be of the strip-chart type, with dust-proof housing. Recorders with circular charts will not be accepted. The measuring range shall preferably be changeable by plug-in modules.

The recording paper shall be of standardized type being the same for all recorders.

The drives of all recorders, including event recorders, shall have synchronous or DC motors as appropriate. Recorders shall have chart speeds adjustable in steps between 20 mm/hour and 60 mm/hour.

Recorders for electrical magnitudes shall be of the pen-type with measuring units of accuracy class 1.5, and shall have a recording width not less than 55 mm.

Flows, pressures and level magnitudes shall be recorded on line recorders, other types of measurements shall be recorded on multi-point recorders.

6.6.3.9 *Contact Devices*

Contacts of level switches, pressure switches, temperature switches, limit switches, and of all other devices shall be of the snap action type (SPDT). Contact devices for interlocking systems shall be separate, i.e. contact devices serving commonly for interlocking and other purposes will not be accepted.

6.6.4 Alarm Systems

The alarm system shall provide all alarms required for a safe and reliable operation of the Plant. Alarms shall be initiated locally, in the control room, individually or grouped as required. All alarms shall be recorded on the event recorder.

6.6.4.1 *Alarm Annunciation System*

Unless otherwise specified the alarm equipment shall operate from a 110 Volt or 24 Volt DC supply and shall give audible and visual warning when any alarm or trip condition occurs, including fleeting alarms. "Accept", "Reset" and "Lamp Test" pushbuttons shall be fitted to each set of alarm equipment.

The following systems shall be applicable:

i) Upon occurrence of an alarm a horn or buzzer shall sound, and a pertinent window shall be illuminated with flashing light. The horn shall be cancelled by pressing a pushbutton. The flashing light shall be acknowledged by pressing an acknowledgement pushbutton. Upon pressing this button, the flashing light shall pass over to steady light. The steady light shall persist until the alarm indicating state returns to normal.

ii) The incidence of the first alarm shall initiate a continuously sounding bell and the flashing of the appropriate illuminated annunciator. The bell shall be silenced and the flashing of the annunciator changed to a steady illumination on the operation of the

"Accept" pushbutton. The alarm shall remain operated until the initiating contacts have restored or until the "Reset" button is operated, whichever is the later.

When several alarms occur before the "Accept" button is operated, the illumination of the annunciator of the first alarm shall flash and the annunciators of the subsequent alarms shall have steady illumination. Any alarm which occurs after the operation of the "Accept" pushbutton and before the first alarm condition has been cleared shall be as for a first up alarm.

Operation of the "Lamp Test" pushbutton shall illuminate all alarm annunciator lamps on that set of alarm equipment. Operation of the lamp test facility shall not operate any alarm sequence.

The alarm equipment shall incorporate an electrically separate pair of contacts for each individual alarm annunciator module which closes on the occurrence of an alarm and remains closed until the alarm is cleared. These contacts are for the remote indication of alarms.

The alarm annunciators shall have individual illuminated windows with the alarm conditions engraved on the front face. The individual annunciators shall be grouped to form multiway alarm units flush-mounted in the cubicle fronts. The Contractor shall provide 20 % spare alarm annunciators for each set of alarm equipment to allow for future alarms.

Buzzers (chimes, horns, bells as appropriate) shall be installed in suitable locations and shall be arranged to sound whenever the main audible alarm is energized.

All fusing and miniature circuit-breakers shall be incorporated in the alarm system so that any and each m.c.b. trip will be announced. These alarms shall be collected in groups and be combined into group alarms. The group alarms shall be connected in such a way that identification of an announced fault within the respective group is easy.

Motor trips and circuit-breaker trips shall be announced with flashing lights via the indicating lamp of the control station. Acknowledgement of this flashing light shall be effected by operating the control pushbutton. Apart from the flashing light of the indicating lamp, such trips shall also be announced audibly by means of the horn and visually as group alarms on the alarm annunciators.

Means shall be provided for testing all alarm and indicating lamps at desk, panel and local panels.

6.6.4.2 Alarm Recording System

An alarm recording system shall be provided if specified in the Particular Specifications. The electronic alarm recording system shall be designed in such a way that a fault analysis is possible after shutdowns or any other trouble is experienced. Therefore all corresponding alarms, indicating positions of shut-off valves, guide-vane position, flows, pressures, load, circuit-breakers etc. concerned shall be scanned by the alarm recorder.

The alarm recorder shall be capable of storing alarms arriving within extremely short periods and of printing them out in their actual order of occurrence along with the exact time, the identification number and the clear text. The memory capacity of the recording system shall be at least 30 % of the total number of signals. As soon as a stored alarm is printed out and transferred to a data acquisition system, the other alarms in memory shall automatically follow up so that the new storage places are rendered free for alarm acceptance.

The internal clock of the alarm recorder shall be synchronised by the impulse time signals received from the master clock system.

6.6.5 Logic Controls and Interlockings

The open loop control and interlocking systems shall comprise all controls of motors, circuit-breakers, disconnecting switches, motorised valves, dampers, solenoids etc., including all process interlockings to properly control the Plant and protect the equipment.

The remote control and interlocking system shall be performed in solid state technology with logic units. The solid state equip¬ment for remote controls and interlocks shall be assembled in cubicles installed in appropriate locations, and plug-in units shall be used for easy maintenance and repair.

The electronic system shall comply with the following requirements:

- application of I&C circuits
- dimensioning according the "Worst-Case-Method" and overdimensioning of components
- short-circuit resisting outgoing feeders
- ohmic decoupling of incoming feeders
- protection against over-voltages by means of lightning arrestors and/or protecting diodes
- transmitting of commands through two different channels to the control unit
- supervision of the operating time of important controls (e.g. valves, gates etc.)
- temporary supervision of starting processes
- supervision of the entire system with respect to active and passive faults
- supervision of the plug-in contacts
- individual signalisation of faulty units by means of "LEDs".

The entire control and supervising system shall, if not otherwise specified in the Particular Specifications, be subdivided as follows:

i) Control desks in the control / monitoring rooms

ii) Control panels in the control / monitoring room

iii) Unit control panels

iv) Automatic devices, comprising the control systems for the unit, the control system for the different functional groups and the protective systems

v) The coupling system, comprising the control of the actuations as well as the transformation and restitution of signals

vi) Contact devices (e.g. pressure and limit switches etc.).

For the discrimination of the different failure conditions and position indications, the colour code in accordance with IEC Recommendation 6073/1955 shall be applied.

Motor-operated valves, flaps, gates, etc. also shall be controlled by pushbuttons. Stand-by drives shall start automatically, when one operating drive fails.

"On"/"Off" controlled valves, flaps, gates etc. shall be provided with position indicating lamps located in the control / monitoring room and/or in the local control boards. Remotely "Open/Close" controlled valves, flaps, gates etc. shall be provided with proportional position indicators in the control room.

For all electrical feeders which are controlled from the control / monitoring room, the CR control panels shall be equipped with discrepancy control switches or, in case of mosaic technology being applied, pushbuttons and position indicating devices for the control and position indication of the breakers. Where necessary additional magnetic or other type position indicators shall be provided.

The steady light of discrepancy control switches shall be possible to be switched off by a separate switch.

The control circuits of disconnecting switches shall have double contacts for make and break operations, whereas the control circuits of circuit breakers shall have double contacts for make and single contacts for break operation.

As far as necessary for appropriate interlocking and for remote open loop control of the Plant, the respective valves, dampers etc. shall be equipped with motor actuators or solenoid actuators. These actuators shall include all necessary position transmitters, limit contacts and torque switches and shall be standardised throughout the Plant. Locally-operated valves, dampers etc. tied into open loop or interlocking circuits shall be equipped with the corresponding limit contacts, which shall be of an approved and reliable design and shall likewise operate as snapaction contacts and shall precisely correspond to the valve or damper position.

Automatic sequence controls shall be provided for important equipment. These group controls shall enable the operator to start or to stop the complete assembly (e.g. turbine unit auxiliaries, air conditioning Plant, dewatering or sewage systems etc.) by operating only one pushbutton. This sequence control equipment should use similar electronic type plug-in units, as used for motor and valve control.

6.6.6 *Automatic Control System*

Unless otherwise specified, a complete automatic closed loop control system shall be provided to ensure a safe operation of the Plant. The control system shall include all the necessary equipment and instrumentation to perform automatically all the required control functions and to allow manual operation of the actuators from the control / monitoring room as well as locally.

Electronic controllers in solid state technology shall be provided. The controllers shall be installed in disintegrated technique (control amplifiers mounted separately from the manual/auto control stations with deviation indicators, position indicators and adjusters desk mounted).

The control equipment shall have a high versatility and shall include all adjusting possibilities to adapt it to the controlled process in order to obtain a stable and optimal control. It shall be possible to transfer the controls smoothly from automatic to manual mode and vice-versa without preliminary manual adjustment.

The "Manual/Automatic" control stations shall normally be equipped with the following devices in order to supervise the controller and to allow manual control of the final control element:

- "Manual/Automatic" transfer pushbuttons
- increase/decrease or open/close pushbuttons
- set point adjuster
- deviation indicator
- position indicator
- signaling LED lamps (indicating the state of the controller).

The type and number of these devices shall be determined according to the requirements of the individual control loops. The actuators shall be of the electrical type with stepwise or continuous working motor or of the pneumatic type, however the electrical type shall be preferred to the pneumatical. The actuator shall be provided with a hand-wheel for local operation.

Each actuator shall include a position transmitter emitting a standard output signal of between 4 mA and 20 mA DC. The actuator shall be equipped with all necessary limit contacts and torque switches for control, protection, interlocking purposes and signalling. Valve actuators shall be directly mounted on the valves as far as possible. In the case of pneumatic actuators, the necessary air modulating devices shall be located on or close to the pertaining actuator.

Operating and positioning forces and speed shall be selected by the manufac-turer to ensure an optimal control quality.

In case of failure of the auxiliary power (electric, hydraulic or pneumatic) the actuators shall remain locked in the actual position or shall reach a safe position, depending on the particular case.

All control valves, etc., shall have a sufficient overload range.

Control valves for pressures of 25 bar and above shall preferably have the following features:

- single seat
- angle-shape with medium flow in closing direction
- valve body of forged steel with welding connections
- pressure sealing bonnet.

All control valves (independent of their type) shall have a tight shut-off. The characteristic shall, dependent on the purpose, be either linear or logarith-mic. The valve stems shall be well-guided, and the valves shall operate without excessive vibration and noise. They shall render a stable fluid control over the entire flow range.

6.6.7 Protection Systems

Electrical/mechanical protection and interlocking systems shall be provided for all Plant components and individual systems to ensure a safe and reliable Plant operation and to limit harm and damage to personnel and equipment to the maximum extent possible.

The primary functions of these facilities shall be to disconnect selectively faulty sections of the systems prior to any influence or damage occurring to other equipment and to maintain operative systems as far as possible.

These devices shall also facilitate the duty of the operation staff and prevent maloperation.

6.6.8 Process Computer

Process computers shall be provided if specified in the Particular Specifications for the purposes below. It shall be a requirement that the operation of the Plant shall not be restricted by the failure of a process computer.

6.6.8.1 Alarm Recording

As an alternative to the alarm recording system described above the process computers shall take over the function of alarm recording with the specified characteristics. The print-out shall give a clear text description of the alarm source in all its details.

6.6.8.2 Plant Data Collection and Recording

Important analogue/digital measurement values of the Plant shall be scanned cyclically, converted, checked, calibrated and an hourly log sheet shall be printed out in order to give a clear status on the general Plant performance. Daily and monthly energy balances shall be calculated and printed out.

6.6.8.3 <u>Failure Recording</u>

The trends of recorded analogue values important for the Plant operation (alarm, required operational steps, tripping etc.) shall be monitored and printed out by the process computer.

6.6.8.4 <u>Maintenance Protocol</u>

A weekly and monthly record shall be printed out indicating the service status of the Plant and the components, which have reached the service time limit and require maintenance.

6.6.9 Central Control Room and Local Control Panels

6.6.9.1 <u>General</u>

The control systems shall be furnished with the necessary devices for local manual, local automatic and remote automatic/manual control of the units, auxiliary systems, switchgears etc.
To achieve these features the systems shall mainly include individual local control panels, one or more separate control / monitoring rooms, and the ancillary installations such as power and air supply systems, transducer racks/panels, interface terminal racks/panels, cable and data-bus installations etc.

6.6.9.2 <u>Design and Construction of Desks and Panels</u>

All desks and panels shall be of manufacturer's standard design and construction complying with the requirements of the Technical Specification. Desks, panels and cubicles shall have adequate space for internal wiring and cable terminations, and all wiring inside the control panels, desks and cubicles shall be factory made.
For electronic equipment cubicles with voltages below 60 Volt, terminals with soldered connections or clamp type connections or preferably plugs shall be used. Wire wrap connections shall be limited to internal connections.
The cable access to cubicles and marshalling racks shall be from the bottom and/or from the top as appropriate. All panels and cubicles shall have a minimum of 10 % spare space after commissioning.
Cubicles shall be equipped with adjustable temperature supervision, giving a local alarm on the front door of each cubicle and a group alarm (for each row of cubicles) to the control room and on the event recorder.

6.6.9.3 Control/ Monitoring Room (CMR)

Unless otherwise specified, from the CMR the operation and supervision of the entire Plant shall be accomplished. All facilities and devices shall be included to provide a clear, overall status of the Plant at any time. Automatic and/or manual control of pump generator sets, generating units, auxiliary systems, HV switchgear, hydraulic structures etc. shall be possible from the CMR.

To provide above features the CMR shall include control panels and desks equipped with all necessary indicating, recording, control, alarm and supervisory devices as specified. Desks and/or panels shall be fitted with mosaic type mimic diagrams and displays as detailed to provide clear images of single line diagrams, hydraulic schemes, processes etc.

The control room layout shall show a clear and logic arrangement of panels, desks, printers, etc. duly considering ergonomical aspects.

6.6.9.4 Electronic Auxiliary Room

Whenever possible an electronic auxiliary room will be made available adjacent to the CMR, in which all control and other equipment not directly involved or required for the Plant control and supervision shall be installed.

If appropriate the communication systems may also be installed in the Electronic Control Room.

6.6.9.5 Local Control Panels

Pump generator sets, generating units, step-up transformers, HV switchgear, station auxiliary systems etc. shall have their individual local control panels, from which manual and/or automatic control of the relevant components/systems in all functions shall be possible.

To facilitate routine control actions (e.g. control of auxiliary systems prior to start-up or shut-down of the associated main units), solid state hardwired or programmable systems shall be applied.

Special attention shall be paid to the unit control panels to be provided for generating units, which as a minimum shall be provided with the following:

- manual and automatic control of the units
- indication of all relevant electrical/mechanical/hydraulic measurements
- alarm annunciation of all relevant individual and group alarms
- control of pertinent auxiliary systems
- manual/automatic synchronising
- speed/voltage control
- emergency stop
- emergency gate close/open.

The unit control panels shall be arranged in-line with the individual turbine control panels to provide a unified appearance, for which close co-operation with the relevant supplier will be required.

6.6.9.6 Transmitter Racks and Piping

Wherever practicable, transmitters for flow, pressure etc. shall be installed readily accessible in the proximity of the measuring point, free from vibration and protected against damage, moisture, dust, corrosive air, and great temperature changes.
The transmitters shall be grouped and assembled as far as practicable on local transmitter racks or in cubicles with glass or Plexiglas front.
The connecting lines between the primary elements and the transmitters shall be installed to a gradient such that no air pockets or water locks are created.

6.6.9.7 Auxiliary Power and Control Air Supply

Unless otherwise specified the auxiliary power supply for control and protection systems shall be derived from the following systems:

- 110 Volt and 24 Volt DC
- 380/220 Volt, 50 Hz normal/emergency supply
- 380/220 Volt, 50 Hz UPS backup.

The equipment shall be capable of working within tolerances of +10 % and -20 %.
Where required, control and protection systems shall have duplicate infeeders with appropriate protection and change-over devices. Great care shall be taken in the general design of the power supply to minimise the risk of failure and damages and to facilitate the detection of faults.
The closed control loops shall be individually protected.
For protection miniature circuit-breakers with auxiliary alarm contacts shall be provided. The alarm shall be indicated by an alarm lamp in each cubicle and as a group alarm in the control room. For each distribution bus, a voltage supervision with alarm in the control room shall be provided.
In order to facilitate interconnecting network design, all components of the control system shall have a common reference, isolated from earth. This will allow the first accidental earthing of a circuit without disturbance, if this earth fault is repaired prior to a second fault occurring. For this purpose an insulation monitoring system shall be provided measuring the total resistance of the circuits against earth. In addition an earth fault detection system shall be provided for fault location. Insulation monitoring as well as fault location detection shall be automatically performed continuously during Plant operation without interfering with the control signals.

In case of power supply failure, it will be necessary that all final control elements automatically switch to a fail safe condition and the control loops transfer automatically to manual mode with necessary annunciation. When the power supply returns, the systems shall remain in the latter mode.

If control air is required, the Contractor shall provide adequate control air supply equipment. Every pneumatic instrument of the Plant shall be supplied with control air. A supply branch shall supply one instrument only. Branches shall be fed from headers or sub-headers which in turn are fed from the control air system. The control air shall be available at a pressure of 5 bar to 8 bar and shall be dry and oil free.

The supply units for individual consumers shall include a manual shut-off valve, an adjustable filter regulator unit and a pressure gauge indicating in bar. The capacity of pressure regulators shall ensure a sufficient air supply for satisfactory operation of the instruments.

Local cabinets containing several instruments shall be provided with two independent supply systems: one system for normal use and the other for emergency. Each system shall include a shut-off valve, a filter and regulator, a safety valve, two pressure gauges (one on the high pressure inlet and one on the low pressure outlet) and one spare supply valve at the high pressure side.

6.6.10 I&C Cabling

Shielded cables shall be provided where required.

The construction of the thermocouple compensation lead shall be as follows:

- core insulation: Teflon
- main insulation: Teflon
- metal shielding: stainless steel
- outer insulation: Teflon
- each pair of wires shall be twisted.

6.7 TRANSPORT AND INSTALLATION

6.7.1 General

Shipping, transportation, loading, storage, erection and test running shall be performed by or under the responsible direction of the Contractor.

The delivery dates, transportation and erection periods required under the Contract shall be strictly adhered to. Changes which are unavoidable or necessary will be regulated in accordance with the stipulations laid down in the Contract.

From the time of manufacturing until commissioning, all parts of the Plant shall be protected and insured at the Contractor's expense against damage of any kind. Parts which are damaged during transport, storage, erection or trial operation shall be replaced at the Contractor's expense.

6.7.2 Packing

The Contractor shall prepare all Plant, devices and materials for shipment to protect them from damage in transit, and shall be responsible for and make good all damages due to improper preparations, loading or shipment.

After the workshop assembly and prior to dismantling for shipment to the Site, all items of machinery and Plant shall be carefully marked to facilitate site erection. Wherever applicable these markings shall be punched or painted so as to be clearly visible.

Dismantling shall be done into convenient sections, such that the weights and sizes are suitable for transport to Site and for handling on the Site under the particular conditions of the Project.

All individual pieces shall be marked with the correct designation shown on the Contractor's detailed drawings and in other documents (packing lists, spare part lists, Operating and Maintenance Instructions, etc.). Marking shall be done preferably by punching the marks into the metal before painting, galvanising etc., and shall be clearly legible after painting, galvanising etc. For the labelling the Contractor shall endeavour to use as few designations as possible, and each part of identical size and detail shall have the same designation, regardless of its final position in the Plant.

All parts of the Plant shall be packed at the place of manufacture. The packing shall be suitable for shipment by sea, if necessary, and for all special requirements of the transportation to Site. Where necessary double packing shall be used in order to prevent damage and corrosion during transportation, unloading, reloading or during intermediate storage.

All identical members shall be packed together, if reasonably possible, in a form convenient for shipment and handling.

Small items shall be packed in boxes and large items shall be protected, where necessary, by timber, straw and sacking. Drums shall be used for electric cables, steel ropes, steel wire and similar materials. All bolts, nuts, washers, etc. shall be packed in containers. Each container shall include only bolts, nuts or washers of identical size and type.

All parts shall be suitably protected against corrosion, water, sand, heat, atmospheric conditions, shocks, impact, vibrations, etc.

All electrical parts shall be carefully protected from damage by sand, moisture, heat or humid atmospheric conditions by packing them in high pressure polyethylene foil. Where parts may be affected by vibration, they shall be carefully protected and packed to ensure that no damage will occur while they are being transported and handled.

6.7.3 Transport and Storage

The Contractor shall provide means for all unloading and reloading for all consignments of Plant, both during transport to Site and on the Site. Consignments shall be unloaded immediately on arrival at Site. The Contractor is required to take the necessary steps in order to provide the carriage, special supporting structures for heavy loads, etc.

All parts of the Plant shall be brought as far as possible to their final place of erection. The Contractor shall prepare storage areas as required for the respective purposes in accordance with the Technical Specification.

Warehouses shall be weatherproof with good ventilation and solid floors. The floors of the warehouses and storage areas shall be designed to carry the loads imposed on them by the stored parts.

The items which shall be stored inside enclosed warehouses shall include bolts, pins, packing, tools, insulation materials, electrical parts with electrical devices attached, electric motors and excitation equipment, instruments, welding material and equipment, all small parts and all parts of the Plant which already have been finally painted.

If large parts are stored in the open air they shall be provided with weather resistant and fire resistant covers. Electrical parts which are not packed in heavy duty polyethylene foil and those so packed but whose packing has been damaged shall be kept in suitably protected places from the moment of storage to the moment of installation.

All insulation materials which will be taken from the warehouse for installation and which are stored elsewhere shall be protected from weather or humidity.

6.7.4 Preparation and Installation

6.7.4.1 Preparation

Prior to commencement of installation the Contractor shall closely inspect the site and all the foundations and other structures on which parts of the Plant supplied under this Contract will be installed. The Contractor shall be responsible for checking that the foundations conform to the installation Drawings. The result of these checks shall be reported to the Engineer in due time to allow any errors to be corrected before the commencement of erection.
All parts of the Plant shall be cleaned carefully of all contamination such as dust, sand, rust, mill scale and other dirt prior to installation.

6.7.4.2 Reference Points

The Contractor shall carefully protect all reference points. Demarcation lines, pegs etc. moved or destroyed by the Contractor shall be fully and accurately restored at the Contractor's expense.
The Contractor shall be responsible for the true and proper setting out of the Works, for the correctness of the positions, levels, dimensions and alignment of all parts of the Works and for the provision of all necessary instruments, appliances and labour in connection with this requirement.

6.7.4.3 General Installation

All transportation and handling of the Plant from the place of storage to the place of installation shall be carried out by the Contractor. He shall provide all hoisting equipment, staging and scaffolding, winches and wire ropes, slings, tackles and all other appliances and temporary materials. The erection staging and scaffolding shall be provided with coverings and barriers and shall guarantee safe working conditions.
The Contractor shall comply with all applicable and approved safety regulations while carrying out the work on Site and with all reasonable requirements of the Engineer. This stipulation shall in no way release the Contractor from any obligation concerning his liability for accidents and damages. He shall be responsible for adequate protection of persons, Plant and materials against injuries and damages resulting from his operations.
The Plant or parts to be installed shall not be overstressed during the process of installation.
The Contractor shall be responsible for the proper execution of the installation of all Plant to the correct lines and levels and in accordance with the manufacturer's instructions and the Contract requirements. Permissible tolerances shall be those indicated by the manufacturers or in the Technical Specification or on the Drawings, whichever are the most stringent.
Setting of parts to be aligned shall be performed by means of fine measuring instruments. All erection clearances and settings shall be recorded and copies of these records shall be

submitted to the Engineer. After alignment, the parts shall be held firmly in position by means of set pins, fitted bolts, etc.

Anchor bolts, baseplates, anchor rails, etc. to be embedded in the first stage concrete shall be delivered in due time with instructions and/or templates to facilitate the locating of such parts into the civil works. All parts to be embedded in concrete shall be set accurately in position and shall be supported rigidly to prevent displacement during the placing of concrete. Adjusting screws and bolts shall be drawn tight and secured adequately. Steel wedges shall be secured by welding. Wooden wedges shall not be used. The Contractor shall verify carefully the position of all parts to be embedded before concrete is poured. All important measurements and dimensions shall be recorded and copies of these records shall be submitted to the Engineer for checking and approval before items are built into the Works. The Contractor shall be responsible for the supervision of the building-in work and shall state the allowable concreting or grouting rates and any required sequence for pouring at each location. After concreting the control measurements shall be verified again, indicated in the above mentioned records and submitted to the Engineer.

Any error in shop work which prevents the proper assembling and fitting of the parts shall be immediately called to the attention of the Engineer and approval obtained for the appropriate correction procedures.

The Contractor shall provide all necessary anchors and braces to ensure the alignment and stability of the parts to be installed. All temporary anchors and bracings shall take care of all dead load, wind load, seismic and erection stresses, e.g. during concreting, and shall remain in place until they can be removed without endangering the stability of the Plant.

Welding, torch-cutting and drilling work on the Plant to be erected shall only be carried out with the approval of the Engineer. If for installation purposes auxiliary structures have been attached to the Plant, they shall be removed after completion of work and the surface restored to proper condition by grinding and repainting. Special care shall be taken not to damage galvanised or specially treated surfaces of Plant during erection. Care shall be taken to prevent or remove any rust streaks or foreign matters deposited on galvanised or otherwise finished surfaces during storage or transport or after installation.

Glass parts or other parts which can easily be damaged shall be provided with suitable protective sheaths or coverings during installation.

Machined or bare metal surfaces which are to receive no coat of paint shall be protected during transportation, storage and erection by a suitable anti-corrosion film.

Special tools which are supplied for maintenance and repair can be used for installation, and shall be handed over at the end of the installation work in good condition in accordance with the Engineer's instructions.

6.7.4.4 *Associated Site Civil Works*

The Contractor is responsible for coordinating his civil works with the mechanical and electrical Plant work and all costs associated with this requirement shall be deemed to be included in the Contract Price.

6.8 INSPECTIONS AND TESTS

6.8.1 General

In addition to the provisions established in the Conditions of Contract regarding general procedures for inspections and tests on the Works, including terms and definitions and time schedules for the inspections and tests, the r stipulations of this clause shall apply.

6.8.2 Workshop Inspections and Tests

6.8.2.1 General

As far as practicable the quality of materials, workmanship and performance of all items of the work and Plant to be furnished under this Contract shall be inspected at the places of manufacture.

When placing orders for material and Plant with suppliers, the Contractor shall send unpriced copies of such orders in triplicate to the Engineer.

Where the Contractor desires to use stock material, not manufactured specifically for the Works, satisfactory evidence that such material conforms to the requirements of the Contract shall be submitted. Tests on these materials may then be waived at the sole discretion of the Engineer.

Arrangements shall be made for expediting the shop inspection by having all shop assemblies or pieces covering a single shipment ready at one time. Any painting work as well as transport to the Site of the Plant shall not commence before the approval of the Engineer has been obtained.

All costs of complying with these requirements relating to workshop inspections and tests shall be deemed to be included in the Contract Price.

6.8.2.2 Material Tests

Unless otherwise specified the quality of materials shall be verified generally as follows:

- chemical analysis
- mechanical tests (yield point, tensile strength, elongations, notch impact strength etc.)
- welding tests (welding procedure, welding material, welding tensile strength, welding bend test, welding reversed bend test etc.)
- non-destructive tests (X-ray, ultrasonic, magnaflux, liquid tests, penetration inspection, etc.)
- electrical tests (voltage, losses, tan delta, insulation, magnetic properties etc.).

Test specimens and samples for analysis shall be plainly marked to indicate the materials they represent.

Castings and forgings shall be tested in the rough state in order to detect flaws in good time in order to avoid delays. Magnetic particle inspection of important castings shall cover the whole surface of the casting. After partial machining further tests can be conducted.

Load tests on crane hooks, steel wire ropes, chains, etc. shall be considered as material tests.

6.8.2.3 Checking of Dimensions

The dimensions, especially clearances and fits (ISO 286) which are essential for operation and efficiency, shall be carefully checked in an approved manner and shall include but not be limited to the following:

- runout and roundness tolerances of shafts, rotors, pistons etc., to be measured on single parts as well as (wherever possible) on the assembled components;
- fits and clearances of bearings, rotors, valves, guiding, distributing and actual actuating elements etc.;
- accuracy, surface roughness and shape of sliding and guiding surfaces of seals, bearings, water passages in hydraulic machinery, valves etc.;
- profiles of pump impellers etc., to be checked by means of templates;
- dimensions of couplings or connections for assembly with other deliveries from the Contractor, Subcontractors or other contractors.

6.8.2.4 Workshop Assembly

In addition to the quality and production control tests, the shop assembly work and tests described in this clause shall be made to check measurements, fitting and functioning.

Plant to be furnished shall be shop assembled to a status sufficient to prove that the design and workmanship have been executed in accordance with the Specification, that the delivery is complete, and that no work remains to be done at Site which reasonably can or should be done in the shop. During workshop assembly all instruments, control devices and piping shall be fitted.

Where applicable, each item of the Plant shall be assembled completely prior to painting.

Field joints shall be temporarily connected.

All parts shall be properly match marked, identified and doweled where practicable, to facilitate correct and quick field assembly and alignment. Where necessary, suitable dowels shall be provided for insertion after field assembly and drilling. The holes for any fitted bolt shall be accurately reamed.

If the assembly shows defects in the design or manufacture or unforeseen difficulties in assembling and dismantling, these defects shall be eliminated. If required design alterations or corrective measures may be executed provided that reliability of operation and the degree of interchangeability are not reduced and provided that the prior agreement of the Engineer has been obtained.

If the corrections cannot be carried out in accordance with the terms mentioned above the components concerned will be rejected. The decision on possible subsequent corrections is reserved exclusively to the Engineer. Faulty parts or Plant shall under no circumstances be delivered.

The assembled parts shall be subsequently subject to tests in accordance with the applicable standards or as required by the Engineer.

6.8.2.5 <u>Pressure and Leakage Tests</u>

a. General

All parts subject to internal or external pressure or containing any liquids or gases temporarily or permanently during operation shall be tested prior to painting. As far as practicable these tests shall be done in the workshop but may be repeated at Site.

Parts exposed during operation to hydraulic pressure, to gas pressure, or to any liquid without pressure shall be treated distinctively.

In addition to the requirements of the Technical Specification the applicable and approved standards and official regulations shall be observed. If any liquid is used for the test that may cause corrosion, all Plant and piping shall be thoroughly cleaned immediately after the test.

As far as practicable and required the influences of temperatures and temperature differences to which each part will be exposed during operation shall be considered in the execution of the tests.

Leaks and defects may be repaired if permitted by the applicable standards and approved by the Engineer. If defects are found the Engineer may reject the defective parts or permit welding repairs with stress relieving, radiographic examination and additional pressure tests.

b. Parts Exposed to Hydraulic Pressure

Unless otherwise specified or required the hydraulic pressure tests shall be carried out using the liquid to be used during operation or a liquid with a lower viscosity.

The hydraulic test pressure shall be 1.5 times the maximum operating pressure and shall be maintained for a period of two hours or longer if required by the applicable standards. Subsequently the test pressure shall be reduced to the operating pressure.

The welded seams of large parts which are not subjected to any heat treatment during or after welding shall be rapped with a 500 g hammer during the pressure decrease or treated otherwise to obtain the required effect of stress relief.

Finally the test pressure as defined above shall be maintained for ten min-utes. Leakages appearing at seals, joints etc. shall be measured and stated in the test report together with the corresponding pressures.

c. Parts Exposed to Gas Pressure

Parts which will be subjected to gas pressure during operation (e.g. pressure air tanks) shall be inspected and tested according to the official regulations with respect to design, construction, fittings, etc.
The pressure test shall be executed by applying the test pressure in accordance with the applicable standards.
d. Parts Exposed to Liquids Without Overpressure
Parts which shall not be closed and which are exposed to only small pressures of any liquid during operation (e.g. bearing housings, oil containers etc.) shall be subjected to a tightness test with a suitable liquid of low viscosity. The testing period shall not be less than 10 hours unless otherwise agreed.

6.8.2.6 Functional Tests

Functional tests shall be defined as tests of the function of assemblies, sub-assemblies or parts of the Plant under no-load conditions. Functional tests shall be performed on all Plant prior to the execution of operational tests.

6.8.2.7 Operational Tests

As far as practicable operational tests simulating operating conditions shall be carried out on all Plant. Parts to be delivered by suppliers shall be tested either at the premises of the supplier or of the Contractor, as agreed by the Engineer.
Before testing the Contractor shall submit a notice containing full information on the tests, including detailed tables or graphs on the latest edition of the characteristic values of the Plant to be tested and on the test facilities and equipment.
Testing of the electrical Plant shall be performed in accordance with the applicable standards and they shall include, but not be limited to, tests for heating, loading, overloading, and losses.
Operational tests of lifting equipment and other machinery shall include tests under nominal load and 125 % of nominal load unless otherwise specified.

6.8.3 Site Inspection and Tests

6.8.3.1 General

During erection, commissioning and trial operation the Contractor shall perform at suitable intervals all inspections and tests in the presence of the Engineer in order to prove the orderly execution of the works in accordance with the Contract.
Special tests to be performed at Site are listed in the corresponding section of the Particular Specifications.

The Contractor's testing at Site shall be complete in every respect to prove the successful performance and operation of all the works and Plant supplied and erected under the Contract.

All costs for testing at site and of the works and charges associated with it shall be deemed to be included in the Contract Price and shall include the measuring devices, properly calibrated, and any pertinent accessories, which shall be made available by the Contractor for the entire duration of the tests. The Contractor shall delegate qualified experts to perform the tests at site.

The Engineer reserves the right to have the Contractor's instruments which are to be used or have been used for any tests checked by an independent, officially acknowledged institution, and all costs associated with this requirement shall be at the Contractor's expense.

6.8.3.2 <u>Commissioning and Trial Run</u>

Commissioning tests shall include "wet" and/or "start-up" and/or "energised" tests and are intended to establish the successful performance and operation of the Works as a whole. Immediately upon completion of commissioning of a part or section of the permanent Plant which can operate as an independent unit a "Certificate of Suitability for Operation" shall be issued by the Engineer and a Trial Run period of not less than one month shall commence.

This Certificate shall be signed by authorised representatives of the Employer, the Engineer and the Contractor and shall state the following:

- details of the supplier of the Plant
- quantity and type of Plant
- conditions of commissioning
- names of the participants in commissioning
- date of commencement of the Trial Run
- list of minor defects, if any.

During the Trial Run the Contractor shall make the Employer's personnel fully familiar with the properties, operation and maintenance of the Plant and its auxiliaries to such an extent that thereafter the duties can be assigned to the trained personnel of the Employer.

The Contractor shall not withdraw his personnel from this training without the consent of the Engineer. In case this period of training should last longer than the agreed period for the Trial Run, the Contractor shall be paid accordingly in accordance with the Contract.

If any defects or irregularities affecting the safety or reliability of the Plant should be observed during the Trial Run, the Trial Run shall be interrupted and started again after such defects or irregularities have been corrected by the Contractor and shall thereafter continue for an uninterrupted period of not less than two weeks.

The Plant and its operation and maintenance shall remain the responsibility of the Contractor throughout this Trial Run period.

6.8.3.3 Acceptance

During the Trial Run the testing for taking-over of the permanent Plant shall be performed in accordance with the standards and regulations laid down in the Particular Specifications and following the test procedure agreed upon between the Engineer and the Contractor.
Provided the Trial Run and the testing for taking-over has been satisfactorily completed, a "Protocol of Acceptance" which shall be deemed to be the Test Certificate shall be issued by the Engineer which shall be signed by authorised representatives of the Employer, the Engineer and the Contractor and shall be a prerequisite for the subsequent issuing of the Taking-Over Certificate.
This 'Protocol of Acceptance' shall state the following:

- date of testing
- quantity and type of Plant concerned
- statement of all minor defects and/or irregularities to be corrected by the Contractor
- confirmation that the guaranteed data have been proven
- confirmation that all contractual documents have been submitted
- confirmation that the Employer's personnel has been familiarized with the Plant and that they will be able to operate and maintain the Plant without further training.

6.9 SPARE PARTS

6.9.1 Spare Parts and Consumables

6.9.1.1 General Requirements

All spare parts shall be strictly interchangeable with the corresponding parts of all the equipment supplied under these Specifications and shall be of the same material and workmanship.
They shall be packed and protected for storage at site over long periods without deterioration due to adverse ambient conditions. Sealed heavy gauge polythene packing or other approved methods shall be used. All parts shall bear clear indelible identification on the packing. The identification labels shall state the part number as well as the description of the item in English.
All spare parts are to be protected against corrosion and provided with identification labels in the English Language. The specification of the identification labels shall be submitted to the Engineer for approval. All rubber packings must be delivered in endless loops whenever installation in this condition is possible. O-ring type packings shall be delivered properly packed for long duration storage in a predetermined storage place.
All spare parts, tools and materials shall be delivered in marked boxes of sufficient sturdy construction to withstand several years of storage and handling.

Two copies of a detailed list of the items supplied together with their respective part numbers shall be handed over to the Employer with each batch of spares delivered.

In order to enable the Employer's staff to carry out all services and maintenance work, common repairs and periodic replacements, the Contractor shall supply the necessary spare parts, tools and equipment including non-standard (i.e. specially made) hand tools or dimensional gauges as required. Any special tools necessary for the assembly, dismantling, alignment, calibration or maintenance of the equipment shall be separately listed.

The Contractor shall supply necessary spare parts and tools and submit a fully detailed list of the necessary spare parts and tools including additional necessary spare parts recommended by the manufacturer.

6.9.1.2 Specified Spare Parts

Specified spare parts shall be provided by the Contractor in accordance with the requirements of this Technical Specification and complete information on these spares relevant to the actual Plant being provided as submitted in Tender Schedule O with the Tender and as approved in detail by the Engineer following award of Contract.

6.9.1.3 Recommended Spare Parts

Additional spare parts shall be provided by the Contractor in accordance with list of these spares recommended by the manufacturers of the Plant as being necessary for the operation and maintenance of the Plant for a minimum period of 3 years, but which are not included under the Specified Spare Parts and Tools, as submitted in Tender Schedule P with the Tender and as amended and approved by the Engineer after award of Contract.

The quantities and types of the actual recommended spare parts to be supplied shall be subject to the Engineer's agreement. At least six months before the Issue of the Defects Liability Certificate the Employer shall issue to the Contractor a written list of the required items and the Contractor will deliver the items on the list at the specified unit prices before the Issue of the Defects Liability Certificate. A receipt for such delivery shall be retained by the Contractor for the Engineer's examination and approval.

6.9.1.4 Consumables

The Contractor shall include for the provision of oils and greases as required for efficient lubrication of all Plant supplied up to the end of the Defects Liability Period.

All materials which must be replaced during an operating period of 3 years are to be included and listed in the breakdown lists.

Production materials such as fuel oil, calcium hypochlorite etc. are excluded and are to be supplied for the Trial Run period only.

6.9.2 General Spare Parts

For a number of like and identical installed assemblies or sub-assemblies the following general spare parts shall be delivered, whereby one set shall be defined as the total quantity for one assembly or sub-assembly:

i) Two complete sets of packing, seals, gaskets, bushings, springs, wearing parts of couplings, wear rings of pumps, pump impellers, drive belts etc. for each identical assembly such as generators, governors, motors, pumps, compressors, valves, internal combustion engines etc.

ii) One complete set of clamps as well as of seals, gaskets, and packing for each 10 valves, identical in size and type, but at least two sets.

iii) 10% of the gaskets and seals identical in type and size of the pipelines, with a minimum number of three.

iv) 10%, but at least two assemblies or sub-assemblies, of all heat exchangers, filter elements, measuring and control instruments, limit switches, relays etc., fuses, signal lights, clamps, installation switches.

v) 5%, but at least two pieces, of all bolts (except foundation bolts), screws, nuts, washers etc. The quality may be taken from the surplus quantity handed over to the Employer after completion of the installation as described in this Technical Specification.

In addition for all items under this Contract the Contractor shall deliver 5 % of the quantity of painting material, with a minimum quantity of one litre, in unused sealed containers for later repair work other than that carried out by the Contractor.

6.9.3 Particular Spare Parts for Pump Units

Unless otherwise specified or extended by the requirements of the Particular Specifications, the Contractor shall provide in each case where the particular type of Plant is included in the Contract the following spare parts as well as any other necessary spare parts recommended by the manufacturer following a careful check by the Contractor of these lists and subject to the agreement of the Engineer.

a. Submersible Pump

- 4 impellers
- 1 sleeve set (upper, intermediate and lower sleeves)
- 1 bearing set (upper, intermediate and lower bearings)
- 1 O-ring set
- 1 submersible motor set
- 1 complete set of other spare parts as recommended by manufacturer
- 1 complete set of special tools for operation and maintenance of the pump.

b. Centrifugal Pump

- 1 Impeller
- 2 seal rings
- 1 shaft
- 2 flexible pad coupling sets
- 2 bearings (drive and pump side)
- 2 O-rings (outer)
- 2 O-rings (inner)
- 3 gland packing sets
- 1 totaliser
- 1 seal ring set (plug joint, seal joint, glass joint etc.)
- 1 complete set of other spare parts as recommended by the manufacturer
- 3 sets of special tools (spanner/key) for opening meter housing and listed spare parts.

6.9.4 General Tools

The Contractor shall provide as a minimum the following general tools equipment:

a. Pipe Fitters Hand Tools

Sets of pipe fitters hand tools for use by local operating units. Each set of tools shall comprise the following:

- 1 steel hacksaw frame, 300 mm
- 50 high speed all hard cutting blades, 7 teeth/cm
- 50 high speed all hard cutting blades, 10 teeth/cm
- 2 wire scratch brushes, for general use
- 2 flat bastard files, 250 mm with handles
- 2 rounded bastard files, 250 mm with handles
- 1 Engineer's ball hammer, 450 grams
- 1 Engineers ball hammer, 1 kg
- 2 Stillson pattern pipe wrenches, 600 mm
- 2 chain pipe wrenches, capacity 25 – 150 mm
- 2 foot print adjustable pipe tongs, 75 mm capacity
- 1 combination pliers, 200 mm with pipe grip, side and joint cutters
- 1 screwdriver, 100 mm long with plastic handle and flared tip
- 1 screwdriver, 200 mm long with plastic handle and flared tip
- 1 screwdriver, 200 mm long with plastic handle and start tip
- 1 pump action oil can, 500 ml capacity
- 1 adjustable wrench, 15° offset 300 mm long with 35 mm capacity
- 2 adjustable wrenches, 250 mm long with 25 mm capacity

- 1 steel tape, 3 m retractable with locking device.

b. Mechanical Hand Tools

- 1 ring spanner set, sizes 6 mm – 36 mm
- 1 open end wrench spanner set, sizes 6 mm – 36 mm
- 1 LNK spanner set, sizes 3 mm – 36 mm
- 1 box-ring spanner set, sizes 3 mm – 36 mm
- 1 torque wrench set, unit sizes 12 mm – 36 mm
- 2 pliers sets (small, middle, and large)
- 3 scale measuring unit sets.

c. Electrical Hand Tools

- 1 flat screwdriver set, sizes 50 mm – 250 mm
- 1 cross screwdriver set, sizes 50 mm – 250 mm
- 1 test screwdriver set, sizes 50 mm – 125 mm
- 1 pliers set (cutting pliers and dismantling pliers, sizes 50 mm – 125 mm).

6.9.5 Special Tools and Appliances

The scope of supply under this Contract shall include all customary and special tools, if and as far as not included in the specified Plant, equipment and spare parts and tools under the Technical Specifications, necessary for total assembly and disassembly of all parts of the supplied equipment. Furthermore all necessary accessories for maintenance as agreed by the Engineer shall be included in the scope of supply under the Contract.

The tools, wrenches etc. provided under the Contract shall be unused. Customary tools for erection shall be of the forged and polished chrome-vanadium type. Use of special tools and devices for erection shall be allowed but must in each case be approved by the Engineer. Special tools and devices shall be provided with means for ready identification.

Suitable hardwood or steel boards arranged for wall mounting as well as tool carts and/or tool boxes shall be included in the delivery. An itemised list and description of all provided tools, auxiliary devices, storage equipment etc. shall be included in the Tender. Acceptance of any tool or device shall not take place before the Contractor has submitted the complete final detailed List of Tools and Appliances.

APPENDICES

APPENDIX A: PAINT SYSTEM

- SYSTEM A

Cleaning Method: Blast Clean

Description: 2 coats Twin pack Polyamide cured lining coating.

Example: Copon EPD2200 (red/paler oxide) or Sigma EHB (green/cream) or Carboline 187

Min. Dry film thickness: 2 x 100 µm

Total for two coats: 200 µm

Areas of application: Mild steel work or pipework passing through water/air interfaces

Structural steelwork in conditions of moderat

- SYSTEM B

Cleaning Method: Blast Clean

Description: 1 coat Corrocote N°1

1 coat HiChem undercoat

2 coats Polyacrythane

Min. Dry film thickness: Corrocote N° 1 : 1 x 20 µm

HiChem undercoat : 1 x 35 µm

Polyacrythane : 2 x 30 µm

Total : 115 µm

Areas of application: Motors, pumps, baseplates

Equipment manufacturers' protective systems of equal standards also permitted with approval of the Engineer

- SYSTEM C

Cleaning Method: Blast Clean

Description: 1 coat Red Oxide/Vinyl-Copolymer

Example: CHC 1 Chemcote or Corrocote N°1

2 coats Micaceous Iron or Structural paint (charcoal/silver grey), or two additional coats Vinyl Copolymer)

Min. Dry film thickness: Red Oxide/Vinyl-Copolymer : 1 x 30 µm

Micaceous Iron : 2 x 35 µm

Total : 100 µm

Areas of application: Structural steelwork in conditions of mild exposure

- SYSTEM D

Cleaning Method: Hand Clean

Description: 1 coat Zinc Phosphate primer

1 coat universal undercoat (within 24 hours)

2 coats high gloss Alkyd enamel

Min. Dry film thickness: Zinc Phosphate primer: 1 x 20 µm

Universal undercoat : 1 x 40 µm

High gloss Alkyd enamel : 2 x 25 µm

Total : 110 µm

Areas of application: pipework indoors

APPENDIX B: REQUIRED DOCUMENTS FOR ELECTRICAL AND MECHANICAL PLANT INSTALLATION

GENERAL

The following documents for the mechanical and electrical Plant shall be supplied to the Engineer for approval (to be marked "A"). Further documents may be required by the Engineer for information (marked "I").
For completely identical items being supplied more than once times such documents shall be submitted once only.

PRINCIPAL REQUIREMENTS

The following documents shall be supplied for approval individually or as a whole for equipment/installations wherever applicable.

Drawings and Diagrams

- General Arrangement Drawings
- Dimension Drawings
- Design Drawings
- Single Line Diagrams
- Circuit Diagrams
- Terminal Diagrams
- Protection Coordination Diagrams

Calculations

- Short circuit calculations
- Earthing network calculations
- Load evaluations
- Selection of LV breakers and minimum cable cross-sections

Tender Schedules

- Tender Schedule N Technical Particulars
- Tender Schedule O Specified Spare Parts and Tools
- Tender Schedule P Recommended Spare Parts and Tools

SPECIFIC DOCUMENTS FOR ELECTRICAL INSTALLATIONS

Low Voltage Installations

- Specifications
- Dimension drawings for complete distribution boards and for each type of feeder
- Single line diagrams
- Standard circuit diagrams
- Individual circuit diagrams
- Arrangement drawings
- Specification for protection relays

Lighting Installations

- Specifications including light distribution curves for individual fittings and illumination level calculations
- Installation drawings
- For lighting main and subdistributors:

i) specifications
ii) dimension drawings
iii) single-line diagrams
iv) circuit diagrams
v) arrangement drawings

Cabling

- Specifications
- Cable list
- Connection diagrams
- Arrangement drawings (cable routing plans) for buried cables
- Cable tray arrangement drawings
- Cable allocation drawing for trays at different locations/trench paths (may be combined with above cable tray arrangement drawings)

Earthing

- Earthing network calculations
- Specifications
- Arrangement drawings
- Execution drawings for earthing system

- Execution drawings for potential gradient control elements in soil and in concrete
- Execution drawings for lightning protection system
- Test results of earthing resistance measurements

APPENDIX C: DATA SHEETS

STANDARD JOINTS FOR DUCTILE IRON PIPES AND FITTINGS DN 60 TO DN 1600

Standard Joints for Ductile Iron Pipes and Fittings DN 60 to DN 1600			
Item	**Description**	**Unit**	**Data**
1	ORIGIN		
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	PIPE CLASS		
4	JOINTS		
4.1	Type		
4.2	Gasket		
5	PROTECTION		
5.1	Internal Protection for pipes		
5.2	Internal Protection for Fittings		
5.3	External Protection for Pipes		
5.4	External Protection for Fittings		
6	STANDARD LENGTH for pipes	m	
7	WEIGHT per standard length pipe	kg	
8	MANUFACTURER CERTIFICATION		
Date:		Signature of Bidder:	

P2 DUCTILE IRON PIPES AND FITTINGS DN 60 TO DN 1600 LOCKED JOINTS

Ductile Iron Pipes and Fittings DN 60 to DN 1600 Locked Joints			
Item	**Description**	**Unit**	**Data**
1	ORIGIN		
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	PIPE CLASS		
4	JOINTS		
4.1	Type		
4.2	Gasket		
5	PROTECTION		
5.1	Internal Protection for pipes		
5.2	Internal Protection for Fittings		
5.3	External Protection for Pipes		
5.4	External Protection for Fittings		
6	STANDARD LENGTH for pipes	m	
7	WEIGHT per standard length pipe	kg	
8	MANUFACTURER CERTIFICATION		
Date:		Signature of Bidder:	

P3 DUCTILE IRON COVERS + FRAMES FOR MANHOLES AND CHAMBERS

Ductile Iron Covers + Frames for manholes and chambers			
Item	**Description**	**Unit**	**Data**
1	ORIGIN		
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	MATERIAL / DUTY / LOADING		
4	AVERALL DIMENSION (LxW)		
4.1	For Φ 60 cm Opening	mm	
4.2	For Φ 80 cm Opening	mm	
5	TOTAL WEIGHT		
5.1	For Φ 60 cm Opening	mm	
5.2	For Φ 80 cm Opening	mm	
Date:		Signature of Bidder:	

P4 GATE VALVES FOR DN < 400 MM

Gate valves for DN < 400 mm			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		

Gate valves for DN < 400 mm			
Item	**Description**	**Unit**	**Data**
2.	NORMS & STANDARDS		
3	TYPE / MODEL		
4	Max RECOMMENDED FLOW	m^3/s	
5	LOSS of HEAD at max. flow	m	
6	MATERIAL		
6.1	Body / Bonnet		
6.2	Stem		
6.3	Bonnet Bolts		
7	WEDGE		
7.1	Material		
7.2	Coating		
8	DIMENSIONS & WEIGHT		
8.1	Length	mm	
8.2	Width	mm	
8.3	Height	mm	
8.4	Weight	kg	
9	OPERATING MECANISM		
10	FLANGES DRILLING STANDARD		
11	INSTALLATION REQUIREMENTS		

Date:	Signature of Bidder:

P5 BUTTERFLY VALVES FOR DN 350 AND ABOVE

Butterfly valves for DN 350 and above			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	TYPE / MODEL		
4	Max RECOMMENDED FLOW	m^3/s	
5	LOSS of HEAD at max. flow	m	
6	MATERIAL		
6.1	Body		
6.2	Disc		
6.3	Disc axle and Shaft		
6.4	Seat		
6.5	Shaft Seal		
6.6	Disc Seal		
	Retaining Ring		
7	GEAR BOX		
7.1	Type		
7.2	Reduction Ratio		
8	DIMENSIONS & WEIGHT		
8.1	Length	mm	

Butterfly valves for DN 350 and above			
Item	Description	Unit	Data
8.2	Width	mm	
8.3	Height	mm	
8.4	Weight	kg	
9	OPERATING MECANISM		
10	FLANGES DRILLING STANDARD		
11	INSTALLATION REQUIREMENTS		
Date:		Signature of Bidder:	

P6 NON RETURN VALVES

Non Return Valves			
Item	Description	Unit	Data
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	TYPE / MODEL		
4	Max RECOMMENDED FLOW	m^3/s	
5	LOSS of HEAD at max. flow	m	
6	MATERIAL		
6.1	Body		
6.2	Flaps		

Non Return Valves			
Item	**Description**	**Unit**	**Data**
6.3	Seating		
7	SURFACE PROTECTION		
7.1	Outside		
7.2	Inside (Body & Disc)		
7.3	Non Toxicity Certificate		
8	PRESSURE RATING	bar	
9	TEST PRESSURE	bar	
8	DIMENSIONS & WEIGHT		
8.1	Length	mm	
8.2	Width	mm	
8.3	Height	mm	
8.4	Weight	kg	
9	OPERATING MECANISM		
10	FLANGES DRILLING STANDARD		
11	INSTALLATION REQUIREMENTS		
Date:		Signature of Bidder:	

P7 FLOW CONTROL VALVES

Flow Control Valves			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		

Flow Control Valves			
Item	**Description**	**Unit**	**Data**
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	TYPE / MODEL		
4	Max RECOMMENDED FLOW	m^3/s	
5	LOSS of HEAD at max. flow	m	
6	MATERIAL		
6.1	Body		
6.2	Internals		
6.3	Seating		
7	SURFACE PROTECTION		
7.1	Outside		
7.2	Inside		
7.3	Non Toxicity Certificate		
8	CHARACTERISTICS		
8.1	Closing Direction		
8.2	No of Turns		
8.3	Kc value		
9	PRESSURE RATING	bar	
10	TEST PRESSURE	bar	
11	DIMENSIONS & WEIGHT		

Flow Control Valves			
Item	**Description**	**Unit**	**Data**
11.1	Length	mm	
11.2	Width	mm	
11.3	Height	mm	
11.4	Weight	kg	
12	OPERATING MECANISM		
13	FLANGES DRILLING STANDARD		
14	INSTALLATION REQUIREMENTS		
Date:		Signature of Bidder:	

P8 PRESSURE REDUCING VALVES

Pressure Reducing valves			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		
3	TYPE / MODEL		
4	Max RECOMMENDED FLOW	m^3/s	
5	LOSS of HEAD at max. flow	m	
6	MATERIAL		
6.1	Body		

Pressure Reducing valves			
Item	**Description**	**Unit**	**Data**
6.2	Internals		
7	SURFACE PROTECTION		
8	PRESSURE RATING	bar	
9	TEST PRESSURE	bar	
10	DIMENSIONS & WEIGHT		
10.1	Length	mm	
10.2	Width	mm	
10.3	Height	mm	
10.4	Weight	kg	
11	OPERATING MECANISM		
12	FLANGES DRILLING STANDARD		
13	INSTALLATION REQUIREMENTS		
Date:		Signature of Bidder:	

P9 AIR RELEASE VALVES

Air Release Valves			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	NORMS & STANDARDS		

Air Release Valves			
Item	**Description**	**Unit**	**Data**
3	TYPE / MODEL		
4	MATERIAL		
4.1	Body, Cover & Cowl		
4.2	Float		
4.3	Orifices (small / large)		
4.4	guides, seats, bushings, internal, external bolts, nuts		
5	SURFACE PROTECTION		
5.1	Surface preparation		
5.2	Inside		
5.3	Outside		
5.4	Non Toxicity Certificate		
6	CONNECTION (Type / Size)		
7	PRESSURE RATING	bar	
8	TEST PRESSURE	bar	
9	DIMENSIONS & WEIGHT		
9.1	Length	mm	
9.2	Width	mm	
9.3	Height	mm	
9.4	Weight	kg	
10	OPERATING MECANISM		
11	FLANGES DRILLING STANDARD		

Air Release Valves			
Item	Description	Unit	Data
12	INSTALLATION REQUIREMENTS		
Date:		Signature of Bidder:	

M1 PUMP SET

Pump Set			
Item	Description	Unit	Data
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2	ORIGIN OF MOTOR		
2.1	Manufacturer		
2.2	Country of manufacture		
2.3	Local Agent		
3.	TYPE / MODEL		
4	DESIGN & CONSTRUCTION		Centrifugal, Horizontal,
5	NORMS & STANDARDS		
6	PERFORMANCE PARAMETERS		
6.1	Min flow / Max head		
6.2	Maw flow / Min head		
7	NOZZLES SIZE		
7.1	Suction side NB	mm	

Pump Set			
Item	**Description**	**Unit**	**Data**
7.2	Discharge side NB	mm	
8	POWER @ RATED DUTY POINT	kw	
9	DIMENSIONS (pump + motor)		
9.1	Length	mm	
9.2	Width	mm	
9.3	Height	mm	
10	WEIGHT		
10.1	Pump		
10.2	Motor		
Date:		Signature of Bidder:	

M2 SUBMERSIBLE PUMPS FOR VERTICAL INSTALLATION

Submersible Pumps for vertical Installation.			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2	ORIGIN OF MOTOR		
2.1	Manufacturer		
2.2	Country of manufacture		
2.3	Local Agent		

Submersible Pumps for vertical Installation.			
Item	**Description**	**Unit**	**Data**
3.	TYPE / MODEL		
4	DESIGN & CONSTRUCTION		
5	NORMS & STANDARDS		
6	PERFORMANCE PARAMETERS		
6.1	Min flow / Max head	m³/s@m	
6.2	Maw flow / Min head	m³/s@m	
7	NOZZLES SIZE	mm	
8	POWER @ RATED DUTY POINT	kw	
9	DIMENSIONS (pump + motor)		
9.1	Length	mm	
9.2	Diameter	mm	
10	WEIGHT		
10.1	Pump	Kg	
10.2	Motor	kg	
Date:		Signature of Bidder:	

M3 SURGE VESSELS

Surge Vessels			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		

Surge Vessels			
Item	**Description**	**Unit**	**Data**
1.3	Local Agent		
2.	TYPE / MODEL		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	VOLUME		
5.1	Vessel volume	m^3	
5.2	Operating Air Volume	m^3	
6	RATED WORKING PRESSURE	mm	
7	DIAPHRAGM (membrane)		
7.1	Material		
7.2	Fixing material		
7.3	Elasticity (at 0° / at +40°)		
7.4	Wall thickness		
7.5	Strain at yield	mm	
7.6	Strain at break	mm	
8	WEIGHT	kg	
9	DIMENSIONS		
9.1	Length	Mm	
9.2	Height	Mm	
9.3	Diameter	mm	

Surge Vessels			
Item	**Description**	**Unit**	**Data**
Date:		Signature of Bidder:	

M4 AIR COMPRESSOR PACKAGE

Air Compressor Package			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	TYPE / MODEL		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	CHARACTERISTICS		
5.1	Discharge Pressure	bar	
5.2	Flow Rate @ Discharge Pressure	m^3/h	
6	SPEED	rpm	
7	BUFFER VESSEL CAPACITY	m^3	
8	WEIGHT	kg	
9	DIMENSIONS		
9.1	Length	mm	
9.2	Width	mm	
9.3	Height	mm	

Air Compressor Package			
Item	**Description**	**Unit**	**Data**
Date:		Signature of Bidder:	

M5 GAS CHLORINATOR

Gas Chlorinator			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	MODEL No		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	CAPACITY	Kg/h	
6	RANGE		
7	ACCURACY	%	
6	PRES. REDUCING VALVE (type)	mm	
7	VACUUM RELIEF VALVE (type)		
8	BYPASS CONTROL VALVE (type)		
9	VACUUM REGULATOR (type)		
10	HEATER		
10.1	Capacity	Kg/h	
10.2	Power Supply (V/Ph/Hz/w)		

Gas Chlorinator			
Item	**Description**	**Unit**	**Data**
11	EJECTOR		
10.1	Type		
10.2	Differential Pressure Required	bar	
10.3	Capacity	l/s	
11	DIMENSIONS (of cabinet)		
11.1	Length	mm	
11.2	Width	mm	
11.3	Height	mm	
Date:		Signature of Bidder:	

M6 RESIDUAL CHLORINE ANALYZER

Residual Chlorine analyzer			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		
2.	TYPE / MODEL		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	RESIDUAL CHLORINE CELL		
6	INDICATOR / TRANSMITTER		

Residual Chlorine analyzer			
Item	**Description**	**Unit**	**Data**
7	RESIDUAL CHLORINE CONTROLLER		
8	CHLORINE GAS DETECTION SYSTEM		
8.1	Manufacturer		
8.2	Country of manufacture		
8.2	Local Agent		
9	CHLORINE GAS NEUTRALISATION EQUIPMENT		
9.1	Manufacturer		
9.2	Country of manufacture		
9.3	Local Agent		
9.4	Neutralisation agent		
9.5	Neutralisation agent tank		
9.6	Dosing pumps		
9.7	Extract fans		
Date:		Signature of Bidder:	

M7 PORTABLE FIRE EXTINGUISHER UNITS

Portable Fire Extinguisher Units			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer		
1.2	Country of manufacture		
1.3	Local Agent		

Portable Fire Extinguisher Units			
Item	**Description**	**Unit**	**Data**
2.	TYPE / MODEL		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	PROPELLANT TYPE		
6	CAPACITY OF EXTINGUISHER		
7	EXTINGUISHING AGENT		
8	WORKING PRESSURE		
7	HOSE LENGTH		
8	DURATION OF DISCHARGE		
9	EFFECTIVE JET LEVEL		
10	CARTRIDGE/CYLINDER FIRE EXTINGUISHER		
10.1	Capacity	kg	
10.2	Pressure	bar	
10.3	TEMPERATURE RANGE OF OPERATIONAL SAFETY	°C	
11	DIMENSIONS & WEIGHT		
11.1	Length	mm	
11.2	Width	mm	
11.3	Height	mm	
11.4	Weight	kg	
1.2	Country of manufacture		

Portable Fire Extinguisher Units			
Item	**Description**	**Unit**	**Data**
1.3	Local Agent		
2.	TYPE / MODEL		
3	DESIGN & CONSTRUCTION		
4	NORMS & STANDARDS		
5	SAFE WARKING LOAD (SWL)	ton	
6	HOISTING SPEED	m/min	
7	CRANE TRAVELLING SPEED	m/min	
8	HEIGHT OF LIFT	m	
7	DRIVING MOTOR (hoist & trolley)		
8	Rated voltage & power	V/kw	
9	Rated speed	rpm	
10	Weight	kg	
10.1	TOTAL WEIGHT	kg	
Date:		Signature of Bidder:	

E1 INCOMING / SUPPLY CUBICLE 2000A

Incoming / Supply Cubicle 2000A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		

Incoming / Supply Cubicle 2000A			
Item	**Description**	**Unit**	**Data**
2	Model		
3	Location		
4	Protection classification		
5	Circuit breaker		
5.1	Manufacture Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5 5.6	Max. s.c Capacity Max . breaking Capacity	KA KA	
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension Length	 mm	
	Width	mm	
	height	mm	
6 6.1	Bus bars Manufacturer Name		

Incoming / Supply Cubicle 2000A			
Item	**Description**	**Unit**	**Data**
	Country		
	Local Agent		
6.2	Metal		
6.3	Max s.c Current	KA	
6.4	Max temperature rise	◦C	
6.5	Dimensions:		
	Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation:		
7.1	Manufacturer Name		
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		
8	Dimensions: Length	mm	

Incoming / Supply Cubicle 2000A			
Item	**Description**	**Unit**	**Data**
	Width	mm	
	height	mm	
9	Total weight	Kg	
Date:		Signature of Bidder:	

E2 INCOMING / SUPPLY CUBICLE 1500A

Incoming / Supply Cubicle 1500A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		
5	Circuit breaker		
5.1	Manufacturer Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		

Incoming / Supply Cubicle 1500A			
Item	**Description**	**Unit**	**Data**
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension Length	mm	
	Width	mm	
	height	mm	
6 6.1	Bus bars Manufacturer Name		
	Country		
	Local Agent		
6.2	Metal		
6.3	Max s.c Current	KA	
6.4	Max temperature rise	◦C	
6.5	Dimensions: Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	

Incoming / Supply Cubicle 1500A			
Item	**Description**	**Unit**	**Data**
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation:		
7.1	Manufacturer Name		
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		
8	Dimensions: Length	mm	
	Width	mm	
	Height	mm	
9	Total weight	Kg	
Date:		Signature of Bidder:	

E3 LOW VOLTAGE SWITCHBOARD/MCC 2000A

Low Voltage Switchboard/MCC 2000A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		

Low Voltage Switchboard/MCC 2000A			
Item	**Description**	**Unit**	**Data**
2	Model		
3	Location		
4	Protection classification		
5	Main Circuit breaker		
5.1	Manufacturer Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	
5.7	Dimension Length	mm	
	Width	mm	
	height	mm	
6	Motor Circuit breakers		
6.1	Manufacturer Name		
	Country		

Low Voltage Switchboard/MCC 2000A			
Item	Description	Unit	Data
	Local Agent		
6.2	Model		
6.3	Type		
6.4	Rated current	A	
6.5	Max. s.c Capacity	KA	
6.6	Max . breaking Capacity	KA	
6.7	Dimension Length		
	Width		
	height		
7 7.1	Motor Starter Manufacturer Name		
	Country		
	Local Agent		
7.2	Model		
7.3	Type		
8 8.1	Bus bars Manufacturer Name		
	Country		

Low Voltage Switchboard/MCC 2000A			
Item	**Description**	**Unit**	**Data**
	Local Agent		
8.2	Metal		
8.3	Max s.c Current	KA	
8.4	Max temperature rise	◦C	
8.5	Dimensions: Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
9	All measurements, PLC, Contactors, Current transformer, Motor protection relays, control instrumentations:		
9.1	Manufacturer Name	For each	
	Country		
	Local Agent		
9.2	Type for each		
9.3	Model for each		
10	Dimensions: Length	mm	
	Width	mm	

Low Voltage Switchboard/MCC 2000A			
Item	Description	Unit	Data
	height	mm	
11	Total weight	Kg	
Date:		Signature of Bidder:	

E4 LOW VOLTAGE SWITCHBOARD/MCC 1500A

Low Voltage Switchboard/MCC 1500A			
Item	Description	Unit	Data
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		
5	Main Circuit breaker		
5.1	Manufacture Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	

Low Voltage Switchboard/MCC 1500A			
Item	**Description**	**Unit**	**Data**
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	
5.8	Dimension Length	mm	
	Width	mm	
	Height	mm	
6	Motor Circuit breakers		
6.1	Manufacturer Name		
	Country		
	Local Agent		
6.2	Model		
6.3	Type		
6.4	Rated current		
6.5	Max. s.c Capacity		
6.6	Max . breaking Capacity		
6.7	Dimension Length		
	Width		
	height		
7	Motor Starter		

Low Voltage Switchboard/MCC 1500A			
Item	**Description**	**Unit**	**Data**
71	Manufacture Name		
	Country		
	Local Agent		
7.2	Model		
7.3	Type		
8 8.1	Bus bars Manufacturer Name		
	Country		
	Local Agent		
8.2	Metal		
8.3	Max s.c Current	KA	
8.4	Max temperature rise	◦C	
8.5	Dimensions: Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
9	All measurements, PLC, Contactors, Current transformer, Motor protection relays, control instrumentations:		
9.1	Manufacturer	For	

Low Voltage Switchboard/MCC 1500A			
Item	**Description**	**Unit**	**Data**
	Name	each	
	Country		
	Local Agent		
9.2	Type for each		
9.3	Model for each		
10	Dimensions: Length	mm	
	Width	mm	
	height	mm	
11	Total weight	Kg	
Date:		Signature of Bidder:	

E5 DISTRIBUTION BOARD UP TO 100A

Distribution board Up to 100A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		

Distribution board Up to 100A			
Item	**Description**	**Unit**	**Data**
5	Circuit breaker		
5.1	Manufacturer Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension Length	mm	
	Width	mm	
	height	mm	
6	Bus bars		
6.1	Manufacturer Name		
	Country		
	Local Agent		
6.2	Metal		

Distribution board Up to 100A			
Item	**Description**	**Unit**	**Data**
6.3	Max s.c Current	KA	
6.4	Max temperature rise	◦C	
6.5	Dimensions Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation:		
7.1	Manufacturer Name	For each	
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		
8	Dimensions: Length	mm	
	Width	mm	
	height	mm	
9	Total weight	Kg	

Distribution board Up to 100A			
Item	Description	Unit	Data
Date:		Signature of Bidder:	

E6 DISTRIBUTION BOARD UP TO 50A

Distribution board Up to 50A			
Item	Description	Unit	Data
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		
5	Circuit breaker		
5.1	Manufacturer		
	Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	

Distribution board Up to 50A			
Item	**Description**	**Unit**	**Data**
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension		
	Length	mm	
	Width	mm	
	height	mm	
6	Bus bars		
6.1	Manufacturer		
	Name		
	Country		
	Local Agent		
6.2	Metal		
6.3	Max s.c Current	KA	
6.4	Max temperature rise	∘C	
6.5	Dimensions:		
	Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation:		
7.1	Manufacturer	For each	

Distribution board Up to 50A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		
8	Dimensions:		
	Length	mm	
	Width	mm	
	height	mm	
9	Total weight	Kg	
Date:		Signature of Bidder:	

E 7 ELECTRICAL CABLES NYY FOR LOW VOLTAGE SYSTEM

Electrical Cables NYY for Low Voltage System			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Type		
3	Conductor type		
4	Conductor screen		

Electrical Cables NYY for Low Voltage System			
Item	**Description**	**Unit**	**Data**
5	Insulation		
Date:		Signature of Bidder:	

E 8 CAPACITOR BANK 25 KVAR

Capacitor Bank 25 KVAr			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Power	KVAr	
5	Design & Construction		
5.1	Protection Classification		
5.2	Dimensions : Length	mm	
	Width	mm	
	Height	mm	
6	Total weight	kg	
Date:		Signature of Bidder:	

E 9 CAPACITOR BANK 50 KVAR

Capacitor Bank 50 KVAr			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Power	KVAr	
5	Design & Construction		
5.1	Protection Classification		
5.2	Dimensions : Length	mm	
	Width	mm	
	Height	mm	
6	Total weight	kg	
Date:		Signature of Bidder:	

E 10 CAPACITOR BANK 65 KVAR

Capacitor Bank 65 KVAr			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		

Capacitor Bank 65 KVAr			
Item	**Description**	**Unit**	**Data**
	Local Agent		
2	Model		
3	Location		
4	Power	KVAr	
5	Design & Construction		
5.1	Protection Classification		
5.2	Dimensions : Length	mm	
	Width	mm	
	Height	mm	
6	Total weight	kg	
Date:		Signature of Bidder:	

E 11 CAPACITOR BANK 80 KVAR

Capacitor Bank 80 KVAr			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		

Capacitor Bank 80 KVAr			
Item	**Description**	**Unit**	**Data**
4	Power	KVAr	
5	Design & Construction		
5.1	Protection Classification		
5.2	Dimensions :		
	Length	mm	
	Width	mm	
	Height	mm	
6	Total weight	kg	
Date:		Signature of Bidder:	

E 12 CABLE TRAYS

Cable Trays			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Metal		
3	Model		
4	Location		
5	Design & Construction		
5.1	Protection Classification		

Cable Trays			
Item	**Description**	**Unit**	**Data**
5.2	Dimensions : Length	mm	
	Width	mm	
	Thickness	mm	
5.3	Color		
6	Total weight	kg	
Date:		Signature of Bidder:	

E 13 AUTOMATIC TRANSFER SWITCH /ATS 2X2000A

Automatic Transfer Switch /ATS 2x2000A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		
5	Circuit breakers		
5.1	Manufacturer Name		
	Country		

Automatic Transfer Switch /ATS 2x2000A			
Item	Description	Unit	Data
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max . breaking Capacity	KA	
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension		
	Length	mm	
	Width	mm	
	height	mm	
6	Bus bars		
6.1	Manufacturer		
	Name		
	Country		
	Local Agent		
6.2	Metal		
6.3	Max s.c Current	KA	
6.4	Max temperature rise	◦C	
6.5	Dimensions:		
	Section (width× thickness)	mm	

Automatic Transfer Switch /ATS 2x2000A			
Item	**Description**	**Unit**	**Data**
	Distance between phases	mm	
	Distance between phase and cover	mm	
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation, signalling :		
7.1	Manufacturer	For each	
	Name		
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		
8	Dimensions:		
	Length	mm	
	Width	mm	
	height	mm	
9	Total weight	Kg	
Date:		Signature of Bidder:	

E 14 AUTOMATIC TRANSFER SWITCH /ATS 2X1500A

Automatic Transfer Switch /ATS 2x1500A			
Item	**Description**	**Unit**	**Data**

Automatic Transfer Switch /ATS 2x1500A			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Protection classification		
5	Circuit breakers		
5.1	Manufacturer Name		
	Country		
	Local Agent		
5.2	Model		
5.3	Type		
5.4	Rated current	A	
5.5	Max. s.c Capacity	KA	
5.6	Max. breaking Capacity	KA	
5.7	Art of installation (Horiz.- Vert.)		
5.8	Dimension Length	mm	
	Width	mm	
	height	mm	

Automatic Transfer Switch /ATS 2x1500A			
Item	**Description**	**Unit**	**Data**
6	Bus bars		
6.1	Manufacturer Name		
	Country		
	Local Agent		
6.2	Metal		
6.3	Max s.c Current	KA	
6.4	Max temperature rise	◦C	
6.5	Dimensions: Section (width× thickness)	mm	
	Distance between phases	mm	
	Distance between phase and cover	mm	
7	All measurements, PLC, Contactors, Current transformer, Protection relays, control instrumentation, signalling :		
7.1	Manufacturer Name	For each	
	Country		
	Local Agent		
7.2	Type for each		
7.3	Model for each		

Automatic Transfer Switch /ATS 2x1500A			
Item	**Description**	**Unit**	**Data**
8	Dimensions: Length	mm	
	Width	mm	
	height	mm	
9	Total weight	Kg	
Date:		Signature of Bidder:	

E 15 STANDBY DIESEL GENERATOR 1500 KVA

Standby Diesel Generator 1500 KVA			
Item	**Description**	**Unit**	**Data**
1.1	Diesel Engine Name		
	Country		
	Local Agent		
1.2	AC-Generator Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Design & Construction		

Standby Diesel Generator 1500 KVA			
Item	**Description**	**Unit**	**Data**
4.1	Diesel Engine Rated speed	rpm	
	Fuel consumption	l/hr	
4.2	AC-Generator Rated Power	kVA	
	Rated current	A	
	Efficiency at 0.8 %P.F.	%	
4.3	Diesel Generator set Dimensions Length	mm	
	Width	mm	
	Height	mm	
5	Protection classification		
6	Total weight	kg	
Date:		Signature of Bidder:	

E 16 STANDBY DIESEL GENERATOR 1100 KVA

Standby Diesel Generator 1100 KVA			
Item	**Description**	**Unit**	**Data**
1.1	Diesel Engine Name		
	Country		

Standby Diesel Generator 1100 KVA			
Item	**Description**	**Unit**	**Data**
	Local Agent		
1.2	AC-Generator Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Design & Construction		
4.1	Diesel Engine Rated speed	rpm	
	Fuel consumption	l/hr	
4.2	AC-Generator Rated Power	kVA	
	Rated current	A	
	Efficiency at 0.8 %P.F.	%	
4.3	Diesel Generator set Dimensions Length	mm	
	With	mm	
	Height	mm	
5	Protection classification		
6	Total weight	kg	

Standby Diesel Generator 1100 KVA			
Item	**Description**	**Unit**	**Data**
Date:		Signature of Bidder:	

E 17 STANDBY DIESEL GENERATOR 35 KVA (PREFABRICATED WITH ATS)

Standby Diesel Generator 35 KVA (prefabricated with ATS)			
Item	**Description**	**Unit**	**Data**
1.1	Diesel Engine Name		
	Country		
	Local Agent		
1.2	AC-Generator Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Design & Construction		
4.1	Diesel Engine Rated speed	rpm	
	Fuel consumption	l/hr	
4.2	AC-Generator Rated Power	kVA	

Standby Diesel Generator 35 KVA (prefabricated with ATS)			
Item	**Description**	**Unit**	**Data**
	Rated current	A	
	Efficiency at 0.8 %P.F.	%	
4.3	Diesel Generator set Dimensions Length	mm	
	With	mm	
	Height	mm	
5	Enclosure classification:		
5.1	Noise :		Noise protected
5.2	Weather :		Weather protected
6	Art of installation		Transportable
7	Total weight	kg	
Date:		Signature of Bidder:	

E 18 UNINTERRUPTIBLE AC POWER SUPPLY SYSTEM (AC-UPS) 10KVA

Uninterruptible AC Power Supply System (AC-UPS) 10KVA			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		

Uninterruptible AC Power Supply System (AC-UPS) 10KVA			
Item	**Description**	**Unit**	**Data**
4	Design & Construction		
5	Rectifier Efficiency	%	
	Load	kVA	
	DC-Output voltage	V	
	Voltage tolerance	%	
6	Battery Rated nominal capacity	Ah	
	Discharge time	min	
	Recharge time	hr	
7	Inverter Efficiency	%	
	Power output	kVA	
	Load	kW	
8	Dimensions : Length	mm	
	Width	mm	
	Height	mm	
9	Total weight	kg	

Date:	Signature of Bidder:

E 19 UNINTERRUPTIBLE AC POWER SUPPLY SYSTEM (AC-UPS) 5KVA

Uninterruptible AC Power Supply System (AC-UPS) 5KVA			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Location		
4	Design & Construction		
5	Rectifier Efficiency	%	
	Load	kVA	
	DC-Output voltage	V	
	Voltage tolerance	%	
6	Battery Rated nominal capacity	Ah	
	Discharge time	min	
	Recharge time	hr	
7	Inverter Efficiency	%	
	Power output	kVA	
	Load	kW	
8	Dimensions :		

Uninterruptible AC Power Supply System (AC-UPS) 5KVA			
Item	**Description**	**Unit**	**Data**
	Length	mm	
	Width	mm	
	Height	mm	
9	Total weight	kg	
Date:		Signature of Bidder:	

E 20 BATTERIES AND CHARGERS

Batteries and chargers			
Item	**Description**	**Unit**	**Data**
1.1	Manufacturer Name		
	Country		
	Local Agent		
1.2	Model		
1.3	Type		
1.4	Dimensions : Length	mm	
	Width	mm	
	Height	mm	
2	Battery Rated nominal capacity	Ah	

Batteries and chargers			
Item	**Description**	**Unit**	**Data**
	Discharge time	min	
	Recharge time	hr	
2.1	Manufacturer		
	Name		
	Country		
	Local Agent		
2.2	Model		
2.3	Type		
2.4	Dimensions :		
	Length	mm	
	Width	mm	
	Height	mm	
2.5	Protection classification		
3	Location		
4	Total weight	kg	
Date:		Signature of Bidder:	

E 21 LIGHT FITTINGS (F2, F1)

Light Fittings (F2, F1)			
Item	**Description**	**Unit**	**Data**
	Name		

Light Fittings (F2, F1)			
Item	**Description**	**Unit**	**Data**
	Country		
	Local Agent		
2	Location		
3	Type of Luminary		
4	Type of Lamp		
5	Protection classification		
Date:		Signature of Bidder:	

E 22 LIGHT FITTINGS (F)

Light Fittings (F)			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Location		
3	Type of Luminary		
4	Type of Lamp		
5	Protection classification		
Date:		Signature of Bidder:	

E 23 LIGHT FITTINGS (G)

Light Fittings (G)			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Location		
3	Type of Luminary		
4	Type of Lamp		
5	Protection classification		
Date:		Signature of Bidder:	

E 24 LIGHT FITTINGS (H)

Light Fittings (H)			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Location		
3	Type of Luminary		
4	Type of Lamp		
5	Protection classification		

Light Fittings (H)			
Item	**Description**	**Unit**	**Data**
Date:		Signature of Bidder:	

E 25 LIGHT FITTINGS (EM)

Light Fittings (EM)			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Location		
3	Type of Luminary		
4	Type of Lamp		
5	Protection classification		
Date:		Signature of Bidder:	

E 26 EARTHING AND LIGHTNING PROTECTION SYSTEMS

Earthing and Lightning Protection Systems			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Location		
3	Earthing equipment material		

Earthing and Lightning Protection Systems			
Item	**Description**	**Unit**	**Data**
4	Earth tape Material, Size,		
	Catalogue Nr:		
5	Earth Rod Material, Size,		
	Catalogue Nr.		
6	Earthing Distributor Material, Size,		
	Catalogue Nr.		
7	Earthing Enhancing Compound Type,		
	Catalogue Nr.		
Date:		Signature of Bidder:	

E 27 EXTERNAL LIGHTING COLUMN 12M

External Lighting Column 12m			
Item	**Description**	**Unit**	**Data**
	Name		
	Country		
	Local Agent		
2	Model		
3	Type		
4	Location		
5	Metal		

External Lighting Column 12m			
Item	**Description**	**Unit**	**Data**
6	Dimension		
7	Protection Classification		
8	Weight		

I&C 1 ELECTROMAGNETIC FLOW METER

Electromagnetic Flow Meter			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Location		
3.1	DN of pipe	mm	
3.2	DN of Flow Meter	mm	
4	Accuracy	% FS	
5	Design & Construction		
5.1	Material and coating of the housing		
5.2	Sensor coating		
6	Velocity range		
6.1	V min	m/s	
6.2	V max	m/s	
7	Flow range		
7.1	Flow min	m^3/hr	
7.2	Flow max	m^3/hr	
8	Max pressure	bar	
9	Processing Unit		

Electromagnetic Flow Meter			
Item	**Description**	**Unit**	**Data**
9.1	Power supply voltage	V	
9.2	Kind of data transmission (type of field bus)		
9.3	Local display	y/n	
9.4	Material of housing and IP protection classification		
9.7	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 2 FLOW METER INSERTION TYPE

Flow Meter Insertion type			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Location		
3.1	DN of pipe	mm	
4	Accuracy	% FS	
5	Design & Construction		
5.1	Material and coating of the housing		
5.2	Sensor coating		
6	Velocity range		
6.1	V min	m/s	
6.2	V max	m/s	
7	Flow range		

Flow Meter Insertion type			
Item	**Description**	**Unit**	**Data**
7.1	Flow min	m³/hr	
7.2	Flow max	m³/hr	
8	Max pressure	bar	
9	Processing Unit		
9.1	Power supply voltage	V	
9.2	Kind of data transmission (type of field bus)		
9.3	Local Display	y/n	
9.4	Material of housing and IP protection classification		
9.5	Self diagnosis function	y/n	
9.6	Remote processor possible	y/n	
9.7	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 3 PRESSURE GAUGES AND TRANSMITTER

Pressure gauges and transmitter			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Accuracy	%	
4	Range		
4.1	Min. pressure	bar	
4.2	Max. pressure	bar	
5	Sensor Design & Construction		

Pressure gauges and transmitter			
Item	**Description**	**Unit**	**Data**
5.1	Kind of element		
5.2	Material of Case		
5.3	Thread Dimension		
5.4	Material of sensor		
7	Transmitter Design & Construction		
7.1	Power supply voltage	V	
7.2	Kind of data transmission		
7.3	Local Display		
7.4	Material of housing and IP protection classification		
7.5	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 4 LEVEL TRANSMITTER

Level Transmitter			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Physical principle		
4	Range		
5	Sensor Design & Construction		
5.1	Kind of mount fixture	V	
5.2	Material of fixture		
5.3	Material of sensor case		

Level Transmitter			
Item	**Description**	**Unit**	**Data**
5.4	IP protection class		
6	Converter Design & Construction		
6.1	Power Supply Voltage		
6.2	IP protection class		
6.3	Mounting		
6.4	Kind of data transmission		
6.5	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 5 LEVEL SWITCH

Level Switch			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Physical principle		
4	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 6 PRESSURE SWITCH

Pressure Switch			
Item	**Description**	**Unit**	**Data**

Pressure Switch			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Physical principle		
4	Thread dimension		
5	Material		
6	Cable type and cable terminal		
Date:		Signature of Bidder:	

I&C 7 PROGRAMMABLE LOGIC CONTROLLER

Programmable Logic Controller			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	CPU		
3.1	Type		
3.2	Program Language		
3.3	CPU time for Bit operation	Micro-sec	
4	Nos. of DI or DO or AI or AO each card/		
5	No. of I/O cards at 1 frame		

Programmable Logic Controller			
Item	**Description**	**Unit**	**Data**
6	Communication		
6.1	Type of communication card to sensors		
6.2	Type of communication card to HMI		
6.3	Type of communication card to SCADA		
6.4	Supported Protocols		
7	Power supply voltage	V	
8	Protection class and coating of the PLC housing		
Date:		Signature of Bidder:	

I&C 8 HUMAN MACHINE INTERFACE (HMI)

Human Machine Interface (HMI)			
Item	**Description**	**Unit**	**Data**
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Screen / frame dimensions	mm x mm	
4	Picture		
4.1	Picture quality	bpi	
4.2	Colour quality		
5	Communication to PLC		
6	Protection class IP front / back		
7	Power supply		

Human Machine Interface (HMI)			
Item	Description	Unit	Data
Date:		Signature of Bidder:	

I&C 9 CABLES

Cables			
Item	Description	Unit	Data
1.1	Name / Country		
1.2	Local Agent		
2	Type / Nos. and diameter of conductors		
2.1	Power supply cable 230V AC		
2.2	Power cable 24V DC		
2.3	Cables for 4 – 20mA		
2.4	Cables for 24V control		
2.5	Data bus cables (Cu)		
Date:		Signature of Bidder:	

I&C 10 FIBER OPTIC CABLES

Fiber Optic Cables			
Item	Description	Unit	Data
1.1	Name / Country		
1.2	Local Agent		
2	Type		
3	Fibre count		
4	Core size @1310nm	micr	
5	Single Mode	y/n	

Fiber Optic Cables			
Item	**Description**	**Unit**	**Data**
5	Cladding Diameter	micr	
6	Attenuation@1310 nm	dB/km	
7	Chromatic dispersion@1310nm		
8	Cable jackets type		
9	Armour material		
10	Cable diameter	mm	
11	Bending Radius	mm	
12	Max. tensile strength	N	
13	Type of connection		
Date:		Signature of Bidder:	