الجمهورية اللبنانية

وزارة الطاقة والمياه

دراسة محطة معالجة مياه بحيرة المسيلحة ومحطات الضخ وخطوط النقل والدفع والخزانات وتصميم محيط الأشغال أسفل سد المسيلحة بما فيها القلعة – قضاء البترون

الجزء الأول: دراسة محطة معالجة المياه وضخها إلى الخزانات الرئيسية

1–4 الخرائط التنفيذية وملفات التلزيم

1–4–2 دفاتر الشروط الفنية وملفات التلزيم

TENDER DOCUMENTS FOR DESIGN, BUILD, OPERATE AND MAINTAIN CONTRACT

VOLUME 3: Technical Specifications

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Mseilha WTP and Main Pumping Stations

Volume 3: Technical Specifications

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Part I: General

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PART 1 - GENERAL

1-A ABBREVIATIONS

Wherever the following abbreviations are used in the specifications or in the plans, they are to be constructed the same as the respective expressions represented :

AC	Asbestos Cement
AASHTO	American Association of State Highway and Transportation Officials
AAMA	Architectural Aluminum Manufacturer's Association
ACI	American Concrete Institute
AFNOR	Association Française de Normalisation
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AWWA	American Water Works Association
AWS	American Welding Society
BS	British Standard
CDR	Council for Development and Reconstruction
CP	Code of Practice
DIN	Deutscher Normausschuss
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
FSS	Federal Specifications and Standards (United States)
gpm	gallons per minute
GRP	Glass Reinforced Plastic
IEC	International Electrotechnical Commission
ISO	International Standards Organization
ITS	Institute of Technical Studies
m	meters
mm	millimeters
m^2	square meter
m^3	cubic meter
NEMA	National Electrical Manufacturers Association
NF	Normes Françaises
UTE	Union Technique de l'Electricité
VDE	Verband Deutscher Electrotechniker

1-B GENERAL

1-B-1 STANDARDS

1- All references to codes, specifications and standards referred to in the Contract Documents shall mean, and are intended to be, the latest edition, amendment or revision of such reference standards in effect.

2- Whenever the Contract Documents require that a product complies with certain Standards or Specifications, the Contractor shall present a certificate from the manufacturer ensuring that the product complies therewith. Where requested or specified, the Contractor shall submit supporting test data to substantiate compliance.

Each and every part of the works shall be designed, constructed, manufactured, tested and installed in accordance with an internationally recognized Standard, Code of Practice, or Regulation applicable to that part of the works. The Technical Specifications could refer to one or more standards, but it is still accepted that any international recognized standard, code of practice or regulation could be applicable with the prior consent of the Engineer.

If any clarification or additional information regarding technical aspects, the Contractor must submit a request for information.

1-B-2 EQUIVALENCY OF STANDARDS AND CODES

Wherever reference is made in the Contract including the Specifications, Drawings and Bill of Quantities to specific standards and codes to be met by the goods and materials to be furnished, and work performed or tested, the provisions of the latest current edition or revision of the relevant standards and codes in effect shall apply, unless otherwise expressly stated in the Contract.

Where such standards and codes are national or relate to a particular country or region, other authoritative standards that ensure a substantially equal or higher quality than the standards and codes specified will be accepted subject to the Engineer's prior review and written consent. Differences between the standards specified and the proposed alternative standards shall be fully described in writing by the Contractor and submitted to the Engineer at least 28 days prior to the date when the Contractor desires the Engineer's consent.

In the event the Engineer determines that such proposed deviations do not ensure substantially equal or higher quality, the Contractor shall comply with the standards specified in the Contract.

1-B-3 SILENCE OF SPECIFICATIONS

The apparent silence of the specifications, plans or other Contract Documents as to any detail or the apparent omission from them of a detailed description concerning any point, shall be regarded as meaning that only the best general practice is to be used. All interpretations of the specifications will be made by the Engineer on this basis.

1-B-4 LANGUAGE OF CORRESPONDENCE AND RECORDS

All communications from the Contractor to the Engineer shall be in the Arabic or English language. All books, time sheets, records, notes, drawings, documents, specifications and manufacturers' literature etc. shall be in the Arabic or English language.

1-B-5 UNITS

The International System of (metric) Units shall be used throughout the Contract except where otherwise provided.

1-B-6 INTENTION OF TERMS

Where “as shown”, “as indicated”, “as detailed” or words of similar import are used, it shall be understood that reference to the drawings accompanying the Specifications is made unless otherwise stated. Where “as approved”, “as directed”, “as required”, “as accepted”, or words of similar import are used, it shall be understood that the approval, direction, requirement, permission, authorization, review, or acceptance of the Engineer is intended, unless otherwise stated. “Provide” shall be understood to mean “complete in place”, that is, “furnish and install”.

Whenever anything is, or is to be done, if, as, or, when, or where “contemplated, required, determined, directed, specified, authorized, ordered, given, designated, indicated, considered, considered necessary, deemed necessary, permitted reserved, suspended, established, approval, approved, disapproved, acceptable, unacceptable, suitable, accepted, satisfactory, unsatisfactory, sufficient, insufficient, rejected or condemned”, it shall be understood as if the expression were followed by the words “by the Engineer” or “to the Engineer”.

The phrases “or equal” and “or equivalent” shall be construed to mean that material or equipment will be acceptable only when composed of parts of equal quality, or equal workmanship and finish, designed and constructed to perform or accomplish the desired result as efficiently as the named brand, pattern, grade, class, make or model.

1-B-7 INTENT OF CONTRACT

The intent of the Contract is to provide for the construction and completion in every detail of the works described. The Contractor shall furnish all labor, materials, equipment, tools, transportation and supplies required to complete the work in accordance with the plans, specifications and terms of the Contract Documents.

Unless otherwise specified, the Contractor shall allow a minimum of 21 days for approval of drawings and documents by the Engineer.

1-B-8 BILLS OF QUANTITIES

Detailed Bills of Quantities shall be prepared by the Contractor in accordance with the measurement rules described in the preamble and as approved by the Engineer.

1-B-9 OPERATION AND MAINTENANCE MANUALS

The Contractor shall submit to the Engineer 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 Engineer in the production of the final Manuals.

The draft O & M Manuals shall be available on site at all times 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.

1-B-10 WORK THROUGH PRIVATE PROPERTY

In order that the necessary easements may be obtained and /or the owners of private property may be served with the requisite notices it shall be an obligation of the Contractor to supply the Engineer from time to time with full information of his program sufficiently in advance of the dates upon which the Contractor will wish to enter upon each parcel of private land.

The Contractor shall consult with Owners and Tenants (if any) and have written approval before entering on their land or cutting through any ditch, bank, hedge, wall, fence or any other form of boundary marking and he shall ascertain and carry out their reasonable requirements as approved by the Engineer in the matter of reinstatement.

1-B-11 PUBLIC UTILITY MAINS AND SERVICES, LOCATING, ETC

It shall be the responsibility of the Contractor to obtain all information available from the Public Utility Authorities regarding the position of mains and services and he shall make this information available to the Engineer as soon as he obtains it.

The absence of such information shall not relieve the Contractor of his liability for the cost of any repair work necessitated by damage caused by him to any mains or services in the course of his work and for the cost of all losses arising from the disruption.

All locating work shall be carried out in advance of further excavation work. The Contractor shall obtain all information and assistance available from the Public Utility Authorities for the locating of the mains and services and shall agree with the Engineer any trial excavation which may be necessary to confirm or establish these locations.

Any temporary or permanent diversion of mains and services will only be permitted after agreement with the appropriate Public Utility Authority.

1-B-12 PROJECT CONTROL

1- The Contractor shall provide within his site organization a project management section to advise and be directly responsible to the Contractor's Engineer. The duties of the section shall include the following:

i. Planning and program preparation particularly in relation to the requirements of public authorities and the requirements to maintain water supply disposal services where careful detailed arrangements have to be made and adhered to.

ii. Planning the execution of the works in a manner which minimizes disruption to the water supply and wastewater systems and will permit the efficient and effective commissioning of the water supply and wastewater systems and its respective components.

iii. Ensuring adequate water supplies are maintained to all consumers. Also, ensuring all existing wastewater systems are functionning during execution.

iv. Continuous surveillance of progress and anticipation of factors likely to affect the timely performance of the Contract.

v. Making proposal for modification to forward planning and to the program at an early stage in the light of factors resulting from (iv).

vi. Continuous appraisal of the Contractor's methods and routines particularly as to their effectiveness relating to speed of execution and to their effect on the community and property.

vii. Forward planning for resource requirements taking due account of possible shortages and delays in the arrival on site of materials, plant, personnel, etc. and their mobilization for effective usage.

viii. Acquisition and process of up-to-date information for progress meetings with the Engineer. The preparation of monthly progress reports including an update of the detailed program and cash flow forecast.

2- The project management section shall be in the charge of a professionally qualified engineer specializing in project management having had at least 10 years experience on similar projects and being versed in modern management techniques. Supporting staff for this section shall be in adequate numbers to carry out their duties and shall be of adequate ability and experience to the Engineer’s approval.

3- Programs shall be based upon C.P.M. networks in precedence format and shall be prepared using a suitable P.C. - based project management software package approved by the Engineer.

4- Reporting shall be in a manner compatible with the Employer’s or Engineer’s requirements.

1-B-13 QUALITY CONTROL

The Contractor shall be responsible for his own quality control and shall provide sufficient competent personnel for supervising the Works, taking and preparing samples and for carrying out all necessary tests.

1-B-14 MONTHLY CERTIFICATES

Monthly certificates shall be submitted in an approved manner and format. The certificate shall detail the measured value of the work completed on each item of the Works. An item shall constitute a single structure or a component of a system such as a single pipeline or valve complex.

1-B-15 PROGRESS MEETINGS

The Contractor shall arrange progress review meetings, to be chaired by the Engineer, at monthly intervals to coincide with submission of monthly progress submissions.

1-B-16 PROPRIETARY MATERIALS

Material shall be supplied in suitable containers and in appropriate batch sizes for the work to be undertaken.

The following information shall be marked:

i. Storage instructions;
ii. The manufacturer's name;
iii. Shelf life and dates of manufacture:
iv. Material identification;
v. Batch reference number;
vi. Net weight;
vii. Mixing instructions;
viii. Any warnings or precautions concerning the contents and their safe use.

The Contractor shall supply with each consignment of proprietary material delivered to the Site, certificates furnished by the manufacturer or his agent stating:

i. The manufacturer's name and address:
ii. The agent's name and address where applicable;
iii. Material identification:
iv. Batch reference numbers, size of each batch and the number of containers in the consignment;
v. Date of manufacture.

1-B-17 REJECTED MATERIALS

Should any materials or manufactured articles be in the judgment of the Engineer, unsound or of inferior quality or in any way unsuited for the purpose in which it is proposed to employ them, such materials or manufactured articles shall not be used upon the Works but shall be branded, if in the opinion of the Engineer this is necessary, and shall forthwith be removed from the Site.

1-B-18 QUALITY

The materials and workmanship shall be the best of their respective kinds and to the approval of the Engineer. The words “to the approval of the Engineer” shall be deemed to be included in the description of all materials and workmanship for the due execution of the Works.

1-B-19 OFFICES, TRANSPORT, EQUIPMENT AND SERVICES FOR ENGINEER AND EMPLOYER’S REPRESENTATIVE (PMU)

The Contractor shall provide and properly maintain, for the duration of the Work, the offices for the use of the Engineer, his staff, the Employer and the Employer’s Representative. This office shall be constructed, equipped and furnished as directed by the Engineer. These facilities shall be completed and ready for occupancy within sixty (60) days from the date of signing the Contract.

The Contractor shall submit to the Engineer, for approval, details of the offices space to be constructed, equipped and furnished before construction is commenced.

The Contractor shall, at the completion of the Work, supply electricity, water and sanitary facilities for the Engineer’s offices. The Contractor shall be fully responsible for the maintenance and operation, including labor and materials, for the offices.

The Contractor shall supply the Engineer with mobile telephones as necessary to enable efficient communication between the contractor and the Engineer’s supervision staff.

The Contractor shall also supply the Engineer, for the duration of the work, with 4x4 wheel drive vehicles as necessary to access all different site locations. These vehicles should be powerful enough to withstand all kind of driving conditions, rough roads, natural terrains and tough weathering conditions.

The Contractor shall additionaly provide and properly maintain, for the duration of the Work, a second quarter of offices for the use of the Employer Representative the Project Management Unit (PMU), his staff, and the Employer. This office shall be located in a suitable office center, then equipped and furnished as directed by the PMU. These facilities shall be completed and ready for occupancy within sixty (60) days from the date of signing the Contract.

The Contractor shall submit to the PMU for approval, details of the offices space to be equipped and furnished.

The Contractor shall, supply and pay all related charges such as electricity, water, telephone and parking lots as required and shall be fully responsible for the maintenance and operation, including labor and materials, for the PMU offices.

The Contractor shall supply the PMU team with mobile telephones as necessary to enable efficient communication between the contractor and the PMU staff.

1-B-20 FACILITIES FOR SURVEY AND INSPECTION BY THE ENGINEER

The Contractor shall make available technicians and such labor, materials and safety equipment as the Engineer may require for inspections and survey work in connection with the Works. The Contractor shall provide all necessary tackle, test equipment, access, labor, staff and any other thing the Engineer may reasonably require in order that he may safely, conveniently and quickly carry out such inspections as he deems necessary at any time during the execution of the Works including the Tests on completion.

1-B-21 INSPECTIONS BY THE ENGINEER DURING DEFECTS LIABILITY PERIOD

The Engineer will give the Contractor due notice of his intention to carry out any inspections during the Defects Liability Period and the Contractor shall thereupon 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 record all matters and things to which his attention is directed by the Engineer.

1-B-22 APPROVAL

As soon as possible after commencement of the Contract, the Contractor shall submit to the Engineer for his approval a list of his proposed suppliers, sources of materials, construction requirements and proposed standards. No materials, plant or equipment shall be procured for the Contract without first obtaining the Engineer's approval. Samples of materials shall be submitted to the Engineer for approval as required by the Engineer. Materials subsequently supplied shall conform to the quality of the samples which have been approved by the Engineer. No standard, method of manufacture or specification shall be changed without the approval of the Engineer. Where possible plant shall be supplied to the same standards or to compatible standards.

1-B-23 PROTECTIVE CLOTHING

The Contractor shall provide for the Engineer, his Representative and assistants the protective clothing necessary for the proper discharge of their duties on Site.

The Contractor shall provide any necessary protective clothing and safety equipment for the use of authorized visitors to the site including the Employer and his staff and representatives and those of any relevant authority and who have reason to visit the Site.

1-B-24 SOURCE OF SUPPLY AND QUALITY REQUIREMENTS

All materials, manufactured articles and machinery incorporated in the permanent works shall be new, recently manufactured and shall meet the quality requirements of the Contract. They must, in all cases, be approved by the Engineer prior to their inclusion into the work.

All shipment of materials must be accompanied by a Manufacturer's Certificate of Guarantee or test certificate from an approved independent laboratory when delivered to the site. The independent laboratory shall be approved by the Engineer before any materials are submitted for tests. However, all materials delivered to the Site are subject to additional laboratory testing when requested by the Engineer even though the materials are accompanied by a certificate of guarantee or laboratory test certificate. All costs in connection with certificates of guarantee or laboratory tests and certificates shall be borne by the Contractor. Falsification of such documents shall be just cause for rejection of the materials and all cost of transportation and handling of the rejected materials shall be the sole responsibility of the Contractor.

In order to expedite the work, the Contractor shall, before placing any purchase order for materials, manufactured articles and machinery to be part of the permanent works, submit for the approval of the Engineer, a complete description of such items, the names of the firms from whom he proposes to obtain such items, together with a list of the items he proposes each firm would supply. No materials, manufactured articles or machinery shall be ordered from any firm without the written approval of the Engineer. When directed by the Engineer or otherwise specified in the Contract, the Contractor shall submit samples for approval.

If it is found after trial that sources of supply for previously approved materials, manufactured articles, or machinery do not produce specified products, the Contractor shall furnish the items from other sources approved by the Engineer.

1-B-25 PRECAUTIONS AGAINST CONTAMINATION OF THE WORKS

The Contractor shall at all times take every possible precaution against contamination of the works.

The Site and all permanent and temporary works shall be kept in a clean, tidy and sanitary condition.

The Contractor shall at all times take measures to avoid contamination of existing water courses and drains by petrol, oil or other harmful materials.

The works shall be kept clean and free from rubbish and remedial works shall be carried out as the work is progressively completed. Before requesting inspection for preliminary or final take-over of the works or any section thereof the Contractor shall inspect the works and assure himself that they are clean and in a satisfactory condition for such inspection, normal usage expected.

1-B-26 ENVIRONMENTAL ASPECTS

The Contractor shall take all reasonable steps to minimize the adverse affects of both the temporary and permanent works on the environment. Before any work commences, the Contractor shall submit an environmental protection plan describing how potential adverse impacts will be mitigated. These adverse environmental impacts could be:

a. Pollution of soil and water due to improper dumping of excavated and construction material, oils used, chemicals/solvents, human wastes.

b. Erosion of soil, sedimentation and drainage due to excavation and bedding.

c. Noise and air (dust, odor) pollution due to operation of machinery and excavation.

d. Traffic increase due to trucks (sand, machinery, equipment) movement and traffic disturbance.

e. Disturbance to recreational, archaeological, touristic sites.

f. Public health and safety due to the operation of the machinery and accidents.

g. Damage to forests, agricultural land, vegetated area and its wildlife habitat.

1-B-27 ACCESS TO PROPERTIES

The Contractor shall not disrupt any private or public access way without first providing alternative arrangements.

Access to properties affected by the Works shall be maintained. Adequate road plates shall be provided for trench crossings.

1-B-28 CONTROL OF DUST

The Contractor shall, throughout the execution and completion of the Works take all reasonable steps to avoid damage or nuisance to persons or property resulting from dust and shall carry out preventative measures, such as spraying the ground with water, and /or soil covering, as instructed by the Engineer.

1-B-29 SAFETY

The Contractor must cover all aspects of site safety during the Works.

1-B-30 PROJECT SAFETY PLAN

Before any work commences on the Site the Contractor shall submit a Project Safety Plan *(PSP)* which shall be specific to the Contract. The plan shall detail the Contractor's site safety organization, his safety rules and procedures and methods of monitoring and enforcing his procedures.

The Project Safety Plan shall cover all aspects of site safety and shall typically include the following:

a. Health and Safety Policy and Primary Objectives:

   The plan shall demonstrate that management of health and safety is an integral part of the management and co-ordination of the project.

b. Organization and Responsibilities:

   A designated competent person shall be specified as the Contractor's Safety Officer with overall responsibility for the establishment, implementation and enforcement of safety procedures and methods of working.

   The Contractor's organization structure and responsibilities with respect to safety shall be detailed.

c. Hazard Identification and Risk Assessment:

   The Contractor shall assess the risks to workers and any others that require access to the site or the works or may be affected by the operations.

   A systematic general examination of each activity and assessment is to include:

- Identification of the hazards present and those hazards their operations will introduce to the site.
- Identification of the people exposed.
- The extent of the risk evaluated after considering the existing control measures.
- Further assessments to be made for new activities.
- Plant and equipment to be identified and those responsible for its provision and maintenance to be defined and designated.
- Review and revision if assessments man no longer be valid or where there has been a significant change.
- Planned review of assessments at regular intervals.
- Inform employees on the nature of the hazard and the risks identified by the assessments, the preventative and protective measures, emergency procedures and the competent personnel.
- Significant findings of assessments to be recorded.

d. Emergency Procedures:

Effective procedures for contingency in event of serious and immediate danger. All employees shall be able to stop work and immediately proceed to a place of safety if exposed to imminent and unavoidable danger.

e. Cooperation and Coordination:

All competent persons to liaise and assist in assessing the shared risks and coordinating any necessary measures, primarily by providing information. The Contractor to take full responsibility in coordination arrangements.

f. Capabilities and Training:

Provision of health and safety training for all employees upon recruitment and on exposure to new or increased risks.

g. Monitoring:

Scheduled hierarchical audit system conducted by the Contractor. Safety performance to be monitored and measured against the PSP; project procedures for safe systems of work; and specified safety performance standards.

h. Health and Safety Performance Standards to be specified, i.e.:

- Relevant statutory legislation
- Standard specifications (BSI/ISO)
- Approved codes of practice
- Specific Project Safety Plan Information:
- <u>Nature of the Project</u>
    - o Name of Employer
    - o Location
    - o Nature of construction work to be carried out

  - Time scale for completion of the construction work

- The existing environment
  - Surrounding land uses and related restrictions - e.g. premises (schools) adjacent to the proposed construction site.
  - Existing services - e.g. underground and overhead lines.
  - Existing traffic systems and restrictions.
  - Existing structures - e.g. special health problems from materials in existing structures which are being demolished or refurbished, any fragile materials which require special safety precautions, instability problems etc.
  - Ground conditions - e.g. contamination, instability, possible
  - subsidence, underground obstructions etc.
- Existing drawings
  - Available drawings of structure(s) to be demolished or incorporated in the proposed structure(s)
- The design
  - Significant hazards of work sequences.
  - The principals of the design and any precautions that might be needed or sequences of assembly that need to be followed during construction.
  - Detailed reference to specific problems with proposals for managing these problems.
- Construction materials
  - Health hazards where either because of their nature or the manner of their use, particular precautions are required.
- Site wide elements
  - Outline emergency arrangements including access and egress.
  - Positioning of site access and egress points.
  - Location of temporary site accommodation.
  - Location of unloading, layout and storage areas
  - Traffic/pedestrian routes.
- Overlap with other undertaking
  - Consideration of the health and safety issues which arise when the project is to be located in premises

occupied or partially occupied by the Employer or other authority.

- Site Rules
  - Specific sites rules which the client or the planning supervisor may wish to lay down as a result of points above or for other reasons - e.g. specific permit to work rules, emergency procedures.
- Continuing liaison
  - Procedures for considering the health and safety implications of work elements
  - Procedures for dealing with unforeseen eventualities during project execution.

1-B-31 HAZARDS

Potential hazards associated with the Sites may include, but will not be limited to the following:

- Any chamber, pipeline, borehole, excavation or other structure (whether above or below ground) not effectively ventilated.
- Compressed air vessels may burst explosively.
- Toxic Fumes and Gases: (generated by combustion engines, chlorine, ammonia, treatment processes).
- Asphyxiating Gases.
- Dangerous Fumes and Gases.
- Chemicals: Chemicals are stored and used in many processes. Most of them are strongly alkaline, acidic, toxic or otherwise aggressive.
- Electricity Cables:

  Buried and overhead cables of all voltage ratings may be encountered.

  Overhead cables of all voltage ratings may be encountered. On operational sites the clearance may be lower than in highways or public areas. Hazards are as for buried cables, with the additional risk of arcing. Arcing may occur from the cables to metal objects or spray.
- Buried services:

  Buried water pipes may be encountered on any operational site. The water may be under very high pressure.
- Moving Machinery:

  Any operational plant may contain moving machinery. Much of this is automatically controlled and may start without warning.

  There is electrical plant associated with such machinery, carrying the same hazards as electricity cables.
- Noise (high frequency noise)

Machinery such as engines, turbines, generators, pumps or compressors operating inside buildings may produce very loud noise. High speed machinery may produce high frequency noise. The hazards are possible short and long term hearing damage if ear defenders are not worn.

- Moving Vehicles:

  Any road on an operational site may carry vehicles which are relatively heavy for the class of road. Such vehicles may carry any of the chemicals or sludge's noted above.

  Tractors and other machinery may operate on unpaved areas.

- Contact Lenses:

  In areas where an arc flash can occur (chambers or where welding processes are carried out) wearers of contact lenses can sustain irreparable damage to their eyes. This can occur whether or not safety spectacles arc worn over the contact lenses.

- Confined Spaces

  a. Provide, when work is in progress, radio or telephone communication, or safe visual and oral communication where this is appropriate and background noise levels permit.
  b. Ensure that all electrical tools and equipment are of the appropriate type.
  c. Provide appropriate protective clothing.
  d. Provide hygiene facilities if appropriate.
  e. Ensure that all persons entering or working in a confined space are trained and authorized to enter.

1-B-32 WATER AND ELECTRICITY SUPPLY

The Contractor shall make his own arrangements for procuring water and electricity supplies, at his own expense. Public water and electricity cuts shall, in no way, justify delays in the progress of the work. He shall be solely responsible for ensuring the continuity of the water and electricity supply. For this purpose he shall install the needed number of generators and water tanks that would meet his needs.

1-B-33 SAFEGUARDS TO EXISTING PIPES, CABLES, STRUCTURES

It shall be the Contractor's responsibilities to safeguard by means of temporary or permanent supports or otherwise all existing pipes, cables, structures or other things which would be liable to suffer damage if such precautionary measures were not taken.

Temporary safeguards shall be to the approval of the Engineer and of the Undertaker or Owner concerned.

Permanent safeguards shall be to the approval of the Undertaker or Owner concerned and the Engineer.

1-B-34 CONNECTIONS TO EXISTING PIPES, CABLES ETC.

The Contractor will be responsible for connections between pipes, cables etc. laid by him and existing pipes, cables etc. The Contractor shall submit to the Engineer a drawing showing the details of the connection, and shall state the date on which the particular connection could be made. The work shall not proceed until the Engineer's approval has been given.

The Contractor shall be responsible for joining up to and ensuring complete compatibility with existing pipework, cables, tubing, equipment etc.

1-B-35 CONTRACTOR'S RESPONSIBILITY FOR UTILITY PROPERTIES

At points where the Contractor's operations are adjacent to properties of telegraph, telephone and power agencies or companies, or adjacent to other property, damage to which might result in considerable expense, loss or inconvenience, the work shall not be commenced until all arrangement for the protection thereof have been made. The Contractor shall cooperate with the owners of any underground or overhead utility lines in their removal and rearrangements operations in order that these operations may progress in a reasonable manner and that duplication of rearrangement work may be reduced to a minimum and that services rendered by those parties will not be unnecessarily interrupted.

In the event of interruption to water or utility services as a result of accidental breakage, or as a result of being exposed or unsupported, the Contractor shall promptly notify the proper authority in the restoration of service. If essential public utility service is interrupted, repair work shall be continuous until the service is restored.

1-B-36 SITE ACCESS ROUTES

The Contractor shall satisfy himself as to the suitability of the access routes he chooses for use during the Contract period. The Employer does not guarantee either the suitability or availability of any particular access route and will not entertain any claim in respect of the non-suitability or non-availability of any such route for continuous use during the Contract period. When needed for the execution of the work, the Contractor shall be responsible for constructing and maintaining temporary access routes at his own expense. The Contractor shall submit for the approval of the Engineer his proposal for the access routes he intends to use and build. He shall be responsible for getting approvals from concerned authorities and/or landowners on the right-of way needed for the construction and use of these access routes.

1-B-37 EXPLOSIVES

When the use of explosives is necessary for the prosecution of the work, the Contractor shall exercise the utmost care not to endanger life or property, including new work. The Contractor shall be responsible for all damages resulting from the use of explosives. The Contractor shall store all explosives in a secure manner marked clearly in Arabic and English "Danger Explosives". Storage shall be in compliance with all local laws and ordinances. It is the Contractor's responsibility to contact the authorities and secure their approval of his proposed method of storage.

Where no local laws or ordinances apply, storage shall be to the satisfaction of the Engineer and, in general, not closer than three hundred (300) meters from the road or from any building or camping area. In no case shall the Contractor store explosives on the Site without prior approval of the local authorities or the Engineer.

Prior to starting any blasting operations, the Contractor shall submit a written comprehensive system of working to be approved by the Engineer. The system shall be approved by the Engineer prior to blasting. Approval of blasting plans shall not relieve the Contractor of his responsibility or liability for the safety of persons and property.

1-B-38 SETTING OUT OF THE WORKS

The Contractor shall prepare detailed setting out drawings and data sheets as necessary and submit them to the Engineer for approval. Any modifications to the setting out drawings or data sheets required by the Engineer shall be made by the Contractor and resubmitted for final approval.

The Engineer will agree with the Contractor the basic information supplementary to that shown on the Contractor's Drawings such as the position of center-lines and base-lines etc. sufficient for the Contractor to locate the Works. Such supplementary information may be provided on drawings, sketches or in writing.

Should it be necessary during setting out or during construction agreed setting out details to be amended, the Contractor shall amend the drawings or data sheets or make new ones for approval as required by the Engineer.

Copies of setting out drawings and data sheets shall be preserved for use by the Contractor in preparing final records and drawings in accordance with the requirements set out elsewhere.

1-B-39 BOUNDARIES OF WORKS

The Employer shall provide the Site upon which the Permanent Works included in the Contract are to be constructed. The existing boundary fences and walls shall not be disturbed without the prior approval of the Engineer's representative and the carriage way shall be left available to traffic.

The Contractor shall not enter upon or occupy with men, tools, equipment or materials and land other than or rights of way provided by the Employer without the written consent of the owner of such land.

The Contractor shall provide temporary fencing, or immediately install permanent fencing where such is required. Where the Permanent Works do not include fencing the Contractor shall submit his proposals to the Engineer as to how he intends to fulfill his obligations under the Contract which shall be to the approval of the Engineer.

1-B-40 SHOP DRAWINGS / EXECUTION DRAWINGS

The execution drawings shall be prepared in the same manner stated thereafter in the preparation of the shop drawings.

Where the Contract Documents require the Contractor to prepare Shop Drawings, or where required by the Engineer during the course of the work, the Contractor shall submit to the Engineer Shop Drawings that shall satisfactorily establish actual details of manufactured or fabricated item and of work to be executed. They shall clearly identify materials, dimensions, thicknesses, components, attachments, relation with adjoining work and spaces, and all other pertinent information. Shop Drawings shall clarify and amplify the design drawings and other design requirements and shall, subject to the Engineer's approval, incorporate minor changes in design or construction as may be necessary to suit the requirements of the work. By submitting Shop Drawings the Contractor thereby represents that he has determined and verified all dimensions, relations to existing work, coordination with work to be installed later, coordination with information in previously submitted Shop Drawings and has verified their compliance with all the requirements of the Contract Documents.

The accuracy of all such information is the responsibility of the Contractor and in reviewing Shop Drawings the Engineer shall be entitled to rely upon the Contractor's representation that such information is correct and accurate.

The Contractor shall be responsible for and shall make any alterations in the work due to discrepancies, errors or omissions in the Shop Drawings supplied by him whether or not such Shop Drawings have been approved by the Engineer.

1-B-41 AS-BUILT DRAWINGS

The Contractor shall submit final as-built record drawings to the Engineer for his review by the specified date. After review and approval by the Engineer of the final as-built drawings, the Contractor shall within 10 days thereof, produce a final set of "as-built drawings" and submit to the Engineer the following :

a. One (1) computerized copy of each as-built drawing on CD.

b. 3 prints of each as-built drawing.

1-B-42 LEVEL DATUM

Where possible, construction drawings and all levels used for construction shall be referred to the National Height Datum. The Contractor shall be responsible for obtaining the location of the permanent bench marks. In cases where such bench marks do not exist, the site datum shall be agreed with the Engineer.

Levels of reservoirs, pumping stations, boreholes, pipes, treatment plant and the like shall be referred to the National Height Datum.

Before the commencement of construction works, the Contractor shall establish at each site in a position, to the approval of the Engineer, a steel datum peg which shall be securely concerted in. The level of this pet shall be established and agreed with the Engineer and all levels used in the construction of the Works shall be referred to this established datum. The correctness of this established datum shall be checked at regular intervals during the construction period as agreed with the Engineer.

1-B-43 LEVELS AND DIMENSIONS

Wherever dimensions or levels are not shown on the Drawings, instructions shall be obtained from the Engineer.

1-B-44 BENCHMARKS

Benchmarks in the area of the work shown on the drawings shall be established by the Contractor.

The Contractor shall be responsible for preserving these benchmarks and re-establishing them in case they are destroyed.

The Contractor shall establish at his own expense temporary benchmarks he might need for the execution of the work.

1-B-45 SIGN BOARDS AND SAFETY BARRIERS

The Contractor shall provide two site sign boards in a form and to the specification specified and erect and mount on suitable temporary supports, in positions and at heights as required by the Engineer.

The Contractor shall maintain, alter, move and adapt the sign boards from time to time as instructed by the Engineer. The display of any named Subcontractors or any other information associated with the Works shall be to the approval of the Engineer.

The Contractor shall provide safety barriers to protect the public, in a form and to the specification specified. The safety barriers shall be erected each side of all open trench and other excavations and at such other locations as required by the Engineer.

Sign boards and safety barriers will not be paid for directly but shall be deemed to be included in the rates of other items of the project.

1-B-46 FLAGGING, LIGHTING, WATCHING AND TRAFFIC CONTROL

Where necessary for the safety of the public or where required by the Engineer or his Representative the whole of the Works shall be properly fenced, signed and lighted from half an hour before sunset until half-an-hour after sunrise and at other times when visibility is poor. On all occasions the Works shall be properly flagged. The lamps shall be approved by the appropriate Authority and shall be kept in a clean and proper condition. The position and number of the lamps shall be such that the extent and position of the works is clearly defined and the arrangement shall comply with the requirements of the appropriate Authority. Each site of the Works shall be provided with night and week-end watchmen as may be required.

1-B-47 TEMPORARY WORKS

The Contractor shall be responsible for designing and constructing any temporary works he requires to undertake the construction of the project. These works shall be to the approval of the Engineer. At Contract completion, the Contractor shall be responsible for removing all temporary works and reinstating the site unless the Employer wishes to purchase some of those works at a mutually agreed price and thereby give them the status of permanent works.

1-B-48 CLEANING THE SITE

During the execution of the work, the Contractor shall keep the site clean by removing and carting away to approved dumping sites all rubbish, debris, wastes, etc.

Upon completion of the work and before acceptance and final payment will be made, the Contractor shall clean the Site and property defaced or occupied by him. He shall clear in connection with the Work all rubbish, excess materials, debris, false work, temporary structure and equipment.

All parts of all types of the Work shall be left in a neat and presentable condition and as approved by the Engineer.

1-B-49 CONTRACTOR'S YARDS, STORES AND ACCOMMODATION FOR WORKMEN

The Contractor shall make his own arrangements for all land, yards, stores, workshops, offices etc. and for all services in connection therewith.

The location of all yards, stores, workshops, offices, etc. shall be agreed beforehand with the Engineer and shall be such as to avoid obstruction and nuisance to the public.

The Contractor shall construct on the Site, or at suitable locations, secure storage compounds and storage buildings where he shall store at his own risk all equipment and plant delivered to Site and awaiting erection. The compound shall be of sufficient size to accept all such plant delivered and awaiting erection.

Storage buildings shall be weatherproof and shall be of sufficient size to accommodate all items requiring covered storage.

The storage compounds and buildings shall be completed prior to delivery of any items of plant and equipment.

The Contractor shall provide and maintain suitable and sufficient shelters and mess rooms for his workmen and supervisory staff as are customary and necessary.

The Contractor shall provide sufficient closets or latrines to the satisfaction of the relevant authority. They shall be properly screened and maintained in a clean and sanitary state at all times.

The mess rooms, closets and latrines shall be located in positions to be approved by the Engineer. The Contractor shall be responsible for making all arrangements for the proper disposal of waste from mess rooms, closets and latrines

Materials shall be so stored as to assure the preservation of their quality and fitness for the work. Stored materials, even though approved before storage, may again be inspected prior to their use in the work. Stored materials shall be located so as to facilitate their prompt inspection. Any costs for the use of privately-owned land for storage and/or for the placing of the contractors plant and equipment shall be borne by the contractor. Private property shall not be used for storage purposes without written permission and release of the owner or lessee, and a copy of such written permission and release shall be furnished to the Engineer prior to any use of the land by the contractor.

1-B-50 DUMPING SITES

The Contractor shall remove and cart away all rubbish, excess materials, debris, etc. to dumping sites approved by the Engineer. It shall be the Contractor's sole responsibility to establish the locations of these sites and get the necessary approvals from concerned authorities for using them.

Dumped material shall be spread over the whole area of the dumping site in layers not exceeding 80 cms. In case a dumping site is abandoned, the Contractor shall grade the area in an acceptable manner and to the satisfaction of the Engineer.

1-B-51 DISMANTLED ITEMS

All items dismantled by the Contractor shall be considered the property of the Employer, and they shall be disposed of as instructed by the Engineer.

Part II: Pipelines

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PART 2 - PIPELINES

2-A GENERAL REQUIREMENTS

2-A-1 INSTALLATION OF PIPES

2-A-1-1 General

Excavation of any part of the project is not allowed until a full supply of pipes and fittings are available on site.

Before using pipes, special parts and apparatuses should be installed on site and thoroughly cleaned and cleared out from any undesirable element.

During pipe laying, all precautions shall be taken to avoid ingress inside the pipe of any foreign material, dirt or soil.

Pipes are lowered down in the trench with adequate equipment and shall be placed in the right position for the jointing purposes.

Pipes and special pieces and apparatus shall be brought down in the trench carefully avoiding any sudden shocks or falls, etc.

Placing and installing the pipes shall be performed by experienced laborers.

During the course of the work(s) executed within the water table it is necessary to keep the trench bottom dry during the placing of gravel or sand pipe bedding.

Temporary wedges shall be placed to get the proper alignment and at the change of direction. These wedges shall be made of compacted earth heaps or wood pieces. Using stone wedges will not be allowed. However, concrete pipes shall be laid on a temporary basis made from solid materials (exicalibrated stones).

Pipe ends shall be temporarily closed with wooden, plastic flanges or with special pieces during the stopping of the works.

2-A-1-2 Excavation For Pipe Trench

See PART III-1- EARTHWORK.

2-A-1-3 Pipe Installation In Trench

- All pipes and fittings are to be present on site and ready for installation by well trained and professional crew.
- Examine and clean all pipes and fittings before installation. Damaged items are to be removed immediately from site for repair or disposal.
- In case of pipe cutting, use slitting disc type cutter or an air operated saw for larger pipes. After cutting and before assembly, it is essential to fillet or chamfer the edge of the cut with file. Finally restore the protective coating on the pipe areas affected by the cutting operations if applicable.

- Install pipes to the invert / crown level indicated on the longitudinal profile using proper survey tools.
- Pipes shall not be dragged along the trench bottom.
- Ensure inner and outer coatings are not damaged and pipe is clean.
- Examine the pipe visually against any break of hair cracks, bends, bumps or deflection along pipe length.
- Use proper ropes and protected hooks when handling pipes.
- Use pieces of soft wood when leveling the pipes in the trench. Do not use stones, bricks, etc… this may damage the coating.
- Install joints as specified on the drawings and where needed and as directed by the Engineer.
- Do not leave ends of pipes opened if installations stopped. Use tight lids supplied by manufacture.
- Whenever part or section of pipes, not exceeding 500 meters, is installed in the trench. Submit a written request for pressure testing before backfilling and compacting the pipe trenches.
- Each portion of pipeline shall be a full pipe span, as much as possible in order to reduce to the minimum pipe joints.
- Pipes and fittings laid in trench shall have at least the minimum cover stated on the Drawings.
- Long radius curves in buried pipelines shall be negotiated by deflections taken up in one or more pipes. The deflection in pipeline shall not exceed the specified limits.
- Pipes shall be laid with a minimum gradient of 1 in 500.

2-A-1-4 Backfilling Pipe Trenches

See PART III-1- EARTHWORK

2-A-2 CUTTING PIPES

2-A-2-1 General

Before cutting the pipe, it is essential to measure the external diameter at the cutting point with a circumference tape or compass calipers, to check that it is compatible with the intended coupling joint dimensions.

Use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. Prepare ends according to the type of joint used and follow manufacturer's recommendations. Take care not to damage lining of other type pipes associated with main pipes. Repair on site, minor damage, if permitted.

After making the cut, and before assembly, it is essential to fettle / chamfer the edges of the cut with a file.

2-A-2-2 Ductile Iron Pipes

Ductile iron pipes shall only be cut with an approved mechanical pipe cutter in conformity with the pipe manufacturer's recommendations. The use of an oxyacetylene flame cutter will not be permitted. The edges of the cut together with those parts of the pipes from which the coating has been removed shall be given two coats of bituminous paint and the internal lining repaired. When the cut pipe is to be inserted in a “Tyton” type joint it shall be beveled for 10mm at 30° to pipe the axis.

2-A-2-3 Polyethylene

Pipes shall be cut with an approved mechanical pipe cutter and in conformity with pipe manufacturer's recommendations. Where the cut end of the pipe is to be incorporated in a joint the pipe shall be turned down to the correct diameter required for forming the joint by an approved mechanical turning machine. The length of turning shall be sufficient to enable the joint to be properly made the ends of the pipe shall be accurately beveled by mechanical means to the dimensions specified in the manufacturers recommendations.

2-A-3 CONCRETE SURROUNDING PIPES

2-A-3-1 General

All concrete works shall comply with the appropriate requirements of PART III-2- CONCRETE AND MASONRY.

Concrete surround shall be broken at all pipe joints to retain flexibility in the pipeline in case of shallow pipes, except for pipes crossing under watercourse, the concrete surrounding shall be continuous and rigid.

When pipes intersect with other utilities, the pipe shall be surrounded with concrete, the joints at such crossing shall be ridged.

All concrete encasements shall not be executed without the prior approval of the Engineer.

2-A-3-2 Materials

Concrete bedding: cast in situ CLASS “C”.

Concrete encasement with reinforcement: cast in situ CLASS “B”.

2-A-3-3 Placing Concrete

After placing pipe, place concrete in trench and thoroughly work under the pipe to provide solid and uniform bedding.

Place the balance of concrete on both sides of the pipe simultaneously.

Introduce vertical construction joints in concrete beds, surroundings etc. at the face of pipe joint with compressible board and finish to profile of concrete and pipe. Fill any gap left in concrete with approved resilient material.

2-A-4 RESTORATION OF SURFACE

1- General: Proceed with surface restoration as soon as other practicable works is completed, but in no case more than 10 days after backfilling of the trench and other excavated areas and complete within a further 20 days.

2- Restoration of asphalt, concrete and/or gravel pavements are to be brought back to its original thickness and materials to match the existing pavement. Material and workmanship are to be in according to the local municipality requirements or as directed by the Engineer.

3- Restoration of pavement: Repave to match existing pavements in quality, shape, size and level to a uniform surface finish with existing surface.

4- Restoration of grassed areas: After backfilling is compacted and brought to the bottom of the previous top soil level, spread approved fertilized soil over affected area and seed, Continue fertilizing and watering until grass is restored to its former condition.

5- Restoration of unsurfaced area: Bring backfill to natural ground level, well compacted and distributed evenly.

2-BDUCTILE IRON PIPES & FITTINGS

All ductile iron pipes and fittings to be supplied under this Specification shall be obtained from an approved manufacturer having an ISO9001-2000 TOTAL QUALITY ASSURANCE system.

Nominal sizes, pressure classes, thicknesses, lengths and coating should comply with the latest version of the ISO9001 / EN545 standards.

The maximum allowable pressures values of PFA, PMA and PEA for components, as defined in EN545 /ISO2531 standards, PMA = 1,2 x PFA , PEA = PMA + 5 bar.

Ductile iron pipeline systems, including pipes, fittings, accessories and joints,. When used for conveying drinking water, the materials in contact with the water shall meet the relevant requirements of the European standards or regulations with respect to effect on water quality or other equivalent international standards or regulations.

2-B-1 Socket And Spigot Pipes

Ductile iron socket and spigot pipes shall be centrifugally cast in accordance with the Standards EN 545/ ISO2531

Works Hydrostatic Test:

Pipes and fittings shall be tested in compliance with requested standards. The test shall be carried out on all pipes and fittings before the application of their external and internal coatings, except for the metallic zinc coating of pipes which may be applied before the test.

The internal hydrostatic pressure for the Centrifugally cast pipes shall be raised steadily until it reaches the works hydrostatic test pressure equal to the pressure class up to Class 50 and limited to 50 bar for classes above Class 50, which is maintained for a sufficient time to allow visual inspection of the pipe barrel.

Allowable Pressures:

The maximum values of PFA, PMA and PEA for components, as defined in EN545 /ISO2531 standards

PMA = 1,2 x PFA , PEA = PMA + 5 bar.

Preferred Pressure Classes and dimensions for socket spigot pipes as per following Table:

DN mm	DE[a] mm	Pressure class	Nominal iron wall thickness e_{nom} mm
40	56	C40	4,4
50	66	C40	4,4
60	77	C40	4,4
65	82	C40	4,4
80	98	C40	4,4
100	118	C40	4,4
125	144	C40	4,5
150	170	C40	4,5
200	222	C40	4,7
250	274	C40	5,5
300	326	C40	6,2
350	378	C30	6,3[b]
400	429	C30	6,5[b]
450	480	C30	6,9
500	532	C30	7,5
600	635	C30	8,7
700	738	C25	8,8[b]
800	842	C25	9,6
900	945	C25	10,6
1000	1048	C25	11,6
1100	1152	C25	12,6
1200	1255	C25	13,6
1400	1462	C25	15,7
1500	1565	C25	16,7
1600	1668	C25	17,7
1800	1875	C25	19,7
2000	2082	C25	21,8
2200	2288	C25	23,8
2400	2495	C25	25,8
2600	2702	C25	27,9

a- A tolerance of +1 mm applies.

b- Thicknesses are greater than calculated for “smoothing” between C40 and C30 and also between C30 and C25.

2-B-2 Flanged Pipes

Ductile iron flanged pipes shall be manufactured in accordance with the European Standard EN 545/ ISO2531. Drilling of flanged joint ISO PN10/ PN 16 / PN 25 /PN40 shall comply with International Standard ISO 7005-2.

The pressure class of the barrel of flanged pipes shall be equal to or greater than a value in bar equal to the PN of the flanges, allowable pressures are shown in Fittings Clause

2-B-3 Fittings

The ductile iron fittings shall be sand cast in accordance with the latest version European Standard EN 545 / ISO2531

Type of Joints and interconnections:

- Flexible Joint ,STANDARD push in joint where fittings are used with Socket and Spigot pipes. Elastomeric gasket materials shall comply with the requirements of EN 681-1, type WA
- The maximum values of allowable pressure PFA, PMA and PEA, for fittings with thicknesses as specified in EN 545 / ISO 2531
- SELF-ANCHORED push in joint where fittings are used with Socket and Spigot pipes and where there is a need to take up the axial forces. Restrained joints for ductile iron pipelines shall be designed in accordance with ISO 10804
- FLANGED joint where fittings are used with flanged pipes. dimensions and tolerances should comply with EN 1092-2

At the manufacturer's option, fittings shall be submitted to a hydrostatic pressure test or to an air test.

Min water test pressure for fittings should comply with EN545 / ISO2531 requirements.

The maximum allowable pressure values for PFA, PMA and PEA are given for flanged fittings and pipes in the following Table:

DN	PN 10			PN 16			PN 25			PN 40		
	PFA	PMA	PEA	PFA	PMA	PEA	PFA	PMA	PEA	PFA	PMA	PEA
40 to 50	See PN 40			See PN 40			See PN 40			40	48	53
60 to 80	See PN 16			16	20	25	See PN 40			40	48	53
100 to 150	See PN 16			16	20	25	25	30	35	40	48	53
200 to 600	10	12	17	16	20	25	25	30	35	40	48	53
700 to 1200	10	12	17	16	20	25	25	30	35	-	-	-
1400 to 2000	10	12	17	16	20	25	25	30	35	-	-	-

All accessories shall be legibly and durably marked and shall bear at least the following information:

- manufacturer's name or mark;
- identification of the year of manufacture;
- DN; PN rating of flanges for flange components;
- reference to this European Standard, i.e. EN 545;

2-B-4 Laying And Jointing

2-B-4-1 Laying

Before Ductile Iron is 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 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 use of tight bulkheads.

2-B-4-2 Jointing

Joints of Ductile Iron Pipes and Fittings shall be of the Push in automatic standard type and where there is a need to take up the axial forces, necessary Self Anchored push in joint shall be used which allows concrete anchor blocks to be dispensed with. Flanged jointing shall be used for pipes inside reservoirs and valve chambers

2-B-4-3 Lubricant Paste

The lubricant paste shall be a mixing of Vaseline, non toxic , non soluble in accordance with French standard AFNOR T90 M DOC8 or similar . The quantities used in the assembly joints shall be as per manufacturer recommendation. It shall be supplied by the Pipes and fittings manufacturer.

2-B-5 Connecting Pieces

All connecting pieces i.e. flexible coupling, flange adaptors, dismantling joint shall be made of ductile iron.

2-B-6 Linings And Coatings

Except for specific lining or coating dictated by aggressive water or particular environment, lining and coating of pipes & fittings should meet the following requirements.

2-B-6-1 *Pipes Internal Protection (Including Welded Flanged Pipes)*

Pipes shall be internally lined with sulphate resisting blast furnace slag cement applied by a centrifugal process. The cement mortar lining shall be in accordance with the International Standard ISO 4179, the compressive strength of the cement mortar after 28 days of curing shall be not less than 50 MPa.

The thickness is given in following table:

	Thickness of mortar	
	Nominal mean Value Mm	Tolerance Mm
80 – 300	4	- 1.5
350 – 600	5	-2
700 – 1200	6	-2.5
1400 – 2000	9	-3

2-B-6-2 *Pipes External Protection (Including Welded Flanged Pipes)*

Pipes shall be externally coated with:

A layer of metallic zinc coating in accordance with the International Standard ISO 8179. The mean mass of zinc per unit area shall be not less than 200g/m2. The purity of the zinc used shall be at least 99,99 %.

The zinc is normally applied on oxide-surfaced pipes after heat treatment; a layer of bituminous varnish or synthetic resin to be applied over the zinc coating in accordance with the International Standard ISO 8179 Part 1, the mean thickness of the finishing layer shall be not less than 70 μm and the local minimum thickness not less than 50 μm.

2-B-6-3 *Fittings Internal And External Protection*

The fittings shall be internally and externally protected with a paint coating blue epoxy cataphoresis in conformity with EN 14901 with mean thickness not less than 70 μm.

2-B-6-4 *Connecting Pieces Internal And External Protection*

The connecting pieces (Flexible couplings, Flange adaptors, Dismantling joint) shall be internally and externally protected with a powder Epoxy coating having a minimum thickness of 150 microns or with a rilsan nylon coating having a minimum thickness of 200 microns. The type of the coating depends of the diameter and the type of the connecting pieces.

2-B-6-5 Transport Loading Unloading

Handling and stacking as per manufacturer recommendation so as not to damage concrete lining or develop additional ovality, the ovality of the spigot end of pipes and fittings shall remain within the tolerances of DE for DN 40 to 200, and not exceed 1 % of DE for DN 250 to DN 600 or 2 % for DN > DN 600.

The manufacturer's recommendations should be followed with respect to the necessity and means of ovality correction

2-B-6-6 Tests On Received Consignments

In addition to the standard pre-shipment compliance certificate, Tensile test shall be carried out according to EN ISO 6892-1 on samples cut from the spigot of the pipe, Tests should be witnessed by the Employer representative (if required by the Employer) and by a Bureau of Control or similar third party approved by consultant in country of manufacturing.

Results should meet with EN545 / ISO2531 requirements in terms of minimum tensile strength and minimum elongation at rupture:

Type of casting	Minimum tensile strength, R_m MPa	Minimum elongation after fracture, A %	
	DN 40 to DN 2000	DN 40 to DN 1000	DN 1100 to DN 2000
Pipes centrifugally cast	420	10	7
Pipes not centrifugally cast, fittings and accessories	420	5	5
The 0.2 % proof stress ($R_{p\,0.2}$) may be measured. It shall be not less than: - 270 MPa when A ≥ 12 % for DN 40 to DN 1000 or A ≥ 10 % for DN > 1000; - 300 MPa in other cases. For centrifugally cast pipes of DN 40 to DN 1000 and having a design minimum wall thickness of 10 mm or greater, the minimum elongation after fracture shall be 7 %.			

2-B-7 Hydrostatic Pressure Testing

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 24 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:

1) Test pressure shall be equal to (1.5 x Rated Working Pressure) for rated working pressure equal to or less than 10 kg/cm^2 ,

2) Test pressure shall be equal to (Rated Working Pressure + 5 kg/cm^2.) for rated working pressures exceeding 10 kg/cm^2 .

For lift pipelines:

Test pressure shall be equal to Rated working pressure plus calculated water hammer surge plus 2 kg/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 30 minutes. For the line to be accepted, the pressure shall not drop by more than 0.2 kg/cm^2 during the said 30 minutes 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.

2-C POLYETHYLENE PIPES

2-C-1 GENERAL TERMS AND CONDITIONS

2-C-1-1 Scope

This specification covers requirements for polyethylene piping system (pipe and fittings) for the supply of water under pressure intended for human consumption both above ground and in buried pipe applications.

2-C-1-2 Engineered And Approved Plans

Construction shall be performed in accordance with engineered construction plans for the work prepared under the direction of a Professional Engineer.

2-C-1-3 Referenced Standards

The most recent ISO standards or European Norms EN12201 / EN12202 or DIN 8074 / 8075 shall apply.

2-C-1-4 Inspections

All work shall be inspected by an Authorized Representative of the Owner who shall have the authority to halt construction if, in his opinion, these specifications or standard construction practices are not being followed. Whenever any portion of these specifications is violated, the Project Engineer or his Authorized Representative shall, by written notice, order further construction to cease until all deficiencies are corrected. A copy of the order shall be filed with the Contractor’s license application for future review. If the deficiencies are not corrected, performance shall be required of the Contractor’s surety.

2-C-1-5 Warranty And Acceptances

The Contractor shall warrant all work to be free from defects in workmanship and materials for a period of [one year] from the date of completion of all construction. If work meets these specifications, a letter of acceptance, subject to the [one year] warranty period, shall be given at the time of Completion. A final acceptance letter shall be given upon final inspection at the end of the [one year] warranty period, provided the work still complies with these specifications. In the event deficiencies are discovered during the warranty period, they shall be corrected b the Contractor without additional charge to the owner before final acceptance. During the warranty period, the Project Engineer shall determine if warranty repairs or replacement work shall be performed by the Contractor. The decision of the Project Engineer shall be binding upon the Contractor.

2-C-1-6 *Qualification Of Manufacturers*

The Manufacturer shall have manufacturing and quality control facilities capable of producing and assuring the quality of the pipe and fittings required by these specifications. The manufacturer's production facilities shall be open for inspection by the Owner or his Authorized representative. Qualified Manufacturers shall be approved by the Project Engineer.

2-C-1-7 *Approved Manufacturers*

Manufacturers must be pre-qualified and pre-approved by the Project Engineer. Products from unapproved manufacturers are prohibited.

2-C-2 POLYETHYLENE PIPES / FITTINGS

2-C-2-1 *Raw Materials*

The polyethylene compounds used in the manufacture of products furnished under this specification shall be made from compounded pellets obtained by the addition of the correct type and amount of *carbon black* and necessary antioxidants and other additives to protect the pipe during extrusion and assure the life expectancy of the pipe. *Pipe produced by the addition of black masterbatch to polyethylene is strictly forbidden*. The compound material shall comply with the requirements as specified in EN 12201-Part 1.

Typical material properties as described by the Raw Material Supplier brochure shall be submitted to the project engineer for analysis and verification of compliance. These properties are not to be misconstrued as specification minimums.

All Raw Material used shall be approved and certified *Pipe Grade Material* for the transportation of potable water.

2-C-2-2 *Polyethylene Pipe*

2-C-2-2-1 *Pipe Coil*

Pipes with OD up to 110 mm shall be supplied in coils where the inside diameter of the coil is 30 times OD. Pressure pipes with OD of 140mm and above shall be supplied in straight lengths. When needed special pipe length can be supplied with the approval between purchaser and manufacturer.

2-C-2-2-2 *Marking of Pipe*

All pipes shall bear permanent identification markings that will remain legible during normal handling, storage, installation, and service life and that have been 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.

Marking on pipe shall include the following and shall be applied at intervals of not more than 1.5 meters:

1) Normal size (i.e. 90mm)
2) Standard PE designation (i.e. PE-HD PE 100)
3) The Standard Dimension Ratio (i.e. SDR 11)
4) Marking the product with the applicable standards designation (EN 12201).
5) Production date
6) Nominal pressure rating of pipe (i.e. PN10)
7) Manufacturer’s Name
8) Country of production

2-C-2-2-3 Service Identification Stripes

PE Pipes shall be permanently color-coded with stripes for instant identification as potable water service pipes. 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***.

2-C-3 MANUFACTURER’S QUALITY CONTROL

The pipe manufacturer shall have an established quality control program responsible for inspecting incoming and outgoing materials. Incoming PE materials shall be inspected for density, melt flow rate, and contamination. The cell classification properties of the material shall be certified by the supplier, and verified by Manufacturer’s Quality Control. Incoming materials shall be approved by Quality Control before processing into finished goods. Outgoing materials shall be checked for:

a) Outside diameter and wall thickness as per EN 12201-Part 2 at a frequency of at last once/hour or once/coil, whichever is less frequent.
b) Out of Roundness at a frequency of at least once/hour or once/coil whichever is less frequent.
c) Quality Control shall verify production checks and test for:
d) Melting Index as per ISO 1133 at a frequency of at least once per extrusion lot.
e) Hydrostatic Strength testing (up to Ø110mm) as per EN 921 at a frequency of at least once per day per line.
f) All fabricated fittings shall be inspected for joint quality and alignment.

2-C-3-1 Permanent Records

The Manufacturer shall maintain permanent QC and QA records.

2-C-3-2 Compliance Tests

Manufacturer's inspection and testing of the materials. In case of conflict with Manufacturer's certifications, the Contractor, Project Engineer, or Owner may request retesting be the Manufacturer or have retests performed by an outside testing service. All retesting shall be at the Contractor's expense, and shall be performed in accordance with the Specifications.

2-C-4 CHARACTERISTICS

2-C-4-1 External Aspect Of Pipes

Pipe surface shall be smooth, free from scoring, pinholes, and other surface defects. Pipe ends must be cut clean and perpendicular to the axis of the pipe. End caps at pipe extremities are required in order to prevent unwanted matter entering the pipe during storage.

2-C-4-2 Engineering Characteristics

The limitation on the outside diameter and ovality shall confirm to PR-EN 12202-2 as follows:

Ovality	OD Max	OD Min	OD
1.2	16.3	16.0	16
1.2	20.3	20.0	20
1.2	25.3	25.0	25
1.3	32.3	32.0	32
1.4	40.4	40.0	40
1.4	50.4	50.0	50
1.5	63.4	63.0	63
1.6	75.5	75.0	75
1.8	90.6	90.0	90
2.2	110.6	110.0	110

The pipes thickness shall depends to the properties used in manufacturing and shall conform to PR-EN 12202-2 and nominal pressures of PN10, PN12.5 and PN16bars for PE80 material and PN10, PN12.5, PN16 bars and PN20 for PE100 material.

STANDARD: PR-EN 12201 - 2/TC 155									
PE 80 MATERIAL									
	PN 10			PN 12.5			PN 16		
	SDR 13.6 S-6.3			SDR 11 S-5			SDR 9 S-4		
OD	E min.	E max.	ID (*)	e min.	e max.	ID (*)	e min.	e max.	ID (*)
Mm	Mm	mm	mm	mm	mm	mm	mm	mm	mm
16	-	-	-	-	-	-	2.0	2.3	11.7
20	-	-	-	2.0	2.3	15.7	2.3	2.7	15.0
25	2.0	2.3	20.7	2.3	2.7	20.0	3.0	3.4	18.6
32	2.4	2.8	26.8	3.0	3.4	25.6	3.6	4.1	24.3
40	3.0	3.5	33.5	3.7	4.2	32.1	4.5	5.1	30.4
50	3.7	4.2	42.1	4.6	5.2	40.2	5.6	6.3	38.1
63	4.7	5.3	53.0	5.8	6.5	50.7	7.1	8.0	47.9
75	5.5	6.2	63.3	6.8	7.6	60.6	8.4	9.4	57.2
90	6.6	7.4	76.0	8.2	9.2	72.6	10.1	11.3	68.6
110	8.1	9.1	92.8	10.0	11.1	88.9	12.3	13.7	84.0
125	9.2	10.3	105.5	11.4	12.7	100.9	14.0	15.6	95.4
140	10.3	11.5	118.2	12.7	14.1	113.2	15.7	17.4	106.9
160	11.8	13.1	135.1	14.6	16.2	129.2	17.9	19.8	122.3
180	13.3	14.8	151.9	16.4	18.2	145.4	20.1	22.3	137.6
200	14.7	16.3	169.0	18.2	20.2	161.6	22.4	24.8	152.8
225	16.6	18.4	190.0	20.5	22.7	181.8	25.1	27.8	172.1
250	18.4	20.4	211.2	22.7	25.1	202.2	27.9	30.8	191.3
OD = Outside Diameter ID (*) = Average Inside Diameter e = Wall Thickness PN = Nominal Pressure Ratings in Bar									

STANDARD: PR - EN 12201 - 2/TC 155												
PE 100 MATERIAL												
	PN 10			PN 12.5			PN 16			PN 20		
	SDR 17 S-8			SDR 13.5 S-6.3			SDR 11 S-5			SDR 9 S-4		
OD	e min.	e max.	ID(*)	e min.	e max.	ID(*)	e min.	e max.	ID(*)	e min.	e max.	ID(*)
mm	Mm	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
16										2.0	2.3	11.7
20							2.0	2.3	15.7	2.3	2.7	15.0
25				2.0	2.3	15.7	2.3	2.7	20.0	3.0	3.4	18.6
32	2.0	2.3	27.7	2.4	2.8	20.0	3.0	3.4	25.6	3.6	4.1	24.3
40	2.4	2.8	34.9	3.0	3.5	25.6	3.7	4.3	32.1	4.5	5.1	30.4
50	3.0	3.4	43.8	3.7	4.2	32.1	4.6	5.2	40.2	5.6	6.3	38.1
63	3.8	4.3	55.3	4.7	5.3	40.2	5.8	6.5	50.7	7.1	8.0	47.9
75	4.5	5.1	65.7	5.6	6.3	50.7	6.8	7.6	60.6	8.4	9.4	57.2
90	5.4	6.1	78.8	6.7	7.5	60.6	8.2	9.2	72.6	10.1	11.3	68.6
110	6.6	7.4	96.4	8.1	9.1	72.6	10.0	11.1	88.8	12.3	13.7	84.0
125	7.4	8.3	108.6	9.2	10.3	88.9	11.4	12.7	100.9	14.0	15.6	95.4
140	8.3	9.3	122.8	10.3	11.5	100.9	12.7	14.1	113.2	15.7	17.4	106.9
160	9.5	10.6	140.4	11.8	13.1	113.2	14.6	16.2	129.2	17.9	19.8	122.3
180	10.7	11.9	157.4	13.3	14.8	129.2	16.4	18.2	145.4	20.1	22.3	137.6
200	11.9	13.2	174.9	14.7	16.3	145.4	18.2	20.2	161.6	22.4	24.8	152.8
225	13.4	14.9	196.7	16.6	18.4	161.6	20.5	22.7	181.8	25.2	27.9	171.9
250	14.8	16.4	218.8	18.4	20.4	181.8	22.7	25.1	202.2	27.9	30.8	191.3
OD = Outside Diameter ID (*) = Average Inside Diameter e = Wall Thickness PN = Nominal Pressure Ratings in Bar												

2-C-4-3 *Mechanical Characteristics*

All manufactured pipes shall pass the stress test conforming to the requirements of PR-EN 12202-2 using test method of EN 921/ISO 1167. Stress test shall be the deciding factor in accepting or refusing the pipe.

Produced pipes shall pass the internal pressure test (acceptance test) using test method per EN 921.

PE class	Reqts	Stress	Temp.
PE 100	>100hrs	12.4MPa	20 °C
PE 80	>100hrs	10.0MPa	20 °C

Note: The Contractor must give the Engineer a report specifying that the pipes he will install fits with the specifications described.

2-C-4-4 *Effect of temperature on working pressure of PE Pipe*

Nominal pressure of PE pipes is the service pressure at 20°C with a service life of 50 years. For the use of Polyethylene pipes at higher temperature (up to a maximum of 60°C) the maximum working pressure according to the following table, should be reduced as shown on the following chart. These values are based on a pipe life time of 50 years.

Permissible Working Pressures For Pipes Transporting Water

Temperature in °C	Years of service	1	2	3	4	5	6
		Pressure rating					
		PN 2.5	PN 3.2	PN 1	PN 6	PN 10	PN 16
		Permissible working pressure					
10	1	3.4	4.3	5.4	8	13.4	21.4
	5	3.2	4.1	5.1	7.7	12.8	20.5
	10	3.2	4	5	7.6	12.6	20.2
	25	3.1	3.9	4.9	7.3	12.2	19.5
	50	3	3.8	4.8	7.2	12	19.2
20	1	2.9	3.8	4.8	6.8	11.4	18.2
	5	2.7	3.5	4.3	6.6	10.8	17.3
	10	2.7	3.4	4.2	6.4	10.8	17
	25	2.6	3.3	4.2	6.2	10.4	16.6
	50	2.5	3.2	4	6	10	16
30	1	2.5	3.1	3.9	5.9	9.8	15.7
	5	2.4	3	3.8	5.6	9.4	15
	10	2.3	2.9	3.7	5.5	9.2	14.7
	25	2	2.5	3.1	4.7	7.8	12.5
	50	1.7	2.2	2.7	4.1	6.8	10.9
40	1	2.1	2.7	3.4	5	8	13.4
	5	1.8	2.3	2.9	4.3	7.2	11.5
	10	1.8	2	2.5	3.7	6.2	9.9
	25	1.8	1.7	2.1	3.1	5.2	8.3
	50	1.2	1.5	1.8	2.8	4.6	7.4
	1	1.7	2.2	2.7	4.1	6.8	10.9
	5	1.2	1.5	1.9	2.9	4.8	7.7
50	10	1.1	1.3	1.7	2.5	4.2	6.7
	15	1	1.3	1.8	2.4	4	6.4
60	1	1.2	1.5	1.0	2.9	4.8	7.7
	5	-	1.1	1.4	2	3.4	5.4

Note: These working pressures do not apply for pipes exposed to UV radiation. The effect of such radiation can be eliminated or considerably reduced for up to ten years of service by the inclusion of suitable additives in the molding material.

2-C-5 PIPE CONNECTIONS

There are seven acceptable methods of joining polyethylene pipe with each other and with other pieces such as valves, flanges, etc.

1- Plastic Compression connection
2- Metal (ductile Iron) Compression connection
3- Electrofusion Fittings
4- Flange connection
5- Fabricated Fittings
6- Butt Fusion Welding
7- Special tapping fittings

2-C-5-1 Plastic Compression Fittings for PE Pipes

This type uses mechanical anchoring that holds the pipe in place (clamp ring usually made of Acetalic resin or C-PVC)and a sealing gasket (EPDM or Rubber/food approved) to create a tight grip and prevent water from leaking. Pipes must be pushed inside the fitting without the necessity to disassemble the fittings. The following pipe OD to PN must apply:

- Pipes up to OD = 63mm with pressure rating maximum PN16
- Pipes OD = 75mm up to 110mm maximum PN10. For PN16 applications metal compression fittings or electrofusion fittings should be used.
- Pipes OD >110mm plastic compression fittings are not used. Metal compression fittings or electrofusion fittings should be used.

All fittings must pass the testing requirements of ISO 3458/3459/3501/3503.

2-C-5-2 Metal (ductile iron) Compression Fittings for PE Pipes

When joining polyethylene pipe or for joining polyethylene pipe to another material with metal couplings, those couplings shall be fully pressure rated and fully thrust restrained such that when installed in accordance with manufacturer's recommendations, a longitudinal load applied to the mechanical coupling will cause the pipe to yield before the mechanical coupling disjoins. External joint restraints shall not be used in lieu of fully restrained mechanical couplings. Nominal pressure rating of fittings shall be 16 bar.

Materials used in the manufacturing of steel compression fittings shall conform to the following:

- Body : GGG 400 - DIN 1693 (epoxy coated, see below for detailed reqts)
- Lip Seal : EPDM
- Grip Ring : Ms 58 (dezincification resistant brass)
- Bolts : A2 (stainless Steel)
- All steel compression fittings must be epoxy coated.

2-C-5-3 *Electrofusion Fittings for PE Pipes*

Electrofusion 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. Nominal pressure rating of fittings shall be 16 bar.

This type of fittings incorporates electrical heating coil that fuses pipe and fitting by sending an electrical current that heats up the polyethylene material of pipe and fitting at a specific voltage for a specified temperature and duration of time after which pipe and fitting fuse together and become integrated on the molecular level. Manufacturer recommendations for the electrofusion operation must be strictly followed.

Electrofusion machines used in the electrofusion process must be supplied by the same manufacturer of fittings. It strictly forbidden to fuse one manufacturer fitting with another manufacturer machine. Installers of Electrofusion fittings must strictly adhere to both fittings and equipment manufacturer's recommended procedures.

2-C-5-4 *Flanged Connections*

Flange connections shall be installed in accordance with the Manufacturer's recommended procedure. Flange faces shall be centered and aligned to each other before assembling and tightening bolts. In no case shall the flange bolts be used to draw the flanges into alignment. Bolt threads shall be lubricated, and flat washers shall be fitted under the flange nuts. Bolts shall be evenly tightened according to the tightening pattern and torque step recommendations of the Manufacturer at least 1 hour after initial assemble, flange connections shall be re-tightened following the tightening pattern and torque step recommendations of the Manufacturer. Nominal pressure rating of fittings shall be 16 bar.

Flanged connections shall consist of the following parts/fittings :

- Coupler (Electrofusion)
- Flanged Adaptor

The coupler for jointing plain-end polyethylene (PE) pipe to PE flanged items shall be of the electrofusion type that heats up the PE material of the pipe to the PE material of flanged fitting. Pressure rating of the coupler shall be no less than 16 bar and made of the same PE resin, class and series as the pipe.

The flanged adaptors for jointing plain-end pipe to flanged items shall be of the socket fusion type and made of polyethylene (PE) material of the same class and series as the pipe. Pressure rating of the flanged adaptor shall be no less than 16 bar.

2-C-5-5 *Fabricated Fittings*

Fabricated fittings shall be made by heat fusion joining specially machined shapes cut from pipe, polyethylene sheet stock, or molded fittings. Fabricated fittings shall be rated for internal pressure service equivalent to the full service pressure rating of the mating pipe. Directional fittings such as elbows, tees, crosses, etc., shall have a plain end inlet for butt fusion and flanged directional outlets. Part drawings shall be submitted for the approval of the Project Engineer.

2-C-5-6 *Butt Fusion Welding*

For pipes with diameters larger than 75mm, joints between end of the pipes and fittings may be made by butt fusion, and joints between the main and saddle branch fittings shall be made using saddle fusion using only procedures that are recommended by the pipe and fitting Manufacturer. The Contractor shall ensure that persons making heat fusion joints have received training according to the Manufacture's recommended procedure. The Contractor shall maintain records of trained personnel, and shall certify that training was received not more than 12 months before commencing construction.

Heat Fusion Training Services - Upon request, the Manufacturer must provide training in the Manufacturer's recommended butt fusion and saddle fusion procedures to the Contractor's installation personnel, and to inspectors representing the Owner.

2-C-5-7 *Tapping Fittings*

Branch connections to the main pipeline i.e. (branch OD 63mm) can be made using either tees or special tapping fittings (saddle fittings). These fittings can be either mechanical type, electrofusion type or metal type (ductile) and should be designed for the connection to polyethylene (PE) pipes

Tapping fittings according to DIN 3543 are provided for welding to PE-HD pipes. They are welded to the main pipe according to the indications of international standards.

Tapping fitting for polyethylene main lines of PVC or PE-HD must have large contact surfaces and particularly for PE-HD special sealing elements in order to limit to a minimum the surface pressure.

When tapping the main pipeline, it is important to adhere to the respective guidelines for the pipe material. Only appropriate drills for the specific purpose, e.g. crown drills with sufficiently dimensioned flutes may be used. The construction of the drill must prevent the milled-out piece from falling into the pipe.

The material of the main pipeline determines the saddle width of the tapping fitting. The minimum width should be 100 mm for mechanically fastened fittings with rubber seals on PE-HD main lines.

2-C-6 INSTALLATION OF POLYETHYLENE PIPE SYSTEM

2-C-6-1 *Foundation & Bedding*

Pipe shall be laid on grade and on a stable foundation. Unstable or mucky trench bottom soils shall be removed, and a minimum of 100mm foundation or bedding of compacted fine gravel or sand shall be installed to pipe bottom grade. Excess groundwater shall be removed from the trench before laying the foundation or bedding and the pipe. A trench cut in rock or stony soil shall be excavated to 100mm below pipe bottom grade, and brought back to grade with compacted fine gravel or sand bedding. All ledge rock, boulders and large stones shall be removed.

2-C-6-2 Pipe Laying

a. In case of outdoor temperatures lower than 0°C, it is recommended to lay polyethylene pipes only under application of particular measures. Pipe ends and pipeline elements must be cleared prior to installation, damaged parts must be removed. Cuts are to be executed vertically to the pipe axle with the aid of suitable equipment, e.g. a fine-toothed saw. Cutting of the pipes can be made, too, using a casing cutter for plastic pipes. Burrs and uneven areas are smoothed down using suitable tools, e.g. a shaver or a scraper. The cut ends are then prepared for the jointing method to be used.

b. When lifting pipes with slings, only wide fabric choker slings shall be sued 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.

c. Exercise care to keep foreign material and dirt from entering pipe during storage, handling, and placing in trench. Close ends of in-place pipe at the end of any work period to preclude the entry of animals and foreign material.

d. Do not lay pipe when trench bottom is muddy or frozen or has standing water.

e. Use only those tools specifically intended for cutting the size and material and type pipe involved. Make cut to prevent damage to pipe and to leave a smooth end at right angles to the axis of the pipe.

f. Unwinding of pipe coils can be carried out by various methods. Pipes with an outside diameter up to 63 mm can be unwound from the coil in a vertical position whilst securing the pipe end. For larger diameters it is recommended to use an unwinding mechanism. The coils can, for instance, be placed flat onto a rotating wooden or steel cross and be unwound manually or with the aid of a slow-moving vehicle.

The pipes must be unwound in a straight manner without any buckling. Spiral unwinding must be avoided.

When unwinding pipes from drums or coils it is essential to pay attention that the pipe end cannot spring outwards when loosing the fastening. As considerable forces are released, particularly from the large diameter pipes, take the necessary measures of precaution (danger of accident !). Drums should unwound from the top.

When unwinding the pipes, note that the flexibility of the polyethylene pipes is subject to the ambient temperature. At temperatures near the freezing point, pipes exceeding 75 mm of outside diameter are to be warmed, if possible. This can be carried out by pumping warm water through the coil or by using non-pressurized steam or hot air (max. 100° C).

Temperature changes cause alterations of length. This must be taken into consideration when cutting and installing the pipeline. 1 m of polyethylene pipe will elongate by 0.2 mm per °C in case of an increase in temperature and will shorten by 0.2 mm per °C in case of a decrease in temperature.

Temperature of Pipe laying	Smallest Admissible Bending Radius
20° C	25 x d
10° C	35 x d

0° C	50 x d

Note: Directional changes of the pipeline profile are achieved by installing pipe bends. To a limited degree the elasticity of the pipe material can be used to bend the pipe even without pre-warming. The smallest admissible bending radius must, however, not fall below the values given in the table above.

Pipes passing through a wall must be lead through a protective pipe sleeve which, as far as drinking water pipelines are concerned, must be in accordance with the requirements of DIN 1988.

2-C-6-3 Backfilling

Refer to Part III-1- EARTHWORK subsection "Backfilling Pipe Trenches – Initial Backfill".

2-C-6-4 Final Backfilling

Refer to Part III-1- EARTHWORK subsection "Backfilling Pipe Trenches – Main Backfill".

Note: Consulting the Manufacturer during installation phases is recommended to obtain detailed information on the methods and techniques used for proper execution.

2-C-7 HYDROSTATIC PRESSURE TESTING

2-C-7-1 General

During pressure tests on polyethylene pipes, the properties of the material cause elongation of the pipes to take place. The test results can be further influenced by changes in the temperature of the pipe wall while the test is in progress. This is due to the relatively high coefficient of thermal expansion of polyethylene pipes. The temperature rise in the pipe wall causes a drop in pressure. When carrying out the pressure test, it is, therefore, desirable to keep the temperature of the pipe wall as constant as possible to ensure that the temperatures at the start and finish of the pressure test are at the same level. For this reason, particular importance attaches to the temperature measurement.

It is also important to ensure that each pipeline is carefully vented, since air trapped in the line can influence the variation of the pressure drop with time. Due to an effect similar to that of a compressed-air chamber, the rate of pressure drop diminishes, which in turn could conceal an increase in the rate possibly caused by a leak. Any air still in the line - at joints and fittings - should be dissolved in water during the preliminary test. A pressure drop also results from temperature fluctuations and expansion of the polyethylene pipes.

In order that the often appreciable temperature influences can be largely eliminated, the tests should where possible be carried out at times of day when temperature fluctuations are small. The temperature level should be approximately the same at the start and finish of the test. Preliminary tests are essential in order that the material related elongation of the line can take place. The increase in the volume of a line at a testing temperature of 20°C and at nominal pressure amounts in the case of polyethylene pipes to 1.5 - 2%. This elongation takes place over a period of time, but is almost completed after 12 hours.

With the air vents open, it is expedient to fill the line slowly from its deep point, so that the air can escape. As regards the filling of the line, the following empirical values can be recommended:

OD (mm)	Inflow in l / s
63	0.1
90	0.2
110	0.3
140	0.5
180	0.7
225	1.5

2-C-7-2 Execution of Test

The length of the pipeline section to be testing shall be reasonable (less tham 500 m). Ensure all fixed point are surely anchored. Pipes shall be backfilled, joints shall be left exposed for inspection. The test section shall be blanked off with steel blank flanges of adequate thickness supported to resist the end thrust forces and shall be filled from the lowest point with all air valves open.

The correct pre-conditioning of the pipeline is absolutely vital for the acceptance of the main test. This preliminary conditioning serves to bring the pressure time and temperature dependent changes in volume to a steady state, thus ensuring that the results obtained during the main test are reliable.

The preliminary conditioning must be carried out using one and a half times nominal pressure of the pipes, to be checked and corrected if necessary at two hourly intervals. Duration of the preliminary test is 12 hours.

During the main test, it must be taken into consideration that the polyethylene pipeline material may not have completed the expansion process; Therefore, the main test shall be started no sooner than 2 hours after the last pressure increase in the preliminary tests.

Test pressure during the main test is at 1.3 of pipeline section the nominal pressure and the test duration is 3 hours.

For the main test, the results are deemed to be satisfactory when the pressure loss observed from the pressure of the polyethylene pipeline is less than 0.3 bar after the completion of the main test (after 3 hours).

2-D STEEL PIPES AND FITTINGS

2-D-1 PREAMBLE

The scope of this document is to define the technical terms of reference for steel pipes coated internally and externally.

These terms of reference are based on the internationally established standards dealing with bare pipes, external coatings and internal linings.

The quality system of the supplier conforms with ISO 9001 and APIQ1.

2-D-2 STEEL PIPE

2-D-2-1 Product Standard For Steel Pipes

Pipes are spiral seam pipe or butt-welded straight-seam pipes and made in accordance with EN 10224, EN 10217-1, NFA 49 150, DIN 1626 and DIN 2460, BS 534 and BS 3601, or AWWA C200 and with the requirements given hereafter. In case of contradiction between standards and the present terms of reference, the requirements of these terms of reference prevail.

The welding process may be either Submerged Arc Welding (SAW) or Electrical Resistance Welding (ERW).

2-D-2-2 Specification Of The Steel Material

Steel material shall meet the requirements of one of the steel grades listed here below:

	EN 10224	BS 3601	NFA 49150	DIN 1626 DIN 2460	API 5L
1	L 235	360	TSE 235	St 37.0	B
2	L 275	430		St 44.0	X 42
3					X 46
4	L 355			St 52.0	X 52

2-D-2-3 Mechanical Testing

The mechanical tests are performed on one sample pipe per heat for a maximum of 200 pipes (1:200/heat).

The following tests should be made during manufacturing of the pipes. One sample pipe per heat for a maximum of 200 pipes (1:200/heat):

Tensile test: one test piece from the parent metal for outside diameter ≤ 500 mm, plus one test piece transverse to the weld for outside diameter > 500 mm

Weld Bend test (root ≠ / or Face): two test pieces shall be taken from the end of the pipe

Required values are given in the relevant standard for steel material listed in § 2-D-2.2.

Each test is recorded and should be made available to any authorized representative.

2-D-2-4 *Hydrostatic Test*

All pipes are tested, during manufacturing, for leak tightness. Tests are performed at 90% of the Specified Minimum Yield Strength for a duration of at least 6 seconds. Each test is recorded and should be made available to any authorized representative.

For hydrostatic tests on site, and for under pressure use of pipes, refer to the requirements of the hydrostatic pressure testing of the Ductile Iron pipes.

2-D-2-5 *Non Destructive Testing On Welds*

All pipe welds are 100% ultrasonically tested prior to the hydrostatic tests during manufacturing and on site.

2-D-2-6 *Visual Inspection*

All pipes should be inspected outside, and inside for OD≥711mm only.

2-D-2-7 *Dimensional Inspection*

All pipes should be dimensionally inspected with reference to the required tolerances.

2-D-2-8 *Tolerances*

- Outside diameter (OD):

  OD ≤ 406.4mm: ± 1%

  OD > 406.4mm: ± 0.75%

- Thickness of the parent material (T):

  OD ≤ 406.4mm: ± 10%

  OD > 406.4mm: T ≤ 14.2 mm: +12% / -8%

  T >14.2 mm: +10% / - 8%

- Ovalisation: ± 1% of the diameter
- Weight of bare pipes:

  ± 10% per pipe

  ± 7.5% per 10 tons'

- Length:

- Minimum length: 6.0 m
- Maximum length: 14.0 m
- Straightness: 0.2% of the length

2-D-2-9 Ends preparation

Outside diameter at the pipe ends shall comply with the following:

OD ≤ 1600 mm: - 0,8 mm + 2,4 mm

OD ≤ 1800 mm: - 0,8 mm + 3,0 mm

OD ≤ 2000 mm: - 0,8 mm + 3,6 mm

OD > 2000 mm: - 0,8 mm + 4,2 mm

Pipes are either:

- Beveled with an angle of 30° (-0° / +5°) and a root face of 1.6 mm (± 0.8 mm),
- Equipped with lap joints OD ≤ 1600 mm: minimum overlapping is 80 mm.

2-D-2-10 Marking

Pipe markings will indicate, as a minimum:

- The pipe producer,
- Reference product standard,
- Manufacturing reference.

2-D-3 THREE-LAYERS POLYPROPYLENE EXTERNAL COATING

2-D-3-1 Product Standard For Three-Layers Polypropylene Coating

Three-layers polypropylene external coating should be applied on steel pipes conforms to NF A 49711 or DIN 30678 and the requirements given hereafter. In case of contradiction between standards and the present terms of reference, the requirements of these terms of reference prevail.

2-D-3-2 Composition Of The Coating

The three-layers polypropylene external coating consists of:

- One first layer made of Epoxy powder resin film applied to optimize anti-corrosion protection. Its minimum thickness is 50 microns at any points,

- A second layer made of a copolymer to ensure adhesion between layer 1 and 3,
- A third layer made of an extruded polypropylene coating.

2-D-3-3 Thickness of the three-layers polypropylene

Minimum thickness of the three-layers extruded polypropylene coating conforms with:

273 mm < OD ≤ 508 mm: 1.8 mm

508 mm < OD ≤ 762 mm: 2.0 mm

762 mm < OD: 2.5 mm

(OD: outside diameter)

2-D-3-4 Preparation Of The Metal Surface

Prior to the surface preparation and coating, the metal surface shall be examined free of impurities, i.e. rust, oil, dirt etc. which could be detrimental to the coating adhesion to the pipe.

The pipes are dried and preheated in order to obtain a temperature at least 3°C above the critical dew point just before the coating application.

The degree of surface cleanliness is SA 2.5, defined by Standard ISO 8501-1.

The roughness level is from 40 to 80 microns Rz.

2-D-3-5 Routine Testing And Inspection

- Visual inspection: All pipes should be visually inspected.
- Non-porosity test: All pipes should be submitted to the non-porosity test (Holiday's detection tests).
- Cut-back inspection: All pipes are visually inspected at each end.
- Thickness test: Coating thicknesses should be checked on three pipes per production shift, i.e. 3 pipes / 8 hours.

2-D-3-6 Required Properties

The three-layers polypropylene external coating should have the following properties:

- Pull-off strength test:

  Adhesion to support at 23° C: > 750N/5 cm

  Adhesion to support at 80° C: > 200 N/5 cm
- Impact strength at 20° C:

  Punch diameter 25 mm: ≥ 10 Nm/mm

- Penetration resistance under punch load:

  Punch diameter 1,8 mm and Pressure 10 MPa :

  at 20° C $\leq$ 0,1 mm

  at 80° C $\leq$ 0,4 mm
- Bendability:

  Radius $\geq$ 20 D
- Resistance to peeling under negative polarization:

  Average radius of peeling < 10 mm after 7 days at 40° C.
- Electrical non-porosity:

  No defect at 10 000 V/mm.
- Insulation resistance:

  R (100 days) > 108 Ω m²

  α < 0,2/30 Rgr (55 days)
- Elongation at break (PP):

  $\geq$ 400 %
- Resistance to ultraviolet rays (PP):

  0,75 MFIo $\leq$ MFI $\leq$ 1,25 MFIo

  (MFI: melt flow index)
- Heat resistance (PP):

  MFI $\leq$ 1,50 MFIo

  (MFI: melt flow index)
- Cracking resistance in a surface wetting medium:

  No cracked test pieces after 1 000 h at 50° C.
- First layer Epoxy:

  Thickness: e $\geq$ 0,05 mm

  Degree of polymerization: $\triangle$ Tg = $\pm$ 3° C

  Tests should be performed according to NFA 49711.

2-D-3-7 Ends Preparation

Cut-backs are:

- For bevelled pipes:

  150 mm from both ends
- For pipes equipped with lap-joints:

  150 mm from the spigot end

120 mm from the bell end

External coating is bevelled at the ends.

2-D-4 BITUMEN OR COAL TAR EXTERNAL COATING

Where required or approved by the Engineer and for pipes and fittings of nominal diameters greater than 100mm, the above described polypropylene external coating could be replaced by reinforced bitumen enamel wrapping, or coal tar enamel wrapping or polyethylene wrapped (buried pipes only).

In addition to the suitable above requirements concerning the pipes ends preparation and the preparation of the metal surfaces, surfaces to be protected shall be thoroughly cleaned to remove all scale, rust, grease or other extraneous matter, by acid pickling, abrasive, mechanical or flame descaling.

Reinforced bitumen or coal tar enamel wrapping shall comprise hot applied, mineral filled, bitumen, or coal tar, giving a minimum finished thickness of 3mm. Reinforcement shall comprise an inner layer of 40 grams/square metre glass tissue, spirally wound with overlap, separated from the pipe surface by at least 1mm thickness of enamel, and an outer sheathing of bitumen or coal tar impregnated, longitudinally reinforced, glass fabric spirally wound onto the pipe with overlap, and separated by at least 1mm of enamel from the inner glass reinforcement.

2-D-5 LIQUID EPOXY INTERNAL LINING

2-D-5-1 Product Standard For Liquid Epoxy Internal Lining

Liquid epoxy internal lining applied on steel pipes should conform to NFA 49709 or AWWA C210 and to the requirements given hereafter. In case of contradiction between standards and the present terms of reference, the requirements of these terms of reference of the present specification prevail.

2-D-5-2 Composition Of The Liquid Epoxy Internal Lining

The internal liquid epoxy is a two-compound product - resin and hardener - which polymerizes at high temperature and the application, is carried-out at high temperature. It shall resist to osmotic blistering and it shell have current potable water certification from an internationally recognized certifying Authority. This certificate shall be enclosed by the Pipe Manufacturer in his offer.

2-D-5-3 Thickness Of The Liquid Epoxy Internal Lining

Thickness of liquid epoxy internal lining measured on a dry film is greater than 300 microns at any point of the surface.

2-D-5-4 *Preparation Of The Metal Surface*

Prior to coating, the metal surface is free of impurities which could be detrimental to the surface preparation or to the coating adhesion on the pipe.

The pipes are dried and preheated in order to obtain a temperature at least 3°C above the critical dew point just before the coating application.

The degree of surface cleanliness is SA 2.5, defined by Standard ISO 8501-1.

Roughness level is from 40 to 80 microns Rz.

2-D-5-5 *Curing The Internal Coating*

To obtain a good polymerization of the liquid epoxy, the coated pipes, after being painted, should pass through a post cure oven where the steel temperature is raised and maintained at a temperature by the paint manufacturer.

2-D-5-6 *Routine Testing And Inspection*

- Surface conditions inspection: The surface conditions of pipes should be checked after blasting.
- Visual inspection of aspect: All pipes should be visually inspected.
- Cut-back inspection: All pipes should be visually inspected at each end.
- Wet film thickness test: Four measurements of thickness on a wet film should be performed for all the pipes.
- Non-porosity test: An electrical non porosity test should be performed on three plates per production shift.
- Adhesion test: Adhesion of the liquid epoxy lining on plates should be checked on one pipe per production shift.
- Dry film thickness test: The thickness of dry films on plates should be checked on one pipe per production shift.

2-D-5-7 *Properties Of The Liquid Epoxy Internal Lining*

The liquid epoxy internal lining shall have the following properties:

- Electrical non-porosity:

  Wet sponge: 67,5 V
- Cross adhesion test:

  Level 2 NFA 49709 - Appendix C
- Pull-off adhesion test:

  10 MPa NFA 49709 - Appendix C

- Hardness Shore D:

  > 50
- Bending flexibility:

  1% at 23°C
- Immersion test in demineralised water:

  Class 1in accordance with ISO 2409.

Tests are performed according to NFA 49709.

2-D-5-8 Ends Preparation

Cut-backs are:

- For bevelled pipes:

  50 mm from both ends
- For pipes equipped with lap-joints:

  150 mm from the spigot end

  20 mm from the bell end

2-D-6 CEMENT MORTAR INTERNAL LINING

2-D-6-1 Product Standard And Lining Process For Cement Mortar Lining

Cement mortar should be applied using centrifugal spraying process and according to NFA 49701 or DIN 2614 and to the requirements given hereafter. In case of contradiction between standards and the present terms of reference, the requirements of these terms of reference of the present specification prevail.

Fresh mortar is applied using a centrifugal applicator head. The lining is then smoothed and the exceeding water in mortar is expelled by rotating the pipe.

2-D-6-2 Composition Of The Cement Mortar Lining

Cement mortar lining should be made of a mixture of cement, sand and water. It shall be suitable for transportation of potable water.

Cement shall be of the CHF type according to NF P 15-301 or equivalent.

Cement mortar shall be composed so that:

- The S/C ratio (mass of sand in terms of mass of cement) is 2.1 (-0 / +0.3). When CHF cement is used, S/C can be reduced to 1.6.

The E/C ratio (mass of water in terms of mass of cement) shall not exceed 0.42.

In case of pipes used for sewage application, the cement used for internal lining should be sulphate resistant high alumina (similar to the cement lining for Ductile Iron pipes according to EN 598).

2-D-6-3 *Thickness Of The Mortar Lining*

For high furnace cement, such as the CHF type according to French Standard NF P 15301, the minimum thickness is:

273 mm < OD ≤ 406 mm : 5 mm

406 mm < OD ≤ 610 mm : 6 mm

610 mm ≤ OD ≤ 711 mm : 8 mm

713 mm ≤ OD ≤ 914 mm : 10 mm

(OD : outside diameter)

2-D-6-4 *Routine Inspection Of The Lined Pipes*

- Visual inspection: All pipes should be visually inspected.
- Thickness inspection: Thickness should be checked on four pipes per production shift.
- S/C and E/C ratio: two determinations per week of production.
- Mechanical resistance: one test per month of production.
- Granulometric curve of the sand: one check per batch.

Tests should be performed according to procedures specified in NFA 49701.

2-D-6-5 *Routine testing and inspection*

After a 28-day storage, the minimum mechanical characteristics of the cement mortar are:

- Resistance to compression: 35 MPa.
- Resistance to flexural tension: 5 MPa.

2-D-6-6 *Ends preparation*

Cut-backs are:

- For bevelled pipes:
- 10 mm from both ends
- For pipes equipped with lap-joints:
- No cut-back for the spigot end.

In the bell, cement mortar ends with a rubber ring placed in such a way that the minimum overlapping is achieved.

2-E UPVC PIPES

2-E-1 GENERAL

UPVC pipes and fittings shall comply in all respects with the following standards:

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

Approved manufacturers shall supply all pipes and fittings. The nominal length of pipes shall be not less than 6.0 m and not greater than 9.0 m.

UPVC 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.

The diameters measured in mm and indicated on the drawings.

2-E-2 GENERAL PHYSICAL PROPERTIES

Density	1650 kg/m^3 – 1950/m^3
ELASTIC MODULES	
Circumferential flexural	13000 Mpa – 15000 Mpa
Circumferential tensile (for pressure pipes)	10000 Mpa – 12000 Mpa
Longitudinal tensile and flexural	6000 Mpa – 7000 Mpa
MINIMUM ULTIMATE STRAINS	
Circumferential tensile	
Initial	1.4
Long term (50 years)	0.9
Circumferential flexural	
Initial	1.4
Long term (50 years)	0.9

Longitudinal tensile	0.4
Initial (pressure pipes)	0.3
Initial (non-pressure pipes)	
Poison's ratio	0.3
THERMAL EXPANSION	
Longitudinal direction	20 x 10-6 per deg. K
Circumferential direction	
Non-pressure pipe	20 x 10-6 per deg. K
Pressure pipe	15 x 10-6 per deg. K

STIFFNESS

The stiffness of a pipe indicates the ability of the pipe to resist external soil, hydrostatic and traffic loads, and negative internal pressures.

According to British Standard and ISO draft, stiffness is expressed as follows :

$S = EI / Dm^3$

Where S = Pipe stiffness N/M2

E = Modulus of elasticity, Pascal

I = Second moment of area per unit length of the pipe wall

Section

In M4 / M

Dm = Mean diameter in M.

2-E-3 HAULING, HANDLING AND STORAGE

Rough handling of pipes shall at all times be avoided, especially at low temperatures. During storage and transport, rigid UPVC 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 height of 1 meter is recommended. For temporary storage on site, care shall be taken to ensure that the ground is level and free front bricks, stones and sharp edges. At high temperatures, rigid UPVC pipes shall be kept in the shade during long term storage. UPVC pipes with spigot and socket shall be stacked with the sockets protruding in alternate layers. Pipes bent, deformed in any way or changed in color shall be rejected and the payment whatsoever shall be made for such pipes.

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

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

a. Tile pipes are clean and free from grit.
b. Suitable covering be provided over the exposed ends of the pipes to prevent tile 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.

2-E-4 CUTTING PIPES

Pipes shall be cut with an approved mechanical pipe cutter and in conformity with pipe manufacturer's recommendations. Where the cut end of the pipe is to be incorporated in a joint the pipe shall be turned down to the correct diameter required for forming the joint by an approved mechanical turning machine. The length of turning shall be sufficient to enable the joint to be properly made. The ends of the pipe shall be accurately beveled by mechanical means to the dimensions specified in the manufacturers recommendations.

The cut end shall be beveled as required to suit the form of joint used.

2-E-5 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 flat might have fallen therein.

All pipe-laying 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 pipe laying is not actually in progress. The plug will be of the screw-up expanding type or of tapered wood.

Where beads 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 length 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 pushing 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.

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.

2-E-6 MECHANICAL TEST:

Samples of pipes taken from different lots shall be tested in the manufacturer's testing laboratory or any other testing laboratory selected by the engineer/owner and in the presence of representatives of the engineer/owner.

a. The following mechanical tests shall be applied:
    1. Resistance to internal hydrostatic pressure. The method for acceptance and quality tests shall be in accordance with ISO 1167.
    2. And at least one of the following tests shall be applied:
        - Resistance to external blows of UPVC pipes shall be tested in accordance with DIN 3127.
        - Tensile characteristics of the pipes shall be tested in accordance with DIN 3504 and DIN 3502.

b. The following physical tests shall be applied:
    - Vicar softening temperature shall be tested in accordance with ISO 2507.
    - Longitudinal reversion test shall be in accordance with ISO 2505 or DIN 4449.

2-F GRP PIPES

2-F-1 GENERAL

GRP (Glass Reinforced Plastic) pipes shall meet the requirements of the most recent edition of ASTM D 3262 together with the requirements specified herein, GRP pipes and fittings shall be purchased locally provided they conform to these Specifications.

The Contractor shall supply to the Engineer, manufacturer's signed certificates stating that the pipes comply in all respects with the provisions of these Specifications and giving the results of all specified tests.

Other methods for manufacturing of GRP pipes may be proposed but such methods will be subject to the approval of the Engineer. Acceptable alternatives to the filament-wound type of pipe described above include the centrifugally cast type complying with BS 5480 subject to independent evidence of a long record of satisfactory use and subject to the Engineer's approval of the detailed specification.

2-F-2 MATERIALS

2-F-2-1 Appearance

The internal surface of all pipes and fittings shall be smooth, hard, durable and free from all tack, protruding fibers, voids, pits, bubbles, cracks, blisters and foreign matter. The external surface of all pipes and fittings shall be a fiberglass surface mat impregnated with polyester resin and shall be commercially free of resin runs, dry areas, dirt and black marks.

The resin reinforcement and aggregates, when combined as a composite structure, shall produce pipes and fittings that satisfy the performance requirements of these Specifications.

2-F-2-2 Design Requirements

All pipes and joints shall be designed for a minimum working life of 50 years.

Pipelines may run beneath roads and be subjected to maximum loading conditions, therefore, design shall be for the worst surcharge conditions and loading applicable in Lebanon.

The pipe shall be designed to withstand the internal environmental conditions specified below:

pH value	1 to 13
BOD	up to 1000 mg/1
Suspended solids	up to 1000 mg./1
Chloride	500 mg/1

Free NH_3	150 mg/1
Sulphate	1000 mg/1
Temperature	5 to 50 °C
Prevailing temperature throughout sewage medium is:	30 °C
Sewage dissolved H_2S	Up to 20 mg/1
H_2S gas concentrations	Up to 2000 mg/1

The ground and groundwater in which the pipes shall be laid are high in salts and are aggressive.

2-F-2-3 Resins

Resins shall comply with the relevant requirements of BS 5480. Details of all resins to be used in the manufacture shall be provided and shall include all the properties listed in the table herein. The resin system adopted shall be that most suitable to the internal and external environmental conditions and resin properties shall be tested in accordance with the following table.

RESIN PROPERTIES

Property	Test Method	Units
Liquid Resin		
- Acid Value	BS 2782, BS 3532	mg KOH/g
- Viscosity at 25 deg C	BS 188 &BS 3532	m Pas
- Specific Gravity	BS 3532	
- Volatiles content	BS 3532 &	BS 2782
- Refractive Index	ASTM	D 1045
Cured Resin		
- Heat distortion temperature	BS 3532 Appendix A	deg C
- Glass transition temperature	Differential thermal analysis	deg C
- Tensile strength	BS 2782	MN/m^2
- Flexural strength	BS 2782 & BS 3532	MN/m^2
- Ultimate elongation	BS 2782	
a.Basic resin		%
b.If flexibilised		%
- Barcol hardness	BS 4549 Appendix A	
- Water absorption	BS 2782 & BS 3532	mg
Information supplied on cured resin shall include details of the cure system employed,		

which shall be the same as that proposed for manufacture of pipes and fittings.

2-F-2-4 Fiber Reinforcement

With the exception of a veil on the inside face of the pipe, all fiber reinforcements used shall be of ECR/ADVANTEX type glass and shall comply with the appropriate standard listed below and shall have a surface treatment compatible with the resin.

BS 3691	Glass fiber roving for the reinforcement of polyester and of epoxy resin system.
BS 3496E	Glass fiber chopped strand mat for the polyester resin systems
BS 3396	Woven glass fiber fabrics for plastic reinforcement
BS 3749	Woven roving fabrics of glass fiber for the reinforcement of polyester resin systems. If a veil is used on the inside face of the pipe, this shall be "C" glass fiber.

2-F-2-5 Aggregates and Fillers

Aggregates and fillers shall comply with the relevant requirements of BS 5480. Silica sand, if used in the manufacture, shall be a minimum of 95% pure silica. The maximum percentage by weight of all aggregates and fillers in the laminate(s) shall not exceed 30%.

No pigment shall be added to any resin used

2-F-2-6 Liner

All pipes and fittings shall have a suitably reinforced resin rich liner to give high corrosion, impact and abrasion resistance. The thickness of this liner shall be determined by the pipe manufacturer, but shall not be less than 1½ mm. No aggregate or fillers shall be included in the liner.

The liner shall consist of two layers, a surface layer and a barrier layer. The surface layer shall be a minimum of 1 mm thick with a minimum of 90% Venylester resin. Any reinforcement in this layer shall be of C type glass or approved suitable synthetic material. The barrier layer shall have 70% to 80% Vinylester resin with ECR/Advantex glass reinforcement.

2-F-2-7 Structural Design

Details of loading and pressures shall be as shown on the drawings. Pipes and fittings shall be designed to these standards for the ground conditions to be encountered. All pipes and fittings shall have a minimum stiffness of 5000 N/m² to accommodate handling and transportation stresses unless specified otherwise.

For buried pipes stiffness shall depend upon depth of cover above the crown of the buried pipe in accordance with the following:

For depths of cover over the pipe more than 6.0 meters or less than 1.5 meters, pipe stiffness shall be minimum 10000 N/m². For depth of cover more than 1.5 m and less than 6.0 meters, pipe stiffness shall be minimum 5000 N/m².

Note: Stiffness factor 'F' shall be calculated as follows:

$$F = \frac{EI}{d^3}$$

where, E = Flexural modulus of elasticity of pipe material in circumferential direction.

$$I = \frac{S^3}{12}$$

S = Wall thickness (m)

d = Mean pipe diameter (m)

Pipe shall have an initial ultimate resistance to longitudinal tensile force per unit of circumference of not less than the following :

DIAMETERS	RESISTANCE
Up to and including DN 600	150 N/mm²
Greater than DN 600 up to and including DN 1200	200 N/mm²
Greater than DN 1200 up to and including DN 2400	250 N/mm²

2-F-2-8 Sizes and Tolerances

2-F-2-8-1 Diameter

The diameter of the pipe shall be designated by the nominal internal diameter. The manufacturing tolerance of the internal diameter shall be in accordance with BS 5480.

All deviations from roundness, with the exception of pipe deformation due to its own weight, shall be contained within the tolerances. Deviations in diameter of spigot and sockets shall be kept to the absolute minimum and shall be such that the seal at the joints is not affected.

2-F-2-8-2 Length

Effective length of pipes and tolerance on effective length shall be as specified in BS 5480.

Where it is found necessary to cut or turn down a pipe in order to form a joint, the exposed surfaces shall be fully sealed with a continuous coating of fully cured resin.

2-F-2-8-3 Wall Thickness

Wall thickness shall be as recommended by the pipe manufacturer and to the approval of the Engineer.

2-F-2-9 Fittings

All fittings and collars such as bends, tees, junctions and reducers shall be equal to or superior in performance to pipes of the same classification and shall comply with BS 5480.

The use of metals for any part of these fittings will not be permitted. However, the Engineer may allow the use of fittings of other materials which are commonly used in the construction of sanitary sewers, provided that the design of fittings and pipes are mutually compatible.

2-F-2-10 Joints and Gaskets

Joints shall be of the collar type incorporating rubber rings. All joints shall be capable of withstanding the various tests specified for the appropriate class of pipe and shall withstand a deflection of not less than 1½ degrees in any direction while maintaining the specified test pressures.

Minimum requirements for the rubber rings shall be as specified in BS 2494. Gaskets shall be of a thickness and design to provide watertight joints. The joints shall be qualified before installation with full testing according to ASTM D 4161. At least one test shall be carried out for each diameter. The Contractor shall ensure that the joint gaskets and joint ring are suitable for use in the prevailing climatic soil, ground water and sewage conditions.

All rubber rings shall be of the type that can pass an acid aging test as directed by the Engineer without any noticeable deterioration in the mechanical or chemical properties of the material used.

Flanged pipes shall incorporate an annular gasket at the joints. The gaskets shall cover the full face of the flanging and shall have holes cut in them corresponding to the bolt holes in the flanges. Alternative forms of gasket may be used, subject to the approval of the Engineer. Flanges shall be drilled to BS 4504, metric units, Type PN16.

2-F-2-11 Testing

2-F-2-11-1 Raw Materials

a. Resins

All deliveries of resin shall be checked for consistency by viscosity and reactivity and refractive indices. Resins deviating from these Specifications shall not be used.

b. Glass

All deliveries of glass shall be checked for consistency by dry strength and chemical resistance to 1.0 N sulphuric acid. Pipes shall only be manufactured from batches of glass exhibiting similar strength and chemical resistant properties. Should these properties change due to variations in suppliers, the pipes produced from this glass shall be tested in accordance with the strain corrosion test as if they were different diameter or class. The Engineer may accept test reports of ECR glass as supplied by the manufacturer and testing of pipe factor glass may be dispensed with.

c. Sand or Aggregate

All deliveries of sand or aggregate shall be checked for consistency of grading, moisture content and purity.

2-F-2-11-2 Manufactured Pipe

a. Strain corrosion Test

Control testing shall be carried out during the manufacture of pipes in accordance with Section 6.3 of ASTM D 3262 using the specified test solution. Control tests shall be carried out for each diameter and class of pipe.

In the event regression curves are not available or any changes to the pipe wall and laminate build-up and/or the properties of the raw materials at any time during the manufacture of the pipes, two complete sets of corrosion tests (including a regression curve) shall be carried out in accordance with ASTM D 3681. One set shall use a 10% W/W solution of sulphuric acid maintained at a temperature of 25°C ± 1 C. The other set shall use a 5% W/W solution of sulphuric acid maintained at a temperature of 23 °C.

Strain corrosion tests shall be run on a minimum of 6 samples from each lot of pipe diameter to ensure that they fall above the regression curve values defined by the manufacturer.

b. Hydraulic Tests in Factory

All pipes shall be subjected to an internal hydraulic pressure test at the manufacturer's plant prior to delivery. The test shall be applied to a pressure equal to two times the working pressure or 6 bars of water head whichever is higher. The test pressure shall be applied for a minimum period of 5 minutes without signs of leakage.

All fittings shall be subject to an internal low pressure test at the manufacturer's plant prior to delivery. The pressure test shall be carried out at 0.1 bar and shall be applied for a minimum period of 5 minutes without signs of leakage or distress. Fittings of metric construction shall be manufactured from pipe which has successfully passed the tests defined above.

c. *Stiffness*

A minimum of one pipe in every 30 pipes, one per shift, or one per production run, whichever is less, shall be tested for stiffness in accordance with ASTM D 2412 "Test for External Loading Properties of Plastic Pipe by Parallel Plate Loading". A minimum of one pipe for each size shall be tested.

d. *Longitudinal Tensile Strength*

For pipes with internal diameters of 600 mm and less, a minimum of one pipe in every 1000 pipes manufactured shall undergo a beam test in accordance with ASTM D 3262, Section 8. A minimum of one pipe for each size shall be tested.

e. *Curing/Hardness Test*

All manufactured pipes shall be subjected to both a Barcol Hardness Test in accordance with BS 4549, Part 1, Appendix A and a commercial acetone test. Both tests shall be carried out on internal and external pipe surfaces.

f. *Loss on Ignition*

A minimum of one pipe for every 30 pipes, one per shift, or one per production run, whichever is less, shall be tested in accordance with ASTM D 2584. From each test pipe, two samples shall be taken for test.

One sample shall comprise the complete laminate including the liner. The second sample shall comprise the laminate without the liner and shall be split off at the interface between the liner and the structural wall.

g. *Other Test and Compilation of Data*

Quality control testing shall include thorough checks of all materials to ensure that they comply with the relevant standards and requirements of the Specifications. All pipes and fittings shall also be subject to a complete visual inspection before shipment. Records of all tests and inspections shall be maintained by the manufacturer and two copies of all test certificates shall be forwarded to the Engineer.

In addition, the Contractor shall submit all necessary data and manufacturer's specifications of the GRP pipes and joints, including details of raw materials, pipe design, manufacturing process, laying instructions and all other relevant information required by the Engineer.

h. *Test Failure*

In the event of a pipe failing the strain corrosion test, two more tests shall be performed: one on a pipe from the previous five pipes and one on a pipe from following five pipes, if any of these two pipes fails, all pipes of that diameter and class which have been manufactured shall be rejected and shall be replaced entirely at the Contractor's expense.

Pipe failing any other test shall be rejected and an additional ten pipes shall then be tested. Five of these pipes shall have been sequentially produced immediately prior to the failed pipe and five immediately following. If anyone of these ten pipes fails, then every pipe shall be tested. Only pipes passing the tests will be accepted.

All pipes and fittings will be subjected to a visual inspection by the Engineer after offloading at Site. All pipes and fittings that have been damaged during delivery shall be repaired and/or replaced by the Contractor and the pipe shall be subject to a further hydraulic test to be carried out by the Contractor as specified herein. Such making good and hydraulic testing at site shall be entirely at the Contractor's expense.

i. Marking and Identification

All pipes, including cut lengths and fittings shall be indelibly marked prior to delivery in the order given below with:

i) The manufacturer's name, initials, or identification mark

ii) The nominal internal diameter in mm

iii) The classification, i.e. pressure rating stiffness (to avoid confusion, pipe rated at 2.5 or 12.5 bars shall be marked 2½ or 12½ and not 2.5 or 12.5).

iv) The date of manufacture.

v) A suitable stamp to indicate that the pipe has satisfactorily passed the required inspection and hydraulic tests at the manufacturer's plant.

These markings may be arranged either in one line or in several lines provided that the order is preserved.

j. Third Party Inspection

All tests shall be supervised and certified by a third party inspection agency approved by the Engineer. All costs for the inspection agency shall be borne by the Contractor and shall be included in the cost of the pipe.

All pipes shall be visually inspected on site prior to installation. The pipes shall be free of defects such as delaminating, air bubbles, protruding or exposed fibers, cracks, air holes, surfaces non-impregnated with resin which can affect, due to their extent, the rigidity and usefulness of the pipe. Defects extent shall be defined by Manufacturer and approved by the Engineer.

The surface of the pipe joints shall be free of all defects and surface irregularities that can affect their integrity. All repairs effected on site shall be agreed to by the Engineer and conducted by qualified personnel from the pipe manufacturer.

2-F-2-12 Loading, Unloading and Transportation of Pipes

GRP pipes are made of delicate elastic materials and, therefore, require special care in loading, unloading and other handling. Nylon lifting strings shall be used for loading and unloading of pipes. Pipes shall not overhang trucks or trailers while being transported and shall be securely tied. Avoid sudden drops or motion while loading and unloading.

2-F-2-13 Storing Pipes, Fittings and Accessories

Pipes shall be stored on flat ground having no stones or debris to prevent any damage to the pipe barrel. It is advantageous to store pipes on timber pieces to facilitate placement and removal of lifting strings. Storage of pipes in heights over 2m shall be avoided. All pipes shall be properly secured to prevent rolling in high winds.

Rubber ring gaskets shall be stored in the shade in the original packing. The store shall be air-conditioned during summer. Gaskets shall be protected from exposure to greases, oils, solvents, or any other petroleum derivatives or chemicals.

Gasket lubricant shall be carefully stored to avoid damage to the container. Partially used buckets shall be properly resealed to prevent contamination of the lubricant. If the lubricant is contaminated by any foreign substance it shall be abandoned.

2-G TEST OF DISINFECTION OF POTABLE WATER PIPES AND RESERVOIRS

Provide equipment, gauges, temporary connections, chlorine and water needed for flushing and disinfection after all work has been completed.

Before commencing disinfection, flush main until effluent is clean and then clean as directed by the Engineer. 1 to 2 times volume of pipe is usually required for such flushing.

After closing all pipeline's exit, the Contractor shall fill pipelines with clean water mixed with chlorine dose of 20 mg per liter. Wait for 24 hours, then measure residual chlorine by taking a sample to the lab and perform a bacteriological test in the presence of the Engineer. If any harmful signs appear, disinfection process must be redone and another test must be taken until the test gives a results acceptable to the Engineer.

After the completion of the work, the Contractor must fill the reservoirs with clear water mixed with chlorine dose of 20 mg per liter and,

1- Wait for 24 hours, then measure residual chlorine by taking a sample to the lab and perform a bacteriological test in the presence of the Engineer. If any harmful signs appear, disinfection process must be redone and another sample must be taken until the test gives a results acceptable to the Engineer.

2- Wait for an additional 48 hours and check if the water level stays as it was. If not, the Contractor has to fix the reservoirs on his own expense and restart the test

The cost of these tests are considerd to be included in the unit rates of the materials and works related to the pipes and reservoirs mentioned in the Bill of Quantities.

2-H 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.

2-I ACCESSORIES

Refer to Part IV- MECHANICAL WORKS.

Part III: Civil and Architectural Works

Part III-1: EARTHWORK

Table of Contents

PART 3.1 - CIVIL & ARCHITECTURALWORKS: EARTHWORK

3-1-A EARTHWORK (GENERAL)

3-1-A-1 DESCRIPTION

This work shall consist of clearing and grubbing, stripping, removal of unsuitable soil, excavation, fill and backfill, and other specified works related to the earthwork.

3-1-A-2 GENERAL REQUIREMENTS

Prior to any excavation in the streets, a license request together with all detailed drawings showing the locations of the excavations and a written commitment to restore the street to its initial condition shall be submitted to the Engineer.

Excavation in streets and roads shall not commence without written approval from the Engineer.

Before the commencement of any earthworks or demolition the sites shall be surveyed as necessary in conjunction with the Engineer's representative to establish existing ground levels.

The Contractor shall not start any earthwork before getting the Engineer's approval on the cross sections.

The Contractor shall correct all disapproved cross sections and resubmit them for approval.

The Contractor shall excavate, refill and restore in advance of his program such trial holes as he may require for determining the nature of the subsoil and the location of existing underground services and obstructions.

The Contractor shall ensure that there are no pipes, cables, mains or other services or property which may be disturbed or damaged by its use. He will take all precautions not to damage these services and restore these services if damaged on his own expense.

3-1-A-2-1 Explosives

The Contractor shall at all times take every possible precaution and comply with the Explosives Laws of Lebanon and regulations relating to the handling, transporting, storing and use of explosives and shall at all times when engaged in blasting operations post sufficient warning flagmen to the full satisfaction of the Engineer's Representative. The Contractor shall also provide a special proper store for explosives in accordance with local regulations and shall provide experienced men with valid blasting licenses for handling explosives to the satisfaction of the Engineer and the authorities concerned.

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

Blasting shall only be carried out on those sections of the Works for which permission in writing shall have been given by the Engineer and the relevant authorities and shall be restricted to such hours and conditions as may be prescribed. Blasting within 10 meters of existing water mains will not be permitted.

Blasting shall be carried out so as not to weaken an existing structures or the foundations or ground adjacent to the existing and proposed works. The Contractor shall take all necessary precautions to prevent loss injury or accident to persons or property and shall be entirely liable for any accident or damage that may result from the use of explosives.

The Contractor shall submit to the Engineer for his approval a method statement including details of the intended drilling patterns, depths of holes, the amounts of explosives at each location, and the method or sequence of setting off what he proposes to use.

3-1-A-2-2 Clearing & Grubbing

3-1-A-2-2-1 Description

This work shall consist of clearing, grubbing, removing and disposing of all vegetation and debris within the limits specified. This work shall also include the preservation from injury or defacement of all vegetation and objects designated to remain.

3-1-A-2-2-2 General Requirements

The areas to be cleared and grubbed shall be as shown on the Plans, as designated in the Specifications or as directed by the Engineer. The Engineer will designate all trees, shrubs, plants and other things to remain. The Contractor shall preserve all things designated to remain.

Before carrying out work, the Site shall be inspected by the Contractor in conjunction with the Engineer to establish its general condition which shall be agreed and recorded in writing, and where in the opinion of the Engineer it is deemed necessary, by means of photography.

Details recorded shall include the location of all boundary and survey beacons, the condition of buildings, surfaces terracing (if any), ditches, watercourses roads, tracks, fences, and other information relating to the Site and elsewhere which may be affected by the works.

In the case of wayleaves for pipelines, the boundaries of the wayleave will be defined by the Employer and the Contractor shall provide, erect, and maintain in position from commencement to final completion of the Works, in every section substantial timber stakes or similar approved markers not less than 1.5m high indicating the position of the boundary at 50m or other such intervals as the Engineer may direct. In the event of any boundary or survey mark established for the purpose of land title being disturbed or displaced, the Contractor shall forthwith replace the beacon. Where necessary the Contractor shall employ the services of an approved licensed surveyor for the purpose of setting out boundaries.

Before beginning clearance in any area the Contractor shall give seven days written notice of his intention to the Engineer who will determine the extent and limits of such clearance.

All surface objects and all trees, stumps, roots, sod and vegetable matter, other protruding obstructions, not designated to remain shall be cleared and grubbed.

Within the limits of clearing and grubbing, all stumps, roots 4 cm in diameter or larger, buried logs, and all other objectionable material shall be removed 90 cm below the existing ground surface or subgrade, whichever is deeper.

Except in areas to be excavated, stump holes and other holes from which obstructions are removed shall be backfilled with suitable material and compacted to 90% of Maximum Dry Density.

Topsoil shall mean the surface layer of soil which by its humus content supports vegetation and is unsuitable, as a formation to roads and concrete structures or as a backfill or bedding material. The extent and depth of topsoil that needs removal shall be agreed with the Engineer.

Topsoil shall be set aside for re-use or disposal off site as directed by the Engineer.

Trees to be removed shall be uprooted or cut down as near to the ground level as possible.

Bushes, undergrowth, small trees, stumps and tree roots shall, where directed by the Engineer, be grubbed out. All holes left by the stumps or roots shall to backfilled with suitable material in a manner approved by the Engineer.

Materials arising out of site clearance shall be disposed by the Contractor off the Site, or where approved by the Engineer on the Site in a manner and place approved by the Engineer.

The Engineer may require that individual trees, shrubs and hedges are preserved and the Contractor shall take all necessary precautions to prevent their damage.

In the case of wayleaves for pipelines and the like, the Contractor shall preserve as far as practicable all grass and other vegetation outside the limits of trenches and permanent works and shall not unnecessarily destroy crops or any vegetation whose removal would not be essential to his operations.

The Contractor shall take 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 warrant.

3-1-B EXCAVATION

3-1-B-1 EXCAVATION IN GENERAL

3-1-B-1-1 Description

This work shall consist of all excavation for structures, chutes, canals, pipelines, trenches, culverts, headwalls, basins, gravel traps, manholes, inlets, retaining walls, roadways and other specified works.

3-1-B-1-2 Classification

All excavation will be classified as one of the following :

- Common Excavation Common excavation consists of the excavation and disposal of all materials of whatever character encountered in the work except rock.
- Rock Excavation Rock is defined as a sound and solid mass, layer, or ledge of mineral matter in place and of such hardness and texture that it cannot be effectively loosened or broken down by ripping in a single pass with a late model tractor-mounted hydraulic ripper equipped with one digging point of standard manufacturer's design adequately sized for use with and propelled by a crawler-type tractor rated between 385 and 410 net flywheel horsepower operating in low gear.

  In areas where the use of the ripper described above is impracticable, rock is defined as sound material of such hardness and texture that it cannot be loosened or broken down by a manual drifting pick.

  Boulders and detached stones having a volume of 0.75 cubic meters or more shall be classified as rock.
- Unclassified Excavation "Unclassified Excavation" shall be that volume of excavation consisting of the removal of all materials regardless of their physical properties.

3-1-B-1-3 General Requirements

Excavation in public streets is subject to the following:

- Decree-law No. 68 dated 9/9/1989
- Decree-law No. 98 dated 9/9/1989
- Circular issued by the Prime Minister's Office No. 6/95 dated 13/3/1995

Excavation shall be made in open cutting unless tunneling or heading is specified or approved by the Engineer and shall be taken out as nearly as possible to exact dimensions and levels so that the minimum of infilling will afterwards be necessary.

The Contractor shall ensure the stability and safety of excavations and shall take all measures necessary to ensure that no collapse or subsidence occurs.

Except where described in the Contract or permitted under the Contract excavation shall not be battered. The sides of all excavations shall be kept true and shall where necessary be adequately supported by means of timber, steel or other type struts, walings, poling boards, sheeting, bracing, and the like. Supporting excavation cost shall be deemed included in the excavation unit rate.

Excavations shall be kept free from water and it shall be the Contractor's responsibility to construct and maintain temporary diversion and drainage works and to carry out pumping and to take all measures necessary to comply with this requirement.

3-1-B-1-3-1 Excavation in Excess

In the event of unsuitable ground being encountered at formation level or if the formation is damaged or allowed to deteriorate, the Contractor shall forthwith inform the Engineer. The Contractor shall excavate to such extra depth and refill with compacted granular or other approved fill or Class D concrete as the Engineer may require. With respect to the side face of any excavation against which concrete or other work will be in contact the Engineer may require that the net dimensions of the work be increased.

If any part of any excavation is in error excavated deeper and/ or wider than what is required, the extra depth and/or width shall be filled with Class D concrete or compacted granular or other approved fill to the original formation level and/or dimensions as the Engineer directs on the contractor’s expense.

In pipe trenches where the pipe is not bedded on or surrounded with concrete, excess excavation shall be filled with compacted granular material. Excess excavation in rock trenches shall be filled with Class D concrete up to 100 mm below the pipe invert.

3-1-B-1-3-2 Excavated Materials Suitable for Re-use

No excavated material suitable for re-use shall be removed without the approval of the Engineer.

During excavation, the Contractor shall ensure that all material suitable for re-use are kept separate and set aside and protected as necessary to prevent loss or deterioration.

The materials forming the surface and foundations of roads, road verges, tracks and footways shall when excavated, and if required for further use, be carefully separated. All hard materials shall be kept free from soil or other excavated materials.

During excavation, the Contractor shall ensure that all granular or other approved material suitable for filling around and over pipes shall be kept separate and re-used for this purpose.

Paving slabs, bricks and similar surfaces shall be carefully removed and stacked. Prior to the commencement of excavation the number of badly broken and unsuitable paving slabs, bricks etc. on the line of the excavation shall be agreed with the Engineer.

In verges and other grass surfaces the grass and top soil shall be stripped and separately stacked.

3-1-B-1-3-3 Damages Caused to the Surface of Roads

Where the surface of the road damaged either by the concentration of traffic caused by an open excavation, by subsidence or other causes arising from the operations of the Contractor. The Contractor shall permanently reinstate the whole of the surface to its original condition.

3-1-B-1-3-4 Safety of Excavations

The Contractor shall ensure that excavation 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.

3-1-B-1-3-5 Mechanical Excavation

Mechanical excavation shall be employed only if the subsoil is suitable and only in such manner which will allow adequate support of the equipments.

3-1-B-2 EXCAVATION FOR STRUCTURES

3-1-B-2-1 Description

This work shall consist of all excavation for structures, gravel traps, chutes, basins, culverts, headwalls, manholes, inlets, retaining walls or other structures, and other excavation for structures.

3-1-B-2-2 General Requirements

The Contractor shall notify the Engineer a sufficient time in advance of the beginning of any excavation for structures which so that the Engineer may observe the cross-sectional elevations and measurements taken of the existing ground and structure. Any materials removed or excavated before these measurements have been taken and approved by the Engineer will not be paid for.

The foundation shall be excavated to the outlines of the footings as shown on the Plans or as required by the Engineer and shall be of sufficient size to permit the placing of the full width and lengths of the footings shown with full horizontal beds. Rounded or undercut corners and edges of footing will not be permitted.

The excavation shall be carried out to the elevation shown on the plans or as established by the Engineer. No concrete shall be poured prior to the approval of the excavation by the Engineer. Overdepth excavation below the footing elevation approved by the Engineer and overwidth excavation beyond the lateral limits for footings shown on the Plans or directed by the Engineer, shall be backfilled with the same class of concrete designated for the footing and shall be poured monolithically with the footing. No payments will be made for unauthorized overdepth and overwidth excavation and the concrete backfill shall be at the Contractor's expense.

Where rock bottom is secured the excavation shall be done in such manner as to allow the solid rock to be exposed and prepared in horizontal beds or properly serrated for receiving the concrete. All loose and disintegrated rock and thin strata shall be removed.

Where unstable material or other unsuitable material is encountered below foundation elevation of reinforced concrete structures, the Contractor, at the direction of the Engineer, shall excavate such unstable material and replace with suitable and stable backfill material or blinding concrete as shown on the Plans or directed by the Engineer. The foundation stabilization, necessary depth of excavation and suitability of the proposed backfill material shall be approved by the Engineer prior to the Work.

Suitable and practically watertight cofferdams, or other watertight equipment and materials to maintain a waterfree excavation shall be used whenever water-bearing strata are encountered above the elevation of the bottom of the excavation. They shall be sufficiently large to give easy access to all parts of the foundation form and shall be of dimensions not less than those for which payment for excavation is made and shall be deemed included in the excavation price.

If cofferdams have to be used, then cofferdams shall be constructed so as to keep the excavations free from earth, water, ice, or snow and to permit the excavations to be carried to depths up to 1m below the foundation elevations shown on the plans. They shall be substantially braced in all directions, and of such construction as will permit them to be pumped free of water, and kept free until the concrete has been placed. They shall be such that leakage can be kept out of the concrete or masonry. Unless otherwise shown on the plans or agreed upon with the Engineer, cofferdams and all sheeting or bracing shall be removed after the completion of the concrete or masonry. When the bottom is of sandy or porous material which will not, in the opinion of the Engineer, permit the footing to be poured in the dry, it shall be sealed with concrete so that it may be pumped dry. The cement content water / cement ratio and the maximum coarse aggregate size will be submitted to the Engineer prior to the work. A seal course shall not be used unless shown on the Plans or authorized in writing by the Engineer. If in the opinion of the Engineer, the necessity for a seal course is due to inadequate or improper cofferdam construction, he may order the removal and/or reconstruction of the cofferdam, or permit the placing of a seal course at the Contractor's expense. Other satisfactory methods of sealing out the water may be approved.

After the seal course has set, the cofferdam shall be cleared of water and the work completed in the dry. When weighted cribs are employed and the weight utilized to overcome partially the hydrostatic pressure acting against the bottom of the foundation seal, special anchorage such as dowels or keys shall be provided to transfer the entire weight of the crib into the foundation seal. Cofferdams shall be constructed so as to protect green concrete against the damage from a sudden rising of the stream and to prevent damage to the foundation by erosion.

The provision of dewatering equipment and all operations required to maintain a water free excavation shall be carried out and considered subsidiary to the items of structural excavation.

Maintenance of natural waterways and allowance for the passage of surface water during construction is the Contractor's responsibility and any damage occurring in this respect shall be corrected at the Contractor's expense.

3-1-B-2-2-1 Excavation for Foundations of Structures

The Contractor shall give sufficient notice and sufficient time in advance to the Engineer to enable him to inspect and approve foundations in advance of placement of the permanent work. The Engineer may withdraw his approval if work is not commenced within 48 hours or the formation is subsequently allowed to deteriorate.

If the Engineer directs it, a bottom layer of excavation of not less than 75mm thickness shall be left undisturbed and subsequently taken out by hand immediately before concrete or other work is placed. Where concrete or other materials is to be placed in contact with the side face of an excavation the Contractor shall, where Engineer directs, excavate the last 75mm thickness of the face immediately before the concrete is placed.

Formations which are to receive concrete blinding or a drainage layer shall be covered with such blinding or layer immediately the excavation has been completed, inspected and approved by the Engineer.

Surfaces against which permanent works are to be placed shall be kept free of oil, water, mud or any material.

No concrete or other materials shall be placed until formations have been approved. Adequate notice shall be given to the Engineer to enable him to examine the formation.

3-1-B-2-2-2 Rock Surfaces Under Concrete Structures

3-1-B-2-2-2-1 Concrete Placed Directly on Rock

Rock under concrete structures shall be prepared by picking, barring, and wedging or other methods which will lease the rock in as sound a condition as may reasonably be expected according to the rock quality.

Rock surfaces shall be thoroughly cleaned by compressed air and water jet or such means as the Engineer may direct before concrete is placed.

3-1-B-2-2-2-2 Concrete Placed on Capping Layer

Where instructed the excavation shall be taken down to a depth of 1.0 m below the underside of the structure and the excavation backfilled with capping materials to the required formation level.

Capping material shall be an approved granular material.

The material shall be compacted in 150mm layers to achieve a density of not less than 95% maximum dry density determined by the Moisture - Density curve of the material.

3-1-B-3 EXCAVATION FOR PIPE TRENCHES

3-1-B-3-1 Description

This work shall consist of excavation for pipes laying to the required line and grade.

3-1-B-3-2 General Requirements

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 minimum trench width for each trench type shall be computed according to the data given on drawings.

In order to ensure a rapid execution, a mechanical crane or shovel is necessary to avoid a major disturbance in the road traffic.

The trench invert level and the trench width 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.

If required by the Engineer, the extraction of backfill materials by means of mechanical engines shall be stopped at a level higher than that of the determined excavation bottom. As for internal walls, the mechanical digging shall stop before reaching the limits of the outline, so as to prevent the engine claws from breaking up the bottom and the walls. The excavation shall then be completed by manual means. The bottom of the trench shall be well levelled and have its longitudinal profile parallel to the pipe.

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. The maximum length of open trench shall be 150 meters or the distance necessary to accommodate the amount of pipe installed in a single day, whichever is the greater. 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 (at least 500 mm away from the trench edge) 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.

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. 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 by removing unstable materials (rock, boulders and hard spots), 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, supporting and stabilizing trench walls either by timbering or shoring, dewatering as and where required if no specific items have been provided in the Bill of Quantities.

3-1-B-3-3 Dumping of backfill materials

Backfill materials shall be directly transported by trucks outside the site and discharged at locations approved by the Engineer. The road shall be thoroughly cleared from any backfill material.

As for roads maintained by the municipality, having favorable width and condition, backfill materials could be placed, upon the prior approval of the Engineer, on both sides of the trench; the blocks and stones close to the sidewalk, the sand and the earth free from stones next to the road center line, so as not to impede the traffic.

3-1-B-3-4 Precautions relating to other utilities

The contractor shall take all necessary precautions to protect the installations in the trench.

In order to choose a good location for the installations, the contractor shall use a device to detect the cables before digging trenches, or dig by hand, probing holes at his own expenses.

During excavation works, if the contractor notices a slight water leak from existing pipes he shall immediately notify the Engineer and the competent authorities.

If he encounters electrical or telephone cables or other pipe works, he shall take necessary measures to protect them. The contractor remains entirely responsible before competent authorities for eventual damages.

The contractor shall not demolish, remove or repair any other utility (rainwater pipes, telephone cables,...) existing in the trench, but in the presence of the Engineer and the competent authority or upon their approval.

In case these damages occur (breaking of a water pipe, telephone cable, electrical cable, drain pipe, etc...), the contractor is bound to repair them immediately at his own expense (providing materials and labor).

3-1-B-3-5 Water drainage

The contractor shall effectively have at his disposal from the beginning of works all necessary equipment to avoid any water flow and ensure a good drainage.

The excavations shall be kept dry during the works period and eventually during the period the Engineer deems necessary.

Water encountered in the excavations, whether resulting from aquifers or any kind of infiltration, shall be drained towards sumps and then discharged by the contractor.

When pumping water from the excavation, the contractor shall take all necessary measures to prevent soil erosion and undermining, as well as necessary measures to maintain the structures' stability.

The contractor shall be responsible for any damage caused by water to foundations or works.

He shall afford any eventual repair.

3-1-C NATURE AND ORIGIN OF THE MATERIALS

3-1-C-1 GENERAL REQUIREMENTS

The materials intended for the construction of the various work, will be supplied by the Contractor and will come from extraction sites that will have to be accepted by the Engineer and must comply with the Technical Specifications.

The approval of the Engineer does not relieve the Contractor from his responsibility as to the quality of materials furnished to the site.

Any change as to the source of the material will have to be approved by the Engineer. Furthermore, the Engineer has the right during the works, to ask for a change of source in the event the quality is not in compliance with the present specifications.

All material must satisfy the French Standard AFNOR and DTU documents, American Standards ASTM or British Standards BS.

3-1-C-2 GENERAL POINTS ON THE QUARRIES

The limestone quarries must be homogeneous, joint free with convenient stratification and little bedding to obtain material of the required quality.

The Engineer will accept or refuse the quarries in a period of 15 days following the Contractor's request. The Contractor must, at his own expense carry out several drillings and trenches that will enable the Engineer to appreciate the quality of the proposed materials.

The cost of searching for a quarry deposits and testing it shall be on the expenses of the Contractor.

If during the works, the excavated material no longer conforms to the required quality, or if the volume of the usable proportion is insufficient, the Contractor must, at his own expense, search for other sites conforming to the specifications.

3-1-C-3 QUALITY AND PREPARATION OF BORROWED MATERIALS

3-1-C-3-1 Norms

All materials shall satisfy with AFNOR, DIN, ASTM or BS norms.

3-1-C-3-2 Material Gradation

– Material of sand and limestone quarries :

The filter material shall be obtained by sieving natural sand in provenance from the sand quarries. The drain material shall be obtained by crushing rocks in provenance from the quarries. These materials shall have a continuous gradation.

- In case of filter and drain materials acting as protection against washing of another material, they shall respect the following conditions:

1- $\frac{d_{15}F}{d_{85}M} < 5$ F for the filter or the drain

M for the material to protect

Note: in case of fine granular soil, this criteria is not valid for filter material. The gradation of filter materials shall be between 0 and 5 mm.

  - $2 < \frac{d_{60}}{d_{10}} < 8$
  - Less than 5% of elements < 80 microns and d_{15} (sand) > 0.1 mm.
- In case of a draining material, the gradation should range between from 1 to 4 cm and less than 5% of elements < 80 microns.

3-1-C-3-3 Rockfill paving, Rockfill, Drain and Filter Materials

Rockfill, drains and filter materials must have sufficient hardness to be discharged in bulk and manipulated by power machines without being broken or disintegrated. They must be homogeneous, freeze resistant, unaffected by water or air and shouldn't contain neither earthly nor organic components, nor soluble components. They must be of a minimum specific weight of 2.6 t/m^3.

3-1-C-4 CRITERIAS FOR THE CHOICE OF LIMESTONE QUARRIES

3-1-C-4-1 Studies and Testing Before Choosing the Limestone Quarries

The Contractor must carry out the following works.

3-1-C-4-1-1 Geological study on the limestone quarries

The Contractor must present a geological report giving the following estimations :

a. The geological formation of the quarry including covering and homogeneity.
b. The apparent quality of the rock.
c. The rate of fractures and their maximum width.
d. The method of preparation of the quarry (removal of altered materials).
e. The method of extraction and exploitation to obtain the best possible blocometric breakage (blasting plans, drilling equipment, explosives, loading and transportation).

3-1-C-4-1-2 Laboratory Test

The Contractor must take 6 rocky samples coming from the materials extracted from the quarry to be the object of laboratory tests. These tests must lead to the following results :

- Micro-Deval attrition test(> 20)- AFNOR P18-572
- Los Angeles Abrasion Test (< 30)- ASTM C131
- Porosity (< 10%)
- Unconfined compression strength (350 kg/cm^2)
- Chemical nature of the material
- Volume weight (>2.6 T/m^3)

These tests much show that the material components are at least 50% from limestone origin.

3-1-C-4-2 <u>Choosing the Limestone Quarries</u>

In the light of the geological report and the laboratory results, the Engineer shall give his approval for the use of the Quarry proposed by the Contractor. His approval does not affect the responsibility of the Contractor.

3-1-D FILL AND BACKFILL

3-1-D-1 FILL AND BACKFILL IN GENERAL

3-1-D-1-1 Description

This work shall consist of all fill and backfill for structures, chutes, canals, pipelines, culverts, headwalls, basins, manholes, inlets, retaining walls, roadways and other specified works.

3-1-D-1-2 General Requirements

Backfilling whether in foundations or in pipe trenches shall be thoroughly compacted by ramming and any subsidence due to consolidation shall be made up with extra compacted material.

Should subsidence occur after any surface reinstatement has been completed the surface reinstatement shall first be removed, the hollows made up and then the surface reinstatement relaid.

Any subsidence that occurs adjacent to the Site of the works which is attributable to the Contractor's activities shall be reinstated to the full satisfaction of the Engineer.

All surfaces whether public or private which are affected by the works shall be reinstated temporarily in the first instance and when the ground has consolidated fully the Contractor shall reinstate the surfaces permanently.

Temporary reinstatement and permanent 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.

Temporary reinstatement shall be carried out immediately after the trenches are backfilled.

Permanent 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 permanent reinstatement, the Contractor shall make the reinstatement good to the approval of the Engineer or responsible authority.

Unless otherwise specified in the drawings or by the Engineer, for the purposes of temporary and permanent reinstatement in bitumen and surfaced roads the surface width of trenches shall be increased by 150 mm on each side of the trench for a depth of 75 mm 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 permanent reinstatement at the Contractor's expense.

Excavation in open ground shall be reinstated to the condition in which the ground 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, 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.

3-1-D-2 COMPACTION OF EARTHWORK

3-1-D-2-1 Description

This work shall consist of the compaction of earthwork by rolling or tamping or any combination of these methods in accordance with the requirements for the Moisture Range and Type designated or ordered by the Engineer.

3-1-D-2-2 General Requirements

Each layer shall be compacted to a density between 90 and 95 % of the maximum density. This maximum density shall be determined by the AASHTO T 180-93, method D test or equivalent Standard Test for cohesive soils, by the ASTM D 2049 test or equivalent Standard Test for cohesionless soils.

In case where borderline materials are encountered, both the above mentioned tests will be utilized and the test which results in the higher laboratory maximum density shall be used as a standard to which the field density is compared.

Each layer of earth fill shall be compacted by approved tamping or sheepsfoot rollers, pneumatic tired rollers, or other mechanical means as requested by the Engineer and depending on the soil nature.

At locations where it would be impractical because of inaccessibility to use such compacting equipment, fill layers shall be compacted to the specified requirements by hand directed compaction equipment.

Whenever fill is placed adjacent to structures or at locations where it is not practicable to use a roller, the fill material shall be well tamped by the use of mechanical rammers or tampers. Each layer shall be compacted to a density equal to or greater than obtained under the above rolling procedure for the type of compaction designated. Each layer must be approved by the Engineer before the next layer is placed. When the quantity of work is small, a hand tamper may be used with the permission of the Engineer.

At the time of compaction, the moisture content of the soil shall be within the moisture range as defined in the Test Methods. When the moisture content of the soil does not fall within the required moisture range, water shall be added and thoroughly mixed with the soil, by approved methods or the material shall be aerated, whichever is needed to adjust the soil to the specified moisture content before compaction.

3-1-D-3 BACKFILL FOR STRUCTURES

3-1-D-3-1 Description

This work shall consist of backfilling with suitable excavated or borrowed material (Selected Fill and Backfill), uniformly distributed and thoroughly compacted, around structures, chutes, culverts, manholes, retaining walls, or other structures.

3-1-D-3-2 General Requirements

Structure backfill shall not be placed until the structure has been inspected by the Engineer and approved for backfilling. In general, no structure shall be subjected to the pressures of backfilling or to live loads until three(3) days after the expiration of the period designated for the removal of forms. At the direction of the Engineer, this period may be extended if subnormal curing conditions exist. Backfill, placed around culverts, abutments and piers, or a particular structure as designed by the Engineer, shall be deposited on both sides to approximately reach the same elevation at the same time. Special care shall be taken to prevent any wedging action against the structure. The slopes bounding the excavation shall be stepped when necessary, to prevent such wedge action. Whenever backfill is placed in back of or over arches, culverts or rigid frames, the fill shall be first placed midway between the ends of the structure, working equally both ways from the center of the structure toward the ends.

The material shall be placed in layers and compacted by means of suitable equipment, or by tamping with mechanical tampers or hand tampers. Each layer shall be compacted to a density equal to or greater than ninety five (95) percent of the maximum density determined by AASHTO T 180-74, Method D. Each successive layer shall contain only that amount of material which will ensure proper compaction, but in no case shall any layer be greater than twenty (20) centimeters (compacted measurement) in thickness. When backfilling and compacting around retaining walls, extreme care shall be exercised to prevent forward movement of the wall. If not specified elsewhere or indicated on the plans, the backfill around structures shall be completed to the level of the original ground or to the finished ground level, whichever is lower unless otherwise specified.

3-1-D-4 BACKFILLING PIPE TRENCHES

3-1-D-4-1 Preparation of the excavation bottom

The excavation bottom shall be shaped according to the pipe's slope, and must not be loosened. However, if it is loosened, the initial bearing capacity shall be restored by compacting or by any other means.

3-1-D-4-2 Laying bed

Generally, the laying bed shall be executed with selected materials (as described below) except for a sandy soil where it is possible, upon the Engineer's approval, to use the excavation bottom that has been leveled and made compact as a laying bed. The theoretical thicknesses of the bed under the pipe works shall be at least equal to 10 cm. Nooks shall be performed in order to facilitate couplings connections. The laying bed shall enable the loads to be uniformly distributed on the support surface. It shall be necessary to lay pipes in such a way that the pressure is not concentrated in one area.

If the laying bed is located in a drain zone or in a pumping zone, it is necessary to prevent the materials of the laying bed from being carried away towards neighboring soils or inside the drainage equipment.

The preparation of the laying bed should not damage an eventual external protection of the pipe works.

The laying bed thickness under the pipe shall be at least equal to 10 cm + 1/10 of nominal diameter in cm, for the pipe works.

3-1-D-4-3 Sand fill protecting layer (initial backfill)

Use only selected fill, sand or other approved material complying with following:

Standard Sieve No. #	% Passing
¾	100
# 4	25-100
# 16	10-75
# 40	5-30
# 100	3-10
# 200	0-5

Initial backfill shall be used as bedding material underneath the pipe, and for filling around the pipe and above the top of the pipe (to the dimensions indicated on Drawings) compacted to 95 % of proctor maximum dry density by a compacting machines suitable for trench width. Material around the pipes shall be compacted with proper tools as recommended by the manufacture, and as directed by the Engineer.

In general, the initial backfill should be sand fill. However where required by the Engineer, the initial backfill could be granular material (or granular with high sand content) according to the recommendations of the concerned pipe supplier.

3-1-D-4-4 Concrete Encasement

In some particular cases (narrow trench not allowing a normal compacting, repartition of loads to be improved, pipes located near foundations, etc...), pipes may be encased partially or totally with concrete. The casing operation shall be performed according to the details indicated on the drawings and to the indications of the Engineer.

The concrete coating shall consist of plain or reinforced concrete, depending on the cases and according to the instructions given by the administration.

The minimal thickness of the encasement shall be equal to 1/4 the nominal diameter with a minimum of 10 cm.

3-1-D-4-5 Main Backfill

Material excavated from the trenches are suitable for compaction and can be used as main backfill over sand protecting layer around the pipes, otherwise use material with a maximum size of 50 mms, well graded and suitable for compaction and approved by the Engineer.

- Backfill shall be laid and well compacted in layers not exceeding 200 mm thick. compacted to 95 % of proctor maximum dry density by a compacting machines suitable for trench width.
- Do not use heavy compactors over pipe trench until there is 600 mm (or as required by the pipe supplier) cover over the pipe.
- If the cover over the top of the pipe is less than 600 mm (or as required by the pipe supplier), use concrete encasement as specified on the drawings and directed by the Engineer.
- When backfilling to pipes with concrete beds and surrounds, do not start backfilling before 24 hours or allow heavy compactors and traffic over the pipes before 72 hours of placing concrete.
- Use temporary crossing over the trench to prevent damaging the pipes.

3-1-D-5 SPECIAL BACKFILLS

3-1-D-5-1 Execution Of Rocks Paving

The rocks in accordance with the required specifications for this particular zone shall be placed to the maximum possible position in its final locations. The finishing of the rock paving demands individual arrangement of each block by means of a heavy mechanical equipment for the big blocks and by hand equipment for the smaller blocks, in a manner that a linear and plain surface is obtained free of any knobs.

If necessary, in some locations that the contractor should proceed with filling the voids between the big blocks by hand width a smaller size in order to obtain a consistent and compact volume.

The contractor must take all necessary measures to ensure safety and security of the site while paving with big chunks of rocks.

3-1-D-5-1-1 Rockfill

These backfills are discharged and leveled by bulldozer in slightly horizontal layers of 100cm after compaction. The biggest blocks, not bigger than 70 cm, are evenly distributed in the mass.

The equipment used and the number of operations must provide a good compaction with results being at least equal to those obtained with an 8 tons per linear meter of width vibrating roll, of a vibration frequency of 1500 to 1800 cycles per minutes with 6 operations at a 1.8 km/h speed.

The faces should present a certain aspect of unity. For that, the Contractor proceeds to a classification of block facings of same size. The blocks are sorted out at the quarry and prepared for the fill layer.

3-1-D-5-1-2 Filters and Drains

These backfills are unloaded avoiding any segregation and are leveled by a bulldozer in slightly horizontal layers of 15 cm after compaction. The equipment used and the number of operations must provide a good compaction with results being at least equal to those obtained with an 8 tons vibrating roll per linear meter of width, of a vibration frequency of 1500 to 1800 cycles per minute at a 1.8 km/h speed (6 to 7 passes). Alternatives leading to the same degree of compaction could be proposed by the Contractor and submitted to the Engineer for approval.

3-1-D-6 RIPRAP

3-1-D-6-1 DESCRIPTION

This work shall consist of furnishing and placing one (1) or more layers of riprap on a prepared surface in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

3-1-D-6-2 MATERIALS

Riprap shall consist of aggregate, from hard, durable, quarried or natural stone having an apparent specific gravity of not less than 2.4, and the absorption shall not exceed 5 percent.

The stone shall be free of weak laminations and cleavages, and shall not disintegrate on exposure to water or weathering. The aggregate shall be round or angular.

3-1-D-6-3 GRADATION REQUIREMENTS

Small size riprap gradation shall be as follows :

SIEVE OPENING SIZE IN CENTIMETERS	PERCENT PASSING (By weight)
20	100
15	50
10	0

Medium size riprap gradation shall be as follows :

SIEVE OPENING SIZE IN CENTIMETERS	PERCENT PASSING (By weight)
40	100
30	50
20	0

3-1-D-6-4 CONSTRUCTION REQUIREMENTS

3-1-D-6-4-1 Subgrade Preparation

The Contractor shall, as a part of this work and prior to the delivery of the material for the riprap, prepare the bed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper slope is obtained for pipe riprap placing. However, in the process of shaping the bed, the originally compacted crust or top portion of the bed shall be disturbed as little as possible. When completed and ready for riprap construction, the bed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

3-1-D-6-4-2 Placing

The material shall be so handled as to avoid segregation. If an aggregate spreader causes segregation in the material or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be discontinued and replaced.. All segregated material shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

Riprap shall be placed to grade in a manner to insure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock fragments in such a manner as will result in well-keyed, densely placed, uniform layers of riprap of the specified thickness. Hand placing will be required only to the extent necessary to secure the results specified above.

All humps and depressions and thickness deficiencies exceeding the specified tolerance of five (5) centimeters shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

3-1-D-6-5 SMALL SIZE RIPRAP WITH BITUMINOUS MASTIC

3-1-D-6-5-1 Description

This work shall consist of furnishing and placing one (1) or more layers of riprap, on a prepared surface, and to fill the joints between the stones with sand-asphalt mastic in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

3-1-D-6-5-2 Materials

3-1-D-6-5-2-1 Gradation Requirements

Riprap shall consist of aggregate, from hard, durable, quarried or natural stone having an apparent specific gravity of not less than 2.4, and the absorption shall not exceed 5 percent. The stone shall be free of weak laminations and cleavages, and shall not disintegrate on exposure to water or weathering. The aggregate shall be round or angular.

Small size riprap gradation shall be as follows.

SIEVE OPENING SIZE IN CENTIMETERS	PERCENT PASSING (By weight)
20	100
15	50
10	0

Sand-asphalt shall consist of a hot-laid mixture of asphalt and mineral aggregates conforming to the requirements below:

AASHTO SIEVE	PERCENT PASSING
1/2 inch	100
3/8 inch	80 to 100
No. 4	55 to 75
No. 10	32 to 47
No. 40	16 to 26
No. 80	10 to 18
No. 200	4 to 10
Asphaltic binder	16 % by weight of the aggregates

3-1-D-6-5-2-2 Physical Requirements for Sand-Asphalt

Mineral Aggregates

Mineral aggregates for "sand-asphalt" shall consist of fine aggregates, and filler material if required. When the grading of the available aggregates is deficient in material passing the AASHTO No. 200 sieve, mineral filler shall be added as approved by the Engineer. Mineral filler shall consist of finely divided mineral matter such as rock dust, including limestone dust, slag dust, hydrated lime, hydraulic cement, or other suitable mineral matter.

The combined mineral aggregate shall meet the following physical requirements :

– Loss of Sodium Sulfate Soundness Test (AASHTO T 104)	10 percent maximum
– Loss of Magnesium Sulfate Soundness Test (AASHTO T 104)	12 percent maximum
– Loss by Abrasion Test (AASHTO T 96)	40 percent maximum
– Thin and elongated pieces, by weight (larger than 1 inch, thickness less than 1/5 length)	5 percent
– Friable Particles (AASHTO T 112)	0.25 percent maximum
– Sand Equivalent (AASHTO T 176) determined after all processing except for addition of asphalt binder	45 minimum
– Plasticity index (AASHTO T 90)	3 maximum

Asphalts

Asphalts for "sand-asphalt" shall be petroleum asphalt cement, grade 60-70 penetration, conforming to the following requirements:

Designation	Test Method	Requirement
Penetration, 25 degrees C, 100 grams, 5 seconds	AASHTO T 49	60-70
Viscosity at 135 degrees C	ASTM E 102	100
Flash point (Cleveland) open cup, degrees C	AASHTO T 48	232.2
Ductility at 25 degrees C	AASHTO T 51	100
Solubility in organic solvents, percent	AASHTO T 44	99.5

The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 176.7 degrees Celsius.

Job-Mix Approval

At least thirty (30) days prior to the date he intends to begin production of plant-mix "sand-asphalt" mixtures, and after receiving approval of the aggregates from the Engineer, and after receiving the approval of the source of asphalt, the contractor shall make written request for the approved job-mix formula from the Engineer.

The job-mix formula shall combine the mineral aggregates and asphalt in such proportion as to produce a mixture conforming to the following composition limits by weight:

	PERCENT
Total Mineral Aggregates	88 - 84
Asphaltic Binder	12 - 16

When tested according to the Marshall method, the bituminous mixture shall conform to the following requirements:

Stability (kilograms)	700 minimum
Flow (millimeters)	2.4 - 4.0
Voids in total mix (percent)	3.0 - 5.0
Voids filled with asphalt (percent)	70 - 80

All trial mixes shall be prepared and tested by the Contractor. Results will be submitted to the Engineer and, if necessary, direct the Contractor to readjust the Plant to maintain conformity to the job-mix formula. If, during production, the grading of the aggregates alters, the mix shall be redesigned and the plant readjusted as outlined above.

The assistance of the Engineer in the preparation of the job-mix formula in no way relieves the Contractor of the responsibility of producing a bituminous mixture meeting the requirements of the specifications.

Preparation of Sand-Asphalt Mixture

Dried aggregate as specified for bituminous construction shall be combined in the plant in the proportionate amounts as approved. Asphalt shall be introduced into the mixture according to the job-mix formula.

The initial mixing time will be designated by the Contractor. Mixing time may be increased by the Engineer if additional time is necessary to obtain a homogeneous mixture and satisfactory coating.

The temperature of the asphalt, except for temporary fluctuations, shall not be lower than fourteen (14) degrees C below the temperature of the aggregate at the time the two (2) materials enter the mixer or plug mill.

3-1-D-6-5-3 Construction Requirements

3-1-D-6-5-3-1 Subgrade Preparation

The Contractor shall, as a part of the work and prior to the delivery of the material for riprap and sand-asphalt mixture, prepare the bed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper slope is obtained. However, in the process of shaping the bed, the originally compacted crust or top portion of the bed shall be disturbed as little as possible. When completed and ready for riprap and sand-asphalt construction, the bed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

3-1-D-6-5-3-2 Placing

The material shall be so handled as to avoid segregation. If an aggregate spreader causes segregation in the material or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be discontinued and replaced.. All segregated material shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

Riprap shall be placed to grade in a manner to insure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock fragments in such a manner as will result in well-keyed, densely placed, uniform layers of riprap of the specified thickness. Hand placing will be required only to the extent necessary to secure the results specified above.

All humps and depressions and thickness deficiencies exceeding the specified tolerance of five (5) centimeters shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

After placing the stones for riprap as described above, in surfaces and thicknesses approved by the Engineer, the Contractor shall fill all the joints between the stones with the approved sand-asphalt mastic.

At least thirty (30) days prior to the date to begin placing of plant-mixed “sand-asphalt” mixtures, and after receiving approval of the sand-asphalt job-mix from the Engineer, the Contractor shall make written request for the approved method of transport and placement of the sand-asphalt from the Engineer. No mixture shall be placed prior to the Engineer’s approval of the Contractor’s methods and procedures for placing the mixture.

All mixed material shall be delivered to their final location in time to permit the mixture to be placed during daylight hours.

All bituminous mixtures shall be delivered to their final location at a temperature between 139 degrees C - 163 degrees C. Mixtures delivered at lower temperatures shall be discarded.

3-1-D-6-5-3-3 Weather Limitations

Sand-asphalt mixtures shall be placed only when the air temperature is four (4) degrees C or above, and when the weather is not foggy or rainy and when the existing surfaces free are free from moisture.

3-1-E TESTS ON MATERIALS

3-1-E-1 TEST METHODS

3-1-E-1-1 Moisture - Density Curve Test

A Moisture - Density Curve (AASHTO T 180-93, Method D or equivalent standard) will be determined for each type of soil to be used in the construction of the work to determine the Maximum Density, the Optimum Moisture content and the Moisture Range required of the soil for satisfactory compaction. The field density and actual Moisture Content of the compacted embankment shall be determined by field curves according to AASHTO T 191 or equivalent standard.

3-1-E-1-1-1 Maximum Density

The Maximum Dry Density as determined by the Moisture-Density curve shall be the density to which the Field Density is referred for comparison or percentage for each type of soil used in the work.

3-1-E-1-1-2 Optimum Moisture

The Optimum shall be the moisture content corresponding to the Maximum Density on the Moisture - Density curve.

3-1-E-1-1-3 Moisture Range

The Moisture Range shall be the limits of moisture content of each type of soil with the Optimum moisture as a reference.

3-1-E-1-1-4 Field Density

The Field Density shall be the density of the compacted fill determined by the Field Density Test.

3-1-E-1-1-5 Moisture Content

It is the percentage of moisture in the specimen based on oven dry mass of soil. The Moisture Content shall be the actual moisture content of the soil in the compacted embankment at the time of compaction.

3-1-E-1-2 Relative Density Test

For cohesionless free draining soils for which impact compaction will not produce a well-defined Moisture-Density relationship curve, the test for the Relative Density of Cohesionless Soils (ASTM D2049 or equivalent Standard) shall be used to determine the relative density.

Relative density is defined as the state of compactness of a soil with respect to the loosest and densest states at which it can be placed by the laboratory procedures described in ASTM D2049 or equivalent Standard. The Field Density and actual Moisture Content of the compacted embankment shall be determined by field tests according to AASHTO T 191-93 or T 238-86 or equivalent Standards.

3-1-E-1-2-1 Relative Density

The Relative Density as determined by the Relative Density Test shall be the standard to which the Field Density is referred for comparison for each type of cohesionless soil used in the Work.

3-1-E-1-2-2 Field Density

The Field Density shall be the density of the compacted fill determined by the Field Density Test.

3-1-E-1-2-3 Moisture Content

It is the percentage of moisture in the specimen based on oven dry mass of soil. The Moisture Content shall be the actual moisture content of the soil in the compacted fill at the time of compaction.

3-1-E-2 GENERAL PRESCRIPTION

The Contractor shall keep a constant control on the works by mean of tests, under the control of the Engineer. These tests shall be done in a laboratory site fit with equipment and staff personnel in order to accomplish the necessary tests specified below and before without delay. The list of equipment and staff will be submitted to the approval of the Engineer.

The Contractor can eventually subcontract a part of the test to specialized laboratories.

The Contractor has to submit to the approval of the Engineer, the laboratories as well as the list of test to subcontract.

The approval of the Engineer to undertake the tests in these laboratories does not relieve Contractor from his responsibility.

If the Engineer refuses to give his approval to accomplish certain tests outside the working field, the Contractor will have to undertake them in the field laboratory and equip it in consequence.

If during the works, the Engineer is not satisfied by the progress of the tests, as planned by the Contractor, he can ask the Contractor to modify his arrangements.

The necessary tests and samplings should be undertaken according to the recommendations of the French, American and British specifications or others agreed by the Engineer.

The Contractor must take into consideration all the necessary expenses for:

1. The samplings (undertaken by the field staff or by a specialized laboratory).
2. The transportation of the samplings from the field to the laboratory.
3. The conservation and treatment of the samples before the tests.
4. The tests and the result reports.

The number and types of tests listed below and above are provided for the control and good execution of the Contract. The Engineer could require other tests or increase the frequency of the tests and their number, if doubting their conformity with the specifications. The Contractor will have to undertake these supplementary tests on his expenses, without any claim or price revision.

3-1-E-3 <u>TESTS ON BORROWED MATERIALS</u>

All borrow material for the construction will be tested before use. The Contractor must submit to the Engineer as soon as possible and at the latest 15 days after the date of the notification of the contract, a detailed program and the time program of the tests.

3-1-E-3-1 TESTS AND SAMPLING RELATIVE TO THE FILTERS, DRAINS AND ROCKFILL MATERIALS

a. On quarry refer to related paragraph above.

b. During execution:

The necessary tests for the approval of the filters and drains materials are:

- Sieve analysis
- Specific gravity
- Proctor (When necessary)
- Compression tests on original rocky materials.

It is necessary to undertake a series of tests per 200 m^3 of filter, drain and rockfill and when requested by the Engineer.

3-1-E-3-2 *TESTS AND SAMPLING RELATIVE TO THE INITIAL BACKFILL, MAIN BACKFILL AND SELECTED FILL AND BACKFILL*

a. On quarry refer to related paragraph above.

b. During execution:

The necessary tests for the approval of these materials are:

- Sieve analysis
- Specific gravity
- Proctor.
- Plasticity Index (When necessary)

It is necessary to undertake a series of tests per 100 m^3 of initial backfill, Main backfill and Selected Fill and Backfill and when the request by the Engineer.

3-1-F WIRE ENCLOSED RIPRAP (GABIONS)

3-1-F-1 DESCRIPTION

This work shall consist of the installation of wire-enclosed riprap (gabions) in the locations designated on the plans.

3-1-F-2 MATERIALS

3-1-F-2-1 Aggregate

Aggregate for riprap shall be hard, durable, quarried or natural stone having an apparent specific gravity of not less than 2.4, and the absorption shall not exceed 5 percent. The stone shall be free of weak laminations and cleavages, and shall not disintegrate on exposure to water or weathering. The aggregate shall be round or angular and not less than 95 percent of the stone shall be retained on a screen having 3 inch square openings.

3-1-F-2-2 Wire-enclosed Riprap (Gabions)

Gabions shall be constructed of wire mesh. The wire mesh shall be made of galvanized steel wire having a minimum size of 0.120-inch diameter (U.S. Wire Gage No.11). The tensile strength of the wire shall be in the range of 60,000 to 85,000 psi, determined in accordance with ASTM A392. The minimum zinc coating of the wire shall be 0.80 oz./sq.ft. of uncoated wire surface as determined in accordance with ASTM A90.

Selvedge, tie, and connection wire shall meet the same strength and coating requirements specified above for wire used in the wire mesh.

3-1-F-2-3 Fabrication

The wire mesh shall be twisted to form hexagonal openings of uniform size. The maximum linear dimension of the mesh opening shall not exceed 4-1/2 inches and the area of the mesh opening shall not exceed 8 square inches. The mesh shall be fabricated in such a manner as to be non-raveling. Non-raveling is defined as the ability to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section is cut.

Gabions shall be fabricated so the sides, ends, lid, and diaphragms can be assembled at the construction site into rectangular baskets of the specified size. Gabions shall be of single unit construction-base, lid, ends, and sides shall be, either woven into a single unit or one edge of these members connected to the base section of the gabion in a manner that strength and flexibility at the point of connection is at least equal to that of the mesh.

Where the length of the gabion exceeds its horizontal width, the gabion shall be equally divided by diaphragms of the same mesh and gauge as the body of the gabions, into cells the length of which does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in a manner that no additional tying at this junction will be necessary.

All perimeter edges of the mesh forming the gabion shall be securely clip bound or selvedges so that the joints formed by tying the selvedges have at least the same strength as the body of the mesh.

Selvedge wire used through all the edges (perimeter wire) shall not be less than 0. 148-inch diameter (US. Wire Gage No. 9) and shall meet the same strength and coating specifications as the wire mesh.

Tie and connection wire shall be supplied in sufficient quantity to securely fasten all edges of the gabion and diaphragms and to provide for at least four cross connecting wires in each cell whose height is equal to the width and at least two cross connecting wires in each cell whose height is one-half the width of the gabion. Cross connecting wires will not be required when the height of the cell is one-third the width of the gabion. Tie and connection wire shall meet the same strength and coating specifications as the wire used in the mesh, except that it may be as much as two gages smaller.

In lieu of tie wire, two gauge galvanized hog rings may be used to connect adjacent baskets and to secure basket lids. Spacing of the hog rings shall not exceed 6 inches.

Vertical joints in the completed work shall be staggered at approximately 1/3 or 1/2 the length of the full baskets.

3-1-F-2-4 Installation

The gabions shall be placed on a smooth foundation. Final line and grade shall be approved by the Engineer.

Each gabion unit shall be assembled by binding together all vertical edges with wire ties on approximately 6 inch spacing or by a continuous piece of connecting wire stitched around the vertical edges with a coil about every 4 inches. Empty gabion units shall be set to line and grade as shown on the plans or as directed by the Engineer. Wire ties, hog rings, or connecting wire shall be used to join the units together in the same manner as described above for assembling. Internal tie wires shall be uniformly spaced and securely fastened in each cell of the structure.

A standard fence stretcher, chain fall, or iron rod may be used to stretch the wire baskets and hold alignment.

The gabions shall be filled with stone carefully placed by hand or machine to assure alignment and avoid bulges with a minimum of voids. Alternate placing of rock and connection wires shall be performed until the gabion is filled. After a gabion has been filled, the lid shall be bent over until it meets the sides and edges. The lid shall then be secured to the sides, ends and diaphragms with the wire ties or connecting wire in the manner described above for assembling.

Part III: Civil and Architectural Works

Part III-2: CONCRETE & MASONRY

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PART 3.2 - CIVIL & ARCHITECTURAL WORKS: CONCRETE & MASONRY

3-2-A CONCRETE

3-2-A-1 DESCRIPTION

Concrete shall consist of a mixture of cement, water and aggregates without air-entraining or water-reducing admixture unless specified otherwise.

Precautions are required to minimize the risk of alkali aggregate reaction. The Contractor shall demonstrate the adequacy of his proposals when he supplies details of his mix design. Unless otherwise agreed, when calculating the cementitious alkali contribution the maximum cement content in the schedule shall be used.

When calculating the alkali contribution of cement replacements Method A of Clause 3.8 of BS 5328 Part 4 shall be used.

3-2-A-2 CONCRETE MATERIALS

3-2-A-2-1 Cement

The types of cement to be used are in general: cement type P for ordinary concrete, cement type PA-S 32.5 for hydraulic concrete and sulfate resisting cement type P-RMS or P-RSS for concrete exposed to sulfate attack. The cement classes should be as defined by the Lebanese norms LIBNOR. However the Engineer has the right to impose the use of any type of cement in any type of concrete and in any structure according to the concrete exposure and other conditions.

3-2-A-2-1-1 Mixing of Cements

Only one (1) type or brand of cement shall be used in any one structural member. Mixing of types or brands will not be permitted.

3-2-A-2-1-2 Tests and Acceptance

Cement shall be tested for conformance with Lebanese Norms or AASHTO M 85 or British Standard 12 and shall have a compressive strength of standard cement mortar samples at twenty-eight (28) days of not less than two hundred fifty (250) kilograms per square centimeter. All cement is subject to the Engineer's approval and shipments of cement shall be accompanied by a manufacturer's Certificate of Guarantee and/or laboratory test certificate. The Engineer reserves the right to order a retest of the cement at any time. Approval of a cement quality shall not relieve the Contractor of the responsibility to fabricate concrete of the specified strength. The Contractor shall bear all costs in connection with the Certificates of Guarantee and laboratory tests. When tests of factory or field tests subsequent to the original approval tests show that the cement does not comply with the specifications, the entire consignment from which the sample was taken will be rejected and the Contractor shall immediately remove the rejected material from the site and replace it with cement, which meets the required specifications.

3-2-A-2-1-3 Storage

Storage capacity shall be sufficient to meet the requirements for 30 (thirty) working days unless in the opinion of the Engineer the supply from the manufacturer is so limited that more storage capacity is necessary. Cement shall be stored in moisture-proof storage sheds in such a manner that the oldest is used first. Neither stale, caked nor reclaimed or re-sacked cement shall be used. The Contractor shall not store cement in areas subject to flooding.

Cement remaining in bulk storage at the mill prior to shipment for more than six (6) months or cement stored in bags in local storage by the Contractor or a vendor for more than three (3) months after shipment from the mill, may be retested before use and will be rejected if it fails to meet any of the requirements of these specifications.

3-2-A-2-2 Aggregates

3-2-A-2-2-1 Fine Aggregates

Fine aggregates shall conform to AASHTO M6 and shall consist of natural sand of sand equivalent of more than 80%, or, if approved by the engineer, crushed rock having hard and durable particles having similar characteristics: 100% passing 5 mm sieve, 65% to 85 % passing 1.25mm and 5% to 10% passing 0.15 mm sieve. The percentage of particles passing the 0.08mm. sieve should be less than: 3% for natural sand and 5% for crushed sand. The fine aggregates shall not contain harmful materials such as iron pyrites, coal, mica, shale or similar laminated materials such as flat and elongated particles or any materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength, durability and texture of the concrete.

3-2-A-2-2-2 Coarse Aggregates

Coarse aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel, or crushed stone free from coating of clay or other deleterious substances. It shall not contain harmful or any other materials in such a form or in sufficient quantity as to adversely affect the strength and durability of the concrete. If necessary, coarse aggregate shall be washed to remove deleterious substances or for consistency of concrete color.

3-2-A-2-2-3 Combined Aggregates

Combined aggregates are composed of a mixture of coarse aggregates and fine aggregates. They shall be used only in proportions with the prior approval of the engineer. In no case shall materials passing No. 200 (0.075 mm) sieve exceed 3% by weight of the combined aggregates.

3-2-A-2-3 Water

All sources of water to be used with cement whether for mixing or curing of concrete, or compaction of backfill around the concrete structures, shall be approved by the Engineer. If at any time during construction, water from an approved source becomes unsatisfactory, the Contractor shall provide satisfactory water from other main sources.

Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt as determined by the Engineer. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of AASHTO T26 and BS 3148. If the specific conductance is less than 1500 micro ohms per centimeter the total solids contents requirement may be waived.

3-2-A-2-4 Admixture

Where directed by the Engineer, all the necessary additives shall be used (Air Entrained Agent, plasticizers, protection of concrete in contact with water from the evaporation of lime, waterproofing,...). In particular a retarding admixture set shall be used. The admixture proposed for use shall be approved by the Engineer before it is incorporated into the Work. The admixture shall be Type D as specified in AASHTO M 194.

3-2-A-3 ASSEMBLY AND HANDLING OF MATERIALS

3-2-A-3-1 Assembly of Aggregates

Aggregates shall be assembled in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient, non segregated materials, having proper and uniform moisture content to ensure continuous and uniform operation. Aggregates shall enter the mixer in a manner approved by the Engineer and in such a manner to ensure that no matter foreign to the concrete or matter capable of changing the desired proportions is included. In the event two (2) or more sizes or types of coarse or fine aggregates are used on the same project, only one (1) size or type of each aggregate may be used on one (1) continuous concrete pour.

3-2-A-3-2 Stockpiling of Aggregates

All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content, to provide uniform conditions for proportioning plant control and to aid in obtaining concrete that is uniform as to materials and moisture content.

The use of equipment or methods of handling aggregates which results in the degradation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles. All equipment used for handling aggregates shall be approved by the Engineer.

Stockpiling of aggregates shall be in the manner approved by the Engineer and in addition, every precaution shall be taken to prevent segregation. Segregation shall be prevented by making no layer higher than one and one-half (1.5) meters and if two (2) or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer.

Aggregates shall not be stockpiled against the supports of proportioning hoppers and weighing devices.

Aggregates shall be stockpiled and protected at locations which preclude contamination by brackish groundwater during periods of high water or contamination from other sources which might detrimentally affect the aggregates. Contaminated aggregates shall not be used in the concrete.

When required, the aggregate stockpiles shall be sprinkled with water, twelve (12) hours prior to use, to maintain a moisture content in the aggregate equivalent to the water absorption value of the aggregate as determined by AASHTO T 84 and AASHTO T 85.

3-2-A-3-3 Segregation

Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform and acceptable gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when ordered by the Engineer.

3-2-A-3-4 Transporting of Aggregates

If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being dumped.

3-2-A-3-5 Cement Storing And Stockpiling

Cement in storage or stockpiled on the site shall be protected from any damage by climatic conditions. Methods of storing or stockpiling shall be approved by the Engineer. Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within one and one-half (1-1/2) hours.

3-2-A-4 COMPOSITION OF CONCRETE

3-2-A-4-1 Requirements

The mix proportions shall be selected to ensure that the workability of the fresh concrete is suitable for the conditions of handling and placing, having regard to the structural element being constructed.

In the event of sulphate exposure precautions requiring lower cement content than those required for normal conditions the latter requirements shall prevail.

The maximum cement content in any mix shall not exceed 500 kg/m3 for normal structures and 450 kg/m3 for liquid retaining structures.

In all cases of mix proportioning, the added water shall be included with due allowance for the moisture contained in the aggregates and shall be the minimum consistent with the workability requirements.

3-2-A-4-1-1 Strength

The characteristic strength of concrete means that value of the 28 day below which 5% of all possible test results would be expected to fall.

3-2-A-4-2 Mix Proportions & Measurement for Proportioning Materials

The Contractor shall be responsible for the design of the concrete and shall consult with the Engineer as to mix proportions at least forty-five (45) days prior to beginning concrete work. The actual mix proportions of cement, aggregates and water shall be determined in accordance with BS5328 Parts 2, 3 and 4, by the Contractor under the supervision of the Engineer.

The Contractor shall, in the presence of the Engineer, prepare trial mixes for each class of concrete required for the project, made with the approved materials to be used in the work. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the cement content specified and meeting the plasticity requirements and one hundred fifteen (115) percent of the strength requirements specified for the designated classes of concrete. If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the proportions will be adjusted so as to require the least amount of cement which will produce concrete of the required plasticity and workability without exceeding such allowable water content. No additional payment will be made for increased quantity of cement. Test cylinders shall be made from the trial-mixes.

The Engineer will review the Contractor's trial-mixes and break the test cylinders at seven (7) and twenty-eight (28) days. The Engineer will then determine which of the trial-mixes shall be used. If none of the trial-mixes for a class of concrete meets the specifications, the Engineer will direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

The approval of the job-mix proportions by the Engineer or his assistance to the Contractor in establishing those proportions, in no way relieves the Contractor of the responsibility of producing concrete which meets the requirements specified in these specifications.

All costs connected with the preparation of trial-mixes and the design of the job-mixes shall be done by the Contractor, including all laboratory tests and the breaking of the test cylinders.

The limiting values which shall govern for each class of concrete are as follows:

- The cement content specified herein shall be determined from a yield test in accordance with AASHTO T 121.
- Concrete for Structures: Cement, water and aggregate sizes requirements for the various classes of structural concrete are specified in the following table:

Schedule for the specification requirements of designed mixes					
The mixes below shall be supplied as designed mixes in accordance with the relevant clauses of BS 5328: Parts 2, 3 and 4.					
1. Mix reference (Class of concrete)	A	B	C	D	E
2. Minimum Compressive Strength at 28 days (Kg/cm^2)	300	250	200	200	400
3. Nominal maximum size of aggregate, mm	20	20	40 or larger by approval	20	10
4. Types of aggregate:Coarse AASHTO FineAASHTO	M80 M6	M80 M6	M80 M6	M80 M6	M80 M6
5. Minimum cement content, kg/m^3	350	300	200	200	400
6. Maximum free water/cement ratio	0.55	0.55	0.60	0.60	0.55
7. Maximum cement content, kg/m3	375	350	250	250	450
Other Requirements					AEA

Note: AEA – Air Entrainment Agent

The minimum compression strength is the strength measured on test cylinders. The seven (7) day compressive strengths shall not be less than seventy-five (75) percent of the required twenty-eight (28) day strength.

The ultimate compressive strength of the concrete shall be determined on test specimens obtained and prepared in accordance with AASHTO T 23 and AASHTO T 126, except that only six (6) inches [one hundred fifty-two (152) millimeters] by twelve (12) inches [305 millimeters] cylinders shall be used for compression tests. The Contractor shall furnish single use cylinder molds conforming to AASHTO M 205, or when approved by the Engineer, reusable vertical molds made from heavy gauge metal.

3-2-A-4-2-1 Changes in Proportion

As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions from time to time if conditions warrant such changes to produce satisfactory results. Any such changes may be made within the limits of the specifications at no additional compensation to the Contractor.

3-2-A-4-2-2 Measurement for Proportioning Materials

3-2-A-4-2-2-1 Cement

Cement shall be measured by weight. The measurement shall be accurate to within two (2) percent throughout the range of use.

3-2-A-4-2-2-2 Water

The mixing water shall be measured by weight. The measurement shall be accurate to within one (1) percent throughout the range of use.

3-2-A-4-2-2-3 Aggregates

The aggregates shall be measured by weight. The measurement shall be accurate to within one-half (1/2) percent throughout the range of use.

3-2-A-4-3 Concrete

3-2-A-4-3-1 Porous Concrete

Porous concrete shall be composed of ordinary Portland cement and 37.5mm single size aggregate complying with B.S 882, 1201: Part 2.

The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.

The concrete shall be mixed by machine or by hand to a uniform color and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout.

The concrete shall be compacted by hand when total thickness does not exceed 40cm, otherwise it shall be compacted by rollers. The placement for roller compaction shall be in layers but shall not exceed 40cm in thickness per layer.

Permeability shall range between 1 x 10^{-2} and 1 x 10^{-3} meter/sec.

Compressive strength: 105 Kg/cm^2.

Contractor shall demonstrate the permeability of porous concrete in place by an effective field testing method that is approved by the Engineer. Contractor shall also install a laboratory on site for testing the permeability of concrete on samples before any placing of porous concrete. The permeability test method shall be approved by the Engineer.

3-2-A-4-3-2 Cyclopean Concrete

Cyclopean concrete shall consist of Class “C” concrete containing large embedded stones. The embedded rubble stones shall be of approved quality, sound and durable, and free from segregations, seams, cracks and other structural defects or imperfections tending to destroy its resistance to the weather. It shall be free from rounded, worn, or weathered surfaces. All weathered stone shall be rejected. The stone shall be kept free from dirt, oil, or any other injurious material which may prevent proper adhesion. The largest dimension of any rubble stone shall not exceed 20 centimeters. The distance between two adjacent rubble stones or between a rubble stone and the form shall not be less than 5 centimeters.

The stone shall be carefully placed-not dropped or cast-so as to avoid injury to the forms or to the partially set adjacent masonry. All stones shall be washed and saturated with water before placing. The total volume of the stone shall not be greater than one third of the total volume of the portion of the work in which it is placed.

3-2-B SPECIAL TYPES OF CONCRETE

3-2-B-1 AIR ENTRAINED CONCRETE

Concrete where specified shall include an approved air-entraining agent capable of producing a 5% air-entrainment with a tolerance of 0.5%.

The mix shall be purposely designed having regard for the nature of grading of the aggregates and air-entraining agent being used.

Preference shall be given to the use of air-entraining agents which can be administered in fixed calibrated amounts through a dependable mechanical dispenser or sachet and which are added to the mixing water.

Frequent air meter tests shall be carried out and the consistency of the air-entrainment maintained to the above tolerances by adjustments in the mix, as may be necessary.

3-2-B-2 CONCRETE IN BENCHING

Concreting for benching in manholes, pumping stations and works structures shall consist of class B concrete (Grade C25) concrete unless otherwise specified. It shall be placed with low workability to the approximate shape required and, while still green, shall be finished with not less than 20 mm of Grade C25 concrete to a steel trowel led finish and to the contours indicated on the Drawings.

3-2-B-3 READY MIX CONCRETE AND CENTRAL MIXED CONCRETE

3-2-B-3-1 Description

“Ready-Mixed Concrete” and “Central-Mixed Concrete” shall consist of a mixture of cement, water and aggregate, without air-entraining or water-reducing admixture. The terms ready-mixed or central-mixed concrete shall include transit-mixed concrete and all will be referred to hereinafter as ready-mixed concrete.

Ready-mixed concrete may be used in the construction of all work, when approved by the Engineer.

Ready-mixed concrete may be manufactured by previously approved commercial plants or by other approved plants furnished for the work.

Approval of any ready-mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling the materials, the production procedures, the transportations and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

Permission to use ready-mixed concrete from any previously approved plant may be rescinded at any time upon failure to comply with the requirements of the specifications.

Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

Mixed completely in a stationary central-mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (known as "Central-Mixed Concrete").

Mixed completely in a truck mixer at the batching plant or while in transit (known as transit-mixed concrete).

Mixed completely in a truck mixer at the point of use following the addition of mixing water (known as truck-mixed concrete).

A Computerised delivery note to be issued from the batching plant with each transit mixer. Copies of all delivery notes shall be submitted to the Engineer and shall include at least the following information:

1. Name of supplier, serial number of ticket and date.
2. Truck number.
3. Name of Contractor.
4. Name of contract and location of site.
5. Grade of concrete.
6. Specified workability.
7. Type and source of cement.
8. Source of aggregate.
9. Nominal maximum size of aggregate.
10. Time of loading at supplier’s works.
11. Quantity of concrete.
12. Arrival and departure times of truck.
13. Time of completion of discharge.
14. Extra water added with the approval of the Engineer.

3-2-B-3-2 Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of "Concrete section".

3-2-B-3-3 Equipment

3-2-B-3-3-1 General

Equipment shall be of the type and number as outlined in the Contractor's Program of Work, as approved by the Engineer.

3-2-B-3-3-2 Check Tests

The Engineer may, from time to time, make slump tests of individual samples of the concrete at approximately the beginning, the mid-point and end of discharging the load. If the slumps vary by more than the allowable tolerance as specified in the specifications, the mixer or agitator shall not be used unless the condition is corrected to the satisfaction of the Engineer. All mechanical details of the mixer or agitator such as water measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit and clearance of the drum shall be checked before further use of the unit will be permitted.

3-2-B-3-3-3 Inspection

Mixers and Agitators shall be examined periodically for changes in condition due to accumulation of hard concrete or mortar or to wear of blades. The mixers shall be cleaned at intervals approved by the Engineer. The pick-up and throw-over blades in the drum or drums shall be repaired or replaced when they are worn down twenty (20) millimeters or more. The Contractor shall:

Have available at the job site a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth, or provide permanent marks on the blades to show points of twenty (20) millimeter wear from new conditions. Drilled holes of six (6) millimeter diameter near each end and at midpoint of each blade are recommended.

Truck mixers and agitators of the revolving-drum type must be equipped with a hatch in the periphery of the drum shell of such design as to permit access to the inside of the drum for inspection, cleaning and repair of the drum and blades.

3-2-B-3-3-4 Composition of concrete

The composition of ready-mixed concrete shall conform to the requirements of "Concrete section".

3-2-C REINFORCING STEEL

3-2-C-1 DESCRIPTION

This Work shall consist of furnishing and placing reinforcing steel in accordance with the specifications and in conformity with the plans.

3-2-C-2 MATERIALS

3-2-C-2-1 Reinforcing Bars

3-2-C-2-1-1 Type

All reinforcing bars shall be of a deformed type in accordance with AASHTO M 31, except that plain bars may be used where specifically indicated on the drawings.

3-2-C-2-1-2 Quality

All steel reinforcement shall be of type FE E40 (min Fy=4,000k/cm2) (deformed), except for ties and stirrups which shall be of type FE E24 (min Fy=2,400k/cm2) (plain). The type of steel to be used shall be as mentioned on drawings.

3-2-C-2-2 Certification and Identification

3-2-C-2-2-1 Certification

Three (3) copies of a mill test report shall be furnished to the Engineer for each lot of billet-steel reinforcement bars proposed for use on the project. The mill test report shall be sworn to for the manufacturer of the steel by a person having legal authority to bind the manufacturer and shall show the following information:

The process or processes used in the manufacture of the steel from which the bars were rolled.

Identification of each heat of open-hearth, basic oxygen or electric furnace and/or each lot of acid Bessemer steel from which the bars are rolled.

Chemical and physical properties of the heat from which the bars were rolled.

3-2-C-2-2-2 Identification

The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator before being offered for inspection. The tag shall show the manufacturer's test number and lot number or other designation that will identify the material with the certificate issued for that lot of steel.

The fabricator shall furnish three (3) copies of a certification which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

3-2-C-2-2-3 Inspection and Sampling

The sampling and testing of reinforcement bars may be made at the source of supply when the quantity to be shipped or other conditions warrant such inspection. Bars not inspected before shipment will be inspected after arrival on the work. Test samples obtained at the destination of the steel shall be duplicate bars not less than one (1) meter in length and bars from which such samples are taken shall be replaced at the Contractor's expense. The Engineer reserves the right to resample and inspect all reinforcement steel upon its arrival at the work site.

All reinforcement bars shall be free from detrimental dirt, mill scale, rust, paint, grease, oil or other foreign substance, fins or tears. The Contractor will not be required to remove slight rusting which discolors the metal, but he shall remove all loose mill scale and scales rust. Brushing to clean blue metal will not be required. There shall be no evidence of piping or visual flaw in the test specimen or on the sheared ends of the bars.

Supports. Metal supports, approved by the Engineer, shall be provided and used to retain the reinforcement at proper distances from the forms. Supports under horizontal bars slabs shall be spaced at not more than eighty (80) diameters of the bar. All reinforcement shall be so rigidly supported and fastened that displacement will not occur during construction. Reinforcing steel shall be inspected in place and must be approved by the Engineer before any concrete is deposited.

3-2-C-2-2-4 Welded Wire Fabric

To be used for the reinforcement of concrete shall conform to the following requirements:

3-2-C-2-2-5 Dimensions

Welded steel wire fabric shall conform to the size and dimensions shown on the plans.

3-2-C-2-2-6 Properties

Wire fabric furnished shall conform to the requirements for "Welded Steel Wire Fabric for Concrete Reinforcement," AASHTO M 55.

3-2-C-3 <u>CONSTRUCTION REQUIREMENTS</u>

3-2-C-3-1 <u>Protection and Storage</u>

Reinforcing steel shall be protected at all times from damage. Reinforcing steel shall be stored above the ground on platforms, skids, or other supports. It shall be stored in such a manner and adequately marked to facilitate inspection and checking. When placed in the Work, the reinforcing steel shall be free from dirt, detrimental scale, paint, oil or other foreign substance.

3-2-C-3-2 Cutting and Bending

All cutting and bending of reinforcement bars shall be done by competent workmen and with equipment approved by the Engineer. Unless shown otherwise on the plans or unless written approval is obtained from the Engineer, all reinforcement bars shall be cut and bent in an on-site fabrication shop.

Bent bar reinforcement shall be cold bent to the shapes shown on the plans, and unless otherwise provided on the plans or by written authorization of the Engineer, bends shall conform to the following requirements:

D = 6d for five (5) millimeter through twenty-two (22) millimeter bar sizes

D = 8d for twenty-four (24) millimeter through twenty-eight (28) millimeter bar sizes

D = 10d for thirty (30) millimeter and over bar sizes

Where D = Minimum pin diameter around which a bar may be bent d = Bar diameter

3-2-C-3-3 Placing, Supporting and Fastening

All reinforcing steel shall be accurately placed and, during the placing of concrete, firmly held by approved supports in the position shown on the plans. Reinforcing bars shall be securely fastened together. Reinforcement placed in any member shall be inspected and approved before any concrete is placed. Laying or driving bars into the concrete after placement will not be permitted. All horizontal reinforcement shall be supported on metal supports or spacers as approved by the Engineer. The use of small stones or wood blocks for supporting reinforcement will not be permitted. The reinforcement shall be held securely in place at the proper position and spacing as indicated on the plans by the use of wire ties at bar intersections and tying to the supports and spacers. The adequacy of the supports and ties to secure the reinforcement properly shall be subject to the approval of the Engineer.

3-2-C-3-4 Splicing

Splices shall be avoided at points of maximum stress. They shall, where possible, be staggered, and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress. Unless otherwise shown on the plans, bars in the bottom of beams and girders, and in walls, columns, and haunches shall be lapped a minimum of twenty (20) diameters and bars near the top of beams and girders having more than thirty (30) centimeters of concrete under. The bars shall be lapped a minimum of thirty-five (35) diameters to make the splice. In no case shall bars be lapped less than thirty (30) centimeters.

3-2-C-3-5 Couplers

Couplers for reinforcement shall be either Standard Swaged Splices or Type II Alpha Couplers manufactured by CCL Systems Limited, Cabco House, Ewell Road, Surbiton, Surrey England, KT9 7AH, UK, or similar approved. Where bars of different diameters are to be joined a CCL Reducer Sleeve or similar shall be used.

Couplers shall be suitable for the type and size of reinforcing bars and shall be capable of developing 115% of the characteristic strength of the smaller of the reinforcing bars being joined in both tension and compression. Couplers shall be installed in accordance with the manufacturer's recommendations. Square twisted reinforcing bars shall not be used with couplers.

3-2-C-3-6 Reinforcing Bar Trusses

Bar trusses shall be placed, supported and secured in proper position before beginning the placement of the concrete. Unless the bar trusses are so designed and fabricated with outstanding legs to be in contact with the forms they shall be supported on metal supports and spacers. If the weight of the trusses causes the supporting legs of trusses to indent into the forms, bar supports shall be used as auxiliary support for the truss legs.

3-2-C-3-7 Mesh Reinforcement for Structures

Mesh reinforcement shall be of the sizes and spacing of bars and sheets as shown on the plans. The sheets of mesh shall be lapped as indicated on the plans. The method of placing the mesh and securing it in proper position shall be approved by the Engineer.

3-2-D CONCRETE STRUCTURE CONSTRUCTION

3-2-D-1 DESCRIPTION

This Work shall consist of furnishing and placing Portland cement concrete for structures and incidental construction in accordance with the specifications and in conformity with the lines, grades and dimensions as shown on the plans or established by the Engineer.

3-2-D-2 CONSTRUCTION REQUIREMENTS

3-2-D-2-1 Falsework

Detailed plans for falsework and centering shall be prepared by the Contractor and submitted to the Engineer for approval. The plans must be approved by the Engineer before the Work is started.

Falsework and centering shall be designed and constructed to provide the necessary rigidity to support all loads placed upon it without appreciable settlement or deformation. Falsework columns shall be supported on wood or metal bases when it cannot be founded on rock, shale, or thick deposits of other compact material in their natural bed. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to approval of the Engineer.

Falsework and centering shall be designed and constructed to support the total anticipated loads with a deflection not to exceed two one-thousandths (0.002) of the falsework span. The Contractor shall submit calculations to support this requirement for all spans over three (3) meters and other spans if requested by the Engineer.

All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing and the splices shall be scabbed in a manner approved by the Engineer.

The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete and shall provide a competent observer to observe and correct the settlement.

In designing forms and centering, concrete shall be regarded as a liquid. In computing vertical loads, a weight of twenty-four hundred (2,400) kilograms per cubic meter shall be assumed, and not less than thirteen hundred and sixty (1,360) kilograms per cubic meter shall be assumed in computing horizontal pressure.

The Engineer may refuse permission to proceed with other phases of the work if he deems the falsework unsafe or inadequate to support properly the loads to which it will be subjected.

The review or approval of falsework plans by the Engineer or permission to proceed with the work shall not relieve the Contractor of the responsibility for successful erection or satisfactory results.

3-2-D-2-2 Formwork

Forms shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incidental to the construction operations, including vibration. Forms shall be constructed and maintained so as to prevent the opening of joints due to shrinkage of the lumber. They shall be designed to permit easy removal without injury to the concrete. Form lining such as smooth, exterior grade plywood or other approved material shall be used for all formed surfaces. The Contractor shall submit samples, specifications and other pertinent information thereon to the Engineer and secure his prior written permission to use the form lining.

Form lining material shall not bulge, warp or blister, nor shall it stain the concrete. Form lining shall be used in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same general direction (all horizontal or all vertical). Thin metal form lining will not be permitted. Undressed lumber of uniform thickness may be used for backing for form lining. Wooden ply form, of adequate thickness, which is properly supported, may be used in lieu of the lined forms specified herein.

Forms shall be maintained after erection to eliminate warping and shrinkage. They shall be checked for dimensions and condition immediately prior to the placement of concrete. The Engineer may at any time require the revision or reconstruction of forms and may refuse permission to place concrete within the forms until they are satisfactorily constructed. If, at any period of the work during or after placing the concrete, the forms show signs of sagging or bulging, the concrete shall be removed to the extent directed by the Engineer, the forms brought to the proper position and new concrete placed. No allowance will be made to the Contractor for such extra work.

Metal forms may be used and are subject to the same requirements and approvals specified for wood forms. The specifications for wood forms with respect to design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse and oiling, also apply to metal forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins of other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease or other foreign matter. Under such circumstances the continuance of use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels with metal frames and wood or combination facing which leave permanent impressions or ridges will not be approved.

The inside of all forms shall be oiled with a light, clear, paraffin base oil that will not discolor or otherwise injure the surface of the concrete.

The oiling shall be done where possible after the completion of the forms and prior to placement of reinforcement.

Unless otherwise directed, the exterior side of all forms shall be painted with an approved, good quality high gloss white oil base enamel prior to placing concrete. When complete coverage is not obtained with one (1) coat, the Engineer will order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

Shrinkage cracks shall be closed by moistening the forms with water prior to concrete placement.

Forms that are to be reused shall be thoroughly cleaned and roiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber will be condemned by the Engineer, and shall be removed from the site.

The width and thickness of the lumber, the size and spacing of studs and wales shall be determined with due regard to the nature of the work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

Form bolts, rods or ties shall be made of steel. They shall be the type which permits the major part of the tie to remain permanently in the structure. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. The ties shall be removed on all exposed surfaces. The ties shall be removed to a depth of at least fifteen (15) millimeters below the concrete surface. Wire ties shall be cut back at least six (6) millimeters below the concrete surface. The cavities shall be filled with cement mortar composed of one (1) part by volume of cement and two (2) parts of sand and the surface left sound, smooth, even and uniform in color. Sufficient white Portland cement shall be mixed with the cement in the mortar, so when dry, the color will match the surrounding concrete. Form ties will not be permitted through forms for handrail. Pipe spreaders shall not be used unless they can be removed as the concrete is placed, as determined by the Engineer. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts that extend through the forms for any concrete section will not be permitted except in unusual situations and then only with the approval of the Engineer.

Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the forms immediately before placing the concrete.

Unless provided otherwise on the plans or directed by the Engineer, all exposed edges shall be beveled by using dressed, mill-cut, triangular molding, having twenty (20) millimeter sides.

All curved surfaces shall be formed with approved plywood or steel.

When instructed by the Engineer the Contractor shall submit formwork drawings and calculations to the Engineer in advance of the concreting.

Formwork shall be of such accuracy, strength and rigidity as to carry the weight and pressure from the concrete to be placed on or against it. together with all constructional wind or other loads likely to be imparted to it, without producing deformation of the finished concrete in excess of the specified tolerances.

Formwork shall be sufficiently tight without plugging to prevent loss of grout during the vibration of the concrete. When required by the Engineer joints between formwork facing boards shall be sealed with foam rubber sealing strips or other approved material.

Faces of formwork shall be clean, free from projecting nails adhering grout and other imperfections or defects. Formwork shall be treated with approved mould oil before positioning. The contractor shall prevent reinforcement or steelwork from being contaminated by the oil.

Formwork, which as a result of prolonged use or general deterioration or is otherwise in the opinion of the Engineer unsuitable shall not be used.

Through-bolts or ties will not be permitted in liquid-retaining structures. The Contractor shall use only such bolts or ties as are capable of being removed in whole or in part so that no part remaining embedded in the concrete shall be nearer the surface of the concrete than the specified thickness of cover to the reinforcement.

Beam soffits shall be erected with an upward camber of 5 mm for each 3 meters of span.

Top formwork shall be counterweighted or otherwise anchored against flotation.

Boxes for forming holes shall be constructed so as to be easily removable without damaging the concrete during removal. They shall be properly vented to permit the escape of entrapped air, and shall be capable of being sealed, subsequently to prevent the loss of grout.

On all external arises of the concrete 25 mm chamfers shall be formed.

Any openings provided in formwork for inspection and for cleaning-out shall be formed so that they can conveniently close before the placing of concrete.

All props shall be supported on adequate sole plates and shall not bear directly on or against concrete. They shall be capable of being released gently and without shock to the formwork. No appliance for supporting the formwork shall be built into the permanent structure without the Engineer's prior approval. Props for upper level support shall be placed directly over those at lower levels. Props shall only bear upon work sufficiently mature to carry the load.

Formwork shall be such as to allow for its removal without damaging the concrete and in the case of suspended floors for the removal of the beam sides and slab soffits without disturbing the beam-bottom boards and their props.

Before concreting, the areas which are intended to receive the concrete shall be cleaned by jetting with compressed air and all water and extraneous material removed.

Where timber is used for formwork it shall be properly cured free from warp straight, clean and free from loose knots.

Where metal forms are used for formwork they shall be of the type strengthened by intermediate ribs or cross bracing.

Moving formwork man be used if the Engineer sees it appropriate.

3-2-D-2-2-1 Sawn Formwork

Sawn formwork shall be properly designed and constructed of closely-jointed Sawn boards sheet metal or other approved material. It shall produce a standard of finish free from substantial voids, hones-combing or other large blemishes. There shall be no loss of grout.

3-2-D-2-2-2 Wrought Formwork

All exposed concrete shall be formed by wrought formwork.

Wrought formwork shall produce a high standard of finish with a hard smooth surface with true clean arises. Only minor surface blemishes shall be permitted. The face in contact with the concrete shall consist of framed plywood or metal panels or other approved material. Joints between boards and/or panels shall be arranged in a uniform pattern.

3-2-D-2-3 *Tolerances*

Unless otherwise indicated on the Drawings, the tolerances of the finished concrete with respect to the dimensions shown on the Drawings shall not exceed the limits set out in the following Table. Formwork shall be constructed to ensure completed work within the following tolerance limits:

Departure from established alignment	0.5 cm
Departure from established grade	0.5 cm
Variations from plumb or specified batter in lines and surfaces of columns, piers and walls	0.5 cm in 3 meters, if exposed 0.5 cm in 3 meters, if backfilled
Variations from level or indicated grade in slabs, beams, etc.	0.5 cm in 3 meters, if exposed 0.5 cm in 3 meters, if backfilled
Variation in cross-sectional dimensions of columns, piers, slabs, walls, beams	-0.5cm, + 0.5cm
Variations in slab thickness	-0.5cm, + 0.5cm
Footings : Plan Dimensions	-0.5cm, + 0.5cm
Eccentricity	2 percent of footing width, not exceeding 5 cm
Reduction in thickness	2 percent of specified thickness

3-2-D-2-4 *Removal Of Forms And Falsework*

To facilitate finishing, forms on handrails, ornamental work and other vertical surfaces that require a rubbed finish shall be removed as soon as the concrete has hardened sufficiently that it will not be injured as determined by the Engineer. In determining the time for the removal of forms, consideration shall be given to the location and character of the structure, weather and other conditions influencing the setting of the concrete.

If removal of forms or falsework is not controlled by beams or cylinders cured with and under the same conditions as the structure, the following periods, exclusive of periods when the temperature is less than four (4) degrees C, for releasing of forms and supports shall be used as a minimum:

- Arch Center 14 days
- Centering Under Beams 14 days
- Supports Under Flat Slabs 14 days
- Floor Slabs 14 days
- Vertical Wall Surfaces 24 hours
- Columns 24 hours

- Sides of Beams 24 hours
- Top Slabs R.C., Box Culverts 14 days

If high early strength cement is used, the time limits may be decreased as determined by the Engineer.

When form and falsework removal is controlled by beams or cylinders cured with, and under the same conditions as the structure, the release of falsework in load or movement carrying members shall not occur until the concrete has reached its specified strength. In no case shall release be permitted in less than seven (7) days.

Methods of form removal likely to cause overstressing of the concrete shall not be used. In general, the forms shall be removed from the bottom upwards. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own weight.

In general, arch centering shall be struck and the arch made self-supporting before the railing or coping is placed. For filled spandrel arches, such portions of the spandrel walls shall be left for construction subsequent to the striking of centers, as may be necessary to avoid jamming of the expansion joints. In arch structures of two or more spans, the sequence of striking centers shall be as specified or approved.

Immediately after the removal of the forms, all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of one (1) part by volume of Portland cement and two (2) parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar, so that when dry, the color will match the surrounding concrete. Patches shall be moistened prior to mortaring to obtain good bond with the concrete. When directed by the Engineer, the Contractor shall at his own expense, substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgment of the Engineer, rock pockets are of such extent or character as to materially affect the strength of the structure or to endanger the life of the steel reinforcement, he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.

3-2-D-2-5 <u>Mixing and Transporting</u>

3-2-D-2-5-1 Mixing

Concrete shall be mixed in quantities required for immediate use. Concrete shall not be used which has developed initial set or is not in place one-half (1/2) hour after the water has been added for non-agitated concrete or if agitated, the concrete must be in place one and one-half (1-1/2) hours after the water has been added. Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

The Concrete may be mixed at the site of the work, in a central-mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are in the drum. Ready-mixed concrete shall be mixed and delivered in accordance with requirements of Section 3.3 "Ready-Mixed Concrete and Central-Mixed Concrete".

When mixed at the site of the Work or in a central-mixing plant, the mixing time shall not be less than fifty (50) seconds nor more than ninety (90) seconds. Four (4) seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The mixer shall be operated at a drum speed as shown on the manufacturer's nameplate on the approved mixer. Any concrete which, in the opinion of the Engineer, is mixed more or less than the specified time shall be discarded and disposed of by the Contractor at his expense. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic meters, as shown on the manufacturer's standard rating plate on the mixer; except that an overload up to ten (10) percent above the mixer's nominal capacity may be permitted when approved by the Engineer, provided concrete test data for strength, segregation and uniform consistency are satisfactory, and provided no spillage of concrete takes place.

The batch shall be so charged into the drum that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first fifteen (15) seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

3-2-D-2-5-2 Central-Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

3-2-D-2-5-2-1 Cement

Means provided for storing cement shall be as approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved cement before starting to manufacture concrete for the work.

3-2-D-2-5-2-2 Aggregate

Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregates shall come from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved aggregate before starting to manufacture concrete for the work.

3-2-D-2-5-2-3 Consistency

The Contractor shall be responsible for producing a concrete that will be of the proper consistency when delivered to the job site.

3-2-D-2-5-2-4 Hauling

Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators, non-agitating trucks having special bodies or other approved containers.

3-2-D-2-5-2-5 Time of Haul

The time elapsing from the time water is added to the mix until the concrete is deposited in place at the site of the work shall not exceed thirty (30) minutes when the concrete is hauled in non-agitating trucks, nor more than ninety (90) minutes when hauled in truck mixers or truck agitators.

3-2-D-2-5-2-6 Delivery

The Contractor when supplying concrete from a central plant shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be such as to provide for the proper handling, placing and finishing of the concrete. The method of delivery and handling the concrete shall be such as will facilitate placing with a minimum of re-handling and without damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved by the Engineer. The Engineer may delay or suspend the mixing and placing of concrete at any site for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

3-2-D-2-5-3 Transporting

Concrete shall be transported to the place of final deposit by approved means.

Barrows, spades and other equipment used in the process of transporting concrete shall be thoroughly cleaned before each day's work or after a long interruption and they shall be free from hardened concrete.

Concrete shall be transported as soon as possible after mixing. by methods which will prevent the segregation, loss or contamination of the ingredients.

Bridging for traffic over reinforcement shall be provided so that the reinforcement is not distorted, damaged or displaced.

Where approval is obtained for concrete to be conveyed by chutes. These shall have a slope (not exceeding 1 vertical to ' horizontal) such as to ensure a continuous flow of concrete. Additional water shall not be introduced to assist the flow. If deposition is to be intermittent the chute shall be arranged to discharge into a storage hopper. In no case a clear fall of more than 1 m be permitted at the discharge end of the chute.

Where approval is obtained for pumping the concrete, the pump manufacturer's recommendations as approved by the Engineer shall be followed. The pumps used shall be of adequate capacity and power to ensure delivery of a continuous supply.

Wherever transport of concrete is interrupted for any period of over half an hour the chutes, pumps, pipes and any other means of distribution shall be thoroughly flushed out and cleaned. These shall also be flushed out immediately prior to resumption of concreting and shall be kept free from hardened concrete. All washing water used shall be discharged outside the formwork and clear of any freshly placed concrete.

3-2-D-2-6 Handling, Placing, Concrete and Compacting

Concrete shall not be placed until forms and reinforcing steel have been checked and approved by the Engineer. The forms shall be clean and free of all debris before concrete is placed. The method and sequence of placing concrete shall be approved by the Engineer.

The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and to bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets, or honeycomb.

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point in the forms and then run or worked along the forms, thus causing segregation of the materials.

The concrete shall be deposited in the forms in horizontal layers and the work shall be carried on rapidly and continuously between predetermined planes agreed upon by the Contractor and the Engineer. Keyways shall be formed between layers.

Where steep slopes are required for placing concrete with chutes, the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of movement. Chutes and the use of chutes must be approved by the Engineer.

All chutes, troughs and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

Concrete shall not be dropped in the forms a distance of more than one and one-half (1-1/2) meters, unless confined by approved closed chutes or pipes and care shall be taken to fill each part of the form by depositing the concrete as near final position as possible. The coarse aggregate shall be worked back from the forms and worked around the reinforcement without displacing the bars. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of projecting reinforcement.

Unless otherwise directed, the concrete shall be compacted with suitable mechanical vibrators operating within the concrete. When required, vibrating shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

Vibrators shall be of an approved type and design.

Vibrators shall be so manipulated as to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. Vibrators shall not be used as a means to cause concrete to flow or run into position in lieu of placing. The vibration at any point shall be of sufficient duration to accomplish compaction, but shall not be prolonged to the point where segregation occurs.

Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement factor of the class of concrete being deposited in water shall be increased ten (10) percent without further compensation and the slump shall be approximately fifteen (15) centimeters. When depositing in water is allowed, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, by means of a tremie, bottom-dumping bucket, or other approved method that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. No concrete shall be placed in running water, and forms which are not reasonably watertight, shall not be used for holding concrete deposited under water.

Pumping will not be permitted from the inside of the foundation forms while concrete is being placed. If necessary to prevent flooding, a seal of concrete shall be placed through a closed chute or tremie and allowed to set.

When casings are used in drilled shafts, the casing shall be smooth and well-oiled and shall extend sufficiently above the grade of the finish shaft to provide excess concrete to be placed for the anticipated slump due to the casing removal. When the casing is to be pulled, the concrete placed in the casing shall have such a slump and be of such workability that a minimum amount of vibrating will be required.

No concrete work shall be stopped or temporarily discontinued within forty-five (45) centimeters of the top of any finished surface, unless such work is finished with a coping having a thickness less than forty-five (45) centimeters in which case the joint shall be made at the under edge of the coping.

Concrete in simple slab spans shall be placed in one (1) continuous operation for each span, unless otherwise indicated on the plans or approved by the Engineer. For continuous slab spans, concrete shall be placed in the sequence shown on the plans, except that with the approval of the Engineer, consecutive placement may be combined in a single placing operation to cover from one end of a unit to the other.

Concrete in simple or continuous T-beam spans may be placed in one (1) continuous operation, or when shown on the plans or approved by the Engineer, may be placed in two (2) separate operations; first, to the top of the girder stems, and second, to completion.

The concrete in arch rings shall be placed in such a manner as to load the centering uniformly.

Arch rings, preferably, shall be cast in transverse sections of such size that each section can be cast in a continuous operation. The arrangement of the sections and the sequence of placing shall be as approved by the Engineer, and shall be such as to avoid the creation of initial stress in the reinforcement. The sections shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings may be cast in a single continuous operation.

Before concrete floors are placed on steel spans, the centering under the spans shall be released and the spans swung free on their supports unless otherwise indicated on the plans. The operation of placing the concrete in any floor slab shall be continuous until complete, except where joints are provided on the plans or authorized by the Engineer. When a special sequence or method of concrete placing operations is indicated on the plans, or designated by the Engineer, this sequence or method shall be followed.

The method used for transporting concrete batches, materials, or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentration of materials will be prohibited on floor slabs until the concrete has attained its design strength.

Where concrete is to be placed in lifts greater than 2.5 m high it shall be placed by suitable tremie pipes. Shutters for lift heights greater than 3 m shall incorporate windows in suitable places to allow placing and vibration.

3-2-D-2-7 *Hot Weather Concreting (for temperatures above 20°C)*

Concreting shall not be permitted if its temperature at placing is in excess of 38°C. In order to maintain the temperature of the concrete below this value the following precautions shall be taken wholly or in part as instructed by the Engineer:

All aggregate stockpiles, water lines and tanks as well as the mixer shall be protected from the direct rays of the sun.

Coarse aggregate shall be cooled by constant watering where possible.

Mixing water shall be cooled by the addition of ice to the storage tanks where necessary.

Rapid-hardening cement shall not be used.

Where the above precautions are inadequate concreting shall be carried out during the cooler parts of the day or during the night as may be directed by the Engineer.

When the air temperature is above 20°C loss of mixing water by evaporation shall be considered in arriving at the amount of water to be added to the mix. To maintain the water/cement ratio within permissible limits an approved water-reducing agent shall be included in the mix.

The maximum water/cement ratios may be increased with the Engineer's permission by 0.05 (or 2.5 litres/50 kg of cement) during mixing, but on no account shall water be added to concrete once it has left the mixer.

In order to reduce premature drying of the concrete during transporting and placing, all chutes, formwork and reinforcement shall be cooled by watering when possible, or shall otherwise be protected from the direct rays of the sun.

As soon as possible after concreting, the formwork shall be stripped and the surface of the concrete shall be treated.

Where drying winds are encountered, wind shields shall be positioned as necessary to protect exposed surfaces of the curing concrete.

3-2-D-2-8 *Wet Weather Concreting*

Concreting during periods of constant rain shall not be permitted unless aggregate stockpiles, mixers and transporting equipment, and the areas to be concreted are adequately covered.

During showery weather, the Contractor shall ensure that work can be concluded at short notice by the provision of stop ends. On no account shall work be terminated before each section, between one stop end and another is complete. Adequate covering shall be provided to protect newly placed concrete from the rain.

3-2-D-2-9 *Cold Weather and Night Concreting*

No concrete shall be mixed, placed or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated and such night work is approved by the Engineer.

Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches five (5) degrees C. When directed by the Engineer, the Contractor shall enclose the structure in such a way that the concrete and air within the enclosures can be kept above fifteen (15) degrees C for a period of seven (7) days after placing the concrete. The Contractor shall supply such heating apparatus as stoves, salamanders or steam equipment and the necessary fuel. When dry heat is used, means of maintaining atmospheric moisture shall be provided.

When directed by the Engineer, all aggregates or mixing water or both, shall be heated to a temperature of at least ten (10) degrees C, but nor more than twenty-one (21) degrees C the aggregates may be heated by steam or dry heat.

The temperature of the concrete shall be not less than fifteen (15) degrees C at the time of placing in the forms. In case of extremely low temperature, the Engineer may, at his discretion, raise the minimum limiting temperature for work, aggregates and mixed concrete. Salt, chemicals or other material shall not be used to prevent freezing.

3-2-D-2-10 Joints

3-2-D-2-10-1 Construction Joints

Wherever the work of placing concrete is delayed until the concrete shall have taken its initial set, the point of stopping shall be deemed a construction joint. So far, the location of construction joints shall be as shown on the plans, but if not shown on the plans, they shall be planned in advance and the placing of concrete carried continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and in general be located at points of minimum shear.

Where dowels, reinforcing bars or other adequate ties are not required by the plans, keys shall be made by embedding water-soaked beveled timbers in soft concrete. The key shall be sized as shown on the details, or as directed by the Engineer, which shall be removed when the concrete has set. In resuming the Work the surface of the concrete previously placed shall be thoroughly cleaned of dirt, scum, laitance or other soft material with stiff wire brushes and if deemed necessary by the Engineer, shall be roughened with a steel tool. The surface shall then be thoroughly washed with clean water and painted with a thick coat of neat cement mortar, after which the concreting may proceed.

3-2-D-2-10-2 Expansion Joints

Expansion joints shall be constructed at the locations of the materials and to the dimensions shown on the plans.

Preformed expansion joint filler for concrete, bituminous type conforming to AASHTO M33 shall be placed in the joint. The joint filler shall cover the full depth minus the thickness required to place the bituminous putty at each joint. One face of the filler shall be held rigidly in place against the face of the concrete previously cast, while fresh concrete is placed against other face of the filler.

3-2-D-2-10-3 Contraction Joints

Contraction joints shall be constructed at the locations, of the materials and to the dimensions shown on the Plans or as directed by the Engineer.

3-2-D-2-10-4 Cold Joints

When the continuous placement of concrete in any structural member is interrupted or delayed, for any reason, for a period long enough for the previously partially placed concrete to take its initial set, the Engineer shall declare such joint a cold joint and the Contractor shall immediately remove the previously partially placed concrete from the forms. No extra payment will be made for the initial placement or the removal of concrete which is wasted because of a cold joint. The Engineer may suspend all or any part of subsequent concrete Work until he deems the Contractor has corrected the cause of the cold joint occurrence.

3-2-D-2-11 Holes, Cavities and Fixing

Holes shall be accurately marked and boxed-out for before concreting operations commence. No holes shall be formed after the concrete has set. Where bars, if placed to specified spacing would foul holes of size less than 250 mm x 250 mm. The full length of the bar shall be moved to one side unless otherwise indicated on the Drawings. For holes exceeding 250 mm x 250 mm, the bars shall be cut on site and lapped with additional equivalent bars.

Wherever possible, the Contractor shall build in all pipe work, Ironwork, and steelwork which passes through walls and floors. The pipe work, ironwork, and steelwork shall first be thoroughly cleaned and freed from any deleterious matter. Every care shall be taken to ensure that it is thoroughly encased in concrete.

Bolts, hooks and other fixings shall be embedded in concrete, or holes shall be drilled and fitted with threaded expanding anchors to receive the bolts. The Contractor shall ensure that bolts, hooks and fixings are accurately positioned Holding down bolts for machinery shall be set to template.

Where brick or stonework is to form a facing to the concrete or where the end of a brick or stone wall butts against a concrete face, galvanized metal ties of approved manufacture to BS 1243 shall be incorporated.

3-2-D-2-12 Finishing

All top surfaces, such as the top of retaining walls, curbs, abutments, rails, etc., shall be treated by tamping and floating with a wooden float in such a manner as to flush the mortar to the surface and provide a uniform surface, free from pits or porous places. The surface thus obtained shall be troweled to produce a smooth surface and brushed lightly with a damp brush to remove the glazed surface.

Unless otherwise shown on the Drawings, all exposed concrete surfaces shall be smooth finish with epoxy paint and shall be free from honey-combing, fins, projections and air-holes. After removal of the forms, the Contractor, at his own expense, shall make good faulty surfaces by filling them with cement and sand (1/2 by vol.) mortar and rubbing them with a fine carborundum stone.

Immediately after the curing period, the Contractor shall repair all minor shrinkage cracks identified by the Engineer. Repairs shall be made as directed by the Engineer using an approved water resistant, high modulus low viscosity epoxy.

Unless otherwise provided on the plans, all true and even surfaces, obtained by use of a form lining, which are of a uniform color, free from stone pockets, honeycomb, excessive depressions or projections beyond the surface shall be considered as acceptable surfaces and a rubbed surface finish will not be required, except as follows:

The above provisions for surface finish shall not preclude requiring the use of a dry carborundum brick for straightening molding lines, removing fins, etc., or requiring a rubbed surface finish on all portions of the structure which do not present an acceptable surface even though a form lining is used.

3-2-D-2-13 Curing and Protection

All concrete shall be cured for a period of time required to obtain the full specified strength, but not less than seven (7) consecutive days beginning immediately after placement. Curing shall be done according to one of the following pertaining methods:

3-2-D-2-13-1 Water Curing

All surfaces, unless sealed by metal forms or submerged, shall be water cured including those surfaces which have previously had liquid curing membrane applied. For construction joints or other surfaces where no liquid membrane is specified, water curing shall begin within one (1) hour of placement. Where liquid membrane is placed, water curing shall begin within four (4) hours of placement.

For structure decks and slabs, the Contractor shall provide sufficient water and equipment to keep the surface of the concrete continually damp until the membrane curing is applied. The water shall be applied with a nozzle that so atomizes the flow that a mist and not a spray is formed. The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface.

Surfaces to be water cured shall be covered with wet sand, cotton mats, double thickness burlap or other equivalent absorbent material. The absorbent material shall cover the concrete surface completely. The material shall be completely saturated with water and kept continuously saturated throughout the curing period. After initial saturation, all surfaces shall be covered with polyethylene sheeting meeting requirements of ASTM C-171 or other approved impervious material. The sheeting shall be weighted or secured to prevent moisture loss. However, the surfaces of the concrete shall be readily available for inspection of the Engineer. The sheeting shall be in good repair. Sheeting that contains holes or is otherwise damaged shall be rejected by the Engineer. The Contractor shall be responsible for thoroughly inspecting and monitoring the concrete surfaces throughout the curing period. Additional water shall be added to any areas which are not still saturated. Inspections by the Contractor shall be conducted at least twice per day for the duration of the curing period and more often if ordered by the Engineer. The Engineer shall be advised of the inspection schedule and may accompany the workman to verify the acceptability of curing.

3-2-D-2-13-2 Membrane Curing

Except for construction joints and surfaces sealed by metal forms, liquid membrane shall be used as follows:

On wood formed vertical surfaces, forms shall be stripped as soon as practical and liquid curing membrane applied immediately except that those areas being rubbed or finished during the curing period shall be kept wet until finishing is complete when clear liquid curing membrane shall be uniformly applied.

On metal formed surfaces, with or without wood lining, liquid curing membrane shall be applied if the Contractor elects to strip the forms within the curing period.

The curing membrane used shall be in accordance with the requirements specified for curing membrane material, AASHTO M 148 Type 1-D. The curing membrane shall be applied in two (2) applications. The rate of each application of curing compound will be -as prescribed by the Engineer with a spreading rate per application of one (1) liter of liquid per five (5) square meters of concrete surface. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and the curing compound applied just as the surface film of water disappears. During curing operations, any unsprayed surfaces shall be kept wet with water. Any curing membrane material on construction joints and/or reinforcing steel shall be completely removed before the following concrete pour.

Hand operated spraying equipment shall be capable of supplying a constant and uniform pressure to provide uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.

No traffic of any kind will be permitted on the curing membrane until the curing period is completed, unless the Engineer permits the placement of concrete in adjacent sections in which case the damaged areas shall be immediately repaired as directed.

3-2-D-2-13-3 Cold Weather-Curing

When concrete is being placed in cold weather, it shall be placed in accordance with the requirements provided in section “Cold weather and night concreting”.

When concrete is being placed and the air temperature may be expected to drop below five (5) degrees C, during the curing period, the Contractor shall provide suitable measures such as straw, additional burlap, or other suitable blanketing materials and/or housing and artificial heat curing to maintain the concrete temperature between ten (10) degrees C and thirty-two (32) degrees C as measured on the surface of the concrete. The surface of the concrete shall be kept moist by the use of an approved moisture barrier such as wet burlap or polyethylene sheeting. The moisture barrier shall be maintained in intimate contact with the concrete during the entire curing period. After the completion of the required curing period, the Contractor shall remove the curing and protection in such a manner that rapid cooling of the concrete will be prevented.

When concrete is placed in cofferdams and subsequently flooded with ground water, the above curing conditions may be waived providing the surface of the water is not permitted to freeze.

3-2-D-2-13-4 Steam Curing

Precast concrete members shall be cured for not less than seven (7) days by water or by steam curing, at the option of the Contractor. Steam curing for precast members shall conform to the following provisions:

After placement of the concrete, members shall be held for a minimum four (4) hours presteaming period. If the ambient air temperature is below ten (10) degrees Celsius, steam shall be applied during the presteaming period to hold the air surrounding the member at a temperature between ten (10) degrees and thirty-two (32) degrees Celsius.

To prevent moisture loss on exposed surfaces during the presteaming period, members shall be covered as soon as possible after casting or the exposed surfaces shall be kept wet by fog spray or wet blankets.

Enclosures for steam curing shall allow free circulation of steam about the member and shall be constructed to contain the live steam with a minimum moisture loss. The use of tarpaulins or similar flexible covers will be permitted, provided they are kept in good repair and secured in such a manner to prevent the loss of steam and moisture.

Steam at the jets shall be low pressure and in a saturated condition. Steam jets shall not impinge directly on the concrete, test cylinders, or forms. During application of the steam, the temperature rise within the enclosure shall not exceed five (5) degrees C per hour. The curing temperature throughout the enclosure shall not exceed sixty-five (65) degrees C and shall be maintained at a constant level for a sufficient time necessary to develop the required transfer strength. Control cylinders shall be covered to prevent moisture loss and shall be placed in a location where temperature is representative of the average temperature of the enclosure.

Temperature recording devices that will provide an accurate continuous permanent record of the curing temperature shall be provided. A minimum of one temperature recording device per sixty (60) meters of continuous bed length will be required for checking temperature.

Members in pretension beds shall be detensioned immediately after the termination of steam curing while the concrete and forms are still warm or the temperature under the enclosure shall be maintained over fifteen (15) degrees C until the stress is transferred to the concrete.

Curing of precast concrete will be considered complete after termination of the steam curing cycle.

All newly placed concrete for precast concrete piles, both conventionally reinforced and prestressed, shall be cured by steam as provided above except that piles with a designation of "Corrosion Resistant" shall be kept continuously wet for their entire length for a period of not less than seven (7) days including the holding and steam curing periods.

3-2-D-2-14 Making Good

The cement mortar used in filling recesses in the concrete formed by hobbins in connection with formwork shall contain an approved expanding admixture.

3-2-E PRECAST CONCRETE

3-2-E-1 PRECAST CONCRETE

This section includes the work for furnishing and installing precast concrete structures. Reinforcement shall be in accordance with detail shown on plans.

Precast concrete units shall be manufactured with air-entrained concrete. The maximum size of aggregate shall be 1.9 cm. The minimum cement content shall be 350 kilograms of cement per cubic meter of concrete. The final finish surface shall be smooth. Precast units shall be true to line, plane and dimensions in accordance with the following special requirements:

3-2-E-1-1 Plant Requirements

The units shall be manufactured in an approved area or enclosed building under the Engineer's control and inspection with guaranteed provision to meet the requirements for curing and protecting the concrete as specified.

3-2-E-1-2 Forms

Metal of tight rigid construction, true to shape, and with smooth finish shall be used.

The forms shall be oiled in any approved manner. Re-use of old, worn, or misshapen forms, will not be allowed.

3-2-E-1-3 Vibration

Vibrators shall be provided and used as directed by the Engineer. Prolonged vibration shall be avoided in order to prevent surface finish susceptible to crazing. Units showing surface checking or crazing will be rejected.

3-2-E-1-4 Protection And Curing

The units shall be cured either by steam or water for a sufficient length of time for the concrete to obtain the minimum compressive strength.

3-2-E-1-4-1 Steam Curing

Two to four hours after the concrete has been placed and attained the initial set, the first application of steam shall be made. Forms shall be removed after the units have been steam cured for 24 hours.

The steam shall be at 100% relative humidity to provide moisture for proper hydration of cement. The steam shall be directly applied onto the concrete. During application of steam the ambient temperature shall increase at the rate not to exceed 4.4° C per hour until a minimum temperature of 54° C is reached.

When discontinuing the steam application, the ambient temperature shall be decreased at the rate of 4.4° C per hour until a temperature of -6.7° C above the atmospheric temperature has been attained. The concrete shall not be exposed to temperature below freezing for a minimum of 6 days after casting.

3-2-E-1-4-2 Water Curing

The units may be water cured with water, saturated material or other acceptable or approved methods that will keep the units moist for a period of 5 days. Under no condition will the use of curing compounds be permitted.

Concrete delivered in outside temperature lower than 4.4° C shall arrive at work having a temperature not less than 15.6° C nor greater than 32.2° C. Water and aggregates shall be heated if necessary but the water shall not be heated above 60° C. The use of direct heating torch in mixer shall not be approved.

3-2-E-1-4-2-1 Testing and Sampling

Representative test specimens of the concrete shall be taken by the Engineer. No precast units will be shipped to the project until the test specimen cured show a compressive strength equal or superior to the concrete type required strength.

3-2-E-1-4-2-2 Inspection

All precast units shall be subject to inspection at the point of manufacture and any units showing defects or damage before the completion of the project shall be removed and replaced at the expense of the Contractor.

3-2-F SAMPLING & TESTING

3-2-F-1 GENERAL REQUIREMENTS

3-2-F-1-1 Sampling & Testing

All concrete, aggregate, cement and water shall be sampled and tested during construction as frequently as deemed necessary by the Engineer. All test samples shall be supplied by the Contractor at his expense. Samples shall be obtained in accordance with AASHTO T 23, T 141, T 2, T 127 and T 26. All costs connected with manufacturer's Certificates of Guarantee, laboratory analysis and all subsequent testing for material acceptance shall be borne by the Contractor

The Contractor shall provide on the Site equipment, staff and labor for carrying out the sampling and testing and he shall carry out any or all of these tests at such times and with such frequency as may be requested by the Engineer.

All equipment shall be calibrated and checked from time to time as the Engineer may require.

The Contractor shall provide all samples required by the Engineer. Those samples to be tested in an off site laboratory shall be carefully forwarded by the Contractor to an approved laboratory. Results of laboratory and site tests shall be kept on site and copies of all test reports shall be forwarded in duplicate to the Engineer.

Frequency of tests and the number of samples required will be governed by the results of the previous tests the quality of the materials revealed during the tests and the uniformity of that quality. Should it become evident that the quality of concrete is deteriorating the Engineer may require additional samples to be taken and test cylinders to be made and tested to determine the cause.

3-2-F-1-2 Quality Control

Compliance with the specified characteristic strength shall be based on tests on cylinders at an age of 28 days. For major structures the frequency of sampling shall be initially three samples taken each day for five days of concreting and thereafter at a frequency of one sample per $10m^3$ of concrete but not less than one sample for each day concreting.

For minor structures the frequency of sampling shall be one sample per 20 m^3 but not less than one sample for each day concreting. For mass concrete works and concrete works at pipeline appurtenances sampling shall be at on average of one sample per 50 m^3.

A minimum of 3 test cylindres shall be made from each sample.

Where materials are of an unfamiliar grading or type, or where directed by the Engineer compression tests shall be carried out at 7 days and adjustments made in advance of the main control methods outlined above.

Cylinders test results will be examined individually in 10 consecutive sets of four and the standard deviation and mean strength of each set calculated. The concrete mix proportions will only be acceptable if all of the following requirements are complied with :

i. Not more than two results in 40 are less than the characteristic crushing strength.

ii. No value of the average for any set of four results is less than the characteristic strength plus one-half of the design margin.

iii. When 40 results have been obtained and the mean strength and standard deviation are calculated, the mean strength minus 1.64 times the standard deviation shall be greater than the characteristic strength.

Where the results do not conform to the above requirements the following action shall be taken :

Adjustments to the mix shall be made to obtain the strength required.

In the case where any result is less than 80° of the characteristic strength, the structural implications shall be considered and action taken as ordered by the Engineer.

For those Prescribed Mixes required to be tested, requirements (i) and (ii) only still be applicable.

3-2-F-1-3 Concrete Compression Tests

The Engineer will make and cure the cylinders from concrete as mixed for the work, which will be tested in accordance with AASHTO T 22 after seven (7) and twenty-eight (28) days. Test specimens shall be made and cured in accordance with AASHTO T 23. These specimens will be the basis for acceptance of the concrete in the structure.

They also provide means for checking the adequacy for laboratory mixture proportions for strength. If the average of the strength tests of the specimens falls below the minimum allowable compressive strength at seven (7) or twenty-eight (28) days, the concrete mix shall be redesigned. In the determination of the average compressive strength of the specimens, no cylinder specimen shall have a strength less than eighty-five (85) percent of the allowable strength.

The Engineer will take a total of four (4) cylinders from each day's run of concrete at each structure site. Two (2) cylinders will be for the seven (7) day test and two (2) cylinders for the twenty-eight (28) day test. All four (4) specimens are to be taken from the same batch. The Contractor shall give the Engineer full cooperation and, when requested by the Engineer, labor assistance in preparing the cylinders. When directed by the Engineer, the Contractor shall transport the cylinders from the structure site to the laboratory.

The Engineer may make additional test cylinders to ascertain the effectiveness of the methods by which the structure is being cured and also to determine when the structure may be placed in service. These cylinders shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders from all damage.

The Contractor shall take every precaution to prevent injury to the test cylinders during handling, transporting and storing. He will be held solely responsible for any test failures caused by improper handling and transportation, or any other cause which may be detrimental to the test cylinder.

In order that the test cylinders may be transported from field to laboratory undamaged, the Contractor shall provide a minimum of two (2) approved metal boxes. [One (1) for the Contractor's use and one (1) for the Engineer's use.] Boxes shall be of such size to receive a minimum of six *(6)* test cylinders and leave space for sawdust packing around all surfaces of the cylinders. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

When test cylinders fail to meet minimum strength requirements, the Engineer may require core samples to be taken to determine the acceptability of such structures. The contractor shall, at his own expense, furnish all equipment required for such core samples.

3-2-F-1-4 Loading Tests

The Engineer may permit that a loading test be made on the works or any part thereof for one or more of the following reasons:

Failure of "Site Cylinders" to attain the strength requirements.

Premature removal of formwork.

Overloading of structure during construction.

Improper compaction and/or curing of concrete.

Any other circumstances attributable to alleged negligence on the part of the Contractor, which, in the opinion of the Engineer, may result in a structure being of less than the required strength.

If the results of the test are not satisfactory, the Engineer will direct that the part of the work concerned be taken down or removed and reconstructed to comply with the Specification, or that such other remedial measures as he may think fit be taken to make the work acceptable.

The Engineer may instruct the Contractor to take out cylindrical core specimens from the structures concerned and have them tested. The cutting equipment and the method of doing the work shall be to the Engineer's approval. The specimens shall be dealt with in accordance with BS 1881. Prior to testing, the specimens shall be available for examination by the Engineer.

3-2-G WATER RETAINING STRUCTURES-SPECIAL CLAUSES

The design, detailing materials and workmanship shall comply with the requirements of BS 8007.

3-2-G-1 MAKING GOOD

The cement mortar used in filling recesses in the concrete formed by bobbins in connection with formwork shall contain an approved expanding admixture.

3-2-G-2 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 Engineer.

3-2-G-3 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 Engineer. In certain situations the Engineer 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.

3-2-G-4 WATERPROOF COATINGS

Waterproof coatings shall be applied only where shown in the drawings or where instructed by the Engineer.

Coating shall be chloride free and suitable for contact with potable water (in case of potable water retaining structure) and sulfate resistant in case of wastewater retaining structure.

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 by the use of compatible sealants as recommended by the manufacturer.

The system shall be cured for a period of not less than 7 days.

3-2-G-5 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, and to other locations as indicated on the Drawings.

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.

3-2-H DEMOLITION & REMOVAL

3-2-H-1 DESCRIPTION

This work shall consist of the complete demolition and removal of a whole, not partial, structural concrete and miscellaneous concrete structures as indicated on the plans or as ordered by the Engineer. All demolition material shall be removed from the work site to approved dumping site.

3-2-H-2 DEMOLITION DETAILS

Care shall be exercised in the demolition so as not to damage neighboring structures designated to remain in place.

3-2-H-3 STRUCTURAL CONCRETE REMOVAL

3-2-H-3-1 Description

This work shall consist of the removal of a section or segment from a structural concrete elements and other concrete removal indicated on the Plans or ordered by the Engineer. All removed material shall be removed from the work site to approved dumping sites.

3-2-H-3-1-1 Removal Of Structural Concrete

All concrete shall be removed to a pay line shown on the Plans or to sound surface as determined by the Engineer. Reinforcing bars and miscellaneous material shall be removed as part of this work unless the Plans or the Engineer specifically direct otherwise. Surfaces from which structural concrete has been removed shall be cleaned, except that surfaces not designated to come in contact with new concrete placements need not be cleaned.

Chipping hammers shall weigh no more than 20 kg with the bit and muffler removed. The hammer shall deliver no more than 1600 blows per minute. The Contractor shall provide the Engineer information from the hammer manufacturer that these requirements are not exceeded. The air pressure used to power the hammer shall not exceed 759 KPa measured at the air compressor. An air pressure gauge in proper working condition shall be provided. Only sharp chisel point bits shall be used. All bits determined by the Engineer to be dull shall be sharpened or replaced. If the Engineer determines that the Contractor's operations are resulting in damage to concrete that is to remain, the Contractor shall make immediate corrections. These corrections shall include the use of a lighter chipping hammer if so ordered by the Engineer.

3-2-H-3-1-2 Materials

Materials used in this work shall conform to the following requirements:

Sandblasting Sand: No. 40 Boiler Slag Grit or

No. 2 Sandblast Sand

3-2-H-3-1-3 Construction Details

General care shall be exercised in removing concrete so as not to damage material designated to remain in place. Reinforcement designated to remain in place shall be cleaned in a manner satisfactory to the Engineer. Saw cutting of concrete shall be performed only where indicated on the Plans or where ordered by the Engineer.

All concrete surfaces which require cleaning, after the concrete removal has been performed, shall be thoroughly sandblast cleaned, or abraded by other mechanical means satisfactory to the Engineer. After blast cleaning, the surface shall be air blown or vacuum cleaned. Air-blowing may be used on vertical or overhead surfaces. Vacuum cleaning will be required for all other surfaces.

For any structural concrete removal item, where a hammer size limitation is specified on the Plans or in the Specifications, the Engineer may order the Contractor to use a lighter hammer than that specified, if, in his opinion, the hammer being used is destroying concrete that should remain.

3-2-I CONCRETE GROUTING MATERIAL

3-2-I-1 SCOPE

This specification covers a grouting material for use in grouting anchor bolts, dowels and other miscellaneous items in concrete.

3-2-I-2 GENERAL

The material shall be a non-metallic, non-shrink grout which, when mixed with water, will harden rapidly to produce a permanent anchoring bond. It shall contain no metals nor rust or corrosion promoting agents. The color shall be light gray matching approximately the color of hardened concrete.

3-2-I-3 MATERIAL REQUIREMENTS

The material when prepared in accordance with the manufacturer's instructions shall be of a tolerable consistency. It shall also have the following properties:

The material shall exhibit no shrinkage on setting but may exhibit slight expansion of no more than 0.40%.

Compressive strength - Two-inch cubes of this material when cured as shown shall have the following minimum compressive strengths:

Cure	Strength
24 hour air cure @ 23° C	27.6 MPa/Min.
7 day air cure @ 23° C	41.4 MPa/Min.
7 day air, 10 day water submersion	41.4 MPa/Min.
7 day air, 24 hour, 10% NaCl solution submersion, 25 cycles freeze-thaw	41.4 MPa/Min.

The material shall have a minimum initial set of 30 minutes.

Pull-out strength - T15 concrete reinforcement bar grouted 15 cm deep in 2.2 cm hole in saturated surface dried concrete shall have a pull-out strength of 4500 kg.

The material shall contain not more than 0.05% chlorides or 5% sulfates. The material shall withstand 25 cycles of freeze-thaw (10% NaCl) with a maximum loss of 4%.

3-2-J REHABILITATION OF RESERVOIRS

3-2-J-1 DESCRIPTION

The following specifications include procedures, materials and workmanship for the rehabilitation of existing reservoirs. Rehabilitation works will include, but will not be limited to structural repairs and general building rehabilitation. Repair works may include the following:

- Repairs to cracked concrete.
- Sealing joints and cracks to prevent leakage.
- Sealing of pipe penetrations including replacement of some pipes.
- Repairs to damaged concrete.
- Repairs and replacement of corroded reinforcement.
- Removal and replacement of plaster and rendering.
- Major structural demolition and reconstruction.
- Internal and external tanking and waterproofing.
- Earthworks.
- Replacement of miscellaneous metalwork, access ladder covers and the like.
- Painting.
- Cleaning and general restoration.

The procedure for the rehabilitation of reservoirs shall be for the Contractor to first undertake an initial Site Survey. This survey will determine the general nature and condition of the site, the structure, pipework and ancillaries. Based upon the results of this survey, the Engineer together with the Contractor shall plan and undertake a detailed structural inspection/survey. This detailed survey will identify the extent and nature of any defects which in the opinion of the Engineer needs to be rehabilitated or repaired. The Engineer will instruct the Contractor as to the extent and method of rehabilitation or repair to be implemented. In the case of major defects, the Engineer may instruct the demolition and reconstruction of the structure either in whole or in part.

Only structural repairs are defined beneath for reservoirs.

3-2-J-2 SITE SURVEY

The Contractor shall record the existing conditions of the site, the structure and its associated equipment and shall produce dimensioned drawings of the structure comprising plans and sections at a scale of not less than 1:100 and dimensioned plans and layouts of any existing mechanical and ancillaries.

The drawings and condition survey shall be supported by photographs and shall be submitted to the Engineer for approval within 10 days of the survey. The cost of this work is considered to be included in the unit rates of the bill of quantities.

3-2-J-3 STRUCTURAL SURVEY

The Engineer together with the Contractor's engineer accompanied by adequate support staff shall inspect the structure to assess its condition and determine the scope of the rehabilitation work. The survey shall include a cover meter survey and rebound hammer survey of concrete surfaces.

Structural surveys may need to be undertaken in stages involving a number of visits by the Engineer and Contractor. The scope of work may be amended by the Engineer, as necessary, to incorporate the findings of the surveys.

To facilitate the structural surveys it may be necessary to remove existing plastering and rendering, clean the structure, excavate to expose buried surfaces, provide temporary accesses and scaffolding, and carry out water tightness testing or other preparatory work. The preparatory work to be undertaken will be instructed by the Engineer after receipt from the site survey. Further instructions may be issued by the Engineer during the course of the detailed survey and the rehabilitation works. The cost of this work is considered to be included in the unit rates of the bill of quantities.

3-2-J-3-1 Cover Meter Survey

Cover meter surveys shall be carried out using normal methods and equipment. On plane members the direction of reinforcement with least cover shall be determined. The cover meter head shall he moved across the surface of the concrete along a line in a direction perpendicular to the direction of reinforcement with least cover and with the head oriented in the direction which enables the cover to that reinforcement to be measured. The lines along which the cover meter head is moved shall be approximately 500 mm apart. The cost of this work is considered to be included in the unit rates of the bill of quantities.

3-2-J-3-2 Rebound Hammer Survey

Rebound hammer for testing the hardness of concrete shall be carried out in accordance with International codes and standards as instructed by the Engineer. The cost of this work is considered to be included in the unit rates of the bill of quantities.

3-2-J-4 ACCESS

The contractor shall provide suitable and safe means of gaining access to all repair areas to enable the works to be carried out and the Engineer to carry out surveys inspections.

3-2-J-5 CONTRACTOR'S METHOD STATEMENT

Prior to commencing rehabilitation the contractor shall submit for approval a detailed method statement which shall include.

- A program detailing the proposed sequence and duration of each item of work.

- Details of any necessary disruption to the operation of the works and the contractor's proposed methods of providing any temporary service.
- Details of all detailed method statements.
- Details of all materials to be used in the rehabilitation works together with all necessary technical documents, catalogues and samples.
- Descriptions of any items including pipework, mechanical and miscellaneous work related to rehabilitation including proposed schedule of design, procurement and delivery.

The cost of the preparation of the method statement for reservoirs rehabilitation should be considered to be included in the unit rates of the bill of quantities.

3-2-J-6 CONCRETE REMOVAL

3-2-J-6-1 General

Where existing concrete is to cut out it shall be removed over the areas defined by the Engineer. The contractor shall ensure that the cutting out is done in such a manner so as not to cause permanent damage to the surrounding structure.

Where practicable, concrete shall be removed by disc cutting, grinding or similar cutting methods and not by percussive tools.

Where percussive methods are approved by the Engineer, the size and power of tool shall be the minimum appropriate.

Before removing any concrete the Contractor shall provide and erect any temporary propping necessary to ensure the safety of the structure.

The Contractor shall be liable for making good of his own expense any damage arising from cutting out.

Where concrete is to be removed the surface of the concrete over the area to be removed, shall be cut by a grid of straight lines using a disc cutter or similar and the concrete removed by chiseling or by percussive tools.

3-2-J-6-2 Removal of Unsound Concrete

1. Removal for concrete replacement. The minimum depth of removal shall be the greater of the following :
    a. A depth no less than 1cm and not greater than the distance from the rearmost point of exposed reinforcement to sound concrete.
    b. The depth necessary to reach sound concrete.

Should the removal depth exceed 15 cm, the Project manager may order supplementary anchoring as part of the replacement procedure. The sides of the cavity shall be made at a slight angle, so that the width of the base of the cavity is greater than the opening at the surface, thereby providing a key.

2. Removal for patching material replacement. Feather edges shall not be permitted. The minimum patch depth shall be 1 cm as measured from the theoretical plane of the original concrete surface.

3-2-J-6-3 Corroding Reinforcement

Where the reinforcement bars are corroded, concrete shall be removed to a depth of 25mm behind and along the actively corroding bars until a continuous length of 50 mm of bar which is free from active corrosion is exposed.

The Contractor may be directed by the Engineer to supplement or replace the existing bars with new bars. Bars to be replaced shall be cut out and not removed by burning.

Replacement reinforcement shall be adequately fixed and tied in position such that it will not be displaced during the subsequent reinstatement works.

Where corroding reinforcing bars are to be retained they shall be brushed and cleaned by grit blasting or other method approved by the Engineer and submitted by the Contractor. Cleaning shall be carried out in such a way to include the hidden faces at the backs of bars and at the intersection of bars. Abrasives shall be new, clean and dry and of a grade suitable for the preparation of steel to the qualification required above. The exposed reinforcement shall be thoroughly washed down with clean water.

3-2-J-6-4 Surface Cleaning

Cleaning of structures shall be undertaken to remove all dirt or other contaminants, previous coatings, paint, moss, plant growth and the like, as directed by the Engineer. Cleaning shall be by methods that cause no damage to the existing structure. The Engineer may instruct a change in the method if the method adopted causes damage to the surface or is otherwise unsuitable or ineffective.

Where instructed by the Engineer cleaning shall be by:

a. Grit blasting (wet, dry or vacuum blasting).

b. High pressure water jetting, steam cleaning employing wax free detergents together with power scrubbing as necessary.

Before cleaning begins, the contractor shall remove all surface attachments from the areas to be cleaned or from positions that obstruct access. Unless otherwise directed. All inserts and fixings which have been cast in or mortared into pockets or otherwise attached to the concrete shall be protected or removed from the area to be cleaned.

Before cleaning commences, trials shall be carried out on areas at typical locations to the approval of the Engineer.

3-2-J-6-5 Reinforcement Protective Treatment

Where directed by the Engineer reinforcement shall be coated with a polymer modified cement based primer or slurry coat prior to reinstatement of the concrete. All exposed surfaces of the bars shall be coated with the primer within 3 hours of cleaning. Any reinforcement remaining uncoated at the end of a 3 hours period shall be recleaned.

3-2-J-7 CONCRETE REPAIR METHODS

Defective concrete shall be cut out and reinstated by either a proprietary repair method or in the case of large volumes, by recasting with new concrete. Any defective or corroded reinforcement will either be cleaned and protected by a corrosion protection system or replaced.

Concrete repair methods shall include, but shall not be limited to, the following:

- Hand application of resin based mortars
- Hand application of cementitious mortars.
- Sprayed concrete and mortar
- Recasting with concrete

The Contractor will determine and submit to the Engineer the extent of the concrete to be removed and will select the appropriate repair method and material of repair depending upon the nature and extent of the defect. Repair methods and materials of repair shall be submitted to the Engineer's approval.

In general hand applied resin based mortars and cementitious mortars will be used for patch repairs to areas of less then 0.5 m² and depths less then 100 mm. Re-casting into formwork will be used for the reinstatement of large volumes and sprayed concrete (Gunite) will be used to cover large areas.

3-2-J-8 REINSTATEMENT OF CONCRETE

3-2-J-8-1 General

Prior to placing repair materials in any section of the works, all profile guides, formwork and reinforcement shall be fully fixed and cleaned over the entire area of the proposed repair. All dust, debris and loose material shall be removed from the area of the repair.

Plant and tools used for mixing, transportation and spraying of repair materials shall be kept clean and free from accumulated deposits of repair material.

Repair materials shall be mixed and applied in accordance with the manufacturer's recommendations as approved by the Engineer. The entire contents of a pack (or any other type of container) shall be mixed at one time.

Transportation of the repair materials to the point of application shall be such as to prevent contamination, segregation or loss of fine constituent materials.

Repair materials shall be placed in position in as short time as possible after mixing and within times stated in the manufacturer s recommendations. The repair material shall be placed in layers not exceeding those recommended by the manufacturer and approved by the Engineer.

Repairs shall not proceed if the air temperature or concrete substrate temperature is 5°C or less, or such higher temperature as may be recommended by the manufacturer and shall cease if the air temperatures falls below this minimum.

Repair may proceed at low temperatures if specific planned and approved procedures are implemented. These may include:

a. Provision of heated tenting which envelopes the repair area and produces an environment with a sustainable air temperature in excess of the minimum.

b. Where approved by the manufacturer warming materials and the substrate to a temperature above 5°C. The method of warming shall be such that the materials are not damaged and are not caused to dry out in the case of cement based repair materials.

c. Insulating the completed or partially completed repairs in accordance with good practice for winter concreting.

In general the concrete reinstatement patching shall be done as follows:

1- Horizontal or essentially horizontal locations. Concrete or approved patching material shall be used. Class A concrete shall be placed only at locations where removal depths average out greater than 8 cm. Patching material shall be placed only at locations where removal depths average out less than 8 cm. Average depths shall be determined by a measurement procedure acceptable to the Engineer.

2- Vertical or essentially vertical locations. Concrete or approved patching material shall be used. Concrete shall be restricted to the depth limitations noted for horizontal locations. Average depths shall be determined by a measurement procedure acceptable to the Engineer.

3- Overhead. Approved patching material shall be used. Lift thicknesses shall not exceed 2 cm, unless formwork or anchoring devices are employed.

3-2-J-8-2 Materials

Where the repair system comprises two or more materials the Contractor shall ensure that the repair materials are compatible and shall submit to the Engineer certificates provided by the manufacture confirming that the proposed repair materials are compatible.

Where possible repair materials, other than replacement concrete, shall be pre-batched.

All materials shall be mixed, applied and cured in accordance with the manufacturer's recommendations as approved by the Engineer or as otherwise instructed by the Engineer.

3-2-J-8-3 Formwork

Formwork necessary to reform arises, profiles, rebates, soffits, and the like shall be so constructed that it remains true to line and level under the loads and pressure imposed by the repair materials.

Formwork shall be struck without causing damage to the repair materials, and the contractor shall be responsible for determining the age at which the repair material attains a sufficient strength to support its self weight and any other loads which may be imposed thereon.

All profiled guides and formwork shall be coated and/or adequately treated such that they do not absorb water from the repair mortar and do not discolor/contaminate the repair mortar or surrounding concrete.

3-2-J-8-4 Epoxy Mortar

3-2-J-8-4-1 Description

Epoxy mortar is a blend of high strength aggregates bonded together with epoxy resin, designed for speedy and permanent repairs, to concrete. The mortar shall provide shrinkage-free hardening and abrasion and impact-resistance. The mixed material is applied to a suitably prepared and primed surface. It is supplied as a three pack material in pre-weighed quantities ready for on site mixing and use.

3-2-J-8-4-2 Preparation Of Concrete Surface

The surface to be prepared will be sandblasted after which it will be thoroughly cleaned and dried prior to epoxy bonding course.

All grease, chemical contamination, dust, cement, laitance, and loose concrete must be removed by scrabbling or light bush hammering to provide a sound substratum.

3-2-J-8-4-3 Priming Surfaces

Surfaces to be repaired shall be primed with an epoxy primer. The epoxy mortar shall be applied when the primer starts to gel but is still tacky, normally between 30 minutes and one hour. If the concrete has absorbed the primer, or the primer has dried, a second primer coat should be applied.

3-2-J-8-4-4 Technical Properties

The contractor shall submit catalogues from manufacturers for approval of the Engineer. It shall conform to the following properties:

	NORMAL TYPE	L.P. TYPE
Compressive strength	70-80N/mm^2	50-60N/mm^2
Flexural Strength	20-25N/mm^2	15-20N/mm^2
Bond Strength to concrete	2-3N/ mm^2	2-3N/mm^2
Young's Modulus	27.000N/mm^2	27.000N/mm^2
Mixing Ratio	1 part epoxy to 3 parts silica sand	

where: Normal type : Have storage conditions above 0°C, max. 25°C.

L.P. type : Have storage conditions above 10°C, max. 35°C.

3-2-J-8-4-5 Application

The mixed material should be applied to the surface with a steel trowel, ensuring that it is pressed firmly into cracks to ensure positive adhesion. Epoxy coatings shall be kept dry and above 16°C.

3-2-J-8-4-6 Safety

For health and safety, the instruction of the epoxy manufacturer should be followed.

3-2-J-8-5 Epoxy Resin Bonding Agent

3-2-J-8-5-1 Description

Epoxy resin bonding agent is a solvent-free bonding agent, based on selected epoxy resins. After application to old concrete surfaces, it shall provide a perfect bond for new concrete. It is supplied as a two component bonding agent ready for mixing with a slow speed electric drill.

3-2-J-8-5-2 Preparation of Concrete Surface

All surfaces must be clean, free from standing water and all loosely adhering particles. Cement laitance must be removed and the surfaces to be treated must be roughened.

3-2-J-8-5-3 Technical Properties

The contractor shall submit catalogues from manufacturers for approval of the Engineer. It shall conform to the following properties:

- Compressive Strength 60-70N/mm^2
- Flexural Strength 30-35N/mm^2
- Tensile Strength 8-20N/mm^2
- Bond Strength to Concrete 2.5-3N/mm^2 (concrete failure)

3-2-J-8-5-4 Application

The mixed material should be applied to the surface by brush, roller or spray, ensuring that it is well brushed in on damp surfaces. New concrete should be poured within specified time when the material is still tacky.

3-2-J-8-5-5 Safety

For health and safety, the instruction of the epoxy manufacturer should be followed.

3-2-J-8-6 Cementitious Mortars.

Cementitious mortars shall be high strength polymer rich proprietary products which produce a dense durable mortar that exhibit minimum shrinkage on drying.

The polymer shall be acrylic, styrene-butadiene rubber or similar polymer which is durable in damp or wet conditions.

Cement shall comply with the Specifications except that cement to BS4027 shall not be used.

The mortar shall exhibit high bond strength and excellent adhesion and shall be free of chloride compounds.

The total chloride content of the mortar arising from the cement, aggregate and any other source shall not exceed 0.1% of chloride ion by mass of cement. The chloride content of the cement shall be determined in accordance with BS EN 196-21 and that of the aggregate in accordance with BS S 12: Part 1 17. The use of calcium chloride is prohibited.

It shall be non toxic suitable for contact with drinking water and it shall demonstrate excellent resistance to long term water immersion.

The minimum strength properties measured in accordance with BS 6319 at 28 days shall be as follows:

Compressive Strength	50 N/mm^2
Tensile Strength	5 N/mm^2
Flexural Strength	10 N/mm^2

3-2-J-8-7 Sprayed Concrete

Sprayed concrete shall be microconcrete (Gunite) material.

The material shall be a proprietary pre-batched microconcrete supplied by a manufacturer who operates quality assurance procedures approved by the Engineer. It shall be cementitious with graded non-reactive aggregate modified with polymer. super plasticisers and silica fume and pre-bagged in the required proportions. Only water shall be added to the mix on site.

The water cement ratio shall not be less than 0.32 or greater than 0.45 and shall comply with the manufacturer’s instructions.

The proportion of silica fume shall not exceed 10% by mass of cement.

The total chloride content shall not exceed 0.1% mass of cement. Calcium chloride or admixtures containing chloride salts shall not be used. The chloride content of the constituents of the mix shall be determined as follows:

– Cement	-	BS EN 196-21
– Aggregate	-	BS 812: Part 117
– Admixtures	-	BS 5057: Part l

Maximum aggregate size shall be 3 mm.

There shall be no expansion agents contained in or added to the repair material.

The material shall exhibit excellent adhesion to the existing concrete and shall exhibit low shrinkage.

It shall have low water absorption and shall demonstrate excellent resistance to long term water immersion.

The minimum strength properties at 28 days shall be as follows:

Compressive strength	45 N/mm^2
Flexural strength	10 N/mm^2
Adhesive Strength	3 N/mm^2

There shall be no change in source or type of material. manufacturer supply, mix proportions or method of mixing without the approval of the Engineer. Such approval will only be given after further site trials have been carried out to the satisfaction of the Engineer.

3-2-J-8-8 Concrete

Concrete used in recasting shall comply with the specification to give a 28 day characteristic strength of 35 N/mm^2.

Approved water reducing additives, superplasticizers, accelerators, may be used subject to satisfactory testing and the Engineer's approval.

3-2-J-8-8-1 Priming

Concrete surfaces within the repair area shall be treated with a suitable bonding aid or primer which is compatible with the repair material.

Priming coats or bonding aids shall be thoroughly worked into all hollows and crevices in the prepared surface and around the reinforcement if required.

If at any time the primer or bonding aid completely dries out before over-laying, the repair surface shall be re-prepared generally by complete removal of the dried primer or bonding aid or as specified by the manufacturer of the repair materials.

When using cementitious based repair mortars the concrete substrate shall be thoroughly wetted to obtain a saturated surface dry condition. Any surplus water shall be remoisted before reinstatement begins.

3-2-J-8-8-2 Filling Resin Based and Cementitious Mortar

Mortars shall be applied in self supporting layers and in any case not exceeding the thickness specified by the manufacturer of the mortar.

Each layer shall be thoroughly worked and compacted into the repair zone and around or between reinforcing bars. The technique employed shall ensure that no air is entrapped and that full contact with the primed substrate is achieved.

Successive layers shall be applied as soon as the preceding coat has become sufficiently stiff to support the weight of the additional build-up layer but is still adequately tacky to provide bonding. The time between layers shall be in accordance with manufacturer's recommendations. If sagging occurs the material shall be completely removed and reapplied at a reduced thickness.

If at any time the last layer applied completely dries out before over-laying, the surface shall be prepared according to the manufacturer's recommendations.

The final build-up layer within a repair shall not be less than 10 mm thick and shall be leveled off or profiled to produce a smooth finish.

The repair shall be cured by the method and for the period recommended by the manufacturer of the repair system. During this period the temperature of the material shall not be allowed to drop below the minimum specified by the manufacturer and the repair shall be shaded from direct sunlight. Curing membranes shall only be permitted where they are recommended by the manufacturer.

3-2-J-8-8-3 Filling Sprayed Concrete

Delivery equipment shall be demonstrated to the satisfaction of the Engineer in site trials. The equipment shall deliver a conical uniform discharge stream of uniformly mixed material at the proper velocity from the discharge nozzle at all heights of the work.

Once placed, the applied material shall be capable of being profiled and steel trowel finished to a high standard without detrimental effects.

3-2-J-9 SPECIFIC WORKS

3-2-J-9-1 Crack Repairs

Cracks requiring repair shall be categorized by the Engineer as follows:

- Live cracks.
- Major cracks.
- Stable structural cracks.

- Repair of Live cracks

Live cracks shall be chased out using a grinding machine to a minimum depth of 30mm and width of 15 mm.

The rebate shall be cleaned of loose material, primed and filled with a gun applied polyurethane sealant onto a debonding tape within the rebate.

- Repair of Major Cracks

Cracks classified by the Engineer as major live cracks shall be repaired by cutting out and subsequent restatement of the concrete.

Reinstatement shall be in accordance with the Engineer s instructions. A joint bridging strip shall be applied over the crack where instructed by the Engineer.

Where the Engineer instructs the concrete shall be cut out over sufficient width and depth to enable examination and any repairs to the reinforcement.

- Repair of Stable Structural Cracks

Stable structural cracks shall be filled with proprietary materials applied by pressure injection such that the crack is completely sealed.

Materials shall be polyurethane resin, epoxy resin or liquid silicate. Polyurethane foam may be used as directed by the Engineer for crack sealing in wet conditions.

The material shall exhibit low viscosity and good adhesion to dry or moist concrete. On curing, the material shall form a hard mass impermeable to water.

3-2-J-9-2 Repair around pipe penetrations

Leaks around pipe penetrations, shall be repaired as follows:

1. Where pipes are in good condition the contractor shall chase out a 20 x 20 mm rebate around the pipe and fill the rebate with gun application of elastomeric polyurethane mastic sealant and provision of a butyl flashing ring.
2. Where pipes must be removed and new pipes installed the contractor shall break out and remove the existing pipe. The new pipe shall be installed complete with a puddle flange, and concrete shall be placed from both sides of the wall. The contractor shall ensure a good bond will he formed between old and new concrete.

3-2-J-9-3 Repair of leaking joints and Cracks

Repairs to leaking joints and cracks shall where directed by the Engineer be made on the internal water face using a proprietary joint bridging strip, with a minimum thickness of 2 mm and made of an inert flexible strip such as Hypalon (By Dupont) or equivalent material.

The adhesive shall be an epoxy resin compatible with the concrete and the flexible strips suitable for use in damp conditions. Full contact between the flexible strip and the concrete shall be ensured by means of a roller.

Surface preparation shall be by grit blasting or other approval method to remove all laitence and in accordance with the manufacturer’s requirements.

3-2-J-9-4 Refurbishment of Roof Structures

Where directed by the Engineer, all existing internal and external roof screeding, rendering and debris shall be removed from the roof and any defective concrete repaired.

The installation of new waterproofing memebrane, thermal insulation and concrete protection of the roof of the reservoir shall be done if required by the Engineer and with the same material used for new reservoirs and described elsewhere.

3-2-K NEOPRENE PADS

3-2-K-1 GENERAL

Elastomeric supports must comply with the following criteria:

1. To be of simple design under normal execution procedures.
2. To permit:
    a. Horizontal displacement due to any cause,
    b. Rotation of the support due to bending under permanent loads, working loads and the effects of hydraulique shrinkage and thermal phenomena, without building liable stresses outside the elastomeric support.

The elastomeric support can fill all the substrate surface of the wearing walls /or/ only a part of this surface; the unoccupied surface. In this case must be filled by a compressible material to avoid the intrusion of concrete grout between the various elements of the elastomeric support.

3-2-K-2 MATERIAL AND APPLICATION

The elastomeric support is generally constituted by a non-hooped elastomeric polychloroprene (neoprene) which under various movements and loads will sustain deformation, transmitting to the underneath wearing walls, vertical and horizontal efforts.

3-2-K-2-1 Eveness Of The Wearing Substrate

The substrate wearing surface must be evened to avoid any accidental contact outside the designed contact surfaces; anyhow the wearing zones must be made horizontal.

The Contractor must furnish to the Engineer all necessary justifications concerning the elastomeric support and the procedures for the execution of the wearing surface.

3-2-K-2-2 Minimal Characteristics

The following minimal characteristics must be submitted by the Contractor for the Engineer's approval:

Maximal constraint which varies with the type of material used (around 30 bars /or/ 3 MPa for the non-hooped polychoroprene = neoprene)

Minimal constraint to be obtained and which is needed to respect the condition of non-slipping of the elastomeric support on its substrate (around 15 bars or 1.5 MPa for the non-hooped polychloroprene = neoprene)

This condition may result for the elastomeric support to have a maximal dimension implicating sometime the impossibility to design a continuous linear elastomeric support. Thus needing to consider the use of strips or pads of elastomeric material.

A continuous break of ties must be then insured between the pads by incorporating between the pads of neoprene of a compressible material (polystyrene type) and making the joints between pads and polystyrene water tight to avoid concrete grout intrusion.

3-2-K-2-3 Minimal Thickness Of The Elastomeric Support

The required thickness of the neoprene support shall depends on the loads, the amount of sliding and permissible rotations.

The Contractor shall submit technical certificate from the manufacturer to the Engineer allowing him to control and approve the chosen sizes and thickness of the elastomeric support.

The minimal thickness is conditioned by two factors:

The maximal distortion of the neoprene (α) which must not exceed $\alpha \leq 0.5$ radians.

The thickness must be large enough to permit rotation of the support avoiding contact in the maximum compression corner zones.

3-2-K-2-4 Determination Of The Horizontal Stresses

As an example, horizontal stresses may be controlled by the following formula (DTU.20.12)

$$H = G \times S \times \frac{U}{e}$$

e = thickness of the support

S = surface of the support in contact with the substrate

G = Transversal elasticity coefficient of the neoprene (around 0.8 to 1.3 MPa or 8 to 13 bars depending of the neoprene quality)

U = displacement

The admissible displacement (U) in relation with the thickness (e) can be first estimated as follows:

Thickness (mm) e =	5	10	15	20
Displacement (mm) U =	2.5	5	7.5	10

3-2-K-2-5 Other Approved Elastomeric Support

The elastomeric constituting the pad may be a mix vulcanised based on Ethylene - Propylene - Diene - Monomer (E.P.D.M) which has the following average characteristics:

A shore hardness of	60 ± 5
Specific weight	1.06 ± 0.02 g/ml
Ultimate resistance (rupture)	≥ 15.0 MPa
Maximum elongation (Rupture)	$\geq 400\%$
Tearing resistance	≥ 15.0 MPa

Permanent deformation after 24 hours at	70oC $\geq$ 20%
Module "G" of transversal elasticity	0.8 $\pm$ 0.1 MPa

3-2-K-2-6 Compression Sollicitation

The admissible load over an elastomeric linear pads support depends of the dimensions and number of elastomeric pads constituting the support.

The average admissible constraint on every single pad is obtained for example by using the following formula

average = 1.2 x $\beta \leq$ 5 MPa

Where β (form factor) = $\dfrac{a \times b}{2xt(a+b)}$

t = thickness of the elastomeric support

a,b = dimensions (in plan) of the elastomeric support

3-2-K-2-7 Special Dispositions

In case the horizontal effort is greater than the value of friction of the interface between the elastomeric support and the substrate, the following dispositions must be taken by the Contractor:

If not otherwise specified by the Engineer the Contractor may stick the pads to avoid uncontrolled displacement when setting the different elements.

A special glue approved by the Engineer must be laid on the primed substrate and on the back side of the pad. After a maturation time, the pad shall be applied on the glued substrate with force.

3-2-K-3 SLIP MEMBRANE

This slip membrane is constituted generally

- A protection sheet
- A slip plate around 3mm thick
- A silicone lubrication or similar
- An elastomeric pad recovered with special slipping cover adhering to it.

This system fulfills most of the usual functions of elastomeric support as:

- Uniform distribution of vertical loads
- Horizontal displacement by slipping of the supported construction over it.

This system will permit under small thickness, wide horizontal displacement with minimum limitation of the horizontal stresses transmitted and after the displacement it does not exercise any underpinning stress on the construction at the contact interface.

The Contractor is asked to submit all technical specifications to the Engineer for approval before any purchase of the material.

3-2-L CONCRETE FLOOR FINISHING

3-2-L-1 GENERAL

Concrete floor finishing consists of a cast in place concrete slab, having the surface colored (optional) and imprinted with pattern (optional) and textured (optional).

The related works that the contractor should complete are as follow:

- Preparation work, including sub-grade preparation, finish grading, setting of forms and screeds, and furnishing of reinforcement.
- Provide and place all concrete
- Provide and apply color hardener
- Provide and apply imprinting tools in the proper pattern
- Grout imprinted joints.
- Outside edges of slabs shall be left uncolored except where indicated to be colored on drawings.

3-2-L-2 PRODUCTS AND MATERIALS

Concrete mix design:

The concrete shall have minimum compressive strength of:

- 4,000 psi in severe freeze-thaw areas
- 3,500 psi in moderate freeze-thaw areas
- 3,000 psi in non-freeze areas.

Portland cement shall conform to LIBNOR depending on soil conditions. Aggregates shall conform to ASTM C 33. Mixing water shall be fresh, clean and potable. In freeze-thaw areas only, an air-entraining agent complying with ASTM C 260 shall be used to achieve an entrained air content for the particular concrete mix used in accordance with the published recommendations of the Portland Cement Association and The American Concrete Institute. No admixtures containing calcium chloride are permitted.

Reinforcement for slabs shall have the same reinforcement as an ordinary concrete slab in the same situation.

3-2-L-3 EXECUTION

Installation procedure:

- The area to receive concrete floor finishing shall have the sub-grade prepared as for any concrete slab on grade.
- The form work shall be installed and the slab thickness shall be as required by the Engineer.
- Provide reinforcement when specified.

- Control joints or expansion joints shall be provided.
- Color hardener shall be applied evenly to the plastic surface by the dry-shake method. It should be applied in two or more shakes, floated after each and troweled only after the final floating.
- While the concrete is still in the plastic stage of set, the imprinting tools shall be applied to make the desired impression to the surface.
- After initial curing, the impressions shall be grouted.

3-2-M EXPOSED CONCRETE

3-2-M-1 DEFINITION

Exposed concrete with texture can be obtained by using a face structured surfaces. These surfaces should be able to avoid unaesthetic defects and irregularities that might occur in smooth finish concrete.

This structured surface should be made of Polystyrene-coated with a hardened surface, and then formed to the required surface. They should be lined using a separation foil.

This lining foil should last for several applications without the risk of staining and coloring of the concrete. This foil should also be able to provide perfectly sealed and smooth concrete surfaces.

3-2-M-2 TECHNIQUE

The structured surfaces or the form elements should be cut at the construction site, joined glued or nailed to the supporting wood shuttering. Concrete should be vibrated thoroughly.

Lining foils should also serve as separation allowing the structured form elements to be stripped off the hardened concrete at any desired time.

It is recommended that the form elements be left in place until the construction work is finished to maintain the cleanliness of the structured surfaces. These form elements should have a glass fiber reinforced backside to ensure dimensional stability.

This form elements should have this specified dimensions:

- Structure thickness 3mm max
- Backside thickness 2mm min
- Total thickness 5mm
- Total weight 3kg/sqm

3-2-N CONCRETE BLOCK MASONRY

3-2-N-1 DESCRIPTION

This work shall consist of concrete blocks laid in cement mortar.

3-2-N-2 MATERIALS

3-2-N-2-1 Concrete Masonry Units

Concrete masonry units shall be of approved manufacture and shall be formed in a press.

Blocks shall be well and evenly formed with true corners and unbroken arises, and shall be carefully handled and stacked.

Unless otherwise specified, The Contractor shall provide standard units with nominal dimensions of 400 x 200 mm and thickness to be standard 100, 150, or 200 mm as indicated on the drawings.

- Solid Block: Blocks shall be deemed to be solid if it does not contain formed holes or cavities other than those inherent in the materials.
- Hollow Block: Blocks shall be deemed to the hollow if the cavities which pass through the blocks is between 50 and 75% of the total volume of the blocks calculated from the overall dimensions.
- Fairfaced Blocks: Blocks for use as fairfaced shall be selected blocks from each delivery to the approval of the Engineer.
- Tests: Blocks for non bearing walls shall comply with the following:
- Average minimum compressive strength of 12 blocks not to be less than 30 kgs/cm^2 of gross area for hollow blocks and 35 kgs/cm^2 for solid blocks in accordance with best local practice and supplied by a manufacturer approved by the Engineer conforming to BS 12 and natural aggregates to BS 882.

Load bearing walls shall comply with BS CP. 111

Blocks should remain intact when dropped on to a hard surface from a height of 1 m. Should any sample of blocks fail to pass the above compressive strength tests above or meet the above requirements, the whole delivery will be rejected removed from the site.

The cement and aggregate of the concrete blocks shall be so proportioned as to meet, when tested at the age of 28 days with the cells placed vertically, the requirements of the ASTM designations.

3-2-N-3 MASONRY ACCESSORIES

Unless specified otherwise, galvanized wire netting: to be 22 SWG of galvanized mesh complying with BS-1085 shall be used in interior partition walls, in addition to providing ties with ends bent to 90 degrees angle to form hooks not less than 50 mm long.

3-2-N-4 MORTAR

Mortar for bedding and jointing shall be composed of 1 part of ordinary Portland cement to 4 parts of sand by volume.

Lay masonry units with full mortar coverage on horizontal and vertical faces, butter ends with sufficient mortar to fill head joints and put into place.

Cure unit masonry construction by keeping wet for at least 5 days.

The materials of mortars shall be measured out in their correct proportions and shall first be thoroughly mixed together in a dry state by turning them over upon a clean wooden stage until they are of a homogeneous appearance in consistency and color. Clean water shall then be added while the mixture is being turned over until it attains a suitable consistency. Mortar is to be mixed in small quantities as required and must be used within one hour of mixing. Plasticizer shall be added in accordance with the manufacturer's recommendations as approved by the Engineer.

The mortar shall be used immediately after it has been mixed. No mortar which has commenced its first set shall be used, or mixed up again. Mortar shall, where possible in hot weather, be protected from too rapid drying action by covering with impervious material such as polyethylene film.

Mixing by hand will be allowed only if the Engineer gives specific approval. Mixing by machine using the same sequence of operations described above shall be carried out whenever possible.

3-2-N-5 GENERAL REQUIREMENTS

Block work shall be set out and built to the respective dimensions shown on the drawings and shall comply with the following code of practice BS 5390 Part 1, BS 5628 Part 1.

Build chases and recesses as shown and as may be required by the Engineer. Provide not less than 200 mm of masonry between chase and jamb of openings, and between adjacent chases and recesses.

Blocks shall be soaked in water before use. The top of walls where work has been left off shall be thoroughly wetted before work is recommenced.

Walls shall be bonded in accordance with best constructional practice. Where required for bond, block shall be carefully cut to size.

Courses shall be properly leveled.

Proper masonry units shall be used for all windows, doors, bond beams, lintels, pilasters, etc., with a minimum of unit cutting. Where masonry unit cutting is necessary, all cuts shall be neat and regular exposed in the finished work and shall be cut with a power driven abrasive saw. Use full units without cutting whenever possible

Lay out walls in advance for accurate spacing of surface bond patterns with uniform joint widths and to properly coated openings. Avoid the use of less than half size units at comers, jambs and whenever possible at other locations.

Lay-up walls with the exposed face plumb and true to line with courses level, accurately spaced and coordinated with other work.

Mortar joints shall be straight, clean and uniform in thickness unless otherwise specified or detailed on the plans, joints shall be approximately 10 mm thick.

No slashing or grouting of a joint will be permitted, nor shall a joint be made by working in mortar after the units have been laid.

Joints between blocks shall be filled solid with mortar and shall be of regular thickness of 5 to 10 mm. The blocks shall be laid in level courses and bonded so that each vertical joint is midway above the face of the block below, except at junctions and piers where a bond of not less than 100 mm shall be provided. The walls shall be raised in lifts not exceeding three meters in height in any one day, and truly vertical.

Walls shall be carried up regularly and no portion shall rise more than one meter above adjacent portions and at such changes in levels work shall be raked back.

The framing of all openings must be in reinforced concrete.

For walls higher than 3m and longer than 4m, the Contractor shall make sure to construct a 20x40cm continuous column at the end of the 4m length. All walls must be chained at the lintel level and related to the main structure. Walls shall be fixed to the ceiling with a steel profile in order to prevent falling under seismic effects.

Joints of exposed block work shall be raked out and neatly flush-pointed in the same mortar. The whole of the visible faces of the walls shall be left perfectly clean and all surface mortar and droppings shall be removed before they have set.

Clean exposed concrete masonry unit by dry brushing at the end of each day's work and after find pointing to remove mortar spots and droppings.

3-2-N-6 FAIRFACED BLOCK WORKS

Where shown on the drawings, walls with fairfaced finish shall be on both sides of selected blocks pointed with a neat flush joint as specified and approved.

3-2-N-7 ANCHORING MASONRY WORK

The Contractor shall:

- Support masonry walls to concrete structure with clip anchors as detailed.
- Provide anchors in every other course of concrete walling.
- Provide anchors as detailed at intersection of concrete block walling.

3-2-N-8 TOLERANCES

a. Alignment of columns	:	max. 3 mm from true line.
b. Variation from unit to adjacent unit	:	1.5 mm maximum.
c. Variation from plane of wall	:	6 mm/3 m and 13 mm/6 in or more.
d. Variation from plumb	:	6 mm per story non-cumulative 13 mm in two stories or more..
e. Variation from level coursing	:	3 mm/m; 6 mm/3 in; 13 mm maximum.
f. Variation of joint thickness	:	2 mm/m.
g. Maximum variation from cross sectional thickness of walls	:	± 6 mm.

3-2-N-9 PARTICULAR SPECIFICATIONS

3-2-N-9-1 Block works 10 cm Thick

The Contractor shall provide, store and build masonry hollow blocks with the following requirements as shown on construction drawings.

Masonry concrete hollow blocks manufactured of cement and crushed aggregate + sand 1.5 mix (300 kg cement to one meter cube of crushed aggregate + sand).

Nominal dimension	:	100 x 200 x 400 mm.
Moisture content	:	< 8% by weight
Cavity	:	Approx. 50% of the total volume of the blocks calculated from the overall dimensions
Compressive strength	:	50 kgs/cm^2
Description	:	The blocks shall be sound, dense, true to shape, uniform in size, straight edges, without any chipping, cracking or other damages resulting from transportation, unloading and storage

Installation and erection

The blocks shall be laid as shown on drawings in true and regular courses on a full bed of mortar min. 10mm thickness, exclusive of any key of the jointing surface of the blocks.

All keys are solidly filled.

Where blocks are against concrete they shall be tied there to by means of approved wire mesh. The contractor shall provide and build into the concrete work patent galvanized steel dovetailed channel grooves and shall build in min. 2 mm thick fishtailed ties which shall fit closely in the grooves and shall generally be embedded in blockwork 150 mm, in every two courses.

All horizontal joints shall be properly level. The vertical joints shall be lined and quoins, jambs and other angles plumbed as the work proceeds.

All walls shall be plumbed vertical.

Standard sizes blocks shall be used. Broken blocks shall be used except where required for bonding purposes.

Blockwork fitting into backs of frames shall be so placed as not to distort alignment of such items. The backs of all frames shall be well buttered up with mortar. Carefully paint around metal frames to detail using an approved sealant.

Where units are to receive glazed wall tiling on render, joints shall be racked 10 mm deep to receive render.

3-2-N-9-2 Block works 15 cm Thick

The Contractor shall provide, store and build masonry hollow blocks with the following requirements as shown on construction drawings.

Masonry concrete hollow blocks manufactured of cement and crushed aggregate + sand 1.5 mix (300 kg cement to one meter cube of crushed aggregate + sand).

Nominal dimension	:	150 x 200 x 400 mm.
Moisture content	:	< 8% by weight
Cavity	:	Approx. 50% of the total volume of the blocks calculated from the overall dimensions
Compressive strength	:	50 kgs/cm^2
Description	:	The blocks shall be sound, dense, true to shape, uniform in size, straight edges, without any chipping, cracking or other damages resulting from transportation, unloading and storage.

Installation and erection

The blocks shall be laid as shown on drawings in true and regular courses on a full bed of mortar min. 10mm thickness, exclusive of any key of the jointing surface of the blocks.

All keys are solidly filled.

Where blocks are against concrete they shall be tied there to by means of approved wire mesh. The contractor shall provide and build into the concrete work patent galvanized steel dovetailed channel grooves and shall build in min. 2 mm thick fishtailed ties which shall fit closely in the grooves and shall generally be embedded in blockwork 150 mm, in every two courses.

All horizontal joints shall be properly level. The vertical joints shall be lined and quoins, jambs and other angles plumbed as the work proceeds.

All walls shall be plumbed vertical.

Standard sizes blocks shall be used. Broken blocks shall be used except where required for bonding purposes.

Blockwork fitting into backs of frames shall be so placed as not to distort alignment of such items. The backs of all frames shall be well buttered up with mortar. Carefully paint around metal frames to detail using an approved sealant.

Where units are to receive glazed wall tiling on render, joints shall be racked 10 mm deep to receive render.

3-2-N-9-3 Block works 20 cm Thick

The Contractor shall provide, store and build masonry hollow blocks with the following requirements as shown on construction drawings.

Masonry concrete hollow blocks manufactured of cement and crushed aggregate + sand 1.5 mix (300 kg cement to one meter cube of crushed aggregate + sand).

Nominal dimension	:	200 x 200 x 400 mm.
Moisture content	:	< 8% by weight
Cavity	:	Approx. 50% of the total volume of the blocks calculated from the overall dimensions
Compressive strength	:	50 kgs/cm^2
Description	:	The blocks shall be sound, dense, true to shape, uniform in size, straight edges, without any chipping, cracking or other damages resulting from transportation, unloading and storage.

Installation and erection

The blocks shall be laid as shown on drawings in true and regular courses on a full bed of mortar min. 10 mm thickness, exclusive of any key of the jointing surface of the blocks.

All keys are solidly filled.

Where blocks are against concrete they shall be tied there to by means of approved wire mesh. The contractor shall provide and build into the concrete work patent galvanized steel dovetailed channel grooves and shall build in min. 2 mm thick fishtailed ties which shall fit closely in the grooves and shall generally be embedded in blockwork 150 mm, in every two courses.

All horizontal joints shall be properly level. The vertical joints shall be lined and quoins, jambs and other angles plumbed as the work proceeds.

All walls shall be plumbed vertical.

Standard sizes blocks shall be used. Broken blocks shall be used except where required for bonding purposes.

Blockwork fitting into backs of frames shall be so placed as not to distort alignment of such items. The backs of all frames shall be well buttered up with mortar. Carefully paint around metal frames to detail using an approved sealant.

Where units are to receive glazed wall tiling on render, joints shall be racked 10 mm deep to receive render.

Part III: Civil and Architectural Works

Part III-3: WATERPROOFING

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PART 3.3 - CIVIL & ARCHITECTURAL WORKS: WATERPROOFING

3-3-A FLEXIBLE WATERPROOFING PVC SHEETS 2 MM THICK

3-3-A-1 DESCRIPTION

This work shall consist of furnishing and placing flexible PVC sheets 2 mm thick on prepared surfaces in accordance with the Specifications, and in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

3-3-A-2 MATERIALS

Waterproof membranes shall consist of uniform flexible sheets of two (2) mm minimum thickness.

3-3-A-2-1 Physical Requirements

The waterproofing PVC sheets shall comply with the following specifications at 20 °C:

Weight	2.80 kg/m^2
Thickness	2 mm
Tensile strength at rupture	17 daN/cm
Elongation %	170 %
Bursting Test (C.T.G.R.E.F.)	> 12 Bars
Hydrocarbon resistance	Good
Chemical resistance	Very good
Satisfactory for potable water	Good (Excluding Chlorinated Water)

The Contractor shall provide all adhesives, tapes and welding material recommended by waterproofing sheets manufacturer for bonding to substrate (if required), and for waterproof sealing of joints between membrane and flashing, adjoining surfaces and projections through membrane. The Contractor shall also provide all types of flexible sheet material and accessories for flashing and welding as recommended by waterproofing sheet manufacturer.

Each side of the waterproof membrane shall be protected by one layer of heavy duty geotextile sheets, in accordance with the Contract Drawings and Specifications.

3-3-A-3 CONSTRUCTION REQUIREMENT

3-3-A-3-1 Manufacturer's Instructions And Recommendations

At least thirty (30) days prior to the date he intends to order the waterproofing sheet materials the Contractor shall make written request for approval of: the brand of materials and method of installation he intends to apply, from the Project Manager.

The written request shall include all necessary manufacturer's instructions and recommendations relevant to the physical properties of the proposed sheets, the methods of storage, handling, laying, jointing, attachment, and protection. No ordering of waterproofing sheet material shall be effected before obtaining the written approval of the Project Manager on the above.

3-3-A-3-2 Subgrade Preparation

Unless other subgrade preparation is called for on the plans or appears as a pay item in the Bill of Quantities, the Contractor shall, as a part of the work and prior to the delivery of the material for the waterproof membrane, prepare the bed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper slope is obtained. However, in the process of shaping the bed, the originally compacted crust or top portion of the bed shall be disturbed as little as possible. When completed and ready for waterproof membrane construction, the bed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

3-3-A-3-3 Placing

The waterproof sheets shall be unrolled directly on the bearing surface, generally constituted by a layer of heavy duty geotextile sheets. Waterproof sheets shall be overlapped to a minimum of twenty centimeters, and shall be welded on site by means of a thermoplastic soldering machine to seal the membranes and ensure water tightness to these joints, all in accordance with Manufacturer's instructions and recommendations. The strength of the welding shall be at least equal to that of the sheets.

Installation shall be scheduled to minimize period of exposure of sheet waterproofing materials.

Equipment and vehicles shall not be operated on the fabric. Damaged fabric shall be repaired, at the Contractor's expense, by placing new fabric over the damaged area in a manner that meets the overlap requirements for horizontal placement. Vertically placed fabric shall be replaced in its entirety.

3-3-B GEOTEXTILE SHEETS

Geotextile sheets shall be of the non-woven heavy duty type, needle punched or needle entangled and shall consist of long chain polymeric filaments of polypropylene, polyester, nylon or any material approved by the Engineer. The fabric shall be a stable network of fibres, which retain their positions relative to each other. The geotextile sheets shall meet the following requirements:

Property		Test reference
Grab strength	: 500N	NFG 38.014
Elongation, Minimum (at peak load) %	: 65/57	NFG 38.014
Puncture strength	: 1500N	NFG 38.019
Permeability m/sec	: $5.5x10^{-3}$	NFG 38.016
Surface weight	: 390 Gr/m^2	NF EN 965
Thickness under 2kPa	: 2.0 mm	NF EN 964-1

Geotextiles shall be furnished in rolls wrapped with protective covering to protect them against ultraviolet radiation and abrasion. Torn wrappers shall be repaired within 48 hours, using an approved protective covering. Each roll of fabric shall be marked or tagged to identify the manufacturer, type, length, width, and production identification number.

3-3-C BITUMINOUS PUTTY

3-3-C-1 PUTTY FILLER

Putty filler must have a consistent, semi-rigid and compatible with flexibility inside the joint. Before fillings the joints must be dry and clean and the concrete surfaces in contact with putty must be primed with compatible material with the putty.

Putty must be of type “IGAS” or similar with bituminous base or rubber having the following characteristics:

Density	: 15
Flexibility at 20°	: null
Adhesivity of cohesiveness	: 3 daN
Maximum elongation under service	: 10%

Excellent adhesivity when laid on cement.

Another type could be used which is the elasto-plastic type conforming to the following requirements:

Black colour

Temperature for use	: 100°C to 130°C
Stable at	: -30°C to 60°C
Penetration at 25°C	: around 55°C
Softening temperature	: around 145°C
Practical elongation	: 10%

Non-toxic

The selection of which type to be used shall be approved by the engineer.

3-3-C-2 APPLICATION OF THE SEALANT

Before proceeding with filling the joint, the Contractor shall complete the following works:

- Widening the joint by grinding or sawing when the joint width is less than required.
- Cleaning by grinding and brushing the sides of the joint all along its length.
- Final cleaning shall be done by blowing air immediately before starting the filling.

The putty is applied at a temperature ranging between 100°C and 130°C. It shall be filled in the joint from the bottom up. In case the putty spreads slowly when applied, especially in horizontal joints, more material is immediately added until the joint is completely filled.

3-3-D WATERSTOPS

3-3-D-1 GENERAL

Waterstops shall be PVC type or Vulcanized Caoutchouc class A (rubber water stop) and shall be installed where shown on the drawings or where directed.

The Contractor shall furnish the waterstops and all materials and equipment for splicing waterstops, for fastening waterstops to the forms and to the supporting reinforcing bars, and for completing the installation of the waterstops.

The Contractor shall provide suitable support and protection for the waterstops during the progress of the work and shall repair at the Contractor’s expense any damaged waterstops, which in the opinion of the Engineer, have been damaged to such an extent as to affect the serviceability of the waterstops. All waterstops shall be protected from oil, grease and curing compound.

3-3-D-2 MATERIAL

PVC waterstops shall be fabricated from a compound, the basic resin of which shall be domestic virgin PVC. No reclaimed PVC or manufacturer’s scrap shall be used. The compound shall contain all additional resins, plasticizers, stabilizers, or other materials needed to ensure that, when the material is compounded, the finished product will have the required physical characteristics listed in the ASTM or similar.

3-3-D-3 FABRICATION

All waterstops shall be moulded or extruded in such a manner that any cross section will be dense, homogeneous and free from porosity and other imperfections.

3-3-D-4 INSTALLATION

Installation of the waterstops shall be in accordance with these specifications and the manufacturer’s recommendations. The location and embedment of waterstops shall be as shown on the Plans, with approximately one-half of the width of the waterstop embedded in the concrete on each side of the joint.

In order to eliminate faulty installation that may result in joint leakage, particular care shall be taken that the waterstops are correctly positioned and secured during installation. All waterstops shall be installed so as to form a continuous watertight diaphragm in the joint unless otherwise shown.

Adequate provision shall be made to completely protect the waterstops during the progress of the work.

Concrete surrounding the waterstops shall be given additional vibration, over and above that used for adjacent concrete placement, to assure complete embedment of the waterstops in the concrete. Larger pieces of aggregate near the waterstops shall be removed by hand during embedment to assure complete contact between the waterstop and the surrounding concrete. Where splices are required between waterstops of different sizes, the splices shall be made as recommended by the manufacturer of the waterstop.

3-3-E WATERPROOFING PROTECTIVE COATING FOR WATER RETAINING STRUCTURES

3-3-E-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.

3-3-E-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.

3-3-E-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.

3-3-E-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”.

3-3-E-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.

3-3-E-1-5 Safety

The use of rubber gloves and goggles during mixing and application is recommended.

3-3-E-2 GENERAL REQUIREMENTS

Waterproofing material shall be applied to interior concrete surfaces.

It is made of cement base, sand, and other chemical. It is composed of two contents:

- Powder: Mixed of cement and other mixes as specified by the Engineer
- Liquid: Resin base and other mixes as specified by the Engineer

The above product must be:

- Waterproofing
- Weather and chemical product resistant
- Suitable for potable water, not harmful nor poisoning nor unhealthy

Before placing waterproofing on concrete surfaces, mastic of hydraulic cement base shall be used in concrete holes and cracks which provides a complete blockage to water. This mastic is a mixture of powder placed in special can closed tightly and shall be mixed with water before usage as directed by the Engineer.

3-3-F ELASTOMERIC SURFACE JOINT (COMBIFLEX)

This joint shall be as shown on the Plans and as specified herein. The joint is formed of an elastomeric sheet painted on both sides with a viscous resin coating and protected by an aluminium or copper sheet riveted on one side only.

The elastomeric sheet shall conform to the following requirements:

- Thickness 10/10 mm
- Resistance to rupture : 12 kg/cm²
- Elongation at rupture : 300%
- Modulus at 100% elongation : 85 kg/cm²
- Elongation at the elastic limit : 15%

The dimensions of the sheet, the method used in welding and the manufacturer's name shall be indicated. The resin shall be of a quality approved by the Engineer.

3-3-G 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 Engineer 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.

3-3-H VAPOR BARRIER

This layer shall meet the following requirements:

- Thickness not less than 2 mm
- Durability against vapor penetration not less than 120,000µ
- Sustains a temperature of minus 10 degrees C without form change.

3-3-I SELF-ADHESIVE POLYETHYLENE SHEET

Flexible, preformed waterproof membrane comprising strong, high density polyethylene film with self-adhesive rubber/bitumen compound, and having the following minimum properties:

- total thickness : min 1.5 mm
- weight : 1.6 kg/m2
- ensile strength : 42 N/mm2
- elongation : 210% long.; 160% trans.
- tear resistance : 340 N/mm long.; 310 N/mm trans.
- puncture resistance : 220 N 65 mm
- Man: Servicised Ltd.
  Ref: Bitu-thene 1000X HC
  or other equal and approved.

3-3-J STEEL ROOF COVER

Steel roof covers to be as follows:

- Coated with natural stone chips, with pressure formed 0.4mm Zinc Aluminum base.
- Tested to withstand:
  - 2000Kg/m2 for snow load.
  - 400 Kg/m2 for uplift wind force.
  - Fire tested (agreed) CSTB T30/1
- Simulated Cyclone Wind loading:
  - 8000 cycles 3.44 kPa (72 psf).
  - 2000cycles 4.13 kPa (86 psf).

- 200 cycles 5.50 kPa (115 psf).

3-3-J-1 STEEL ROOF COVER TO BE WATER PROOF

Tiles withstand: 100mph Wind speed

160Km/h Wind speed

With rainfall intensity of 203mm of rain/Hour without any leakage.

3-3-J-2 HAIL RESISTANCE

Roof covers should resist damage from hailstone up to 90mm.

3-3-J-3 TECHNICAL SPECIFICATIONS

Base steel	0.39mm
Zinc-aluminum coating	150g/m2
Total substrate thickness	0.43mm
Tile coverage	2.15 tiles/m2
Tile weight	7 Kg/m2

Steel roof cover composition:

1. Backing coat
2. Epoxy primer
3. Aluminum-Zinc coating
4. Steel base
5. Aluminum-Zinc coating
6. Epoxy primer
7. Seal coat
8. Acrylic base coat
9. Natural stone chips
10. Acrylic overglaze.

Part III: Civil and Architectural Works

Part III-4: DOORS & WINDOWS

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PART 3.4 - CIVIL & ARCHITECTURAL WORKS: DOORS & WINDOWS

3-4-A METAL WORKS

3-4-A-1 SCOPE

This work shall include for the supply, installation and fixing of welded steel hollow doors and decorative steel doors as shown on the drawings and door schedules and as indicated in Bill items.

The term "doors" in this section shall also include rolling shutters, louvers and frames manufactured in steel.

3-4-A-2 PERFORMANCE AND STANDARDS

3-4-A-2-1 Steel Doors

Steel doors shall comply with BS 1245. All mild steel shall comply with BS 4630 and with BS4, Part 1. All sheet steel shall comply with BS 1449 Part 1. Other equivalent codes could be proposed by the Contractor and submitted to the Engineer approval.

3-4-A-2-2 Quality Assurance

a- Provide steel doors and frames as manufactured by a single firm specializing in the production of this type of product.

b- Applicable standards: comply with British standards.

3-4-A-3 SUBMITTALS

3-4-A-3-1 Samples of Doors

The Contractor shall provide for the Engineer's approval one full sample installed on site.

3-4-A-3-2 Drawings

Fully detailed shop drawings showing door frame and hardware shall be submitted to the Engineer for approval before fabrication commences.

3-4-A-3-3 Ironmongery

The Contractor shall supply to the manufacturer of doors samples of all item of ironmongery as specified which will be fixed to the frame to ensure that proper provision is made for their fixing, and all details are to be given to the manufacturer as to which items apply to which frames.

The samples and information are to be given to the manufacturer before production is commenced.

3-4-A-4 PRODUCT HANDLING

3-4-A-4-1 Handling Generally

All doors shall be carefully handled at works, during transportation and storage and on site to prevent damage. Any damaged or defective frames shall be removed from the site and replaced at no additional cost.

3-4-A-4-2 Identification

All doors shall have suitable identification in terms of the door frame schedule marked on them or attached in such a way that the labeling will not easily become detached. Crates shall similarly clearly identify their contents.

3-4-A-4-3 Protection

The doors are to be suitably protected and crated to prevent damage during transportation and storage. The protection shall be such that doors are not subject to damp.

3-4-A-4-4 Storage

Storage on site shall be in dry conditions. Doors shall be stored in such a way that they are not liable to distortion caused by undue weight in stacking.

3-4-A-5 MATERIALS

3-4-A-5-1 General

Doors shall be manufactured from metal angles, plate & sheets, and shall comply with BS4, Part 1 and BS 1449, Part 1. Dimensions and frame profiles shall conform to the detail drawings.

3-4-A-5-2 Welding

Welding shall be in accordance with BS 693 or BS 5135 as appropriate.

3-4-A-5-3 Corrosion inhibiting coatings

a- Primer powder coating paint compatible with respective specified finish paint.

b- All steel doors shall be supplied factory powder coating finished with the specified finish paint.

c- Touch up damaged paint of same material at the building site after installation.

3-4-A-5-4 Inserts, Bolts and Fasteners

Manufacturer's standard units suitable for the function required.

3-4-A-5-5 Fabrication General

a- Fabricate hollow steel units to be rigid, neat in appearance and free from defects, wrap or buckle. Accurately form steel to required sizes and profiles. Whatever practical, fit and assemble units in the manufacturer's plant. Clearly identify work that cannot be permanently factory assembled before shipment, to ensure proper assembly at project site. Metallic filler to conceal manufacturing defects is not acceptable.

b- Exposed Fasteners: Counter sink heads of exposed screws and bolts.

c- Finish hardware preparation: prepare hollow steel units to receive mortised and concealed finish hardware, including cut outs, reinforcing, drilling and topping in accordance with final finish hardware schedule and templates provided by the hardware supplier, comply with applicable requirements of British standards.

d- Locate Finish hardware as shown on final shop drawings.

3-4-A-5-6 Painting

a- Pretreatment: Surface of metal to be pretreated with zinc salt phosphatizing for proper chemical conversion and protection of surface.

b- Composition of paint: Hybrid resin epoxy polyester to provide paint with excellent resistence, light fastness, and heat resistance.

c- Application: Apply zinc salt phosphatizing for pretreatment, final powder coating paint furnace treated at a temperature of 180ºC for proper quality and durability paint, in addition to complete application and immersion of powder film.

d- Thickness: Medium thickness of film to be between 60 to 100 microns.

e- Finish: Ral color to be specified by architect. Appearance (gloss, semi gloss, matt, semi matt) to be specified by architect.

3-4-A-5-7 Frames

a- Frame Construction: Frames are constructed of 1.5mm (16 gauge) commercial quality galvanized steel sheet for doors of 45mm thickness. All bends shall be formed with a true sharp radii.

Each jamb shall be provided with a sill anchor and two (2) jamb anchors for heights up to and including 1524mm and an additional anchor for each additional height of 762mm or a fraction thereof.

a.1. Frames: To be factory corner welded and assembled smooth. All welded frames shall be provided with a removable shipping strut welded across the jambs at the base. All welded frames must include the appropriate anchors to match the wall construction they are intended to be installed in and the appropriate hardware reinforcing. All frames to be installed grouted. Knock down frames are not acceptable.

a.2. Slip-On Drywall Frames: All slip-on dry wall frames shall be provided with steel corner tabs, steel corner tabs, steel corner reinforcing and compression lugs for field assembly over the finished wall. Attachment at the base of the frame shall be by screws through holes provided in the face of the frame or by screws through concealed base clips. All frames must include appropriate hardware reinforcing.

b- Hardware Preparation

b.1. Hinge Preparation: Provide frames with 5.0mm thick steel hinge reinforcements welded to the frames in compliance with BS 7352. Standard hinge preparation is to be 4" x 3" for regular weight, three preparations through 2286mm (7'6") height and four preparations over 2286mm (7'6") and up to 3048mm (10') height.

b.2. Strike Preparation: Provide frames with 3.0mm thick steel lock strike reinforcement with tapped holes welded to the frames. Standard strike preparation is to be for locks in compliance with doors manufacturer test.

b.3. Closer and Other Reinforcements: Provide all frames with minimum 2.0mm (14 gauge) reinforcement as necessary to support the scheduled hardware. Closers to be in compliance with EN 1144.

b.4. Plaster Guard: Provide 1.2mm thick steel plaster guard or mortar boxes at the back of hardware cut-outs in the frames.

3-4-A-5-8 Hollow Doors

a- Hollow Door Construction: Provide doors of 45mm thick full flush construction fabricated from 1.25mm (18 gauge) galvanized steel sheet to BS 4630. Provide top and bottom channel of 1.5mm thick steel welded to door skins on 150mm centers. Top channel is to be flush, bottom channel inverted.

b- Core Construction: Provide doors with structurally bounded resin impregnated honey comb to give extra sturdiness and rigidity, complying with BS 476 parts 20 & 22.

c- Hardware Preparation:

c.1. Hinge Preparation: provide doors with 5.0mm thick steel hinge reinforcements welded to the door skins. Standard hinge preparation is to be 4" x 3" for regular weight, three preparations through 2286mm height and four preparations over 2286mm and upto 3048mm height in compliance with BS 7352.

c.2. Lock Preparation: Provide doors with 3.0mm thick steel formed lock reinforcements with tapped holes welded to the door skins. Provide internal reinforcements to support door skins as required for the type of lock that is specified. Standard lock preparation is to be for mortise lockset with a 76mm backset to manufacturer's test.

c.3. Flush Bolt Preparation: Provide inactive leaf of pair door with 3.0mm thick steel flush bolts reinforcements at top and bottom.

c.4. Closer and Other Reinforcements: Provide all doors with minimum 2.0mm (14 gauge) reinforcements as necessary to support the scheduled hardware. Closers to be in compliance with EN 1144.

d- Glazing: Where required by the plans, doors are prepared for installation of glazing. Door supplier shall provide the cut-out and steel glazing bead.

e- Louvers: Where required by the plans, provide louvers in the doors in compliance with BS 476 part 1.

f- Painting: After fabrication provide doors and frames thoroughly cleaned, coated with a factory powder coating with the required finish paint. Touch up damaged paint with the same finished paint material to be applied at the building site after installation.

g- Certificates: All sizes and construction of doors to be within the acceptable manufacturers test.

3-4-A-5-9 Decorative Doors

Decorative Door Construction: Provide doors of dimensions, thickness and details as shown on drawings, fabricated from commercial quality steel members. Doors shall be supplied shop primed and factory painted with the required finished paint. Touch up damaged paint with the same finished paint material to be applied at the building site after installation.

3-4-A-6 WORKMANSHIP

3-4-A-6-1 Preparation:

Steel shall be free of scale, dust, grease, oil and surface adhesives before priming.

3-4-A-6-2 Profiles

Profiles shall be formed as shown on drawings and shall be appropriate to the thickness of the doors.

3-4-A-6-3 Joints

Joints shall be welded to proper lines.

3-4-A-6-4 Provision for Ironmongery

The frames and door panels shall be factory-prepared to receive specified ironmongery.

a- The hinges shall be welded to doors and frames.

b- Striking plates for the specified locks and latches shall be fitted, complete with mortar guards.

c- Bolt holes for double doors shall be drilled at works and provided with mortar guards.

d- Fixings or all other specified ironmongery which fixes to the frame shall be provided, tapped as necessary, reinforced by back plates where necessary, and provided with mortar guards where the fixing penetrates the frame.

e- The manufacturer shall make provision for and shall fit all items of ironmongery for the steel doors and frames.

f- Where ironmongery is not specified for a particular door, the provision of the Engineer shall apply.

3-4-A-6-5 Frame Fixings:

The provisions for jamb fixing shall be as shown on drawings. In addition there shall be a mild steel horizontal plate at the foot of each jamb welded in all drilled with 6mm holes for fixing down to the floor.

3-4-A-6-6 Alignment

The doors supplier shall provide a steel for alignment purposes.

3-4-A-6-7 Fixing

3-4-A-6-7-1 Frame Installation

Contractor to provide installation of the frames plumb, square and in true alignment in compliance with BS 476 part 8. Use wood installations spreader at base, strike and mid-top locations to ensure constant and proper jamb opening for door.

Where frames are built in temporary struts shall be positioned between jambs to prevent bowing.

3-4-A-6-7-2 Doors Installation

Contractor to provide installation of the door plumb, square and in true alignment. Adjust doors to required clearances and tolerances complying with BS 476 parts 20 & 22.

3-4-A-6-8 General Quality of Finished Work

Any parts of the installation which are indented, distorted, out of alignment, visible welds not ground flush, or defective in any way shall be rejected and replaced at no additional cost or made good to the satisfaction of the Engineer.

Any damage to the painting shall be made good immediately on completion of the frame and door fixing.

3-4-A-6-9 Painting

All frames and doors shall be factory painted in accordance with the Specification for Painting.

3-4-B ALUMINUM WORKS

3-4-B-1 GENERAL

Aluminum used for windows and doors shall have the following properties:

Proof stress at strain 0.2% = 150 N/mm²

Ultimate stress = 200 N/mm²

Modulus of elasticity = 5100 N/mm²

Aluminum shall not be in direct contact with iron or any metals. All joints between frames and wall surrounds shall be filled with sealant to the approval of the Engineer. All external doors and windows shall be water tight.

Furnishing and installing aluminum windows, panels, doors, louvers, aluminum claustra, ladders, etc. of the sizes and combinations indicated on the drawings shall conform to the DTU P22-702 specification or as approved by the Engineer.

The Contractor shall provide all necessary tools for installation.

3-4-B-2 GENERAL SUBMITTALS

The Contractor has:

- To submit to the Engineer manufacturer's specifications (Elastic limit, Modulus of elasticity) and installation instructions and other data to show compliance with these Specifications.
- To submit shop drawings of all components for review by the Engineer. Including full size sections of all typical members, dimensioned elevations, anchors and other accessories required.
- To submit to the Engineer sets of samples for each type, finish and color required. Sample submittal and approval shall be for color, texture and specular floss only. Compliance with all other requirements is the exclusive responsibility of the Contractor.
- To submit sample corner window unit, with hardware, representative of fabrication techniques and workmanship of the final products.

3-4-B-3 MATERIALS

Unless otherwise specified the following shall apply:

3-4-B-3-1 Aluminum Linear Suspended Ceiling

1. Size:

   Channel shaped, as per drawings and or as described in the particular description.

2. Shop cut:

To accommodate mechanical and electrical items.

3. Internal and External comers:

   Of the same material, thickness finish, and performed to profile to match exposed linear panels.

4. Finishing:

   As described in the particular item.

   One) Natural anodization to 25 microns.

   Two) Shall be prime coated on both sides with the visible side stone enamelled, color as selected by the Engineer and as described in the particular item.

3-4-B-3-2 Acoustical Panel Ceiling

1. Two types of acoustical panel ceiling:
   a. Acoustical panel ceiling, exposed suspension.
   b. Acoustical panel ceiling, concealed suspension.
2. Sizes : As shown on the drawings or as described in the particular specifications.
3. Finishing: Factory applied paint capable of scrabbling with a brush and detergent for not less than "2000 strokes" without deterioration of finish.
4. Expansion joints: Provide joints to accommodate plus or minus 25 mm movements and maintain visual closure.

3-4-B-3-3 Suspension System Materials And Components

1. All suspension members, hangers, wire strips, clips, clamps etc... shall be of the sizes and types recommended by the manufacturer of the suspended ceiling systems.
2. Metal grid systems for suspended ceilings shall be made of aluminum sections or factory hot dipped galvanized steel sections and the concealed system shall be made of steel sections painted with approved rust inhibitive primer as recommended by the manufacturer of suspended ceilings and approved by the Engineer.
3. Wire Hangers: As recommended, not less than 12 gage 2.7 mm diameter, -galvanized soft annealed, mild steel wire.
4. Where hanger cannot be directly wire-tied to structure or intermediate framing members, provide attachment devices designed for the type of construction used in the work and with a capacity not less than 5 times the design loads involved.

3-4-B-3-4 Metal Lath Suspended Ceiling

Metal supports for suspended and metal lath to receive plastering shall be as follows or as specified and directed by the Engineer.

1. Channels: cold-rolled steel, 1.52 mm minimum thickness of base metal, allowable bending stress of 124 MPA, protected with rust inhibitive or galvanizing.
2. Wire for hangers and ties ASTM A 64 1, class 1 zinc coating, soft temper.
3. Rod hangers: Zinc or cadmium coated.
4. Carrying channels: 38 mm deep x 11 mm wide flanges each meter long weight not less than 7 KGs.
5. Hangar Devices: Screws, cast in place concrete inserts or other device anchorage to form of structural framing indicated size device to develop full strength of hanger but not less than 3 times calculated hanger loading.

3-4-B-3-5 Lath

Expanded metal lath to comply with BS 1369 sheets shall not be less than 1.60 kg/m2 when fabricated, using 0.7 mm thick steel sheet tying wire shall be 1.2 mm diameter galvanized annealed iron wire.

3-4-B-3-6 Aluminum Extrusions

Shapes as required to fulfill performance requirements, but not less than 2 mm thick. Frame depth shall be 80 mm minimum. Suitable alloy and proper temper for extruding and fabricating with adequate structural characteristics, and suitable controlled alloy and temper as recommended by aluminum manufacturer to provide color and color matching.

3-4-B-3-7 Aluminum Sheets and Plates

Sizes and minimum gauge as required to fulfill performance requirements. Suitable alloy and proper temper for forming and fabricating with adequate structural characteristics, and suitable for finishing as required.

3-4-B-3-8 Reinforce Assembly of Aluminum Components

Must follow international standards, galvanized or, if galvanizing is not compatible with alloy or component parts, shop painted with zinc chromate primer after curing to size.

3-4-B-3-9 Reinforce Aluminum Components

Alloy recommended by manufacturer or fabricator to develop required strength of assembly.

3-4-B-3-10 Fasteners

Stainless steel type 300 series, selected to prevent galvanic action with the components fastened.

3-4-B-3-11 Weather Stripping

Molded PVC gaskets, molded expanded neoprene gaskets or molded neoprene gaskets, factory applied in an integral dovetail self-locking groove.

3-4-B-3-12 Bituminous Paint

The bituminous paint has to be approved by the Engineer.

3-4-B-3-13 Louvers

The louver windows shall be of the horizontal glass slats type, thickness equal to 6 mm, known under the name of louvers. They shall be made of powder coated steel.

The chassis shall be submitted to be approved by the Engineer and shall comprise a non apparent rod system that requires no maintenance with an efficient stop system. In case the chassis is not easily accessible to the hand, a remote control system shall be installed by ring and hook or any other approved method. An operation lever with a hook shall be provided with each series of these chassis.

3-4-B-3-14 Hardware

1. Provide manufacturer’s standard hinges, supporting arms, pull and locking handles, and all other hardware required for the operation indicated.
2. Hardware shall be fabricated of stainless steel complying with ASTM A-167 and finished to match the component to which it is fixed.
3. All hardware shall be approved by the Engineer.

3-4-B-3-15 Screws

All screws shall be made of chromium plated steel or stainless steel alloys. The use of aluminum screws are forbidden.

3-4-B-4 PRODUCT DELIVERY, STORAGE AND HANDLING

The Contractor shall deliver materials to job site in original, unopened packages, clearly marked to indicate manufacturer's name and label, identifying each type of materials and shall handle units carefully to avoid damages.

The Contractor shall store materials in conformity with the printed manufacturer's recommendations.

3-4-B-5 WORKMANSHIP

3-4-B-5-1 Installation Generally

The contractor shall examine the conditions under which acoustical ceiling work shall be performed, and correct any unsatisfactory conditions.

Workmanship and fixing of the various suspended or false ceilings shall be in accordance with the shop drawing, the manufacturer's recommendations and technical specification, using any metallic grids, hangers etc... as supplied by the same manufacturer.

The installation shall be done by skilled labor thoroughly experienced with the particular suspended ceiling specified.

The grid for suspension shall be constructed to true level and shall produce perfect alignment of the joints, truly parallel to the building line sand completely free from waviness to the satisfaction of the Engineer.

All works shall be delivered sound and clean.

The contractor shall protect the false ceiling system until handing over the building and if required by the Engineer, he shall clean, paint, remove and replace units which are defective, damaged or improperly installed at his own expense to the satisfaction of the Engineer.

The fixing of flush mounted lighting fixtures, spot lights, air conditioning grills etc... in the suspended ceiling shall be done with utmost care and due regard to good appearance and best practice and to the satisfaction of the Engineer.

Measure each ceiling area and establish layout of acoustical units to balance border width at opposite edges of each ceiling.

3-4-B-5-2 Inspection

The contractor shall examine the conditions under which acoustical ceiling work shall be performed, and correct any unsatisfactory conditions.

3-4-B-5-3 Suspended Systems

1. Install suspension systems to comply with BS 8290 Part 3 code of practice for installation and maintenance. Locate hangers not less than 150 mm from each end and spaced 1200 mm along each carrying channel or direct-hung runner. Provide additional hangers for support of fixtures and other items to be supported by the ceilings system leveling to tolerance of 3 mm in 4 meter in any direction.
2. Moldings: Provide molding where ceilings meet walls, partitions and other vertical elements and at locations where necessary to cancel edges of elements units.

3. Installation of units elements : Units shall not be installed until the following requirements are met:

   One) Dry area: Plastering, floor finish, roof etc… have been completed and allowed to dry.

   Two) Mechanical, Electrical and other work above ceilings have been completed, temperature and relative humidity have reached levels which comply with the manufacturer's recommendations regarding each element.

   Three) Comply with reflected ceiling plan, spot lights, lighting fixture, air-conditioning grills etc…

   Four) Special access hatches as required shall be provided next to air conditioning and ventilation units and where ever required by the Engineer. Mounting details shall be applied for the surrounding edge of lightning fixtures and air inlets and outlets and edge of ceiling.

   Five) After the installation of the panel carriers for ceiling panels, the panels shall be clipped on to the carriers without the use of any tools.

   Six) Install suspended grid system in accordance with BS 8290 suspended ceiling and liming of dry construction using metal fixing systems.

   Seven) Install electrical, mechanical works prior to suspended ceiling work and co-ordinate where ducts or other equipment's prevents regular pacing of hangers, reinforce nearest adjacent hangers to span the required distance.

   Eight) Access Panels: Where required they shall be retained in the grid by chips in a way to be rigidly fixed in place and easily demountable.

   Nine) Expansion joints: Provide expansion joints to accommodate plus or minus 25 mm movement and maintain visual closure.

3-4-B-6 ALUMINUM WINDOWS

3-4-B-6-1 Generally

Aluminum windows shall be executed by a manufacture and in accordance with the requirements of the Contract Documents.

Aluminum windows shall be provided to the sizes and with opening portions. The windows shall be fixed in position in walls or precast concrete surrounds by means of non-corrodible screws firmly screwed into PVC plugs set in correctly sized holes drilled into walls or previously formed. Opening portions shall be hung on strong alloy hinges with nylon bearings and shall be provided with locking handles and stays.

Aluminum windows shall be anodised or powder coated as shown on the drawings.

The aluminum windows work hereby defined to include (but not necessarily be limited to) the following components :

1. Aluminum window testing
2. Tilt and turn aluminum windows
3. Sliding windows

4. Hinged windows
5. Fixed windows
6. Hinged doors
7. Operate hardware in conjunction with the above items
8. Sealants, caulking, joint fillers and gaskets in conjunction with the above items
    - Construct aluminum window units to the sizes and dimensions shown on the drawings or as specified. Openable parts of the window unit (ventilators) shall be complete with all necessary hardware.
    - Tilt and Turn Windows: Provide complete tilt and turn window units including manufacturer's standard supporting arms, assemblies, non-ferrous mechanisms, concealed hinges, hardware, trim pieces, etc. as required for a complete and finish installation.

For openable parts of the window unit:

- Meter cut all corners, weld throughout entire section profile and dress welds smooth on all exposed and contact surfaces.
- Vent members shall be designed to overlap the frame members to provide an uninterrupted compression seal around the entire perimeter of the window members providing true pressure equalizing and to allow frictionless operation during opening and closing.
- Frames shall be in one piece of largest size possible. Provide intermediate support members where shown on drawings or as required.

3-4-B-6-2 Performance Criteria of Window Units

- Except as otherwise indicated, comply with all applicable requirements including air infiltration tests, water resistance and applicable load tests specified in the standards.
- Design, fabricate and install aluminum window so that the total installed, glazed unit will withstand the gravity loads and wind pressure as approved by the Engineer.
- Maximum full load deflections, normal to the plane of the wall for any member of the window frame shall not exceed 1/175 of the span of the glass.
- Permanent deformation, disengagement or breakage of frame members and weld or fastener damage or failure shall not occur under loading equal to 1.5 times the design load and pressure, positive or negative. Permanent deformation is defined as deflection without recovery exceeding length /1000.
- Anchorage disengagement of breakage shall not occur when installed unit is subjected to a force equal to 2.5 times the design load.

- Make provisions at sill to drain water and condensation to exterior face of the frames.
- Provide tight joints and effectively seal windows against water leakage and .air infiltration. Water leakage is defined as appearance of uncontrolled water, other than condensation, on any inboard part of window, either during testing or under actual weather conditions.
- Place at least 2 holes of 50 mm² each (1 hole/1m) are needed in the outside frame, against water infiltration.

3-4-B-7 ALUMINUM DOORS

Aluminum doors unit shall be manufactured from heavy duty extruded sections and obtained from an approved manufacturer. Door units shall comprise complete frames including stiles, heads, transoms, thresholds, lock rails, bead and fixing lugs for building into blockwork or masonry bed joints. They shall also include robust hinges with steel bearing washers, steel striking plates and bolts as necessary and all furniture and fittings. Aluminum doors shall be anodised or powder coated as shown on the drawings.

- Where noted, the Contractor shall fabricate and install all aluminum doors.
- Aluminum used for door work shall be similar to the material specified for aluminum windows.
- The Contractor shall allow for all cut outs as required to receive hardware specified under other division of this specification.
- Where aluminum doors are shown on the drawings and specifications to be sliding, the Contractor shall supply and install the complete sliding gear, both top and bottom channels complete with hard clear plastic rollers and runners.

3-4-B-8 FABRICATION

- Complete the welding, curing, drilling and fitting of joints prior to finishing. Weld with electrodes and by methods recommended by the metal manufacturer in accordance with applicable recommendations. Use only methods which will avoid distortion or discoloration of exposed faces. Grind weld areas smooth before proceeding with other treatment.
- Conceal all fastenings unless otherwise shown or specified.
- Fit and assemble all work in the shop insofar as practicable mark and disassemble units which are too large for transportation to project site, retaining units in sizes as large as possible for transportation and erection.
- Carefully fit and mark all work with continuity of line and design, using rigidly secured joints with hairline contact, metered corners, unless otherwise shown.

- Reinforce members and joints with steel or aluminum plates, bars, rods or angles for rigidity and strength as needed to fulfill performance requirements. Use concealed fasteners for jointing which cannot be welded.
- Separate unlike metals or alloys with a heavy coating of bituminous paint or other suitable permanent separation as required to prevent galvanic action.

3-4-B-9 FINISHES

3-4-B-9-1 Aluminum Finishes

Remove die markings prior to finishing operations. Where necessary to remove die markings from any part of the work, all members must be finished by the same process, whether or not die marking exists. Perform this work in addition to the finish specified. Scratches, abrasions, dents and similar defects are unacceptable.

All exposed aluminum surfaces shall be of anodized aluminum of average thickness of anodization of 16-18 micron or powder coated as shown on the drawings.

3-4-B-10 CONSTRUCTION REQUIREMENTS

3-4-B-10-1 Condition Of Surfaces

Examine the substrates and adjoining construction and conditions under which the work is to be installed. Do not proceed with the work until unsatisfactory conditions detrimental to the proper and timely completion of the work have been corrected.

3-4-B-10-2 Installation

Vary dimensions of openings by field measurements so that aluminum windows will be accurately designed, fabricated and fitted to the structure.

Coordinate aluminum windows, with the work of other trades and provide items to be placed during the installation of other work. Check the location of such items and verify that they have been set accurately in relation to the final location of windows.

Erect the windows, in accordance with the manufacturer's written instructions and recommendations. Employ only experienced erectors.

Erection Tolerances: Erect aluminum window within the following tolerances:

1. Variation from plumb: 3mm maximum.
2. Variation from level: 3mm maximum.

Cut and trim component parts during erection only with the approval of the manufacturer or fabricator and in accordance with his recommendations. Do not cut through reinforcing members. Restore finish completely to protect material and remove all evidence of cutting and trimming. Remove and replace members where cutting and trimming have impaired strength or appearance.

Do not erect members which are observed to be warped, bowed, deformed or otherwise damaged or defaced to such extent as to impair strength or appearance. Remove and replace members damaged in the process of erection, as directed.

Set units level, plumb, and true to line, with uniform joints. Support on metal shims and secure in place bolting to clip angles and similar supports anchored to supporting structure. Use only the types of equipment, ropes, wedges, spacers, shims and other items during erection which will not stain or mark the finish of units.

The slat-holders of louvers shall not rub on the frames and shall present a good tightness when closed with the frames. The rigidity of the slat-holders shall be ensured independently from the glass. Once the slats are installed and the jalousies closed, no play shall be tolerated between two blades. Pivots and axes shall be of the best quality and shall be mounted according to the rules of the art. They shall be, as well as their fixing screws, made of chromium-plated steel or of a special stainless alloy. The aluminum screws shall not be accepted.

Paint concealed contact surface of dissimilar materials with a heavy coating of bituminous paint, or provide other separation as per manufacturer's recommendations.

Solder and braze only to fill or seal joints (not to form structural joints), and in accordance with components parts manufacturer's recommendations. Grind smooth and restore finish.

Paint clip angles and other ferrous metal parts which will be concealed, with zinc chromate paint.

Seal joints in a concealed manner, unless exposed sealant is shown.

Adjust ventilators and hardware to provide a tight fit at contact points and at weather stripping. Lubricate hardware and other moving parts.

3-4-B-10-3 Isolation Of Aluminum

All items of aluminum construction shall be isolated from concrete by the use of bituminous felt or DPC material or two coats of bituminous paint. The aluminum shall be isolated from dissimilar metal by the use of fiber washers and spacers.

3-4-B-10-4 Protection And Cleaning

In addition to specific protection and cleaning methods required for each component part of the respective Sections of the specifications and recommended by the respective manufacturers, maintain the work throughout the construction period in a clean and properly protected condition that it will not be damaged at the time of completion of the works.

Cleaning and protective methods shall be carefully selected applied and maintained so that finishes will not become uneven or otherwise impaired as a result of unequal exposure to light and weathering conditions.

Remove deleterious materials from surfaces of aluminum immediately.

3-4-C GLAZIARY

3-4-C-1 GENERAL

The applied standards are the D.T.U. No. 39.1 published in February 1980 and D.T.U. No. 39.4 published in March 1977.

The work shall include glazing on wood, aluminum, exterior and interior ironworks. The Contractor shall be fully responsible for ensuring a perfect coordination with all work bodies concerned by glaziery works, such as carpenters and painters. The implementation particularities, the clearances that should be arranged, the perfect implementation of window panes shall be executed by specialized labor.

The thickness of the glass, according to the measurements of the panel, wherever not indicated on the drawings, shall be:

a. 4mm for panes whose perimeter does not exceed 400 cm.

b. 6mm for panes whose perimeter is between 400cm and 900 cm.

c. 8 mm, 10 mm and 12 mm shall be used for panes having bigger dimensions than above as shown on the drawings.

d. Laminated glass shall be used in double glazed windows and doors, one of the two pans shall be made of laminated glass. Laminated glass shall be used also wherever required for security and safety regulations. Laminated glass is specified in BS 952.

The Contractor shall locate and repair, before any execution, all defects in the rebates, carpentries, elements to be glazed that could affect the solidity of the glass or the conditions of execution. He shall ensure especially the elements needed to be glazed are undercoated before being painted.

Materials shall be stored according to the specifications that are specific to the materials used while taking all usual precautions. The Contractor remains, in all cases, responsible for all breakage. All damaged or broken glass or mirrors shall be rejected and must be replaced. When finished, cleaning up is a must.

The Contractor shall inspect work of glass framing assembling for compliance with manufacturing and installation tolerances, including those for size, squareness, offsets at corners; for presence and functioning of weep system; for existence of minimum required face or edge clearances; and for effective sealing of joinery. The Contractor shall not allow glazing work to proceed until unsatisfactory conditions have been corrected.

The Contractor shall also clean glazing channels and other framing members to receive glass, immediately before glazing. Remove coatings which are not firmly bonded to substrates. Remove lacquer from metal surfaces where elastomeric sealants are indicated for use.

The Contractor shall comply with combined printed recommendations of glass manufacturers, of manufacturers of sealants, gaskets and other glazing materials, except where more stringent requirements are indicated, including those of referenced glazing standards.

Glazing channel dimensions as indicated in details are intended to provide for necessary bite on glass, minimum edge and face clearances, and adequate sealant thicknesses, with reasonable tolerances. Adjust as required by job conditions at time of installation.

e. Protect glass from edge damage during handling and installation; use a rolling block in rotating glass units to prevent damage to glass corners. Do not impact glass with metal framing,. Use suction cups to shift glass units within openings; do not raise or drift glass with a pry bar. Rotate glass with flares or bevels along one horizontal edge which would occur in vicinity of setting blocks so that these are located at top of opening. Remove from project and dispose of glass units with edge damage or other imperfections of kind that, when installed, weakens glass and impairs performance and appearance.

f. Apply primers to joint surfaces where required for adhesion of sealants, as determined by preconstruction sealant-substrate testing.

3-4-C-2 DELIVERY, STORAGE, AND HANDLING

The Contractor shall protect glass and glazing materials during delivery, storage and handling to comply with manufacturer's directions and as required to prevent edge damage to glass, and damage to glass and glazing materials from effects of moisture including condensation, of temperature changes, of direct exposure to sun, and from other causes.

Where insulating glass units will be exposed to substantial altitude changes, avoid hermetic seal ruptures by complying with insulating glass fabricator's recommendations for venting and sealing.

3-4-C-3 PROJECT CONDITIONS:

The Contractor shall not proceed with glazing when ambient and substrate temperature conditions are outside the limits permitted by glazing material manufacturer or when joint substrates are wet due to rain, frost, condensation or other causes.

3-4-C-4 SYSTEM DESCRIPTION

The Contractor shall provide glass and glazing that has been produced, fabricated and installed to withstand normal thermal movement, wind loading and impact loading (where applicable), without failure including loss or breakage of glass. failure of sealants or gaskets to remain watertight and airtight, deterioration of glass and glazing materials and other defects in the work.

1. Normal thermal movement is defined as that resulting from an ambient Temperature range of 49 degrees C and from a consequent temperature range within glass and glass framing members of 82 degrees C.
2. Deterioration of insulating glass is defined as failure of hermetic seal due to other causes than breakage which results in intrusion of dirt or moisture, internal condensation or fogging, deterioration of protected internal class coating, if any, resulting from seal failure, and any other visual evidence of seal failure or performance.
3. Deterioration of laminated glass is defined as the development of manufacturing defects including edge separation or delamination which materially obstructs vision through glass.

4. Deterioration of coated glass is defined as the development of manufacturing defects including peeling, cracking or other indications of deterioration in metallic coating due to normal conditions of use.

3-4-C-5 SUBMITTALS

The Contractor shall submit manufacturer's technical data for each glazing material and fabricated glass product required, including installation and maintenance instructions.

The Contractor shall submit samples for verification purposes, 300mm square samples of each type of glass indicated, and 300mm long samples of each color required for each type of sealant or gasket exposed to view. Install sealant or gasket sample between two strips of material representative of adjoining framing system in color.

The Contractor shall submit certificates from respective manufacturers attesting that glass and glazing materials furnished for project comply with requirements.

Separate certification will be required for glazing materials bearing manufacturer's permanent labels designating type and thickness of glass, provided labels represent a quality control program involving a recognized certification agency or independent testing laboratory acceptable to authorities having jurisdiction and to Engineer.

Compatibility and Adhesion Test Report: Submit statement from sealant manufacturer indicating that glass and glazing materials have been tested for compatibility and adhesion with glazing sealants and interpreting test results relative to material performance, including recommendations for primers and substrate preparation needed to obtain adhesion.

3-4-C-6 QUALITY ASSURANCE

The Contractor shall comply with recommendations of Flat Glass Marketing Association (FGMA) "Glazing Manual" and "Sealant Manual" except where more stringent requirements are indicated. Refer to those publications for definitions of glass and glazing terms not otherwise defined in this section or other referenced standards.

Safety Glazing Standard: Where safety glass is indicated or required by authorities having jurisdiction, provide type of products indicated which comply with ANSI Z97.1 and testing requirements of 16 CFR Part 1201 for category II materials.

Subject to compliance with requirements, provide safety class permanently marked with certification label of Safety Glazing Certification Council (SG-CC) or other certification agency acceptable to authorities having jurisdiction and to Engineer.

Fire Resistance Rated wire Glass: Provide wire glass products that are identical to those tested per ASTM E 163 (UL 9) and are labeled and listed by UL or other testing and inspecting agency acceptable to authorities having jurisdiction and to Engineer.

Insulating Glass Certification Program: Provide insulating class units permanently marked either on spacers or at least one component pane of units with appropriate certification label of inspecting and testing organization indicated below:

1. Insulating Glass Certification Council (IGCC) or other certification agency acceptable to authorities having jurisdiction and to Engineer.

Single Source Responsibility for Glass: To ensure consistent quality of appearance and performance, provide materials produced by a single manufacturer or fabricator for each kind and condition of glass indicated and composed of primary glass obtained from a single source for each type and class required.

Preconstruction Compatibility and Adhesion Testing: Submit samples of all glass, gaskets, glazing accessories, and glass framing members proposed for use in contact with, or proximity of, glazing sealants, to sealants for compatibility and adhesion testing in according with manufacturer's standard testing methods and the following requirements:

1. Submit not less than 9 pieces of each type and finish of glass framing member and of each type, class. kind, condition, and form (monolithic, laminated, insulating units) of glass for adhesion testing and one sample of substrates (gaskets, setting blocks and spacers) for compatibility testing.
2. Schedule sufficient time for testing and analysis of results to prevent delay in the progress of the Work.
3. Investigate materials failing compatibility or adhesion tests and obtain sealant manufacturer's written recommendations for corrective measure, including use of specially formulated primers.

3-4-C-7 WARRANTY

The Contractor shall provide written warranty signed by manufacturer of laminated glass agreeing to furnish c.i.f point of manufacture, freight allowed project site, within specified warranty period not less than 10 years after date of substantial completion. Replacements for those laminated glass units which develop manufacturing defects. Manufacturing defects are defined as edge separation or delamination which materially obstructs vision through glass.

The Contractor shall provide written warranty signed by manufacturer of insulating glass agreeing to furnish c.i.f. point of manufacture, freight allowed project site, within specified warranty period not less than 10 years after date of substantial completion. Replacements for those insulating glass units developing manufacturing defects. Manufacturing defects are defined as failure or hermetic seal of air space (beyond that due to glass breakage) as evidenced by intrusion of dirt or moisture, internal condensation or fogging, deterioration of protected internal glass coatings, if any, and other visual indications of seal failure or performance; provided the manufacturer's instructions for handling, installing, protecting and maintaining units have been compiled with during the warranty period.

3-4-C-8 MANUFACTURERS

The Contractor shall provide glass from an approved manufacturer.

3-4-C-9 GLASS PRODUCTS

3-4-C-9-1 Ordinary Glass

The glass shall be of a quality approved by the Engineer, and shall be 4 and/or 6mm thick as specified in the preceding article whenever indicated on the drawings or as directed by the Engineer. It shall be free of air bubbles, scratches, streaks, undulations or any other defects. It shall not deform the image showing through or reflected on it. In particular, objects seen crosswise, at a distance of 0.25m and an angle of 20 degrees, shall not be deformed.

The Contractor shall submit to the Engineer for approval samples of the glass to be used. Glass shall be cut to the exact measurements by taking into account possible dilation (the play between the glass and the framework shall not exceed 2mm). The panes shall be set up under mastic strips or as indicated on the drawings. The mastic shall be of the white mastic type with pure linseed oil. The use of bituminous mastic is forbidden.

Wedging of the glass is obligatory.

After execution of all works, the Contractor shall proceed to clean the glass on both sides and to remove all wastes resulting from the said works.

The glass shall be transparent, translucent, or of a special type.

All glazing in windows and doors shall be polycarbonate sheeting (purpose made for anti-vandal and security use), obtained from an approved manufacturer.

The glazing sheets, extruded from polycarbonate resin, shall be a minimum of 4 mm thick. The polycarbonate sheets shall be installed in the frames in strict accordance with the manufacturer's recommendations and only sealant specified by the manufacturer shall be used.

3-4-C-9-2 Primary And Heated Glass Standard

The Contractor shall provide primary glass which complies with ASTM C 1036 requirements, including those indicated by reference to type, class, quality, and, if applicable, form, finish, mesh and pattern.

The Contractor shall provide heat-treated glass which complies with ASTM C 1048 requirements, including those indicated by reference to kind, condition, type, quality, class, and, if applicable, form, finish, and pattern.

The Contractor shall fabricate glass to sizes required for glazing openings indicated, with edge clearances and tolerances complying with recommendation of glass manufacturer. The Contractor shall also provide thicknesses indicated or, if not otherwise indicated, as recommended by glass manufacturer for application indicated.

3-4-C-9-3 Primary Glass Products

A. Clear Float Glass: Type I (transparent glass, flat), Class I (clear), Quality q3 (glazing select).

B. Tinted Float Glass: Type I (transparent Class, flat), Class 2 (tinted heat absorbing and light reducing), Quality q3 (glazing select):

1. Refer to coated glass product requirements for tint and performance characteristics of coated tinted glass for single. glazing, relative to visible light transmittance, U-values, -shading coefficient and visible reflectance.
2. Refer to requirements for sealed insulating glass units for performance characteristics of assembled units composed of tinted glass. coated or uncoated, relative to visible light transmittance, U-values, shading coefficient and visible reflectance.

C. Wired Glass: Type II (patterned and wired class, flat), Class I (translucent), Quality q8 (glazing); complying with ANSI Z97.1- 6 mm thick; of form and mesh pattern indicated below:

1. Polished Wire Glass: Form I (wired, polished both sides), Mesh m2. (square).

3-4-C-9-4 <u>Heat-Treated Glass Products</u>

The Contractor shall provide manufacture heat-treated glass as follows:

By vertical (tong-held) or horizontal (roller hearth) process, at manufacturer's option, except provide horizontal process where indicated as "tongless" or "free of tong marks".

Uncoated Clear Heat-Treated Float Glass: Condition A (uncoated surfaces), Type I (transparent glass, flat), Class I (clear), Quality q3 (glazing select), kind as indicated below :

1. Kind HS (heat strengthened) where recommended by glazing manufacturer.
2. Kind FT (fully tempered) at all doors, sidelights and glazing units below 1050mm.

Uncoated Tinted Heat-Treated Float Glass: Condition A (uncoated surfaces), Type I (transparent -lass, flat), Class 2 (tinted heat absorbing and light reducing), quality q3 (glazing select), with tint color and performance characteristics for 6mm thick glass matching those indicated for non-heat-treated tinted float glass; kind as indicated below :

1. Kind HS (heat strengthened) where recommended by glazing manufacturer.
2. Kind FT (fully tempered) at all doors, sidelights, and all glazing units below 1050mm.

Uncoated Etched Heat-Treated Float Glass: Condition C (other coated Class). Type I (transparent glass, flat), Class 2 (tinted heat absorbing and light reducing). Quality q3 (glazing select), with coating type and performance characteristics complying with requirements specified under coated glass products; kind as indicated below:

1. Kind FT (fully tempered).
2. Etched Pattern: Sandblast glazing units on one or both surfaces of pattern.
3. Provide clear etched glass sealer on all sandblasted glass types.

Ceramic-Coated Heat-Treated Spandrel Glass (Interior Conditions): Condition B (spandrel glass, one surface ceramic coated), Type I (transparent glass, flat), Class I (clear), Quality q3 (glazing select), with ceramic coating applied to second surface and complying with the following requirements:

1. Kind HS (heat strengthened), where recommended by glazing manufacturer.
2. Kind FT (fully tempered) at all doors, sidelights and glazing units below 1050mm.
3. Color: Match Engineer's custom color.

3-4-C-9-5 Laminated Glass Products

A. General: Refer to primary and heat-treated glass require properties of uncoated glasses making up laminated glass products.

B. Plastic Interlayer: Provide glass fabricator's standard polyvinyl butyral interlayer for laminating panes of class, with a proven record of showing no tendency to bubble, discolor or lose physical or mechanical properties after laminating and installation, in clear or colors and of thickness indicated.

C. Laminating Process: Fabricate laminated glass using laminator's standard heat-plus-pressure process to produce glass free from foreign substances and air/glass pockets.

D. Laminated Safety Glass: Two panes of glass of equal thickness, laminated together with not less than 0.76 mm thick plastic interlayer and complying with requirements indicated below:

1. Glass Characteristics: Float glass, complying with requirements for class, tint, kind and thickness of each pane (ply) indicated below:
    a. Class 1 - clear for both panes.
    b. Class 2, gray tint, outer pane only.
    c. Kind HS (heat strengthened), where recommended by manufacturer.
    d. Thickness: 6 mm unless otherwise indicated.
2. Color of Plastic Interlayer: Clear.
3. Provide etched glazing units that match Engineer's sample in areas indicated on Drawings.

3-4-C-9-6 Sealed Insulating Glass Units (To Be Applied On All Facades)

The Contractor shall provide preassembled units consisting of organically sealed panes of glass enclosing a hermetically sealed dehydrated air space and complying with ASTM E 774 for performance classification indicated as well as with other requirements specified for glass characteristics, air space, sealing system, sealant, spacer material, comer design and dessicant.

The Contractor shall provide heat-treated panes of kind and at locations indicated or, if not indicated, provide heat-strengthened panes where recommended by manufacturer for application indicated and tempered where indicated or where safety glass is designated or required.

Performance characteristics designated for coated insulating glass are nominal values based on manufacturer's published test data for units with 6 mm thick panes of glass and 12 mm thick air space.

Performance Classification per ASTIM E 774: Class A.

Thickness of Each Pane: 6 *mm.*

Air Space Thickness: 12 mm.

Sealing System: Manufacturer's standard.

Spacer Material: Aluminum.

Dessicant: Manufacturer's standard; either molecular sieve or silica gel or blend of both.

Corner Construction: Manufacturer's standard corner construction.

Low Emissivity-Coated Insulating Glass Units: Manufacturer's standard units with one pane of glass coated with a durable, neutral-colored, low-emissivity metallic coating, of type and on surface indicated, and complying with the following requirements.

Exterior Pane: Tinted float glass, coated on second surface.

a. Tint: Gray.
b. Kind HS (heat strengthened), where recommended by manufacturer.
c. Kind FT (fully tempered), at all doors, sidelights and glazing units below 1050mm.

Interior Pane: Clear float glass, uncoated.

Coating type: Vacuum deposited.

Performance Characteristics: Visible transmittance of 26 percent, summer daytime U-value of 1.82 W/(m^2 K) [0.321, winter nighttime U- value of 1.7 W/(m2.K) [0.30], shading coefficient of 0.30 and outdoor reflectance of 9 percent.

Sloped Insulating Glass Units: Provide manufacturer's standard insulating units with interior pane of laminated sloped glass and with exterior pane complying with requirements indicated below:

1. Kind HS (heat strengthened), tinted float glass.
2. Provide units with cermaic frit coating of pattern indicated on Drawings.
3. Units Performance Characteristics: Visible light transmittance of 30%, overall U-value of 2.27 W/(m2.K) [0.40] and shading coefficient of 0.36.

Sloped Insulating Glass Units (Control Tower): Provide manufacturer's standard insulating units with interior pane of laminated sloped glass_and with exterior pane complying with requirements indicated below:

1. Tint: Green
2. Kind: HS/FT, where recommended by manufacturer.
3. Thickness: 10 nun
4. Units Performance Characteristics: Visible light transmittance of 0.53, summer daytime U-value of 3.18 W/(m2.K) [0.56], winter night-time U-value of 2.78 W/(m2.k) [0.49], shading coefficient of 0.40 and outdoor reflectance of 0.09.

Insulating Spandrel Glass: Manufacturer's standard units with Kind HS (heat strengthened) exterior pane and location of reflective coating matching that of coated insulating glass units for type, class and coating characteristics, and with interior pane complying with the following additional requirements:

Ceramic-Coated Heat-Treated Spandrel Glass: Condition B (spandrel glass, one surface ceramic coated), Kind HS (heat strengthened), Type I (transparent glass, flat), Class I (clear), Quality q3 (glazing select), and complying with the following requirements:

a. Color Match Engineer's sample.
b. Location of Ceramic Coating : Third surface of insulating spandrel unit. Overall U-value: 0.45 W/(m2.K), [0.08].

3-4-C-9-7 Elastomeric Glazing Sealants And Preformed Glazing Tapes

The Contractor shall provide products of type indicated and complying with the following requirements:

1. Compatibility: Select glazing sealants and tapes of proven compatibility with other materials with which they will come into contact, including glass products, seals of insulating glass units, and glazing channel substrates, under conditions of installation and service, as demonstrated by testing and field experience.
2. Suitability: Comply with recommendations of sealant and glass manufacturers for selection of glazing sealants and tapes which have performance characteristics suitable for applications indicated and conditions at time of installation.
3. Elastomeric Sealant Standard: Provide manufacturer's standard chemically curing, elastomeric sealant of base polymer indicated which complies with ASTM C 920 requirements, including those for Type, Grade, Class and Uses.
4. Colors: Provide color of exposed sealants indicated or, if not otherwise indicated, as selected by Engineer from manufacturer's standard colors.

One-Part Non-Acid-Curing Silicone Glazing Sealant: Type S; Grade NS, Class 25; Uses NT, G, A, and, as applicable to uses indicated, 0; and complying with the following requirements for modulus and additional joint movement capability.

1. Low Modulus: Tensile strength of 172 kPa [45 psi] or less at 100 percent elongation when tested per ASTM D 412 after 14 days at 25 degree C and 50 percent relative humidity.
2. Additional capability, when tested per ASTIM C 719 for adhesion and cohesion under maximum cyclic movement, to withstand the following percentage increase and decrease of joint width, as measured at time of application and remain in compliance with other requirements of ASTM C 920.
   a. 40 percent.

Preformed Butyl-Polyisobutylene Glazing Tape: Provide manufacturer's standard solvent-free butyl-polyisobutylene formulation with a solids content of 100 percent; complying with AAMA A804.1; in extruded tape form; non-staining and non-migrating in contact with nonporous surfaces; packaged on rolls with a release paper on one side; with or without continuous spacer rod as recommended by manufacturers of tape and glass for application indicated.

3-4-C-9-8 Glazing Gaskets

Dense Elastomeric Compression Seal Gaskets: Molded or extruded gaskets of material indicated below, complying with ASTM C 864, of profile and hardness required to maintain watertight seal:

1. Neoprene.
2. EPDM.
3. Thermoplastic polyolefin rubber.
4. Any material indicated above.

3-4-C-9-9 Miscellaneous Glazing Materials

A. Compatibility: Provide materials with proven record of compatibility with surfaces contacted in installation.

B. Cleaners, Primers and Sealers: Type recommended by sealant or gasket manufacturer.

C. Setting Blocks: Neoprene, EPDM or silicone blocks as required for compatibility with glazing sealants, 80 to 90 Shore A durometer hardness.

D. Spacers: Neoprene, EPDM or silicone blocks, or continuous extrusions, as required for compatibility with glazing sealant, of size, shape and hardnes recommended by glass and sealant manufacturers for application indicated.

E. Edge Blocks: Neoprene, EPDM or silicone blocks as required for compatibility with glazing sealant, of size and hardness required to limit lateral movement (side-walking) of glass.

F. Compressible Filler Rods: Closed-cell or waterproof-jacketed rod stock of synthetic rubber or plastic foam, flexible and resilient, with 35-69 kpa [5-10psi] compression strength for 25 percent deflection.

3-4-C-9-10 6mm Mirrors

They shall be of the measurements indicated on the drawings, and shall be fixed with invisible fasteners. Their backside shall be plastic-coated with PVC

3-4-D WOOD WORKS

3-4-D-1 GENERAL

The work consists of providing labor, and performing all operations in connection with carpentry work including the execution of built-in, assembled on-site, and all necessary materials and accessories of the sizes and combinations indicated on the drawings and as approved by the Engineer.

Woodwork shall be in accordance with the last issue of D.T.U. No. 36.1 and with the following codes and standards:

BS 1186	Quality of timber and workmanship
BS 1455	Plywood manufactured from tropical hardwoods
BS 3444	Blackboard and lamina board
BS 4787	Internal and external wood doorsets door.
BS 5450	Specification for sizes of hardwood and methods of measurement
BS 5669	Part 1 Methods of sampling conditioning and test.
BS 5669	Part 2 Specification for wood clipboard.
BS 6566	Plywood manufactured from tropical hardwoods

Woodwork shall be executed in coordination with other works namely, masonry, plastering and tiling.

The wood used shall be sound, dry, without knots, splits, fissures or imperfections.

Wooden pieces shall be stacked in a dry place, far from humidity.

3-4-D-2 MATERIALS

Generally, timber shall comply in all respects with British Standard No 881 and 589. Timber shall be properly seasoned with a moisture content not exceeding 10% of the dry weight and shall be free from defects.

Joinery timber is divided into two grades:

- Grade A which is the superior grade and shall be used wherever joinery is to receive a clear finish, correspond to BS 1186 part 1 class 15.
- Grade B which is the normal quality for joinery which is to be painted correspond to BS 1186 part 1 class 2.

Joinery timber softwood shall comply with BS 1186 and 447 1.

Joinery timber Hard Wood Shall comply with BS 1186, and 5450.

Plywood: Shall comply with BS 1455. Interior plywood is to be MR bonding Exterior plywood is to be WP bonding minimum thickness of 5 mm.

Melamine Surfaces: Shall be standard grade sheets in approved colors, (min 1.5 mm thick) cigarette proof quality all to conform to BS 4965, fixed with heat proof adhesive to comply with BS 1204 grade WPB.

Wood Screws: Shall comply with BS 12 1 0.

Glue: Shall comply with BS 1204, is to be synthetic resin glue of an approved type.

Timber Connectors: Shall comply with BS 1579.

3-4-D-3 SUBMITTALS

Unless specified otherwise, the Contractor shall:

- Product Data: Submit manufacturer's specifications, installation instructions and certification stating that the fabricated work meets the woodwork grade selected.
- Shop Drawings: Submit shop drawings showing location of each item, dimensioned plans and elevations, large scale details, attachment devices and other components.
- Wood Treatment Data: Submit chemical treatment manufacturer's instructions for proper use of each type of treated material.
- Samples: Submit the following samples for each species and cut or pattern of architectural woodwork.
- Prefinished solid work.
- Prefinished plywood.
- Samples of miscellaneous accessories required for any item specified for review and selection by the Engineer.

3-4-D-4 SKIRTING

The Contractor shall provide and install 10x1 cm hardwood skirting as specified on the drawings and as directed by the Engineer.

3-4-D-5 INSTALLATION

The installation shall be executed with accuracy and perpendicular plumb shall be respected.

The Contractor shall verify on site, the exact dimensions of the openings and shall take all precautions in order that the carpentry do not get deformed during setting and before the plaster dries.

The maximum play tolerated between mobile parts or between permanent and mobile parts shall be 1mm.

When closed, the doors shall be absolutely tight and the split hinges shall be vertical.

Door frames shall be fixed to walls or to concrete, each by means of seven sealing flaps and anchored well and deep enough as compared to the plastering. The length of the groove in the frame intended for fixing the sealing flap, shall not exceed the width of joint-cover.

All the used iron parts and notably the sealing flaps shall be coated with, at least, two layers of paint before using them. Each of them shall be long and shall have a section of 25mm.

The tip of the case side shall be fixed to the case by screws and not nails. The other tip shall be split.

Sealing shall be made with cement mortar well stuffed in the pending holes. The backside of the frames and all door or window frames in contact with the concrete or the masonry shall be coated with creosote, xylophone or any other similar protective product, before fixing.

All carpentry and wooden pieces shall receive a priming layer before the installation.

It is forbidden to use wedges or mastic to conceal the defects of the wood, or of the defective assembling. Mastic shall only be tolerated in order to cover a metal part embedded in the wood (nails, hinges).

3-4-D-6 HARDWARE

All hardware and various equipment shall be in accordance with the last issue of NFP 26-303.

Samples of the various equipment shall be presented to the Engineer as soon as possible for the selection of the models that are to be used.

The Contractor shall supply all locks, split hinges, braces, handles, bolts, various door stops, automatic door pushers, stops, pegs, etc. unless otherwise specified by the Engineer.

All locks shall be of the best marks, safety locks with a mortise and a cylinder.

1- All internal one leaf doors shall comprise:

One safety lock with a mortise and a cylinder mechanism.

Three split hinges with 140mm blades, square ends, and a brass ring.

A pair of handles.

Two plates.

A door-stop.

Accessories shall be made of dull chromium-plated brass and shall comprise all necessary rings and washers for the installation and mounting of the hinges, leaving no play, and shall be approved by the Engineer.

Two-leaves doors shall comprise, in addition, three split hinges for the second leaf, two bolts, covers for fixing holes to be fixed on the tiling or in the wood.

Part III: Civil and Architectural Works

Part III-5: FINISHES

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PART 3.5 - CIVIL & ARCHITECTURAL WORKS: FINISHES

3-5-A PLASTER WORKS

3-5-A-1 DESCRIPTION

This work shall consist of furnishing and installation of Portland cement plaster for the areas designated on the Plans or where specified. Work shall begin after the Contractor's request to start work has been approved.

3-5-A-2 MATERIALS

3-5-A-2-1 Portland Cement

Portland cement shall conform to LIBNOR.

3-5-A-2-2 Water

Water shall be clean, pure and free from all deleterious substances.

3-5-A-2-3 Aggregates

The aggregate shall be natural sand, clean, sharp, free from impurities and conforming to granularly hereafter described.

3-5-A-2-4 Hydrated lime

Lime shall be used only where mentioned and after being approved by the Engineer.

Quantities used in the mixtures must be approved by the Engineer.

3-5-A-2-5 Waterproofing additive

Waterproofing additive shall be a brand approved by the Engineer.

3-5-A-3 PLASTER MIXES

3-5-A-3-1 Designation

Plaster work shall be designated as follows :

a. Ordinary Interior Plastering : Plaster work applied to interior surfaces.

b. Ordinary Exterior Plastering : Plaster work applied to exterior surfaces.

c. Water Resistant Exterior Plastering : Plaster work containing waterproofing additive applied to exterior surfaces.

d. Tyrolean Plastering : Plaster work applied to exterior surfaces.

3-5-A-3-2 Batching and mixing

Mixing of the ingredients shall be done either manually or mechanically. In both cases, measurement of cementitious material should be based on full bag increments of cement whenever possible.

3-5-A-3-3 Manual mixing

The mixing process shall be done in a clean area away from natural soil and any other substances. First, the dry ingredients shall be mixed before any water is added. Then water is added only enough to produce a workable mix. The volume of the sand shall be measured in calibrated boxes such that each volume of plaster requires a whole number of 50 Kg cement bags. The mortar shall be used in the first half hour after its preparation and before it starts to set.

3-5-A-3-4 Mechanical mixing

Portland cement plaster shall be mixed in a paddle drum mixer for 3 to 10 min. Excessive mixing which could be detrimental to the quality of the plaster shall be avoided. Only sufficient water shall be added to produce a suitably plastic mortar.

3-5-A-4 PREPARATION OF SURFACES

Before proceeding with the plaster work, the substrates and the conditions under which the work is to be installed shall be examined and any unsatisfactory conditions detrimental to the proper and timely completion of the work shall be corrected. The following background conditions shall be satisfied before coatings are applied :

- Adequately true and level to achieve specified tolerance
- Adequately fixed
- Free from contamination and loose layers
- Adequately prepared to give a good bond
- Free of any coating of bituminous compound or any other detrimental waterproofing or damp-proofing agent.

3-5-A-5 SAMPLES

One square meter of each plastering sample shall be executed before starting the plaster work. The approved samples shall be kept until all the plastering work is finished. Plaster work shall be of a quality the same or better than the sample.

3-5-A-6 PROTECTION

All fixtures, frames, inserts and other contiguous work shall be protected from rusting, soiling or clogging due to plastering.

3-5-A-7 PLASTER COATS

Unless otherwise specified plaster work shall consist of three coats :

1- Scratch coat which is the first coat

2- Brown coat which is the second coat

3- Finish coat which is the final coat and can be replaced or covered with decorative plastering.

3-5-A-8 APPLICATION OF PLASTER

3-5-A-8-1 General

Immediately prior to the application of plaster, surfaces shall be thoroughly sprayed with water few hours before plastering and all free water shall be allowed to run off.

All arises, corners and internal angles shall be straight and level or plumb.

Plaster shall be made good up to frames and skirting and around fittings and pipes. Angles shall be rounded to a 5 mm radius.

Undercoats and finish coats shall be protected from the weather until they have set and shall not be allowed to “dry out” or “sweat out” to the detriment of the surface and shall be kept covered with damp sacking or other approved means for the period specified.

Thickness guide markers of porcelain tiles splinters or similar markers shall be placed at the rate of one marker per square meter of surface to be plastered.

Unless otherwise specified the surface of the plaster shall be rendered smooth and level by the use of a felt. Rough patches, ridges or any other flaws shall not be permitted.

Plastering shall be executed under almost horizontal light so that any flaw such as undulations, ridges, etc. can be detected and repaired.

A straight edge, a plumb, a spirit level, a square and an electric lamp shall always be kept at the site so it can be possible to check the plastering work.

Plaster work containing cracks, blisters, pits, checks or discoloration will not be accepted. Such plaster shall be removed and replaced with new plaster. Patching of defective work will be permitted only when approved. Such patching shall match existing similar work in texture and color as determined by the Engineer. Moistening must occur twice a day.

The Contractor shall provide easy and secure access to all surfaces to be plastered.

Plastering is forbidden when one of the following weather condition occur:

- Temperature below 5 degrees C.
- Dry air (Unless approved by the Engineer)
- Rainy day (Unless approved by the Engineer)
- Hot weather (Unless approved by the Engineer)

3-5-A-8-2 Application of coats

3-5-A-8-2-1 Scratch Coat Plastering

This coat shall be a plastic workable mix. It shall be laid on with sufficient material to form full key with the base material. It shall be cross raked and allowed to set for 48 hours before applying brown coat. It shall be continuously damp during the entire period between coats.

This coat is not to be used on interior or rough surfaces.

This coat is to be used on exterior and flat surfaces.

Properties of the ingredients in the plaster mix shall be as follows:

- 600 Kg Portland Cement for 1 cubic meter of sand, or 1 part Portland Cement for 3 part sand.
- Sand granulometry: 0.1 - 0.3 mm. Particles less than 0.1 mm shall be less than 10%.

Using of lime for exterior plastering coat is forbidden.

Scratch coat thickness shall be between 5 and 8 mm.

3-5-A-8-2-2 Brown Coat Plastering

The scratch coat shall be moistened with water before applying the brown coat. The water sheen on the surface of the scratch coat shall be allowed to disappear before applying the brown coat. If the prewetting operation interferes with the proper floating of the plaster surface, it may be reduced or eliminated depending upon the moisture condition of the scratch coat.The brown coat shall be hand-troweled with enough force to key this coat to the scratch coat. After obtaining the desired thickness, it shall be rodded to a plane surface. Sufficient stiffening shall be allowed to occur prior to floating. The brown coat shall be damp proofed for a period of 5 to 15 days depending on weather conditions.

Proportions of the ingredients in the plaster mix shall be as follows:

- 600 Kg Portland Cement for 1 cubic meter of sand
- Sand granulometry: 0.1 - 0.5 mm.

Using of lime for exterior plastering coat is forbidden.

Brown coat thickness shall be between 5 and 8 mm.

3-5-A-8-2-3 Finish Coat

Finish coat shall not be applied until brown coat has cured for seven days. Before application of finish coat, wet brown coat to a true, even surface and trowel in a manner that will give a level, even surface of sandy texture, free from trowel marks, checks and other blemishes.

Care should be taken to apply finish coat continuously between natural breaks in the surface plane. On multiple-level staged walls, lower levels of plaster in the same panel shall be continued immediately to avoid joining stains, shouldering and texture variation. The finish coat shall be moistened for at least three days; thereafter it shall be protected against rapid drying until properly, thoroughly cured.

Proportions of the ingredients in the plaster mix shall be as follows:

- 600 Kg Portland Cement for 1 cubic meter of sand.
- Sand granulometry: 0.1 - 2 mm.

Using of lime for exterior plastering coat is forbidden.

Thickness of the finish coat is between 5 and 8 mm.

When Tyrolean coat is applied as a finish coat, plaster shall have the same characteristics of cement plaster, but with finishing layer of white cement sprayed with a machine in many passes to get a homogeneous rough surface.

The roughness of the finished layer is as per sample approved by the Engineer.

Approximate thickness is 10 mm.

Proportions of the ingredients for Tyrolean coat are:

- 1 part Portland Cement
- 4 part fine sand

3-5-A-8-3 <u>Internal Plastering</u>

Internal plastering shall be applied in two coats of minimum total thickness of 15 mm on vertical faces and 10 mm on ceilings (excluding the thickness of any initial dash coat).

On vertical faces the plaster shall be applied in widths not exceeding one meter between screed laths prepared and set up true and plumb.

The finished faces of plaster shall be true to shape and angle even in all directions, free of cracks and trowel marks to the complete satisfaction of the Engineer.

The plastering of each face between two corners shall be carried out in one operation and work must in no case be interrupted and continued the following day, all reveals for jambs, lintels shall be plastered in one operation with the respective wall faces.

At least one day shall elapse between the execution of consecutive coats of plaster.

Floated coat for tiled surface shall be applied as for internal plastering in general. It shall be plumb, true and level and shall bring the finished tiled face to required plane.

The surface of floated coats should be left with a steel float finish.

3-5-A-8-4 External Plastering

External plastering shall be applied in two coats to a minimum total thickness of 20 mm.

The finishing surfaces of plaster shall be true to shape and angle even in all directions, free of cracks and trowel marks to the complete satisfaction of the Engineer.

3-5-A-8-5 Tolerances and permissible deviations

- The finished plaster shall be straight, true, square with adjoining work, smooth where required, free from imperfections impairing appearance or performance. Angles shall be plumb and true.
- A 3 m. ruler placed on the surface in any direction shall not show a tolerance more than 3 mm.

3-5-B WALL TILES

3-5-B-1 DESCRIPTION

This work shall consist of furnishing, installing cutting, grinding and fitting of tiles and cladding as shown on the drawings or as approved by the Engineer.

3-5-B-2 GENERAL

Tiles and cladding plates shall be perfectly plane (no warping shall be tolerated) and shall have exactly the required specified dimensions.

All defects in the work shall be repaired by the Contractor as directed by the Engineer.

The Contractor shall not begin work before the approval of the Engineer and after finishing all necessary civil works.

The Contractor shall leave openings for sanitary, electrical works and others as specified on the drawings or as required by the Engineer.

The area shall be clean from dirt before placing any mortar for tiling.

Tile skirting shall be placed correctly so they will cover tile edges without leaving gaps. The thickness of the concrete bed beneath skirts shall be 1 cm. at least after skirts have been placed.

The Contractor shall make sure that all work shall be executed by a competent and experienced tile layer.

Laying may not proceed in temperatures exceeding 35 degrees C except with the approval of the Engineer. Laying may then only proceed under temporary shades.

All tiling shall be thoroughly soaked in clear water for at least 2 hours prior to laying.

Before laying commences, all tiling shall be checked for size to insure a correct fit into the area chosen for the day's laying schedule.

The concrete or floor screed sub-base shall be cleaned of dirt, dust and loose particles, and saturated with clean potable water several hours before placing the setting bed. About one hour before placing the setting bed, any surface water shall be removed.

About 15 minutes prior to placing setting bed a slush coat of cement grout 1.5 mm thick shall be applied to the sub-base. The slush coat shall be applied by trowel or brush in a limited area in order to avoid drying out.

The setting bed (cement and sand screed, 1:4 nominal mix) shall be level in plan or uniformly slopped for drainage as shown on floor plans. The screed shall be mixed and placed in limited amounts prior to the initial set of bed.

All tilings shall be locally manufactured.

3-5-B-2-1 Materials

Portland cement: Shall comply with the requirement of BS 12 ordinary and rapid hardening Portland blast furnace complying with BS 146 high alumna cement complying with BS 915. Cement used in preparation for Mortar for bedding Marble slabs shall be Portland White Cement to BS 12.

Sand for floated coat: shall comply with the requirements of BS 1199, of BS 1198: 1200 building sands from natural sources; Table 1.

For cement-sand bedding mix, sand or crushed rock should be clean, moderately sharp not too fine and free from clay, organic and soluble matter.

Lime: shall comply with the requirement of BS 890 " Building Lime " and should be properly hydrated.

Water: shall be fresh clean drinkable and complying with the requirement of BS 3148.

Reinforcement: Where required for flooring or screed it shall be expanded metal (10 mm. to 20 mm. mesh) complying with BS 405 expanded metal ; or wire netting (1 mm. to 25 mm. mesh) complying with BS 1485 galvanised wire netting.

Cement based adhesive: Shall comply with B.S.C.P. 212 Part 1. Appendix (B).

Mastic adhesive: Shall comply with B.S.C.P. 212 Part 1. Appendix (A).

Metal anchorages: Should be made of suitable non-ferrous metal e.g. Copper, Phosphor-Bronze, Gun metal or other approved metal. They shall be of such shape, dimension and strength and properly fixed to the wall and to the marble sand stone that they are adequate to carry the loads and stresses to be imposed on them.

Brass and Bronze cramps, ties and connections for wall cladding and other elements shown on drawings shall conform to the applicable requirements of BS 2870, rolled copper and copper alloys.

Floor dividing strips: Shall be non corrosive metal as shown on drawing and shall be used at the junction between different floor finishing.

The profile shall be uniform in size and capable of being cut, drilled and where necessary around the profile shall be adjustable to level tolerances in the slab.

3-5-B-2-2 Product Delivery, Storage And Handling

The Contractor shall transport, handle and store all materials with proper equipment, and in a manner to prevent soiling, staining and damage. Any damaged, broken , or permanently stained products will be replaced at the Contractor's expense.

3-5-B-2-3 Workmanship

3-5-B-2-3-1 Surface Preparation

Before laying any kind of tiles on floor screed or plastered walls, the surfaces shall be thoroughly cleaned of all dust and sand. Extra Mortar shall be knocked off with a hammer and removed. The surfaces shall be profusely sprayed with water and allowed to drain.

3-5-B-2-3-2 Laying Screed

Screed battens carefully levelled and trued should be fixed at the correct height for the required thickness of screed. In hot or drying weather care should be taken to ensure that portland cement mixes do not stiffen or dry out to an extent that prevents full compaction. After compaction, the surface must not be allowed to dry out quickly and protection by plastic sheeting or other suitable means may be necessary.

A base make-up slab may be laid, bonded to the structural slab with a PVA type bonding agent, and the floor tiles bedded on the make-up slab using a pre-mixed rubber-latex : cement mortar.

These mortars are specialist mortars with the manufacturer's instructions .

3-5-B-2-3-3 Mortar

Mortar for setting and backing up shall be cement and sand.(1:4) mix by volume of white, non staining portland cement mixed to a stiff consistency. Do not use mortar if more than 2 hours has elapsed since initial mixing.

Mortar bed shall be placed in specified locations with accurate thickness and measures as shown on the drawings or as required by the Engineer.

Mortar bed shall be poured and leveled with a leveling rod. The leveling rod shall be flat and clean. The percent water in the mix shall be adequate not to leave a foam on the surface of the layer after spreading it.

The Contractor shall verify with the Engineer whether the strength additives he wishes to mix with the concrete is applicable for use and shall also provide the name of the manufacture.

White cement grout for joints shall be from the best quality and approved by the Engineer.

Sand to be used for the mix shall conform to the requirements of sand specification.

3-5-B-2-3-4 Floated Coat

Floated coats of Portland cement and sand (1:4) mix with a total thickness to be 1.5 cm applied on the whole surface to be tiled.

The materials should be mixed together thoroughly before adding water. Only sufficient water should be added to make the mix workable, and should be used within two hours of the addition of the water.

It is very important that the floated be plumb, true and level, any unevenness should be such that a variation of no more than 0,15 cm. In any distance of 3,00 meter is required to bring the finished tiled face to the required plane.

It is necessary to apply the floated coat in two separate operations render and float. The surface of floated coats should be left with a steel float finish.

3-5-B-2-3-5 Precautions

The Contractor shall make sure that tiles are immersed in clean water for 6 hours and surplus water drained off, before bedding. Tiles shall be fixed to the floating coats with an approved adhesive, in accordance with B.S.C.P 212 a true vertical joints and pointed in neat white or colored cements, any surplus which adheres to the face of the tile shall be wiped off with a damp cloth before it sets hard.

Where tiling abuts against wood or metal frames or other tiling at angles and around pipes etc... It shall be carefully cut and fitted to form a close neat joint.

Whenever specified, the sand beds shall be of the thickness necessary to make up the finished floor level. They shall be salt free.

3-5-B-2-3-6 Grouting

All paving shall be grouted up on completion, care being taken to fill all joints completely. The grout shall consist of neat cement of a color to match tilling. Any surplus grout shall be cleaned off the face of the tiling and surrounding surfaces immediately and all tiling shall be carefully cleaned.

3-5-B-2-3-7 Allowance For Movement

The Contractor shall give due allowance for movement of the marble slabs. Therefore the Contractor is to take all necessary precautions in respect of these movements by providing compression and expansion joints in his design and detailed working drawings taking into consideration the type of structural backing, climatic conditions and exposure to sun, as well as the type of marble being used.

These joints should be filled with Polysulphide mastic compound.

3-5-B-2-3-8 Tolerances

The height and length dimensions of individual slabs shall be worked to within plus or minus 1 mm from those specified. Thickness shall be within 3mm from the specified, except where the thickness of the slab, forms a "seen" end. In such cases the thickness must be accurate to close limits.

All blocks, concrete or other backing must be formed so as to allow 13 mm clearance (void) between it and the back of any marble slab cladding.

3-5-B-2-3-9 Protection

After setting, all work liable to staining and damage shall be protected with an adequate type of covering approved by the Engineer. Any paper or wood used in connection with such protection shall be free of coloring matter and shall be of an approved non-staining type. This protection shall be kept in position and in repair, and shall be removed only at the direction of the Engineer.

3-5-B-3 CERAMIC TILES FOR FLOORS AND SKIRTINGS

Ceramic tiles shall be of the best quality. They shall present qualities and properties of the highest standard, and in particular flatness, orthogonality, resistance to wear, porosity, etc.

They shall be resistant to acids, bases, grease and hydrocarbons. The back of the tile and skirting shall carry the type and name of manufacture.

The Contractor shall submit samples for the Engineer's approval.

Tiles shall conform to the following requirements:

- Water absorption 0.3 % max.
- Erosion: Less than 7 mm.
- Breaking Resistance: At least 150 Kg/cm²
- Sound: No hollow sounding
- Tolerance (composed of a pack of 10 pieces)
    1. Width: ± 2 mm.
    2. Thickness: ± 1 mm.
- Weight: Approximately 2.3
- Porosity: 0.2 max.
- Size: As shown on the drawings or as required by the Engineer with a thickness ranges from 9 to 10 mm.
- Exterior appearance: No defects shall be apparent

Tiles shall be laid on sand bed 7 cm. thick or more, or as shown on the plans or as required by the Engineer. The sand bed shall be saturated and compacted well.

Sand used for floors shall be of the best quality and clean of all dirt.

Tiles shall be laid on a 2.5 cm. thick mortar bed proportioned at 600 kg. of Portland Cement CPA 210/325 per cubic meter of sand. The thickness of the mortar bed shall be 2 cm. at least after tiling.

The Contractor shall place all necessary installations before tiling.

The alignment of tiles shall be attained by means of perfectly straight tight strings.

The joints of the skirting shall be aligned with those of the tiles. During tile laying, tiles shall be taped on softly to assure that they are dipped enough in the mortar.

Levelling rod and level shall be placed on top of the tiles to make sure that the alignment and levelling are correct and even in every direction.

In the case of a step in tiling, and unless otherwise shown on the plans or directed by the Engineer, the two tiles forming the angle, shall be chamfered so that the joint is along a straight line.

After the laying, circulation shall not be allowed on ceramic tiles for 4 days.

24 hours after laying the tiles, the joints shall be covered with white cement grout.

The Contractor shall take all necessary measures to ensure protection of the executed works until their receival. He shall be responsible for repairing any damage.

The Contractor shall, at the end of works, clean the tiles and skirtings with spirits of salt.

Tile works shall include all necessary tools to cut the tiles either on site or in the factory if needed. This work shall also include transporting the tiles to the factory, cutting it, and transport it back to the rooms.

Tile works shall also include all tile skirting works including mixing, transferring the sand, cement, water and all necessary tools for a perfect tile skirting job as shown on drawing or as required by the Engineer.

All defects in the work shall be repaired by the Contractor as directed by the Engineer on his own expense.

The Contractor shall provide water drains in bathrooms and balconies.

The Contractor shall provide and install factory mounted dry pressed flat tile complying with the following requirements or as directed by the Engineer.

Unglazed vitrified ceramic tile.

Nominal dimensions	:	20x20 cm
Nominal thickness	:	10 mm or as specified and required
Breaking strength	:	1500N – 3000N
Stress group	:	U4 – EN 102Plain with square edges
Resistance to deep abrasion	:	< 300 mm^3 - EN 186-1
Wearing surface	:	Smooth
Face	:	Plain with square edge
Water absorption	:	E < 3% - Group B1
Density by Volume	:	2.4 g/cm^3
Quality	:	First choice
Color of the tile	:	Selected by the Engineer
Type of installation	:	Layed with enriched cement sand mortar (1:3) over floor creed(measured separately)
Joints	:	1- 1.5mm (to the approval of the Engineer)
Grout	:	Colored grout and joint filler as per Manufacturer's recommendation and to the approval of the Engineer. Waterproofing additives shall be added to the grout for the damp areas.

Installation and grouting as per BSCP 202 Tile flooring and BS 6431 Ceramic wall and floor tiles.

All Corners vertical and horizontal in damp areas, shall receive adequate silicone filler to the approval of the Engineer.

3-5-B-4 MARBLE TILES

3-5-B-4-1 Light ivory color marble tiling for floor and skirtings

The Contractor shall provide and install factory polished flat tile complying with the following requirements:

Descrpition	:	Light Ivory Color Marble Tiles.
Nominal thickness	:	40x40x2cm thick
Country of origin	:	Lebanon
Absorption by weight	:	0.16% - C97
Density	:	2688Kg/m^3 - C97
Compressive strength	:	1209 kg/cm^2 - C170
Abrasion resistance	:	4.72mm
Thermal expansion coefficient	:	0.0072 mm/m°C
Ultimate tensile strength	:	174 kgs/cm^2
Face	:	Plain
Type of installation (measured separately)	:	Laid with enriched cement sand mortar (1:3) over floor screed
Joints	:	1 - 1.5 mm (to the approval of the Engineer)
Grout	:	Colored grout and joint filler as per Manufacturer's recommendation and to the approval of the Engineer. Waterproofing additives shall be added to the grout for the damp areas.
Grinding and polishing	:	Grinding and polishing shall be done after laying and grouting the marble tiles of a minimum of 21 days. The crystallisation of the finished surface shall be refused.

A setting tile layout drawing shall be submitted to the Engineer for approval before starting any tiling works.

The edges of the marble tile shall be sound without any chipping or fractures subject to the refusal of the tiling works.

3-5-B-5 LIGHT IVORY COLOR MARBLE TREADS AND RISERS

The Contractor shall provide and install factory manufactured precast flat treads and risers with the following requirements:

Source of fabrication: One source for each type in conformity with BS 4131 or equivalent.

Description: Light Ivory Color marble treads and risers shall each be in one piece. In general they shall be identical in specification to perlato tiles as specified previously, but the thickness of the tread shall be 3 cm while the riser is 2 cm with sizes as specified on the drawings and approved by the Engineer. Reinforcement shall be provided if required by the Engineer according to the length of tread or riser.

The treads shall incorporate a cast iron nosing, minimum 30 x30 x 3 mm with tangs cast in. The nosing shall incorporate a non-slip textured top surface, all to the approval of the Engineer. The treads shall incorporate handling/anti crad reinforcement. Treads and risers shall be solidly bedded on cement and sand, all in accordance with the approval of the Engineer.

The height of the risers shall be in conformity with the detail drawings and checked on site prior to any ordering of material.

The Contractor is bound to produce to the Engineer approval, detailed drawings for the as-built staircase with the treads and risers to be ordered.

3-5-B-6 GLAZED CERAMIC WALL TILES (CHINESE PORCELAIN TILES)

Wall tiles shall be of the best quality with sizes as shown on the drawings.

Before installation, samples shall be provided to the Engineer for approval.

Walls shall be cladded with chinese porcelain tiles as shown on the drawing with the consideration of tile and tile bed thickness.

The bed beneath the tiles shall be white grout and shall meet the requirement of the manufacture that provides the tiles. These tiles shall conform to the following requirements:

- Porosity: less than 10%
- Breaking resistance: Under pressure of (7±0.5) Kg/cm² , it shall not show any breaking signs. Under pressure of (10±0.5) Kg/cm².
- Width tolerance: ±0.3 mm.
- Thickness tolerance: ±0.4 mm.
- Maximum offset in the surface: Less than ±0.7 mm.

Tiles shall be saturated with water before being laid and shall be laid with narrow joints without sticking to each other. Wall joints shall be aligned with floor joints. 24 hours after laying the tiles, the joints shall be covered with white cement grout.

The Contractor shall, at the end of the works, clean the tiles with spirits of salt.

If a ruler of 2 m. long is used, no unevenness shall be allowed of more than 2 mm.

If a plumb is used, no unevenness shall be allowed for more than 5 mm. of the total height.

3-5-C PAINTING

3-5-C-1 DESCRIPTION

This work shall consist of painting work as shown on the plans.

3-5-C-2 GENERAL REQUIREMENTS

Unless specified otherwise, the Contractor shall:

Have painting work conform to D.T.U. Standard No. 59.1 or BS 6150.

Provide samples showing the brand, quality, ingredients and shall be approved by the Engineer.

Supply all paints, primers, varnishes, distemper, oil, etc. ready mix in original sealed containers bearing the brand maker's name identifying the contents and giving directions for its proper use.

Have painting materials to be of the best quality products of recognised manufacturer's and shall be subject to the approval of the Engineer. The quality of the finishing colors shall be capable of giving three years minimum satisfactory performance under conditions of high temperatures and humidity, and capable of withstanding temperatures of up to 40 degrees C for long periods without color change. Paints shall also be resistant to oils, acids and alkalis.

Execute all paint works for flat concrete, plaster, wood, or steel as shown on drawings or as required by the Engineer.

Clean surfaces to be painted before applying paint or surface treatments. Remove oil and grease prior to mechanical cleaning. Program cleaning and application so that contaminants from cleaning process will not fall on wet, newly-painted surfaces. Paint shall only be applied on a properly brushed surface, so as to eliminate all loose sand or mortar particles.

Not be undertaken the application of paints in a temperature over 30 degrees C or below 5 degrees C, in a humid atmosphere over 80% and when weather is dry, in a dusty or foggy, or rainy weather, or on frozen or overheated surfaces.

Take every precaution to keep down dust before and during painting and decorating operations. No paint shall be applied to surfaces structurally or superficially damp and all surfaces shall be free from condensation, effloresce, crease, oil, dirt and like before the application of each coat.

Have primed or undercoated wood or metal not to be left in an exposed or unsuitable situation for an undue period before completing the painting. No exterior or exposed painting shall be carried out during adverse weather conditions.

Have metal hardware and door furnishings not required to be painted to be fitted first and then removed before any painting processes are commenced. When all painting is completed the fittings shall be cleaned and refixed.

Keep clean all brushes, pails, kettles and the like used in carrying out the work and free from foreign matter. They shall be cleaned before being used for different types or classes of materials.

Use the undercoats, primers and the like manufactured or recommended by the manufacturer of the finishing paint and not withstanding anything herein specified and shall prepare the surfaces, mix and apply the materials in accordance with the manufacturer's specification and as required on the drawings.

Not allow tile mixing of materials of different brands. No dilution of materials will be allowed except as detailed by the manufacturer. All paints for the site shall be ready mixed for use and brought on site in their original containers as supplied by the manufacturer.

Submit complete color charts for the paints to the Engineer for approval and the preparation of the color schedules. The number of coats and film thickness required is the same regardless of the application method. Do not apply succeeding, coats until the previous coat has cured as recommended by the manufacturer. Sand between applications where sanding is required to produce an even smooth surface in accordance with the manufacturer's directions.

Apply additional coats when undercoats, stains, or other conditions show through final coat of paint until paint film is of uniform finish, color, and appearance. Give special attention to ensure that surfaces, including edges, corners, crevices, welds, and exposed fasteners, receive a dry film thickness equivalent to that of flat surfaces.

Extend coatings in exposed surfaces to maintain the system integrity and to provide desired protection.

Paint surfaces behind movable equipment and furniture same as similar exposed surfaces. Paint surfaces behind permanently fixed equipment or furniture with prime coat only before final installation of equipment.

Paint interior surfaces of ducts, where visible through registers or grills, with a flat, non-specular black paint.

Paint back sides of access panels and removable or hinged covers to match exposed surfaces.

Finish interior of wall and base cabinets and similar field-finished casework to match exterior.

Finish exterior doors on tops, and side edges same as exterior faces.

Sand lightly between each succeeding enamel or varnish coat.

Omit primer on metal surfaces that have been shop-primed and touch unpainted.

Remove before painting commences, all hardware, furniture and accessories for doors and windows, together with any exposed electrical installation in walls. Upon completion of all paint work, all such hardware, furniture and accessories etc. shall be re-installed and left in a good working order.

Have all woodwork to be painted to be reasonably dry and humidity must be less than 12% and its surface shall be cleaned and made smooth by sanding it with sand paper obliquely across the grain. The surfaces shall then be dusted off with a dusting brush and wood glue completely removed.

Have concrete surfaces to be painted to be washed down first and then allowed to dry. Any efflorescence present shall be thoroughly removed, and the areas so affected shall be given a coat of porous alkali-resistant primer. After any traces of grease have been removed, the surfaces shall be painted with two coats of emulsion paint of the copolymer acrylic type.

Any cracks in walls shall be cleaned, filled and puttied up then left to dry before application of paint.

Follow the manufacturer’s instructions on the use of paint and shall be delivered to the site unopened with the original cover.

Submit for approval all types of paint he intends to use with manufacturer’s certificate showing the following physical properties:

- Viscocity
- Adherance
- Durability
- Abrasion
- Permeability
- Resistance to washing
- Stability of color

All tests shall meet the requirements of U.N.P. and the Contractor is the sole responsible for these materials and their use for the particular job.

Have mastic base water for gaps filling components for concrete or plaster to be compose of the following materials:

- Sealer 8.5%
- Water 25%
- Powder 40%
- Zinc 20%
- Oil 6.5%

3-5-C-3 PARTICULAR SPECIFICATIONS

3-5-C-3-1 Emulsion Paint

The Contractor shall provide, store and apply emulsion paint to substrates with the following requirements complementary to the general specifications including all needed materials, accessories, tools and scaffolding.

Emulsion based flat finish, to be used in water thinnable paint systems applied on interior and exterior walls and ceilings

Recommended thinner	Sweet water
Volume of thinner	*0-5%*
Description	Superior quality thixotropic paint based on a copolymer emulsion. Alkaline resistant
Mass Density	Approx. 1.4g/cm^3
Solid Contents	31-33% by volume, depending on colors

Overcoating intervals	min. 2 hours
Flash point	> 65degreesC - Din 53213
Type of application	Spray, brush or roller
Total thickness of paint	7-8 dry mils
Number of coats	To the satisfaction of the Engineer and the following minimum application
Plastered walls and ceilings	Cleaning - Sealer - Putty - Sanding- Undercoat - Putty - Sanding - Paint – Checking –Paint
Masonry Concrete Cleaning	Masonry filler – Sanding – Undercoat - Putty - Sanding - Paint – Checking –Paint
External walls and ceilings	Cleaning - Sealer - Putty - Sanding-Undercoat Paint Putty Sanding - Paint – Paint

3-5-C-3-2 Acrylic Paint

The Contractor shall provide, store and apply emulsion paint to substrates with the following requirements complementary to the general specifications including all needed materials, accessories, tools and scaffolding.

Emulsion based semi-glass finish to be wed in water thinnable paint systems applied on interior and exterior walls and ceilings.

Recommended thinner	Sweet water
Volume of thinner	*0-5%*
Description	High quality semi-gloss water borne thixotropic paint based on a pure acrylic emulsion. Alkaline resistant.
Mass Density	Approx. 1.2g/cm^3
Solid Contents	Approx. 34-36% by volume depending on colors
Overcoating intervals	min. 2 hours
Flash point	> 65 degrees C - Din 53213
Type of application	Spray, brush or roller
Total thickness of paint	7 - 8.5 dry mils
Number of coats	To the satisfaction of the Engineer and the following minimum application
Plastered walls and ceilings	Cleaning - Sealer – Putty - Sanding- Primer - Putty - Sanding - Paint – Checking -Paint
Masonry Concrete	Cleaning - Masonry filler – Sanding – Primer - Putty - Sanding – Paint
External walls and ceilings	Cleaning - Sealer - Putty - Sanding-Primer Paint – Putty – Sanding – Paint

3-5-C-3-3 Oil Paint

The Contractor shall provide, store and apply oil paint to substrates with the following requirements complementary to the general specifications including all needed materials, accessories, tools and scaffolding.

Finishing coat in an alkyd system applied on interior and exterior walls and ceilings.

Recommended thinner	Thinner flash point = 39 degrees C
Volume of thinner	*0-5%*
Description	High glass coating on alkyd resins
Mass Density	Approx. 1.0g/cm^3
Solid Contents	40-50% by volume, depending on color
Overcoating intervals	min. 16 hours
Flash point	> 39° C - Din 53213
Type of application	Spray, brush or roller
Total thickness of paint	8 dry mils
Number of coats	To the satisfaction of the Engineer and the following minimum application.
Plastered walls and ceilings	Cleaning - Sealer – Putty - Sanding- Undercoat - Putty - Sanding - Paint – Checking -Paint
Masonrv Concrete	Cleaning - Masonry filler – Sanding –Undercoat - Putty - Sanding - Paint –
External walls and ceilings	Cleaning - Sealer - Putty - Sanding-Undercoat Paint Putty Sanding –Paint

3-5-C-3-4 Epoxy Paint

The Contractor shall provide, store and apply epoxy paint to substrates with the following requirements complementary to the general specifications including all needed materials, accessories, tools and scaffolding.

General purpose, epoxy based, corrosion resisting, adhesion primer for steel, galvanized steel, aluminum and synthetic.

Recommended thinner	Thinner flash point = 26°C
Volume of thinner	*0-5%*
Description	Epoxy solvent-free heavy abrasion and chemical resistant coating – Epoxy paint applied after Epoxy primer coating to the recommendation of the manufacturer.
Mass Density	Approx. 1.4g/cm^3
Solid Contents	57% by volume
Overcoating intervals	Approx. 7 days
Flash point	Base and hardener
Type of application	Spray, brush or roller
Total thickness of paint	Min. 140 microns cured film
Number of coats	To the satisfaction of the Engineer and the following minimum application
Plastered walls and ceilings	Cleaning - Sealer - Putty - Sanding-Undercoat - Putty - Sanding - Paint - Checking - Paint
Masonrv Concrete	Cleaning - Masonry filler - Sanding- Undercoat - Putty - Sanding - Paint
External walls and ceilings	Cleaning - Sealer - Putty - Sanding-Undercoat Paint - Putty - Sanding - Paint

3-5-C-3-5 Anti-Acid Paint

The Contractor shall provide, store and apply Anti-acid paint to the substrates with the following requirements complementary to the general specifications, with all needed materials, accessories, tools and scaffolding.

Epoxy enamel coating applied on interior and exterior walls and floors.

Recommended thinner	Depends on the epoxy paint Manufacturer’s recommendation.
Description	Epoxy resin chemical coating highly resistant to extreme chemical attack, preferable bis-phenol type.
Solid Contents	Approx. 40% by volume

Pigment concentration	Approx. 20% by volume
Overcoating intervals	min. 8 hours
Flash point	26°C
Type of application	Spray, brush or roller
Number of coats	To the satisfaction of the Engineer and the following minimum application Cleaning – Primer – Paint

3-5-C-4 PAINT ON CONCRETE OR PLASTER

The Contractor shall prepare concrete or plaster surfaces to be painted as follows:

- Concrete or plaster surfaces shall be allowed to dry completely.
- Any signs of salt present shall be brushed away with steel brush then wait for a week. If salt reappears, it shall be brushed again and treated with phosphoric acid and zinc chloride.
- Check all cracks and holes in the concrete and putty them in a special mastic.
- Sand paper concrete and plaster surfaces.
- Clean concrete and plaster surfaces from all dust, sand, oil, etc.
- Surfaces shall receive one or more applications of putty filler until smooth surface is obtained to the Engineer's approval.
- Emulsion paint shall be applied by brush or roller and shall consist of a priming coat and two coats of paint internally and a priming coat and three coats of paint externally.
- Oil paint shall be applied by roller or brush and shall consist of a priming coat, two under coats and one finishing coat of paint.

The finishing coat of paint shall be applied after the completion of the electrical installation, sanitary work and false ceiling.

No oil paint shall be applied when the humidity exceeds 70% RH

3-5-C-4-1 Interior Oil Or Water Base Paint On Concrete Or Plaster With Mastic

After preparing concrete or plaster surfaces, painting shall be executed as follows:

- First coat - Prime coat (paste)
    - Apply first mastic layer. When dries, sand it with sand paper and clean it from dust.
- Second coat - 50% less fluid than the first coat.
    - Apply second mastic layer. When dries, sand it with sand paper and clean it from dust.

- Third coat - Color coat as required.
    - Check mastic and sand it with sand paper it, then apply mastic at needed locations.

Finally, apply two paint coats in conformity with the color approved by the Engineer either by brush or roller.

If the required paint is water base, mastic and prime coat shall be water base too. If the required paint is oil base, mastic and prime coat shall be oil base too.

3-5-C-4-2 Oil Or Water Base Paint On Concrete Or Plaster Without Mastic

After preparing concrete or plaster surfaces to be painted either inside or outside, painting shall be executed as follows:

- Applying a base coat with the required color.
- Repairing small holes with mastic then rubbing it with rough cloth until the textures matches the wall on it.
- Finally, applying two paint coats in conformity with the color approved by the Engineer either by brush or roller.

If the required paint is water base, mastic and prime coat shall be water base too. If the required paint is oil base, mastic and prime coat shall be oil base too.

3-5-C-4-3 Exterior Paint Protection On Concrete

Concrete surfaces shall be prepared to paint by a base coat, then paint brush with the required paint with one coat to reach a transparent cover, or two coats to reach a complete colored paint as required by the Engineer.

3-5-C-4-4 Coarse Texture Or Scratch Paint On Concrete Or Plaster

Interior or exterior concrete surfaces shall be prepared to paint by a base coat the same color as the final coat, then applying the paint either by the roller or spray as required by the Engineer.

3-5-C-5 WOODWORK

Woodwork shall be prepared for paint as follows:

- Wood shall be dry and humidity must be less than 12%
- Knots shall be sealed with knotting putty.
- Wood shall be rubbed and dusted off.
- Place special base layer on joints and leave until dry.
- Clean wood from all dirt.

3-5-C-5-1 Woodwork With Mastic

Woodwork to be painted shall be cleaned of impurities. Teak surfaces shall be cleaned with white spirit to remove free oil.

Knots shall be treated with two coats of knotting.

Items of rough woodwork, which are to be built into walls shall first be treated by twice coating with creosote or other preservative suitable for the position in which the timber is to be built.

The moisture content of wood at the time of painting should not exceed 18.%

Priming paint shall be applied by brush. Priming paint shall be applied on site after the Engineer's Representative has approved the joinery and before it is fixed.

When the priming, paint is dry, all cracks, holes, open joints and the like shall be filled with stopping and rubbed down with fine glass paper.

After preparing woodwork, it shall be painted as follows:

- First coat - Prime coat (paste) and saturate wood well.
  - Apply first oil base mastic layer. When dries, sand it with sand paper and clean it from dust.
- Second coat - 50% less fluid than the first coat.
  - Apply second oil base mastic layer. When dries, sand it with sand paper and clean it from dust.
- Third coat - Color coat as required.
  - Check mastic and sand it with sand paper, then apply mastic at needed locations.

Finally, applying two paint coats in conformity with the color approved by the Engineer either by brush or roller.

3-5-C-5-2 Wood Paint With Varnish Or Clear Lacquer

3-5-C-5-2-1 Varnishing

Woodwork to be varnished shall be cleaned and prepared as described in item above.

Where wood is required to have a clear finish the sanding shall follow the line of the grain.

Knots shall be treated with two coats of knotting.

Where shown on the drawings or require by the Engineer the wood shall be stained with an approved stain.

Before applying the second or third finishing coats of alkyd varnishes, then preceding coats shall be thoroughly dry and hard and shall be rubbed down with fine abrasive paper to get a smooth matt surface unless otherwise recommended by the manufacturer of the varnish.

Two or three coats of clear varnish shall be applied as recommended by the manufacturer of the varnish or as directed by the Engineer.

3-5-C-5-2-2 Lacquer To Wood

Woodwork to be lacquered shall be cleaned of impurities and rubbed down with fine -lass paper to a smooth finish, knots shall be treated with two coats of knotting and the whole surface filled with stained putty filler.

Where shown on drawings or required by the Engineer the wood shall be stained with an approved water and spirit stain.

Woodwork surfaces shall be rubbed down after filling and between coats of lacquer to obtain a surface of high quality to the Engineer's satisfaction.

Two or more coats of lacquer shall be applied by spray gun to obtain an approved standard thickness of finish.

3-5-C-6 METAL WORK

Metal shall be prepared for paint as follows:

- All metalwork shall be cleaned free from all rust, scales, grease, oils and any other surface stains and painted with one coat of priming paint applied by brush .
- Cracks and holes shall be filled with steel mastic and sand cleaned, then dusted.
- Two prime coats matches the specified color if possible.
- Two coats of finish paints as required by the Engineer.

Steelworks delivered to the Site primed shall be cleaned of impurities and damage to the priming paint made good with priming.

Metalwork which is concealed shall be. prepared and primed as above and shall be painted with two undercoats and one finishing coat of paint applied by brush.

In cases where protection coat against chemical effects such as chlorine is used (Chlorine bottle’s door room), special prime and base paint shall be used to resist such effects as approved by the Engineer.

3-5-C-7 SAFETY & CLEANLINESS

Unless specified otherwise, the Contractor shall:

keep all painted works until the end of the project. In case of damages or deterioration, the Contractor shall repair them on his own expense as required by the Engineer.

During progress of work, remove from site discarded materials, rubbish, cans and rags at end of each work day.

Upon completion of painting work, clean window glass and other paint-spattered surfaces.

Remove spattered paint by proper methods of washing and scraping, using care not to scratch or otherwise damage finished surfaces.

Protect work of other trades whether to be painted or not, against damage by painting and finishing work. Correct damage by cleaning, repairing or replacing, and repainting, as directed by the Engineer.

Provide "Wet Paint" signs in Arabic/English and laborers' native languages as required to

protect newly-painted finishes. Remove temporary protective wrappings provided by others for protection of their work, after completion of painting operations.

At completion of work by other trades, touch-up and restore all damaged or defaced painted surfaces

Finally, at the end of the project, the Contractor shall deliver all paint work in a perfect way.

3-5-D NATURAL STONE CLADDING

3-5-D-1 NATURAL BUMP STONE

Stone shall be from the best quarries and approved by the Engineer.

It shall meet the following requirements:

- No hollow sounding.
- Free of defects.
- Weighs at least 2.5
- Breaking strength greater than 600 Kg/cm^2

Natural bump stone shall not be affected by ice or any porosity signs. The size of stones shall follow the requirements of the drawings.

The Contractor shall submit a sample for the Engineer’s approval and shall stay at site during the whole period of cladding.

3-5-D-2 BUSH HAMMER NATURAL STONE

Stone shall be from the best quarries and approved by the Engineer.

Stone shall not be affected by ice and shall be free of any scratches, cracks or defects to give an even appearance. Under the hammer, stone shall give a clear sound.

It shall meet the following requirements:

- Resistance to breaking: 600Kg/cm^2 at least.
- Weighs: 2.5 at least.

The Contractor shall submit a sample for the Engineer’s approval and shall stay at site during the whole period of cladding.

3-5-D-3 MORTAR

Mortar for laying the stone and pointing shall be composed of 600 kg CPA 250/315 cement for 1 cubic meter of sand. The thickness is 3 cm of the mortar after stone has been laid. The quantity of water to be used in the preparation of mortar shall be only that required to produce a mixture sufficiently workable for the purpose intended. Mortar shall be used as soon as possible after mixing and shall show no visible signs of setting prior to use. Retempering of mortar will not be permitted.

The materials of mortars shall be measured out in their correct proportions and shall first be thoroughly mixed together in a dry state by turning them over upon a clean wooden stage until they are of a homogeneous appearance in consistency and color. Clean water shall then be added while the mixture is being turned over until it.

Part III: Civil and Architectural Works

Part III-6: EXTERNAL WORKS

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PART 3.6 - CIVIL & ARCHITECTURAL WORKS: EXTERNAL WORKS

3-6-A AGGREGATES

3-6-A-1 SOURCES OF MATERIALS

All aggregates for use in the construction of the base course shall be obtained only from sources approved by the Engineer. The quarry pits or quarry extracted gravel shall be in all cases approved by the Engineer.

The Contractor shall determine the location, suitability and quantity of material available as well as the cost and the amount of work required to obtain the material available.

The Contractor shall provide the Engineer prior to the schedule beginning operations with a complete statement of the origin and composition of all stone and/or gravel aggregates to be used in the work. All materials shall comply with the specified requirements for the various aggregates.

The locating and the manufacture of aggregates which will meet the requirements of the specifications are the sole responsibility of the Contractor.

The approval of the Engineer shall in no way relieve the Contractor of the responsibility of producing aggregates which meet the specifications.

No aggregate producing equipment shall be put into operation prior to the approval of the equipment by the Engineer. If after the equipment is put into operation it fails to perform as proposed, the Contractor shall provide additional approved equipment or replace the original equipment with more suitable equipment, as may be directed by the Engineer.

3-6-A-2 TESTING

In order to ascertain the properties of all aggregate materials, the Contractor shall submit, for approval by the Engineer, test certificates from an approved testing laboratory for all materials intended for incorporation in the work prior to starting quarry or pit operations.

Representative samples for such testing shall be taken by the Contractor, at his expense, in the presence of the Engineer, and duplicate samples shall be submitted to the Engineer for future reference.

The Contractor may, if approved by the Engineer, conduct the necessary tests in the laboratory. The tests shall be conducted in the presence of the Engineer. The resume of the qualifications must be submitted to and approved by the Engineer prior to any testing operations.

This testing, whether performed at an approved testing laboratory or in the project laboratory, shall be solely the Contractor’s responsibility and will be at the Contractor’s expense.

3-6-A-3 APPROVAL AND INSPECTION

All sources of materials shall be approved by the Engineer prior to procuring or processing material from such sources. Test certificates obtained by the Contractor or performed by the Contractor at his expense are intended to assist the Contractor in his estimate of the location, extent, and quantities which will comply with the specifications when properly processed, and will no way obviate the need for further testing by the Engineer. Only materials from approved sources shall be processed for incorporation into the work. Approval of specific sources of materials shall not be construed as final approval and acceptance of materials from such sources.

All processed materials shall be tested and approved before being stored on the site or incorporated in the work and may be inspected and tested at any time during the progress of their preparation and use. Questionable materials shall not be unloaded and incorporated with materials previously approved and accepted. If however, the grading and quality of the material delivered to the site do not conform to the grading and quality as previously inspected and tested, or do not comply with the specifications, the Engineer reserves the right to reject such materials at the site of the work. Only materials conforming to the requirements of the specifications shall be used in the work.

Samples must meet all test requirements. The Contractor shall permit the Engineer to inspect any and all material used or to be used at any time during or after its preparation, or while being used during the process of the work or after the work has been completed. All such materials not complying with the required specifications, whether in place or not, shall be rejected and shall be removed promptly from the work. The Contractor shall supply, or arrange with any producer or manufacturer to supply, all necessary materials, labor, tools and equipment for such inspection.

3-6-A-4 STORAGE

Materials shall be stored so as to insure preservation of their specified quality and fitness for the work. They shall be placed on hard, clean surfaces and, when required by the Engineer, they shall be placed under cover. Stored materials shall be located as to facilitate prompt inspection and control. Private property shall not be used for storage purposes without written consent of the owner or lessee and payment to him, if necessary.

The center of the storage area shall be elevated and sloped to the sides so as to provide proper drainage of excess moisture. The material shall be stored in such a way to prevent segregation and coning to insure proper control of gradations and moisture. Course aggregate storage piles shall be built-up in layers not exceeding one (1) meter. The height of a stockpile shall be limited to a maximum of five (5) meters.

The equipment and methods used for stockpiling aggregates and for removing aggregates from the stockpiles must be approved by the Engineer and shall be such that no detrimental degradation of the aggregate will result and no appreciable amount of foreign material will be incorporated into the aggregate.

3-6-B AGGREGATE BASE COURSE

3-6-B-1 DESCRIPTION

This work shall consist of furnishing and placing well graded aggregate afggregate base course in successive layers of 15 cm, including additives if required, on a prepared surface in accordance with the specifications, and in conformity with the lines, grades, thicknesses and typical cross sections given in the drawings or as required by the Engineer.

3-6-B-2 MATERIALS

Materials shall conform to the requirements for the class of “Aggregate Base Course”, specified on the plans or directed by the Engineer. All aggregates for base course shall consist of clean, tough, durable, sharp angle fragments free of any excess of thin or elongated pieces, and reasonably free of soft, disintegrated or decomposed stone, dirt or other deleterious matter.

3-6-B-2-1 Physical Requirements

All base course aggregate shall conform to the following physical requirements:

Loss of Sodium Sulfate Soundness Test	10 percent maximum
Loss of Magnesium Sulfate Soundness Test	12 percent maximum
Loss by Abrasion Test	35 percent maximum
Thin and Elongated Pieces, by Weight (larger than 1-inch, thickness less than 1/5 length	5 percent
Friable Particles	0.25 percent maximum

3-6-B-2-2 Aggregate Base Course - Class A

Material for class A shall consist of crushed gravel or stone fragments conforming to the following requirements:

AASHTO SIEVE		PERCENT PASSING
2	inch	100
1-½	inch	90 - 100
3/4	inch	50 - 80
No. 4		25 - 45
No. 40		10 - 20
No. 200		2 - 7

- Sand equivalent: 40% minimum (Aggregates passing through AASHTO SIEVE no: 4)
- Regular graded aggregate curve
- Loss of abrasion test: 40 % maximum

3-6-B-2-3 Aggregate Base Course - Class B

a. Materials for Class B shall be crushed rock or crushed gravel conforming to the following grading requirements:

AASHTO SIEVE		PERCENT PASSING
2-½	inch	100
2	inch	90 - 100
1-½	inch	35 - 70
1	inch	0 - 15
½	inch	0 - 5

b. Fine materials for Class B base course shall be quarry screenings or natural material and of suitable binding quality as approved by the Engineer. The material shall be free from foreign or organic matter, dirt, shale, clay and clay lumps, or other deleterious matter and shall conform to the following requirements :

AASHTO SIEVE	PERCENT PASSING
3/8 inch	100
No. 4	85 - 100
No. 100	10 - 30

Plasticity Index (AASHTO T 90)	6 maximum
Sand Equivalent (AASHTO T 176)	30 minimum

c. The combined material shall consist of a mixture of all aggregates uniformly graded from course to fine to conform to the following gradation requirements:

AASHTO SIEVE	PERCENT PASSING
2-½ inch	100
2 inch	90 - 100
1-½ inch	60 - 90
1 inch	42 - 77
3/4 inch	35 - 70
½ inch	25 - 60
No. 4	15 - 40
No. 10	10 - 26
No. 40	5 - 15
No. 200	2 - 9

3-6-B-2-4 Aggregate Base Course - Class C

Material for Class C base course shall consist of uniform mixture of crushed rock and/or gravel with sand, silt and clay, conforming to the following requirements

AASHTO SIEVE	PERCENT PASSING
1-1/2 inch	100
1 inch	60 -100
3/4 inch	55 - 85
No. 4	35 - 60
No. 10	25 - 50
No. 40	15 - 30

AASHTO SIEVE	PERCENT PASSING
No. 200	8 - 15

The grading is based on aggregates of uniform specific gravity, and the percentage passing the various sieves are subject to correction by the Engineer, when aggregates of varying specific gravities are used.

Liquid Limit (AASHTO T 89)	25 maximum
Plasticity Index (AASHTO T 90)	4-8 maximum
Sand Equivalent (AASHTO T 176)	50 minimum

3-6-B-2-5 Aggregate Base Course Class D

- Density >2.45 kg/dm^3
- Resistance of compression = 500 kg/cm^2 on a test cube 7cm x 7cm x 7cm
- Sand equivalent: 40 min (Aggregates passing through AASHTO SIEVE No. 4)

AASHTO SIEVE		PERCENT PASSING
2	inch	100
1	inch	40 - 95
1/2	inch	40 - 75
No. 4		30 - 60
No. 10		20 - 60
No. 40		15 - 30
No. 200		5 - 20

3-6-B-2-6 Acceptance

The aggregate will be accepted immediately following mixing, based on periodic samples taken. When the aggregate is a total aggregate, it may be accepted at the crusher. Acceptance of the material by the Engineer does not constitute acceptance of the base course, only that the material is approved for use in the base course.

3-6-B-3 CONSTRUCTION REQUIREMENTS

3-6-B-3-1 Subgrade Preparation

The subgrade shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down for construction.

At all special grade control points, the subgrade shall be leveled to such depth that the proper thickness of base course may be constructed flush with the existing surface. The transition from normal to special section shall be of sufficient length to present no abrupt or noticeable change of grade and shall be excavated in accordance with the grades and lines shown on the plans or directed by the Engineer.

3-6-B-3-2 Maintenance of Subgrade

The roadbed being prepared shall be maintained true to cross section and grade until the base course is completed.

3-6-B-3-3 Method of Construction

3-6-B-3-3-1 Combining Aggregates and Water

Aggregates for base course shall be combined into a uniform mixture and water added either in a central mixing plant or by watering in a manner approved by the Engineer, before final placement of the material. When binder is to be added, if approved by the Engineer, it may be combined with the aggregate base by thoroughly mixing separate quantities of binder and aggregate base or it may be combined in the central mixing plant. Adding binder by spreading it will not be permitted.

The moisture added to the aggregates shall be that required, as designated by the Engineer, to obtain the specified density thereby preparing an aggregate completely ready for compaction after spreading on the subgrade. In no case will the wetting of aggregates in stockpiles or trucks be permitted.

3-6-B-3-3-2 Spreading and Combining Aggregates

Unless otherwise specified, aggregate for base courses shall be delivered to the roadbed as a uniform mixture and shall be placed on the site prepared subgrade, in a uniform layer. Spreading shall be done by means of approved self-propelled stone spreaders, distributing the material to the required width and loose thickness.

The material shall be so handled, as to avoid segregation. If an aggregate spreader causes segregation in the material, or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be discontinued and replaced. All segregated material shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

3-6-B-3-3-3 *Compaction*

Immediately after placing, the base course material shall be compacted as required by AASHTO or equivalent.

The surface of the finished base course will be tested with a three (3) meter straightedge at selected locations. The variation of the surface from the testing straightedge between any two (2) contacts with the surface shall at no point exceed ten (10) millimeters, unless otherwise specified, when placed on or parallel to the centerline or when placed perpendicular to the centerline.

3-6-B-3-3-4 *Maintenance*

Following the construction of the aggregate base course, the compacted course shall be maintained by the Contractor at his expense. The Contractor shall, broom and maintain the base, keeping it free from raveling and other defects until such time as the bituminous prime or other surface is applied.

3-6-C BITUMINOUS BASE COURSE

3-6-C-1 DESCRIPTION

This Work shall consist of aggregate and bituminous material mixed in a central plant, and spread and compacted on an approved primed subgrade in accordance with the specifications and in conformity with the lines, grades, thickness and typical cross sections or as required by the Engineer.

3-6-C-2 MATERIALS

3-6-C-2-1 Mineral Aggregates

Mineral aggregates for “Bituminous Base Course” shall consist of course aggregates, fine aggregates, and filler material, if required, all complying with the following requirements :

a. Course aggregate which is the material retained on an AASHTO No. 4 sieve, shall consist of crushed rock or crushed gravel. It shall be clean, hard, tough, durable and sound, and shall be of uniform quality and free from decomposed stone, organic matter, shale, clay, lumps and other deleterious substances.

   The course aggregate shall be free of excess of flat elongated pieces (in no case more than ten (10) percent) and shall be of such character that when coated with asphalt shall pass a stripping test performed in accordance with AASHTO T 182.

   Crushed gravel for use as course aggregate shall consist of the product obtained by crushing material that has first been screened in such a manner that not less than ninety (90) percent of the material to be crushed is retained on a Standard AASHTO No. 3/8 inch sieve, The amount of crushing of gravel shall be regulated so that at least ninety (90) percent by weight of the material retained on an AASHTO No. 4 sieve shall consist of pieces- with at least one (1) mechanically fractured face, and when tested for stability of bituminous mix shows satisfactory stability. Course aggregate, used for “Bituminous Base Course” only, may be uncrushed angular material which meets the angular and other requirements herein.

b. Fine aggregates shall consist of that portion of the total aggregate that passes a standard AASHTO No. 4 sieve and after crushing at least eighty-five (85) percent by weight of the material passing the AASHTO No. 4 sieve and retained on the AASHTO No. 10 sieve, shall consist of pieces having at least one (1) mechanical fractured face. Should natural material passing the AASHTO No. 4 sieve be included in the mixture, this material shall be fed to the dryer as a separate aggregate and the amount used shall be so limited that the mixture of fine aggregates will contain not less than twenty-five (25) percent by weight of the crushed aggregates.

c. When the combined grading of the course and fine aggregates is deficient in material passing the AASHTO No. 200 sieve and depending on laboratory analysis of the Asphalt Institute, mineral filler shall be added as approved by the Engineer. Mineral filler shall consist of finely divided mineral matter such as rock dust including limestone dust, slag dust, hydrated lime, hydraulic cement, or other approved mineral matter. At the time of use it shall be sufficiently dry to flow freely and essentially free from agglomerations.

Filler material shall conform to the requirements of AASHTO M-17. Gradation requirements as follows :

SIEVE	PERCENT PASSING (BY WEIGHT)
No. 40	100
No. 200	75 – 100

d. The combined mineral aggregate shall meet the quality requirements and, shall conform to the following physical requirements :

- Loss by abrasion test (L.A.) : 30% max.
- Sand equivalent: 50% min. (Aggregates passing through AASHTO SIEVE No. 4)
- Absorbtion shall not exceed 2%

Gradation requirements are as follows:

AASHTO SIEVE SIZE	PERCENT PASSING
¾ inch	100
½ inch	75 - 100
3/8 inch	60 - 85
No. 4	35 - 50
No. 8	20 - 35
No 30	10 - 16
No. 50	6 - 16
No. 100	4 - 12
No. 200	2 – 8

3-6-C-2-2 Asphalts

Asphalt for “Bituminous Base Course” shall be petroleum asphalt cement, grade 40-50 penetration, conforming to the requirements in the following table :

The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 176.7 degrees C

Specifications for Asphalt Cements

GENERAL REQUIREMENTS	Unit	Asphalt	Asphalt	Asphalt
Penetration, 25° C 100 grams 5 seconds	0.1 mm	40-50	60-70	80-100
Flash point in ° C (Cleveland open cup)	°C	232	232	232
Thin film test (weight loss in % at t = 163 ° C during 5 hours)	%	1	1	1
Ductility : at 25°C	cm	100	100	100
Solubility in Trichloroethylene, percent	%	99.5	99.5	99.5

3-6-C-2-3 Job-Mix

At least thirty (30) days prior to the date the Contractor intends to begin production of the Bituminous Base Course, and after receiving approval of the aggregates from the Engineer and after the delivery on site, of the asphalt specified for “Bituminous Base Course”, the Contractor shall make written request for the approved job-mix formula from the Engineer.

The job-mix formula will be prepared by the Contractor, under the supervision of the Engineer, in the project laboratory.

The job-mix formula shall combine the mineral aggregates and asphalt in such proportion as to produce a mixture conforming to the following composition limits by weight :

	PERCENT
Total Mineral Aggregates	94 - 95
Asphaltic Binder	5 - 6 (of the total volume)

When tested according to the Marshall Method, the bituminous mixture shall conform to the following requirements :

Stability (kgs)	700 minimum
Flow (mm)	4mm & Less than 4 mm
Voids in total mix (percent)	3 - 6

All trial mixes shall be prepared and tested by the Contractor and results are given to the Engineer. The Marshall Test procedure will be used to determine the percentage of liquid asphalt that is to be incorporated into the mixture. For the same reasons, a low asphalt content in the mix is detrimental. The job-mix formula will therefore provide for as high as possible for a mix designed by the Marshall Test procedure. The mix formula will also take into consideration the absorption of asphalt into the aggregates. Thus, for calculations for voids, the adjusted bulk specific gravity of the Marshall specimens, adjusted for the portion of asphalt lost by absorption, shall be used.

The gradation of the combined aggregate, including the mineral filler shall be within the limits specified in the specifications for the Class of "Bituminous Base Course" to be used. The Engineer may vary the specified limits where he deems it necessary, on the basis of the Marshall tests, to obtain optimum stability and life of the completed mix.

Upon receiving the job-mix formula, approved by the Engineer, the Contractor shall adjust his plant to proportion the individual aggregates, mineral filler and asphalt to produce a final mix that, when compared to the job-mix formula, shall be within the following limits:

MAXIMUM VARIATIONS OF PERCENTAGE OF MATERIALS PASSING

AASHTO No. 10 and less	± 2	percent
AASHTO No. 4 and larger	± 5	percent

The Engineer will test the mix periodically and, if necessary, direct the Contractor to readjust the plant to maintain conformity of the job-mix formula. If, during production, the grading of the aggregates alters, the mix shall be redesigned and the plant readjusted as outlined above.

The assistance of the Engineer in the preparation of the job mix formula in no way relieves the Contractor of the responsibility of producing a bituminous mixture meeting the requirements of the specifications.

3-6-C-2-4 Equipment

Equipment used by the Contractor must fit with his obligations and results to fulfill to best the works within the technical specifications and as directed by the Engineer. Trucks used for hauling bituminous mixtures shall have tight, clean, smooth metal beds which have been thinly coated with a minimum amount of paraffin oil, lime solution, or other approved material to prevent the mixture from adhering to the beds. When required by the Engineer, each vehicle shall be equipped with a canvas cover or other suitable material of such size as to protect the mixture from the weather.

3-6-C-3 CONSTRUCTION REQUIREMENTS

Rolling equipment shall be self-propelled. The wheels on the rollers shall be equipped with adjustable scrapers and the rollers shall have water tanks and sprinkling apparatus which shall be used to keep the wheels wet and prevent the surface material from sticking.

Weights of two-axle tandem steel rollers, three-axle tandem steel rollers, three-wheel steel rollers, and self-propelled pneumatic-tired rollers and the total weight of the pneumatic-tired roller shall be as directed by the Engineer.

3-6-C-3-1 Preparation of Asphalt Cement

Asphalt cement shall be heated within a temperature range of 135 degrees °C to 163 degrees °C at the time of mixing. Asphalt cement spreading will be made at 135 degrees °C. Asphalt cement received at temperatures in excess of 163°C but not exceeding 191°C may be used.

3-6-C-3-2 Preparation of Mineral Aggregates

Each aggregate ingredient shall be heated and dried at such temperatures that the temperature as recorded in the hot fines bin after screening shall not exceed 163 degrees C. If the aggregates contain sufficient moisture to cause foaming in the mixture or their temperature is in excess of 163 degrees C, they shall be removed from the bins and returned to the respective stockpiles. Immediately after heating, the aggregate or aggregates shall be and conveyed into separate bins ready for batching and mixing with bituminous material.

3-6-C-3-3 Preparation of Bituminous Mixture

Dried aggregate as specified for bituminous construction and prepared as prescribed above shall be combined in the plant in the proportionate amounts as approved. Asphalt cement shall be introduced into the mixture in the proportionate amount determined, all according to the job-mix formula.

3-6-C-3-4 Preparation Of Subgrade Or Existing Surface

Prior to the placing of the mixture, when designated on the plans or directed by the Engineer, a prime coat shall be applied to the subgrade or existing surface in accordance with the standards specified in Section “Bituminous Prime Coat”.

3-6-C-3-5 Placing of the Mixture

The bituminous mixtures shall be spread and finished true to crown and grade by the automatically controlled bituminous paver. Bituminous mixtures may be spread and finished by hand methods only where machine methods are impractical as determined by the Engineer.

The automatically controlled paver shall spread the bituminous mixtures without tearing the surface and shall strike a finish that is smooth, true to cross section, uniform in density and texture and free from hollows, transverse corrugations and other irregularities.

The paver shall be operated at a speed which will give the best results for the type of paver being used and which coordinates satisfactorily with the rate of delivery of the mixture to the paver so as to provide a uniform rate of placement without intermittent operation of the paver.

Bituminous mixtures, except on leveling courses, shall be spread so that, after rolling, the nominal thickness of the compacted bituminous material will fit with the finished level as given on shop drawings.

The maximum thickness for layers may be increased slightly when such increase is more adaptable to total pavement thickness with the permission of the Project Engineer.

3-6-C-3-6 Compaction of Mixtures

After spreading and strike-off and as soon as the mix conditions permit the rolling to be performed without excessive shoving or tearing, the mixture shall be thoroughly and uniformly compacted.

Rolling shall not be prolonged till cracks appear. Rollers shall be of the steel wheel and/or pneumatic-tire type and shall be in good condition, capable of reversing without backlash, and shall be operated at speeds slow enough to avoid displacement of the bituminous mixture. The number and weight of rollers (between 10 T and 12 T) shall be sufficient to compact the mixture to the required density while it is still in a workable condition. The use of equipment which results in excessive crushing of the aggregate will not be permitted.

Initial or breakdown rolling shall be done by means of either a tandem power steel roller or a three (3) wheel power steel roller. Rolling shall begin as soon as the mixture bear the roller without undue displacement. Rolling shall be longitudinally, beginning at the low side of the spread of material and proceeding toward the high side, overlapping on successive trips by at least one-half (1/2) the width of the rear wheels. Alternate trips of the roller shall be of slightly different lengths.

The motion of the roller shall at all times be slow enough to avoid displacement of the mixture and the speed of the roller controlled. To prevent adhesion of the mixture to the rollers, the wheels of the rollers shall be kept properly moistened with water, but an excess of water will not be permitted.

The initial or breakdown rolling shall be followed by rolling with a pneumatic-tired roller. Final compaction and finish rolling shall be done by means of a tandem power steel roller unless otherwise designated. When the specified density is not obtained, changes in size and/or number of rollers shall be made as corrective measures to satisfy the density requirement .

Rollers shall be operated by competent and experienced roller men and shall be kept in operation continuously, if necessary, so that all parts of the pavement will receive substantially equal compaction at the time desired. The Engineer will order the mixing plant to cease operation at any time proper rolling is not being performed.

The road density requirements shall be equal to or greater than ninety-six (97) percent of the Marshall Density of each day's production.

Any mixture that becomes loose, broken, mixed with foreign material, or which is in any way defective in finish or density, or which does not comply in all other respects with the requirements of the specifications shall be removed replaced with suitable material, and finished in accordance with the specifications.

3-6-C-3-7 Joints

Joints between old and new pavements or between successive days work shall be made so as to insure thorough and continuous bond between the old and new mixtures. Transverse construction joints in previously laid material shall be constructed by cutting the material back vertically for its full depth so as to expose a fresh surface.

Before placing the fresh mixture against a cut joint or again old pavement, the contact surface shall be sprayed or painted with a thin uniform coat. Where a finishing machine is used, the longitudinal joint shall be made by over lapping the screed on the previously laid material for a width of at least three (3) centimeters and depositing a sufficient amount of mixture so that the joint forced will be smooth end tight.

3-6-C-3-8 Introduction of Fresh Mixture

The Contractor shall protect all sections of newly compacted mixture from traffic until they have hardened properly.

3-6-C-3-9 Surface Tolerances

The surface will be tested with a four (4) meter straightedge by the Engineer at selected locations. The variation of the surface from the testing edge of the straightedge between any two (2) contacts with the surface shall at no point exceed six (6) millimeters when placed on or parallel to the centerline or six (6) millimeters when placed perpendicular to the centerline of the roadway. The top of the base shall not vary from the required elevation by more than five (5) millimeters. All humps and depressions exceeding the specified tolerance shall be corrected by removing the defective Work and replacing it with new material as directed by the Engineer.

3-6-C-3-10 Weather Limitations

Hot asphaltic mixtures shall be placed only when the air temperature is five (5) degrees C or above and less than 40 degrees C, and when the weather is not foggy or rainy and when the existing surface is free from moisture.

3-6-D BITUMINOUS PRIME COAT

3-6-D-1 DESCRIPTION

This work shall consist of applying a liquid asphalt prime coat on previously constructed aggregate base course before spreading the bituminous base course, and as otherwise specified; in accordance with the specifications, and in conformity with the lines shown on the plans or established by the Engineer.

3-6-D-2 MATERIAL

Medium-curing cutback asphalt shall consist of an asphaltic base fluxed with suitable petroleum distillates. The product shall be free of water and shall conform to all the requirements of Grade MC-0/MC-1 as shown in the following Tables.

CHARACTERISTICS	MC-0	MC-1	MC-2	MC-3	MC-4	MC-5
Flash point (Open Tag), degrees C - Minimum	38	38	66	66	66	66
Furol Viscosity at 25 degrees C, seconds	75-150					
Furol Viscosity at 50 degrees C, seconds		75-150				
Furol Viscosity at 60 degrees C, seconds			100-200	250-500		
Furol Viscosity at 82 degrees C, seconds					125-250	300-600
Max % of water in volume	0.1	0.1	0.1	0.1	0.1	0.1
Distillation						
Distillate (percent of total distillate to 360 degrees C - Max	50	40	33	27	22	18
To 225° degrees C	0-25	0-20	0-10	0-5	-	-
To 260° degrees C	40-70	25-65	15-55	5-40	0-30	0-20
To 316° degrees C	75-93	70-90	60-87	55-85	40-80	20-75
Texts on Residue form Distillation: Penetration, 25 degree C,						
100 grams, 5 seconds	120-300	120-300	120-300	120-300	120-300	120-300
Ductility, 25 degrees C in centimeters (minimum)	50	50	50	50	50	50
Solubility in carbon Tetrachloride, percent (minimum)	99	99	99	99	99	99
General Requirements	The materials shall be free from water					

	Temperature for Mixing	Temperature for Spraying
Asphalt Cement		
40 - 50	150 - 160	-
60 - 70	135 - 162	140 - 165
80 - 100	135 - 163	140 - 165
Prime Coat		
MC - 0	10 - 49	11 - 60
MC - 1	27 - 66	47 - 85
MC - 2	47 - 82	60 - 102
MC - 3	66 - 93	80 - 121
MC - 4	79 - 107	88 - 130
MC - 5	105 - 121	105 - 143

3-6-D-3 CONSTRUCTION REQUIREMENTS

It shall be the Contractor's sole responsibility to maintain the surface in an approved condition, conforming to the required grades and sections. Any defects which may develop shall be immediately corrected at the Contractor's expense.

Equipment used by the Contractor must fit with these obligations and results to fulfill to best the works within the technical specifications and as directed by the Engineer.

Prior to the application of the bituminous material, all loose materials shall be removed from the surface and the surface shall be cleaned by means of approved mechanical sweepers or blowers and/or hand brooms, until it is as free from dust as is deemed practicable. If deemed necessary by the Engineer, the cleaned surface shall be given a light application of water and allowed to dry to a surface-dry condition before the bituminous material is applied. No traffic shall be permitted on the surface after it has been prepared to receive the bituminous material.

3-6-D-3-1 Application of the Prime

Medium-curing cutback asphalt, Grade MC-0 / MC-1, shall be applied at the rate as directed by the Engineer, by approved pressure distributors operated by skilled workmen. The spray nozzles and spray bar shall be adjusted and frequently checked so that uniform distribution is insured. Spraying shall cease immediately upon any clogging or interference of any nozzles, and corrective measures taken before spraying is resumed.

Hand sprays will be approved only for priming small patches or inaccessible areas that cannot be primed by normal operation of the distributor.

Care shall be taken that application of bituminous material at the junction of spreads is not in excess of the specified amount. Any excess shall be squeezed from the surface when ordered by the Engineer. Any skipped areas or recognized deficiencies shall be corrected by means of approved hand sprays.

3-6-D-3-2 Rate of Application

The rate of application for prime material is 1000g/m², the Engineer may alter the previously established rate so the Contractor shall, prior to the time he intends to begin his priming operation, prepare a test section of an approved length for the determination of the rate of application for the prime coat.

3-6-D-3-3 Protection of Adjacent Structures

When bituminous materials are being applied, the surfaces of all structures and any roadway appurtenances shall be protected in a manner approved by the Engineer to prevent them from being splattered with bituminous material or marred by equipment operation. In the event that any appurtenances become splattered or marred, the Contractor shall at his own expense, remove all traces of bituminous materials, and repair all damage and leave the appurtenances in an approved condition.

3-6-D-3-4 Blotting

If deemed necessary by the Engineer after the bituminous material has been applied for forty-eight (48) hours under favorable conditions and the prime coat has not dried sufficiently that it will not be damaged by traffic, a light application of aggregate shall be applied. The blotter material shall be a clean fine sand, chat sand, or other material as approved by the Engineer. Blotting material shall be applied sparingly on only the areas that have not dried. Blotting of the prime coat shall be done only when directed by the Engineer. Normally, additional time shall be allowed for drying of the prime coat when in the opinion of the Engineer this procedure does not seriously delay subsequent operations.

3-6-D-3-5 Maintenance of Prime Coat

The Contractor shall maintain the prime coat treatment, and the bituminous base of the subgrade or base course intact until it shall have been covered by the surface course. Any area where the prime coat has been damaged by traffic or by the Contractor’s operations, shall be cleaned of all defective base course or subgrade repaired to the satisfaction of the Engineer and the maintenance and repair of the prime coat and the underlying subgrade shall be done at the Contractor’s expense.

3-6-D-3-6 Traffic Control

The Contractor shall provide detours for the traveling public and for operational use in areas where priming is being done. Where no convenient detour can be made available, the Contractor shall provide traffic control and the priming operation shall be confined to a part of the roadway.

3-6-D-3-7 Weather and Temperature Limitations

Application of prime coat shall be performed only when the surface is dry, when the atmospheric temperature is above ten (10) degrees °C and less than 40°C, and when the weather is not foggy or rainy.

Part III: Civil and Architectural Works

Part III-7: METAL WORKS

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PART 3.7 - CIVIL & ARCHITECTURAL WORKS: METAL WORKS

3-7-A STEEL DOORS/WINDOWS

See part III-4- Doors and windows.

3-7-B HARDWARE

Hardware sets, hinges, bolts, doors closers, door stops, signs and other items of hardware, unless otherwise specified, shall be satin, anodised aluminum finished. Door hinges shall comply with BS 7352 whereas locks and latches shall comply with BS 8572. Door lock, latch lever and knob furniture are to be products of one approved manufacture.

For all hardware to be used, samples shall be submitted to the Engineer for approval.

3-7-C GRILLS, SCREENS, ETC.

All grills, screens, protective meshes, louvers and guards shall be obtained from an approved manufacturers and shall be entirely suitable for their purpose.

All ferrous metal shall be galvanized, sherardized or coated with bonded zinc. All non-ferous metal shall be finished with an appropriate process to minimize corrosion.

3-7-D COVERS AND FRAMES

Covers recessed for floor finishes shall be provided with galvanized rolled steel angles of height equal to the thickness of floor finishing and fixed to the surface of the structural floor slab along all edges of the trenches so that the top edge is level with the finished floor level. The angles shall be laid so as to form seatings for covers and all additional galvanized rolled steel tee. Sections shall also be provided to support the duct covers.

The covers shall be galvanized to suit the ducts and the seatings described above. A lightweight galvanized steel mesh shall be fixed to the upper surface of the trays to provide a key for floor finishes. The seatings and the trays shall be laid that the finished floor is perfectly level and all trays fully supported at all edges without the use of loose packings. At least one tray in every series of trays covering a length of duct shall be provided with cast-in lifting eyes and a pair of suitable lifting keys. The above shall be handed to the Engineer on completion.

3-7-E FENCES AND GATES

Fences generally shall be in accordance with the relevant parts of BS 1722 Part 1 1986.

Chain link fencing shall be Type PLC.213 Grade A with high plastic covered chain link mesh. The mesh and line wires shall be galvanized prior to being plastic covered.

The straining posts, intermediate posts shall be manufactured and erected complete as specified in BS 1722. The fencing shall be true to line and vertical, following the profile of the ground, previously graded so as to prevent access beneath the bottom wire.

Gates shall be hung on reinforced concrete column, and shall be truly vertical.

Ornamental fabricated metalwork fences and gates shall be constructed of mild steel bar, strip or tube in accordance with the Drawings. All welded joints and drillings for bolts shall be made before painting, and all bolts, nuts and washers shall be galvanized or plated with two coats of bituminous paint.

3-7-F STRUCTURAL STEELWORK

Material for structural steelwork and workmanship shall comply with french standards. The steelwork shall be securely fixed to the foundations or buildings and designed to have such strength and stiffness that its deflection and movement under the loads to be applied shall be within tolerable limits.

All bolts and nuts, mild steel electrodes and high yield steel as well as all structural steel fabrication shall comply with French Standards.

All structural steelwork shall be fabricated using welded joints where possible for shop joints and bolted for field assembly.

3-7-G STAIRCASES

Staircases shall be suitable for superimposed load of 5kN/m² calculated on the plan area of the stair.

Open mesh type flooring shall be used for the treads and on the landings.

Stairs and landings shall be guarded on each side with a continuous handrail which shall be between 840 mm and 1000 mm in height on stairs measured from the tread nosings, and 1000 mm high on landings.

The riser / go dimensions shall fit the formula:

Twice the riser plus ONE TREAD = not less than 570 mm nor more than 635 mm. Consecutive treads shall overlap by not less than 16mm or as shown on the drawings.

3-7-H LADDERS

Ladders shall comply with BS 4211 and shall be of galvanized steel.

Stringers shall be extended 1000 mm above the upper platform and suitably opened out for access, or where ladders are below manhole covers, separate hand holds shall be fixed to the upper platform.

After fabrication, ladders under manhole covers shall dipped with hot galvanized.

3-7-I HANDRAILING

Handrailing shall be designed for horizontal loadings.

Standards and rails shall be manufatured from black mild steel or from extruded aluminum alloy approved by the Engineer. The nominal bore of steel tubing shall not be less than 32 mm.

Adequate provisions shall be made for thermal movement.

Steel handrailing shall be hot dip galvanized after fabrication.

3-7-J RAILWAY

This work shall consist of furnishing and installing railways as and where shown on the drawings or as directed by the Engineer. The anchorage system shall be approved by the Engineer. The Contractor shall submit to the Engineer's approval all the elements and dimensions of the railway. The materials of construction of the railway shall be structural steel.

Structural steel used for railings shall conform with the requirements of the AFNOR.

All elements shall be protected by zinc coating (galvanizing, refer to paragraph below).

The anchorage system shall be such that damaged metal posts and rails can be readily replaced without the need for cutting or coping edge unit into which the anchorage is located.

During erection the railway units shall be securely held in their correct positions until all connections and fixings are complete and the post fixings have gained adequate strength to develop the full holing down moment. The assessment of the adequacy of the post fixing shall be subject to the Engineer's approval. The finished railways shall be true to line and level throughout their length.

3-7-K STEEL ACCESS COVERS

Steel access covers shall be to the duty required and sized to suit the opening shown on the Drawings. They shall be complete with frame and shall be weatherproof (prevent the ingress of water) when closed and shall in all respects be strong and durable.

The covers shall be hinged and lockable and provided with stays to prevent the covers opening more than 105°. The Contractor shall provide with each cover a heavy duty non-corrodible padlock and four keys.

The covers and frames shall be galvanized or painted.

3-7-L GALVANIZING

Where galvanizing has been specified the items shall after fabrication be hot dipped galvanized in accordance with BS 729, or where approved zinc coated in accordance with BS 2569 Part 1 to a thickness of 0.15 mm .

All items to be protected shall be prepared as specified in the above standards.

Articles altered as the minor alternations at site or requiring minor repair at site shall be wire brushed to remove all rust and coated with 3 coats of approved zinc rich cold galvanized compound.

The minimum weight of coating and other requirements shall be as shown in the following table. If there is a conflict between the ASTM and minimum weight columns, the minimum weight column shall apply. The weight shown is ounces per square foot of surface area. The weight of coating shall be determined in accordance with ASTM A 90, modified to determine the coating of each surface separately. All surfaces, when tested separately, shall meet the minimum requirements.

Material	ASTM	Minimum Weight of Coating (oz./sq.ft.)
Steel products including structural shapes, tie rods, handrails, manhole steps, and miscellaneous items.	A 123 A 153 B 633 B 695	2.00 2.00 2.00 2.00
Hardware including cast, rolled, pressed and forged articles.	A 153 B 633 B 695	2.00 2.00 2.00
Bolts, screws, nuts and washers	A 153 B 633 B 695	1.25 1.25 1.25
CSP culverts and underdrains	A 444	1.00
Chain link fence fabric, tie wire only	A 392	1.20
Steel pipe (includes fence posts, braces and rails)	F 1083	1.80
All other chain link fence articles	A 123	1.80
Iron or steel wire fencing	A 116	0.80
Steel or iron sheets	A 525	1.20
Barbed wire	A 121	0.80
Electrolier standards, 7 gage steel and over	A 386	2.00
Electrolier standards, under 7 gage steel	A 386	1.50

The zinc coating shall adhere tenaciously to the surface of the base material. The finished product shall be free from blisters and excess zinc, and the coating shall be even, smooth and uniform throughout. Machine work, die work, cutting, punching, bending, welding, drilling, thread cutting, straightening, and other fabricating shall be done as far as is practicable before the galvanizing. All members, nuts, bolts, washers, etc. shall be galvanized before a structural unit is assembled. All uncoated spots or damaged coatings shall be cause for rejection.

Products that are warped or distorted to the extent of impairment for the use intended shall be rejected.

Zinc coating which has been field or shop cut, burned by welding, abraded, or otherwise damaged to such extent as to expose the base metal, shall be repaired and recoated by one of the following methods :

3-7-L-1 HOT-DIP PROCESS

The damaged areas shall be thoroughly stripped and cleaned and a coating of zinc shall be applied by the hot-dip process.

3-7-L-2 METALIZING PROCESS

This process can not be used unless the Contractor has the approval from the Project Manager.

The damaged area shall be thoroughly cleaned by blasting with sharp sand or steel grit. The blasted area shall lap the undamaged zinc coating at least ½ inch.

Zinc wire containing not less than 99.98 percent zinc shall be used in the metalizing operation. A zinc coating shall be applied to the damaged area with a metalizing gun

to a thickness of not less than 0.005 inch on the damaged area, and shall taper to zero thickness at the edge of the blasted undamaged section.

3-7-M WELDING

3-7-M-1 QUALIFICATION

In addition to the welding of structural steel, all welding shown on the plans or ordered by the Engineer shall conform to the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society.

Before assigning any welder to work covered by this Section of the specifications, the Contractor shall provide the Engineer with the names of the welders to be employed on the Work together with certification that each of these welders has passed qualification tests using procedures covered in The American Welding Society Standard B3.0, Part II, or such other qualification test acceptable to the Engineer. If required by the Engineer, the Contractor shall submit identifying stenciled test coupons made by any operator whose workmanship is subject to question. The Contractor shall require any welder to retake the test when, in the opinion of the Engineer, the work of the welder creates a reasonable doubt as to the proficiency of the welder. Tests, when required, shall be conducted at no additional expense to the Employer. Recertification of the welder shall be made to the Engineer only after the welder has taken and passed the required retest. Welders shall have passed the qualification tests within the preceding twelve (12) month period.

3-7-M-2 INSPECTION OF WELDS

Radiographic inspection of welds will be required, as specified in the current edition of the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society. Additional welds to be inspected radiographically will be specified on the plans.

When specified on the plans, other methods of nondestructive inspection of welds will be required.

The Contractor shall secure the services of an approved organization qualified in the inspection of welds and will bear the cost of this inspection service.

Inspection of all welds shall be done only by persons skilled in such inspection and who are acceptable to the Engineer. The Engineer shall review and interpret radiographs and other non-destructive or destructive testing and has the sole authority to accept or reject the inspection or Works.

All film and/or other records of weld inspection shall become the property of the Employer.

In the inspection of welds, the presence of any of the following defects in excess of the specified limits will result in rejection of the weld as being detective:

(1) Cracks. Cracks, regardless of length or location, will not be allowed.

(2) Overlaps. Overlaps, lack of penetration or incomplete fusion will not be allowed.

(3) Inclusions, Including slag, Porosity and Other Deleterious Materials. Inclusions less than one and one-half (1.5) millimeters in the greatest dimension will be allowed if well-dispersed, such that the sum of the greatest dimensions of the inclusions in any twenty-five (25) millimeters of welded joint does not exceed nine and one-half (9.5) millimeters and there is no inclusion within twenty-five (25) millimeters of edge of a joint or a point of restraint.

(4) Inclusions, Including Slag, Porosity and Other Deleterious Material. Inclusions one and one-half (1.5) millimeters or larger in greatest dimension will be allowed provided that such defects do not exceed the following limits:

(a) Six and one-half (6.0) millimeters, for T up to nineteen (19) millimeters, one-third(1/3) T, for T from nineteen (19) millimeters to fifty-seven (57) millimeters, nineteen (19) millimeters, for T over fifty-seven (57) millimeters, where T is the thickness of the thinner plate being welded.

(b) Any group of inclusions in line that have an aggregate length greater than T in a length of twelve (12) T will not be allowed.

Defects shall be removed by mechanical means or by oxygen grooving, after which the joints shall be welded again.

Part IV: Mechanical Works

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PART 4 - MECHANICAL WORKS

4-A INTRODUCTION

This Specification sets out the general standards of the Facilities to be supplied by the Contractor and mention of any specific Plant and Equipment does not necessarily imply that such is included in the Facilities.

All component parts of the Facilities shall, unless specified otherwise, comply with the provisions of this Specification.

The names of the manufacturers of the Plant and Equipment proposed for incorporation in the Facilities together with performance, capacities, certified test reports and other significant information shall be provided, when requested, for consideration by the Engineer. The Engineer shall have power to reject any Plant and Equipment which in his opinion is unsatisfactory or not in accordance with this Specification and such Plant and Equipment shall be replaced by the Contractor at no extra cost to the Buyer.

4-B STANDARDS

All ductile iron pipes, pieces, joints, connections, parts and accessories shall comply with the following Standards, Norms and Specifications:

Pipes:	NF A 48-801, NF A 48-806, NF A 48-841, ISO 2531, EN 545-2002, EN598.
Connections and joints:	NF A 48-863, NF A 48-842, NF A 48-830, NF A 48-860, NF A 48-870, BS EN 545-1998, ISO 2531.
Joint's fittings:	NF T 47-305, ISO 4633
External Protection (Zinc coating):	NF A 48-852, ISO 8179
External Protection (Bituminous coating):	EN 545-2002, EN 598
Internal Protection (Cement mortar):	NF A 48-901, NF A 48-806, ISO 4179, EN 545, EN 598.
Excellency of Productions and Installations:	ISO 9001
Testing:	ISO 2531
Special Protection (Polyethylene):	ISO 8180

4-C GENERAL PLANT DESIGN MATERIALS AND WORKMANSHIP

4-C-1 PLANT DESIGN

Plant shall be new, of sound workmanship and robust design, and of a grade and quality suitable for the climatic and working conditions at the Site.

Due attention shall be given to expansion due to temperature changes, the stability of paint finish for high temperatures, the rating of engines, electrical machinery, thermal overload devices, cooling systems, and the choice of lubricants for the possible prolonged high operating temperatures. Suitable precautions, such as lagging or trace heating, shall be taken where necessary for protection against damage by frost.

Plant shall be designed to provide protection against damage by the entry of vermin and dust, and to minimize fire risk and consequent fire damage. It shall also be protected against damage due to dampness and condensation by sealing or temperature compensation.

All manually controlled Plant located outside a building shall be provided with facilities for making it tamperproof. This is in addition to any requirements for securing Plant under operational conditions.

All component parts of Plant shall be manufactured to strict limits of accuracy and shall be interchangeable with the component parts of similar Plant.

Plant shall be designed for continuous operation for prolonged periods with a minimum of maintenance and shall have a high resistance to change in these properties due to passage of time, exposure to light or any other cause which may affect the performance or life of the Works. Tenderers should be called upon to demonstrate this for any equipment under consideration either by service records of similar equipment, or by the records of extensive type tests.

Materials shall be selected taking into consideration their location and duty. In the case of Plant conveying water, particular attention shall be given to the risk of electrolytic reaction between differing materials of construction and to the effects of corrosion and, where there are impurities in the water, erosion.

Where wear is likely to occur during normal operation, the Plant shall be designed to enable a potentially affected area of a component part to be replaced without replacing the whole component. No part subject to wear shall have a life from new to replacement or repair of less than one year of continual operation. Where major dismantling to replace a part cannot be avoided, the life of such parts shall not be less than 5 years.

4-C-2 SUBSTANCES AND PRODUCTS

Substances and products used in the Works which may be applied to or introduced into water which is to be supplied for drinking, washing or cooking shall not contain any matter which could impart taste, odor, color or toxicity to the water or otherwise be objectionable on health grounds.

4-C-3 METALS

Unless stated otherwise cast iron shall be gray iron to ISO 185 Grade 220.

Mild steel shall be to ISO 1052.

Stainless steel shall have a corrosion resistance, in the relevant environment, not less than required for steel in accordance with ISO 683 - 13. The minimum grades of stainless steel used shall be:

a- Submerged conditions; Austenitic grade 316S12

b- Exposed to the ambient atmosphere; Martensitic grade 416S21

Stainless steels used for welding shall be a grade not subject to inter-granular corrosion.

Prevention of seizure, by fretting where two corrosion resistant metals are in contact, shall be by selection of suitable relative hardness and surface finish and/or lubrication.

Where bronze is specified, or used, it shall be zinc free.

Dissimilar metals in contact shall be selected so that the electrolytic potential difference does not exceed 0.6 volt unless the surface area of the lower potential metal is negligible. Alternatively an approved insulation material shall be used.

When the Engineer requires the submission of material samples for assessment they shall be submitted by and at the expense of the Contractor not less than thirty calendar days prior to the time that the material is required for incorporation into any Plant and Equipment. Samples shall be subject to written approval by the Engineer and shall not be used without such approval.

4-C-4 WELDING

Metal arc welding shall comply with ISO 3834.

In all cases where welds are liable to be highly stressed the Contractor shall supply to the Engineer before fabrication commences detailed drawings of all welds and weld preparations proposed. No such welding shall be carried out before the Engineer has signified his approval of the details proposed. No alteration shall be made to any previously approved detail of weld preparation without prior approval of the Engineer.

All other welding shall be carried out by welders qualified in accordance with the requirements of the appropriate section of ISO 9606.

Radiographic examination which may be required of highly stressed welds shall comply with the provisions of ISO 1106 or ISO 2504, except as otherwise specified or ordered by the Engineer.

Mechanical and other non-radiographic tests, if required, shall be carried out in the presence of the Engineer.

All welded constructions shall be heat treated to relieve residual stresses prior to finish machining.

4-C-5 CASTINGS

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

Minor defects not exceeding 10 mm in depth or 10% of total metal thickness whichever is less or which will not ultimately affect the strength and serviceability of the casting may be repaired by welding. If the removal of metal for repair should reduce the stress-resisting cross-section of the casting by more than 25%, or to such an extent that the computed stress in the remaining metal exceeds the allowable stress by more than 25%, then that casting shall be rejected.

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

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

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

Flake graphite cast iron	BS 1452 Grade 220
Carbon steel	BS 3100 Steel alloy
Stainless steel	BS 3100 Steel 316C16
Copper & copper alloy	BS 1400 Group A grade LG2 Group B grade CT1, AB2 Group C grade G1

4-C-6 FORGINGS

All major stress-bearing forgings shall be made to a standard specification which shall be submitted to the Engineer for approval before work is commenced. They shall be subject to internal examination and non-destructive tests for the detection of flaws, and shall be heat-treated for the relief of residual stresses. The name of the maker and particulars of the heat treatment proposed for each such forging shall be submitted to the Engineer. The Engineer may inspect such forgings at the place of manufacture with a representative of the Contractor.

4-C-7 BALANCING

All complete rotating assemblies shall be dynamically balanced. Balance quality shall not be less than G6.3 in accordance with ISO 1940/1

4-C-8 NON-METALLIC MATERIALS

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

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

The use of wood shall be avoided as far as possible. If used, woodwork shall be thoroughly seasoned teak or similar hardwood which is resistant to fungal decay and other blemishes. All woodwork shall be treated to protect it against damage by fire, moisture, fungus, vermin, insect, bacteria or chemical attack, unless it is naturally resistant to all these. All joints in woodwork shall be dovetailed or tongued and pinned. Metal fittings on wood shall be of non-ferrous material. Adhesives shall be impervious to moisture and fungus growth. Synthetic resin cement only shall be used for joining wood. Casein cement shall not be used.

4-C-9 BOLTS, SCREWS, STUDS, WASHERS AND NUTS

Bolts, screws, studs and nuts shall comply with ISO 225, ISO 272, ISO 885, ISO 888, ISO 898, ISO 8992 and ISO 4759/1. Washers complying with ISO 887 and ISO 4759/3 shall be used under all nuts and hexagon bolts and screws.

Bolts, screws, nuts and washers exposed to the weather or in damp atmospheres inside buildings shall be zinc coated and painted or stainless steel.

Zinc coated items shall be hot dip galvanized, in accordance with ISO 1459, ISO 1460 and ISO 1461, and centrifuged. The threads of nuts shall be cut oversize.

Stainless steel items shall be manufactured from Grade 316S31.

Bolting for pipes and fittings shall comply with ISO 7005. Spheroidal graphite iron bolts for use with ductile iron pipes and fittings shall be manufactured from iron complying with ISO 1083.

Bolt lengths shall be sufficient to ensure that nuts are full threaded when tightened in their final position.

4-C-9-1 Fixing Bolts

Fixing bolts, nuts and washers for concrete, brick or masonry shall be of stainless steel. The bolts may be rag or indented bolts, expansion bolts, or resin bonded bolts. The Contractor shall submit details of the type he proposes to use, including manufacturer’s specification literature, for the Engineer’s approval.

When the bolts etc., are used for fixing aluminum items they shall be insulated from the aluminum by a non-metallic sleeve and under-washer.

The building-in material for use with rag or indented bolts shall be a proprietary epoxy non-shrink grout or a proprietary non-shrink mortar or caulking compound. Bolts shall not be brought into service until they are effectively anchored and the building in material has achieved adequate strength.

4-C-10 SAFEGUARDING PLANT

All designs and equipment shall be safe. The installation layout and plant design shall not allow any item of plant to be so positioned that danger to operating personnel could arise during normal operation and maintenance. Particular attention shall be paid to the position of hot pipes, valve hand wheels, air vents and rotating machinery.

4-C-11 RATING PLATES, NAME PLATES AND LABELS

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

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

Nameplates, rating plates and labels shall be of a non-flame propagating material, either non-hygroscopic or transparent plastic, with engraved lettering of a contrasting color. Fixing shall be by means of screws. No drive rivets or adhesives shall be used.

4-C-12 LUBRICATION

4-C-12-1 General

Provision shall be made for suitable lubrication to ensure smooth operation, heat removal and freedom from undue wear. Plant selected shall require minimum lubrication attendance and down time for lubricant change.

All grease nipples, oil cups and dip sticks shall be readily accessible, being piped to a point as near as practicable to the lubrication point.

4-C-12-2 Oil Lubrication

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

Roller chain drives shall have oil bath reservoir lubrication.

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

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

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

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

The design of breathers shall take into account the humidity and atmospheric contamination at the vent point and measures be incorporated to prevent contamination of the lubricant.

4-C-12-3 <u>Grease Lubrication</u>

Grease application shall be by steel lubrication nipples.

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

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

A separate nipple shall be provided to serve each lubrication point. Where a number of nipples supply remote lubricating points they shall be grouped together on a conveniently placed battery plate.

4-C-13 <u>GASKETS AND JOINT RINGS</u>

Joint rings suitable for hot or cold water or specified hydrocarbon fluids or for drainage applications shall be of chloroprene rubber or other approved synthetic material suitable for temperatures up to 80 C, or greater to suit the application.

Until immediately required for incorporation in a joint, each rubber ring or gasket shall be stored in the dark free from the deleterious effects of heat or cold, and kept flat so as to prevent any part of the rubber being in tension.

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

4-C-14 <u>ELECTROPLATING, GALVANIZING AND SHERARDIZING</u>

Hot dip galvanizing shall be carried out with a deposition rate of at least 460 g/square meter. After galvanizing all parts shall be passivated to minimize discoloration.

Electroplating or galvanizing will be acceptable as an alternative to painting for small ferrous components.

All fixing bolts, washers, nuts and other fixings required for erection shall be spun galvanized, or sherardized unless otherwise specified. Stainless steel shall be used in wetted areas.

4-C-15 <u>NOISE</u>

No item of Plant intended for installation in a building shall produce a sound pressure level exceeding 85 dB (A) and preferably 56 dB(A) when measured at a distance of 1 m from the reference surface of that item in a horizontal direction and under environmental conditions appropriate to the test requirements of I.S.O. 3746 "Acoustic Determination of Sound Power Levels of Noise Services - Survey Methods".

Plant such as compressors, diesel engines, blowers etc. where reduction of noise emission to below 85 dB at 1 m is impractical will be installed in a separate room constructed in or containing sound absorbing material.

4-C-16 VIBRATION

All items of rotating machinery shall be dynamically balanced so that the level of vibration is within the limits set by BS4675, Pt 1, for a class IV machine to grade B.

This limit on vibration shall extend to the communicating pipework and mounting arrangements and include adjacent machinery either in operation or not.

4-C-17 ACCESS STEELWORK

Gaps between items of Plant and the surrounding structure shall be covered, and access ladders, platforms and handrails must be attached to items of Plant to facilitate operation, inspection or maintenance.

Adequate access shall be provided to all hand wheels, sight glasses, gauges, lubrication points and any other items to which access is necessary for routine maintenance.

Handrails shall consist of double ball forged steel standards with tubular rails. Chequer plating shall be of 'Durbar' or other non-slip pattern, not less than 4.5 mm thick (exclusive of pattern).

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

All components for access steelwork shall be hot dip galvanized after manufacture.

4-C-18 HANDRAILING

Handrailing shall be double rail 1,100 mm high and 900 mm high on stairs measured vertically from the nose of the tread.

In case of no special requirements of the Engineer or on drawings, standard handrailing shall be 38 mm diameter solid forged steel with 60 mm diameter solid forged steel balls at handrail locating points. Standards shall have a minimum base width of 65 mm and be set at maximum 1 800 mm centers.

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

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

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

All components for handrailing shall be hot dip galvanized after manufacture.

4-C-19 PAINTING AND PROTECTION

4-C-19-1 General

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

Where dissimilar metals are in contact, insulation shall be provided to prevent electrochemical corrosion.

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

All coatings applied to any part of the plant in contact with water to be used for drinking, washing or cooking shall be non-toxic, non-carcinogenic, shall not impart taste, odor, color or turbidity to the water or foster microbial growth and they shall be approved by an international recognized authority for use on potable water.

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

Lead based paints shall not be used.

All machined, polished or bright surfaces, both external and internal, shall be afforded suitable and adequate protection against corrosion, damage and deterioration.

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

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

All iron and steelwork to be painted shall be blast cleaned to achieve a surface profile with a minimum amplitude of 0.025mm and a maximum of 0.100mm.

Following blast cleaning, steel surfaces shall be pure zinc metal sprayed where specified.

Aluminum structures and fittings shall not necessarily be painted.

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

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

4-C-19-2 Coating Systems

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

TABLE A: REQUIRED COATING SYSTEMS AND MINIMUM COATING THICKNESSES FOR PLANT AND EQUIPMENT

	APPLIED PRIOR TO DELIVERY AND ERECTION					APPLIED FOLLOWING INSTALLATION
	SUBSTRATE	PRETREATMENT	FIRST COAT	SECOND COAT	THIRD COAT	FINISHING COAT
ABOVE WATER LEVEL Machinery & Steelwork not in contact with Sewage, sludge or Water to be used for drinking, washing or cooking	Steel (galvanized)	Etch Prime or T Wash	Zinc Phosphate/CR Alkyd Primer Undercoat (0.050mm)	High Build Chlorinated rubber Paint (0.075mm)		High Build chlorinated rubber paint (0.075mm)
	Steel Zinc Sprayed (0.070mm)	Etch Prime				
	Steel, Cast iron, Ductile iron	Blast clean BS 4232 2nd quality	Zinc Phosphate/CR Alkyd Blast Primer (0.050mm)	Zinc Phosphate Alkyd Primer (0.050mm)	High Build Chlorinated Rubber (0.075mm)	
BELOW WATER LEVEL Machinery and Steelwork in Contact with Water to be used for drinking, washing or cooking	Steel (Galvanized)	Etch Prime or T Wash	Epoxy Primer High Build (0.125mm)	Epoxy High Build (0.50mm)	Epoxy High Build (0.075mm)	
	Steel, Cast iron, Ductile iron Zinc Sprayed (0.70mm)	Etch Prime				
Pipework	Steel	As specified				
Switchboard Shells, Frames and Backplates	Steel	As specified				

TABLE B: REQUIRED HEAT RESISTANT COATING SYSTEMS FOR STEELWORK

WORKING TEMPERATURE	AL: SURFACE TREATMENT	FIRST COAT	SECOND COAT	THIRD COAT
50°C to 175°C	Blast clean BS 4232 2nd quality	Polyvinyl Butyral (0.025mm) Zinc Chromate Primer (0.023m-0.015mm)	Aluminum heat resistant @ 200°C (0.025mm)	Aluminum heat resistant @ 200°C (0.025mm)
175°C to 500°C	Blast clean BS 4232 2nd quality	Aluminum pigmented silicone heat resistant (0.025mm)	Aluminum pigmented silicone heat resistant (0.025mm)	
	NB A minimum temperature of 350°C within a short time after application is required.			

4-C-20 MACHINERY, LIFTING AND DISMANTLING

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

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

Tapped holes or other provision must be made in all main castings, for the insertion of jacking screws or the fixing of drawing gear to facilitate dismantling on items of machinery subject to frequent dismantling. Bolts or studs shall be employed in preference to set screws.

4-C-21 SEALS

4-C-21-1 General

Seals compatible with the Plant and best suited for the worst conditions likely to be met when the Plant is in operation shall be selected.

All seal materials shall be compatible with and/or resistant to the fluid or gas being handled. For potable water, seal materials shall be specifically approved.

4-C-21-2 Soft Packed Glands

Shafts shall be provided with renewable gland sleeves. Glands subject to abrasive liquors or negative pressures shall embody suitably positioned lantern rings and a clean water continuous flushing system, operative whenever the Plant is in motion.

Gland adjustment nuts shall be readily accessible for routine maintenance.

Gland drain pipework, shall be installed, incorporating rodding facilities and adequate inclines, of 25mm minimum diameter on water reclamation plant and 12.5mm on water supply plant, discharging to the nearest sump or drainage channel.

4-C-21-3 Mechanical Seals

Mechanical seals which are subject to abrasive liquor or gas, negative pressures or corrosive elements, shall be provided with a clean water continuous gland flushing system, operative when the item of plant is in motion or the corrosive element present. A back-to-back sealing arrangement with a flushing/cooling system shall be accepted as satisfying the requirements of this clause.

4-C-22 BEARINGS

4-C-22-1 Below Water Bearings

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

Equipment with vertical shafts shall have thrust and guide bearings. All bearings shall be designed to exclude the ingress of dust and water.

Sealed for life units are acceptable subject to a minimum design life of 50,000 hours operation at maximum loading.

Plant which may be subject to vibration whilst stationary shall be provided with bearings designed to withstand damage from such a cause.

Below water bearings shall be of the journal type, of ferrobestos, gunmetal or equivalent and journals of stainless steel.

4-C-22-2 Above Water Bearings

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

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

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

Bearings fitted to gear boxes shall a minimum design life of 100,000 hours at maximum loading.

4-C-23 GEARBOXES

Where driven plant requires a drive system incorporating a speed reducing or increasing gearbox, the drive system shall be supplied by the driven plant manufacturer.

The gear form shall be in accordance with the relevant ISO or AGMA standard. The gear load carrying capacity for strength and wear shall be determined in accordance with the relevant ISO or AGMA standard but the following parameters shall be taken as a minimum.

- i- 24 hours per day operation
- ii- Service factor of 1.4 based on the rated output of the respective prime mover.
- iii- Rated life of 100,000 hours

The surface hardness of gears shall be determined in accordance with the relevant ISO or AGMA standard and for case hardened gears the depth of case shall be not less than 0.4 mm after profile grinding to counteract distortion.

The gears shall be enclosed in a cast or fabricated case. Fabricated steel cases shall be stress relieved prior to final machining. The case shall be split or provided with covers to facilitate inspection of the gears without dismantling the shafts.

Shaft bearings shall be selected with a rated life of 100,000 hours at the maximum speed and power rating of the gears. Any end thrust from the gears shall be accommodated by the shaft bearings.

Input and output shafts shall be adequately sealed to retain lubricant and prevent ingress of contaminants under all operating conditions.

Drain and filling plugs shall be provided. Where necessary extension tubes shall also be provided to facilitate filling and draining. Breathers shall be provided with filters to prevent ingress of dust and moisture etc.

Oil lubricated gearboxes shall be fitted with a sight glass indicating both the hot and cold oil levels.

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

Each gearbox shall be equipped with an embossed nameplate including at least the following information:

- i- Manufacturer’s name
- ii- Gearbox type reference
- iii- Serial or Order Number
- iv- Power rating of gears
- v- Speed ratio
- vi- Lubrication specification (type and viscosity)

4-C-24 FLEXIBLE COUPLINGS

Flexible couplings where supplied, shall be generously rated to cover the full range of duty.

Couplings liable to impregnation by oil shall be of the all metal flexible type.

General service couplings shall be of the flexible multi-pin and bush type, having not less than six bushes and each bush shall have an inner sleeve to allow rotation on the pin (bushes shall not be in direct contact with the pin). All pins shall have shoulders to allow positive location and securing to the bosses.

Bosses shall be a tight fit on the shafts and secured with hand fitted keys.

Couplings shall be supplied in matching balanced sets and shall be machined, balanced and marked before leaving manufacturer's works.

4-C-25 STRAINERS

Strainers shall be flange mounted type. Foot strainers shall be installed at least 0.5m (or as directed by the Engineer) above the bottom of the water reservoirs. The strainer basket shall be of the perforated cylinder type made from galvanized steel or stainless steel. It shall be easily accessible via a removable flange.

Also inline strainers shall be installed upstream the flow and water meters.

4-C-26 SAFETY SIGNS

Safety signs are required for all hazardous plant areas. The signs shall be of durable quality and shall comprise a substrate of 22 gauge aluminum, pre-drilled for fixing and with radiussed corners free of burrs or sharp edges. Symbols and lettering shall be screen printed.

4-C-27 SAFETY GUARDS

All sections of the plant which constitute a safety hazard shall be covered by substantial guards or barriers.

All moving parts of plant shall be adequately guarded to ISO/TR 12100.

All parts that in normal working are hotter than 60°C or colder than -5°C shall either be adequately fenced or shall be lagged.

All live electrical conductors, including conductors forming part of electrical apparatus, shall be either insulated or so fenced or placed as to prevent danger.

Guards shall be fabricated in mild steel wire mesh or expanded steel sheet, or should a fully enclosed type be necessary, in mild steel sheet.

Guards shall be designed to provide ready access to bearings, greasing points, thermometer pockets and other check points to allow routine observations to be made by the operating staff without danger or the need to dismantle any part of the guard. Hinged doors let into the guards with padlocking facilities shall be provided where necessary to facilitate access to the check points.

Guards shall be bolted in position in such a way that they cannot be unintentionally dismantled or removed.

All mild steel used in the construction of guards, including bolts, nuts, washers and brackets shall be hot dip galvanized unless otherwise specified.

Drawings of safety guards shall be submitted to the Engineer for approval before manufacture.

4-C-28 PLANT IDENTIFICATION

All pipework equipment, panels and valves shall be identified. Pipework shall be painted or color banded and labeled. Adhesive labels shall be used to identify tanks. Equipment shall be identified using engraved plates of a non-corrodible metal fixed on to the item using four screws. Engraved tags of a non-corrodible metal shall be used for valve identification. Tags shall of a uniform shape and shall be fastened by a jack chain.

4-D PUMPS

4-D-1 GENERAL REQUIREMENTS

4-D-1-1 Materials

Materials of construction of pumps shall be in compliance with the following requirements unless specified otherwise. Other materials of superior quality may be used subject to the approval of the Engineer.

SERVICE ITEM	DRINKING WATER
CASING	ZINC FREE BRONZE (MAX 3% ZINC)
IMPELLER	STAINLESS STEEL Or NICKEL ALUMINIUM BRONZE
TRIM	ZINC FREE BRONZE (MAX 3% ZINC)
MECH. SEAL	EXTRA HARD CARBON AND CERAMIC
STUDS	ASTM A193 GRADE B7
NUTS	ASTM A194 GRADE 2H

4-D-1-2 Pump Units

All pump units shall have means of isolation from their associated pipework system.

In dry well installations, the suction valve will normally be left open, unless used for isolation when the pump is out of service.

The delivery side of the pump set shall include a non-return device to prevent back circulation when the set is not running. This shall be a fail-safe device such that in the event of pump failure or loss of external services, the device shall independently close e.g. ball valves, check valves or gate valves closed by gravity or stored energy systems in exceptional circumstances. A gate valve will normally also be installed on the pump delivery side, downstream of the non return device, for pump isolation.

4-D-1-3 Pump Unit Control

The pump unit control panel shall include all control and indication elements for the pump motor, together with any associated valve actuators, lubricating systems and valves, cooling fans, flushing pumps and other ancillary control equipment required by a pump drive, all arranged to operate in a safe and proper sequence.

Where external services are required to open the delivery valve, the control system shall initiate the valve opening procedure as soon as the pump is up to a speed sufficient to overcome any existing delivery pressure.

Normal starting sequence will therefore cause the pump to run-up to operating speed then initiate opening of the delivery valve. Normal stopping sequence will first initiate delivery valve closure; after valve has closed then pump motor will be de-energized.

Failure of the valve to open within the time allowed or closure occurring whilst running, shall initiate an alarm and shut down the pump set. The maximum running time with the delivery valve closed shall be 3 minutes unless otherwise specified.

4-D-1-4 Pump Duty

Pumps shall be of the type specified. They shall be designed to give specified output against all losses including those relating to the pump.

The Contractor shall match his pump characteristics to the pipe system network to achieve high pump efficiency and reliability.

Each set must be capable of running satisfactorily in parallel with other sets in the system without throttling and by itself, without cavitation or overload under all operating conditions within the system characteristics given.

The pump section and arrangement shall be such as to ensure that the head available exceeds the N.P.S.H. requirements of the pump under all operational conditions.

Where the system and pump characteristics are such as to give rise to the possibility of surge in the pipeline with consequential damage, a surge investigation shall be undertaken; if the results of the investigation show that there is a problem, measures shall be proposed by the contractor to alleviate the problem. These measures shall be agreed with the Engineer.

Centrifugal pumps shall have a non-overloading characteristic over the complete range of head and quantity delivered and the drive shall be capable of starting the pumps against a closed valve, i.e. maximum pump head conditions.

The whole pumping unit shall be capable of withstanding without detriment, reverse rotation to a speed that would occur if the pump were to stop when the differential head was at a maximum and the delivery and/or non-return valve failed to close.

The design of the pumps shall be such that there will be no tendency to unlock any part due to possible reversal of rotation and shall not pass through or approach a critical speed.

The pumps shall be capable of working for long periods without cleaning or attention.

For sewage pumps the ability to operate with the maximum reliability is of prime importance, with efficiency being a secondary consideration. The pump shall operate without clogging, being designed to pass a sphere as specified where the size of the delivery mains permits. Whilst the pumps shall be designed to meet a specific duty they shall also be capable of operating over the duty range specified for prolonged periods and for standing idle for long periods without attention as in the case of storm pumping.

4-D-1-5 Pump Duty Control

Each of the pump units shall be capable of operating in any combination of duty sequence.

Any starting sequence, including those following restoration after a supply failure shall be time sequenced to prevent excessive load on the supply system. Each duty circuit shall include its own timer, arranged to be initiated in the selected duty sequence by the preceding duty, the delay periods between each re-start being adjustable up to 20 secs.

Pumping sets shall be automatically operated according to water levels in the discharge and suction side reservoirs unless otherwise specified.

Successive levels shall be carefully chosen in order to ensure a smooth and safe operation of the pumping system, taking into consideration the characteristics of the pumps, networks, hydraulic inertia of the installation, as well as the sensitivity of the instrumentation.

Two sets of level measuring devices operating in redundancy shall be installed in each reservoir unless otherwise specified.

Where valves with motorized actuator are installed on pump outlet pipe section, the pump shall be started with a closed valve: each pump shall start when the valve is still closed. The valve begins to open at the starting command of the pump and shall be controlled by the discharge pressure. The time of the total opening of the valve shall be chosen according to the pump manufacturer recommendation. At the pump stop command, the corresponding valve shall receive a closing signal and shall close fully prior tot he shutdown of the pump.

Where more than one pumpset is installed for a water network and unless otherwise specified, pumps shall be operated with a cyclic duty program automatically executed by the supervisor system. However, a selection of pump duty order by the operator shall be possible.

4-D-1-6 Pumps Casings

Pump casings shall be capable of withstanding all pressures which may be produced due to operating pressure surges.

Particular attention shall be paid to the wear characteristics of the pumps. In the case of sewage pumps, due to the presence of grit in the sewage wear, could be appreciable.

The pump design shall ensure that alignment is maintained between the various assemblies by recesses, spigots and dowels and shall be such that all components liable to wear can be replaced.

Components shall be permanently marked with the manufacturer's number and where dowels are not used, permanently marked for correct assembly. The pump casing shall have detachable wear rings.

The casings of the pumps shall have flanges to match the specified pipework.

The waterways through the pumps shall be smooth in finish and free from recesses and obstructions.

Sewage pump casings shall be of substantial construction to give long life under abrasive conditions and suitably stiffened to withstand shock due to solids in suspension. Inspection holes shall be provided in any section bend and in the pump casing above the impeller for access to facilitate the clearance of obstructions. The inspection hole covers shall be shaped to conform to the interior profile of the waterway when in place and shall be fitted with starting screws where necessary.

4-D-1-7 Impellers

Impellers shall be enclosed type, statically and dynamically balanced for highest efficiency and best wear life. Impellers shall be securely fitted to pump shafts in such a manner to prevent them becoming loose or detached when the pump is in operation, or when rotating in the reverse direction, either by liquid flow or motor rotation.

The impellers and guide vanes (if any) shall be accurately machined and smoothly finished to minimize hydraulic losses.

The rotating elements type shall be as specified and shall be statically and dynamically balanced before final assembly.

For sewage pumps the impeller shall be of the open type with the inlet ends of the vanes being of bulbous design and the impeller passages being as large as possible consistent with good performance. The impeller shall be readily withdrawable from the pump casing without the need to disconnect pipework. The inlet ends and surfaces of the vanes shall be dressed to give a smooth finish to prevent fouling by rags and fibrous matter within the pumps.

Impellers for both sewage and storm water pumps shall be of the non-shrouded type designed to exclude gritty matter from the shaft and gland.

The impellers should have replaceable wear sings. The clearance at the wear rings shall be kept to a minimum, and where it is found necessary to cut back the impeller this is to be done on the vanes only.

4-D-1-8 Pump Shaft

The pump shaft shall be adequately sized, with good fatigue, shock load and corrosion resistance. The duty speed range shall be well below the first critical speed of the shaft. Where a change in diameter of the shaft occurs the shoulder shall be radiussed or undercut to the appropriate BS to reduce stress concentration.

The shaft shall be made of stainless steel series 319 or series 400 and shall be complete with easily renewable protecting sleeves of suitable material (stainless steel) at glands and bearings.

4-D-1-9 Shaft Seals

Pump shaft sealing arrangement shall be suitable for the water pressures and shaft speeds involved.

Pumps shall be fitted with mechanical shaft seal type spring loaded flat faces arranged such that replacement of wearing components can be carried out without the need to dismantle the pump.

Special care in the selection of materials shall be taken in order to avoid binding and electrolytic action between the shaft sleeve and the mechanical seal components, particularly where long periods of idleness are inherent in the duty cycle as in the case of standby and storm pumping.

Each mechanical seal shall be equipped with leakage collection facilities and separately piped as specified.

4-D-1-10 Bearings

All pumps shall incorporate bearing arrangements which prevent the escape of lubricant into the liquid being pumped. The bearings shall be located in dust/moisture-proof housings.

All bearings shall be liberally rated to ensure cool running and meet the load factors specified.

For vertically mounted pumps, the top bearing shall be a combined thrust and journal type, designed to prevent any thrust loads being transmitted to the drive motor. The pump bottom bearing shall be lubricated by an enclosed water lubricated sleeve bearing for potable water applications but by grease or other approved means for sewage use. Storm pump bearings shall also be suitable for standing idle for periods up to 2 months without attention or movement.

Where grease points are necessary they shall be fitted with removable screwed plugs which shall be accessible without removing guards. All bearings having automatic lubrication shall also have provision for hand lubrication.

4-D-1-11 Baseplates and Stools

For vertical pump units, heavy cast iron or fabricated steel floor plates and motor stools shall be provided for direct mounting on concrete floors or supporting steelwork. Suitable journal and thrust bearings shall be provided in the baseplates to carry the vertical drive shaft.

Where necessary the motor stools shall be designed to accommodate flywheels and bearing housings.

Floor plates shall be recessed and so arranged that the tops and fixing bolts are level with the finished floor.

The pump units shall be accurately aligned and located on the baseplate by set screws and parallel dowels or machined spigots. Approved means of dowel withdrawal shall be provided.

4-D-1-12 Lubrication/Cooling Monitoring

A lubrication system shall be arranged for the lubrication of all grease points on the pumps and shafting from motor room level. Individual bearings within the support tunnel tubes and on the pump sets themselves shall receive separate supplies of grease fed by pressure tubes laid from each bearing to battery plates readily accessible from motor floor level for grease gun operation.

Pressure tubes shall be grouped together where possible and securely attached by brackets, straps etc. to tunnel tubes, with connectors located near to the motor support plate for easy removal of shafting in the event of maintenance work. In exposed positions pressure tubes are protected from damage. Motor grease points will not be included in this lubrication system but shall receive individual attention.

The battery plates shall have sufficient greasing points for all bearings and be located on or adjacent to each pump motor stool.

A notice is to be supplied and fixed on the wall in a prominent position detailing the manufacturer's recommended greasing schedule. The notice shall include a warning of the dangers to bearings from `over greasing'.

A grease gun shall be supplied for all greasing purposes.

Bearings which require a continuous supply of lubricant shall incorporate a means of monitoring such a supply, either by flow or temperature rise as appropriate for the type of bearing employed; separate monitors being fitted for each bearing feed or housing.

Such monitors shall include all necessary ancillary power or pulse counting devices to enable the operation of any monitor to initiate a volt free contact rated at 240V 0.5A AC.

4-D-1-13 Pump Tundish

Where specified, each pump shall be equipped with a cast aluminum or fabricated steel tundish to accommodate the drain lines from mechanical seals, casing vent and other minor drainage points on the pump. A single drain pipe shall be run from the tundish to the house drainage system.

4-D-1-14 Air Release Cock

The highest point on the pump casing shall be fitted with a manual air release cock having a removable handle or an automatic air release valve with a lockable isolation valve as specified. Air release pipework on sewage pumps shall be not less than 30mm bore and shall discharge back into the wet well at high level and have facilities for rodding. The drain from each air release cock shall discharge via pipework as specified.

4-D-1-15 Couplings

Coupling materials shall be chromium stainless steel.

All couplings shall be of an approved type and the Contractor shall arrange for the provision and fitting of both coupling halves to each respective shaft and shall include for all necessary modifications to any existing shafts to be coupled.

Where specified, the Contractor shall include any equipment required to prevent damage to any part of the drive in the event of reverse rotation of the pumps.

4-D-1-16 Intermediate Shafts

Intermediate shafts between the pump and drive shall include universal couplings at each end allowing free axial movement to avoid end thrust being transmitted. The shaft and coupling shall be fitted with a full length guard manufactured from mild steel mesh on a mild steel framework, easily removable for maintenance purposes.

The frame and mesh shall be hot dip galvanized.

4-D-1-17 Gear Unit

Each unit shall be continuously rated to transmit the full power of the drive either directly in line or through a right angled, helical gear system, having an input/output speed ratio to suit the duty.

The gear case shall be made of substantially ribbed cast iron with machined mounting feet and shall form a totally enclosed, oil tight casing.

The gear unit case and bearings shall be designed to accommodate the total weight of any suspended drive shafting and couplings in addition to any dynamic load imparted during service, and run for a minimum of 10,000 hours before a major overhaul is required.

Where specified, an electric tachometer shall be fitted to indicate the output shaft speed.

(i) Lubrication:

The gear unit shall be grease or oil lubricated, arranged to provide an adequate supply of lubricant for the duty.

Where oil lubrication is employed, the casing shall include an oil breather, level indicator and drain plug.

Units having a rated output greater than 500kW shall have inspection covers and include a forced lubrication system comprising an oil circulating pump, reservoir tank and full flow `Duplex' type oil filters having re-usable elements together with associated pipework; the oil being circulated by either (a) an internal mechanically driven gear pump and an external electrically driven pump arranged to prime the gears as pre-set timings as recommended by the unit manufacturer, or (b) duplicate external electrically driven pumps, each of which may be selected to prime at pre-set intervals and run when the gear unit runs.

Such a lubrication system shall include dial gauges and alarm switches to monitor high oil temperature and low oil pressure.

(ii) Reverse rotation:

Where specified, the gear unit shall be capable of withstanding reverse rotation for a limited period with no detriment to the unit. Where a forced lubrication system is used, this shall continue to operate satisfactorily under such conditions.

4-D-2 DOUBLE DISC PUMPS

The double disc pump shall comprise two reciprocating, mechanically driven, tough resilient discs with a sufficiently large cavity between the discs to produce displacement in a smooth continuous flow.

The pump shall be valveless and glandless and be capable of operating dry indefinitely without pump damage occurring.

The double disc pump shall be available as a static or mobile unit, as specified. It shall be suitable for either electric motor or diesel engine drive, as specified.

The pump body shall be manufactured from cast iron to BS 1452 Grade 220, as a minimum.

The discs shall be manufactured from Nitrile rubber or equivalent.

4-D-3 DIAPHRAGM PUMPS

The pump shall be of the diaphragm type utilizing a bullfrog type valve, suitable for pumping viscous solutions containing solids up to 55mm diameter as specified. It shall be driven by an electric motor through an oil bath reduction gear unit.

The main body of the pump shall be manufactured from LM6 aluminum and all wetted parts shall be supplied in 316 stainless steel.

The diaphragm shall be manufactured from neoprene, nitrile, hyperlon or viton elastomers and shall be reinforced with polyester fabric.

4-D-4 SUBMERSIBLE BOREHOLE PUMPS

4-D-4-1 General

Pumps impellers shall be closed or semi open type made from zinc free bronze or such other material required for use with the particular water to be pumped.

Pump body shall be treated against corrosion. The bowls shall be joined by flanges or by tie rods.

The shaft main guide bearings located in the suction and delivery end housings of the pump shall utilize a leaded-bronze material, and shall be provided with protection guards to prevent ingress of sand and grit. Pump bowl guide bearings shall utilize either leaded bronze or other approved abrasion resistant material. All pump bearings shall be lubricated by the water to be pumped. The pump delivery end housing shall incorporate a thrust washer of suitable material at the shaft end to absorb upthrusts that occur during pump starting. Unless otherwise specified, the pump shall incorporate a delivery check valve of hydrodynamic shape fitted with a spring to prevent reverse rotation of the shaft from back flow of water through the pump. The pumps shall be provided with a flanged discharge connection suitable for operating against the pump closed valve head or 16 bar whichever is the greater. The shaft coupling connecting the pump and driving motor shall be accurately machined and keyed to ensure precise shaft engagement and alignment. A strainer of suitable corrosion and abrasion resistant material, designed to guard against entry of foreign matter but permitting unrestricted flow of water into the pump, shall be provided on the pump suction housing.

Protection against the effect of sand shall provided by renewable wear rings (made from a hard smooth flexible material such as polymethane) mounted at the seating of the impellers and the passages of the shaft.

The pump shall be designed to pump water having a sand content of up to $40g/m^3$, unless otherwise specified.

A centralizer shall be fitted to every pump to ensure central alignment of the pumpset in the borehole casing.

Efficiency shall be greater than 70% at the operating point.

4-D-4-2 Borehole Pumps Rising Column

Borehole rising column shall be seamless steel and provided in section lengths not exceeding 3 meters with flanged joints or screwed couplings according to API5L grade B or equivalent. The rising column shall allow for small deviations in borehole verticality. Cables and water level dip tubing shall be securely fixed to the rising column by straps or bands at approximately 2 meter intervals.

The rising column shall be sufficient to take the stresses generated by the hanging weight of the pump, motor and rising column, the stresses produced by the water pressure together with any dynamic stresses which may occur under any circumstances including valve closure.

The rising column shall be protected internally and externally in factory against corrosion by a non toxic epoxy resin coating (300 μm minimum thickness) suitable for use with potable water.

4-D-4-3 Borehole Pumps Headworks

A fabricated steel discharge head piece shall be provided at the top of the borehole to support the complete rising column and electro-submersible pumpset assembly, and shall be complete with lifting eye bolts. The discharge head piece shall comprise a heavy duty sealing plate arranged for bolting to the borehole outer casing flange, and a 90° discharge bend arranged for flanged connection to both rising column and horizontal surface pipework. Lifting eyes shall be provided in the sealing plate. A flange shall be provided and welded by the Contractor to the top of the borehole outer casing. The flange shall be suitably drilled to accommodate the discharge head piece sealing plate bolts. Holes shall be provided in the sealing plate to accommodate an air vent pipe, motor and control cables, water level dip tubing, etc. and shall include adequate sealing arrangements to protect against borehole contamination.

A 25mm diameter screwed removable plug shall be provided over the dip tubing for water level measurement with electrical contact tape. A stainless steel air vent pipe shall be fitted to the discharge head sealing plate, terminating in an insect proof screen and arranged to prevent entry of rain or surface water.

4-D-5 VERTICAL TURBINE PUMPSETS

The pumps shall be of the vertical line shaft type. The discharge head shall be bolted onto a substantial steel bedplate or frame which shall in turn be bolted to the pump room floor. The discharge head shall have a flanged discharge. Replaceable seal rings shall be fitted on the impeller suction side if required to maintain pump hydraulic efficiency.

The pump shaft shall be of chromium stainless steel (13% chromium) minimum supported by bearings above and below each stage. Protection shall be given against the effects of entrained solids in the water being pumped intermediate bearings shall be lubricated by the liquid being pumped.

The line shaft shall be of the same material as the pump shaft, supplied in lengths not exceeding 3.0m, with screwed couplings. The line shaft bearings shall be spider type to locate the shaft in the tube and may also double up as line shaft tube couplers. Lubrication shall be provided to the bearings.

The pump suction shall be of at least equal diameter to the pump and shall be fitted with a suction strainer.

Means shall be provided of adjusting the pump shaft tension and position.

4-D-6 SUMP DRAINAGE PUMPSETS

Sump drainage pumps shall be vertical spindle submersible motor driven close-coupled units comprising a single stainless steel shaft, a squirrel cage electric motor and an end suction pump.

Electric motors shall comply with IEC 34 & IEC 72. Motors shall have IP68 protection and be SI continuously rated for use both when submerged at ambient temperature and when in air. Motor windings shall be fitted with normally closed thermostats complying with IEC 34-11. Motor feed cables shall be ethylene propylene rubber insulated flexible cable with each power core of tinned copper wire, insulated and polychloroprene sheathed overall.

4-D-7 CHEMICAL METERING AND DOSING PUMPS

Chemical dosing shall be by means of electrically driven metering pumps unless otherwise specified.

Metering pumps shall be of the plunger or progressive cavity type.

The effective range of the metering pumps shall be between zero and maximum with an overall repeatable accuracy within ±3%. Output shall be adjustable through a stepless variable stroke mechanism in the case of plunger pumps and variable speed motor or gearbox in the case of progressive cavity pumps.

The metering pumps shall be manually adjusted, and shall be calibrated to allow setting at the required dosage. Dose adjustment shall be possible whilst the units are in operation. Accurate dosing shall be maintained down to 10% of the maximum dosing rate.

The Contractor shall consider the liquid to be pumped and select the materials of construction so as to avoid corrosion. Mechanical glands are generally undesirable but where unavoidable, shall be to the approval of the Engineer.

For metering pumps of the plunger type the materials in contact with the liquid shall be polypropylene, stainless steel grade 316, UPVC or PTFE. Plungers shall be a high-alumina ceramic or stainless steel, grade 316.

Metering pumps shall be mounted on bed plates which shall be protected from gland drip. The pumps shall be driven by close coupled motors with reduction gears and have mechanisms housed in a totally enclosed oil bath.

At least one standby pump, fully connected into the chemical dosing system, shall be provided for each chemical, with local manual selection of duty and standby units. When pump duty change-over is effected the appropriate suction and delivery isolating valves shall be manually operated.

Stators and rotors for progressive cavity pumps shall be of materials selected having regard to the liquids being pumped.

The design and location of the metering pumps shall be such as to facilitate easy dismantling for the removal of any foreign matter.

Flushing facilities shall be provided for all chemical pipework at the inlet and outlet of each metering pump, together with drip trays to contain any spillage or leakage and piped to the nearest drain point. Provision shall be made for priming the systems to eliminate any air.

Each chemical dosing pump shall be provided with suitable isolating valves, an inter-connecting manifold system and, where necessary, loading valves. A calibrated glass container shall be provided connected into the suction manifold of each chemical pump so that its output can be checked.

Calibration curves shall be provided by the Contractor for all chemical dosing pumps.

4-D-8 PACKAGED BOOSTER SETS FOR COLD WATER SUPPLY

4-D-8-1 General

The set shall be a self-contained, fully automatic packaged unit which requires the minimum of maintenance to give maximum trouble-free operation. The systems consist of either 2, 3 or more individual pump and motor units which operate independently of one another and react immediately to fulfill system demand.

Each set incorporates diaphragm pressure vessels ready with a supply of water when demand arises. When draw-off exceeds the vessel's storage capacity, the lead pump is automatically started by a pressure switch to cope with the demand. In the event of unusually high demand, or failure of the lead pump, the support pump (or pumps) will immediately start.

4-D-8-2 Pumps

Vertical multistage or horizontal end-suction centrifugal pumps. Pumps shall be closed coupled type with stainless steel casing and bronze impeller, complete with electric motor.

4-D-8-3 Control Panel

Sheet steel enclosure incorporating all electrical components necessary for an automatic operation of the pumpset. Interwired with motors and pressure switches, requiring only connections to main supply on site. In the event of malfunction of any pump a stand-by pump will start automatically and panel will visually identify the faulty unit. The control panel incorporates a manual selector switch to allocate the role of lead pump in turns, to ensure an even distribution of work load. The control panel should be dust proof and splash proof.

4-D-8-4 Motors

Totally enclosed fan cooled (TEFC) direct-coupled motors, for 50 Hz supply, 380 voltages class F insulation.

4-D-8-5 Pressure Vessel

Mild steel construction incorporating replaceable non-toxic butyl rubber diaphragm. Factory pre-charged to required pressure, eliminating the need for a compressor on site.

4-D-8-6 Valves

Each individual pump has an inlet and outlet isolating valve and a non-return valve on the discharge of each pump. This allows any pump to be removed from the set without the necessity to shutdown the system. An isolating valve is fitted on the pressure vessel line.

4-D-8-7 Pressure Manifold

Each pump is controlled by its own individual pressure switch, factory set for system requirements and mounted with a common discharge pressure gauge on an aluminum manifold block. Receiving their signal through a high pressure PVC pipe which is connected to the discharge pipework.

4-D-8-8 Pipework

Pipework supplied in galvanized steel or polypropylene or as directed by the Engineer.

4-D-8-9 Baseframe

To be fabricated from 6 mm, flat mild steel plate, complete with panel support and holding-down lugs drilled and tapped to secure all pumpset components.

4-E SURGE SUPPRESSION EQUIPMENT

Surges in pipelines are usually caused by opening, closing or regulating valves or pumps starting and stopping. These surges, also called hydraulic transients may range in importance from a slight pressure or velocity change to sufficiently high pressure or vacuum to rupture the piping system, to damage pumping equipment and cause extensive shutdown time.

4-E-1 SURGE ANALYSIS

Surge protection analysis will be performed on critical sections of the piping system to verify design and surge control equipment selection. If excess transient pressures are predicted by the analysis, design and mechanical equipment application will be modified. Hydraulic surge control is a specialized field. A detailed surge protection study is required, it should be provided by engineers or consulting engineering firms specialized in this field. Detailed pipeline surge analysis by an expert should be considered to find out appropriate surge control methods

4-E-1-1 Protection Tools

The most common devices to overcome the effects of excessive hydraulic surge pressures in water system:

- Pressure relief valves , spring loaded or pilot operated
- Surge anticipating valves & Pump Control valves
- Inline check valves with bypass
- Anti-shock air valves at critical summits and ascents
- Anti-slam check valves closing at low reverse velocities under high deceleration.
- Stand pipes
- Surge vessels , Standard hydro pneumatic or open one way

4-E-1-2 Poor Maintenance Requirement

Should a surge vessel is recommended as surge control the particular scenario of power failure with vessel out of service should be considered to check for additional backup protection against burst failure.

4-E-1-3 Allowable Negative Pressure

Sub atmospheric (Negative) pressures should not be allowed to form in a potable water pipeline as this may cause disintegration of the cement lining of pipes, suction of flanges gaskets and intrusion of contaminants, Air valves should also not normally be allowed to open under unsteady conditions due to negative pressures. The minimum pressures are generally limited to +0.2 bar above pipeline crest.

4-E-1-4 *Allowable Positive Pressure: PMA*

Installed fittings dictate pressure limit of pipeline PMA

PMA: permissible maximum operating pressure surge included

Flanged fittings limit PMA override normally limit of all others components, pipes & push-in fittings.

PFA: PN flanged fittings	PMA, Max pressure surge included
10 bar	12 bar
16 bar	20
25 bar	30
40 bar	48
64 bar	77

4-E-1-5 *Cyclic Loading*

A de-rating factor should be applied to PMA of metallic pipes & fittings in the instance of cyclic loading or high frequency of on/off operations, PMA and pressure rating of thermoplastic pipes should be re-calculated accordingly.

4-E-2 *SURGE VESSELS*

The Surge Vessel shall consist of a vertical steel tank mostly of bladder type, connection valves, pipes and all necessary appurtenances .

4-E-2-1 *Vessel Design & Materials*

The surge vessel shall be made of welded steel shells and dome ends according to European Directive DESP 97/23 CE and EN 13480 -3, EN13445 or ASME boiler &Vessel codes, section ASME VIII-1 / VIII-2 - Construction of Pressure Vessels, ASME II – Materials

4-E-2-2 *Painting*

Painting of surge vessel shall be in accordance with the standard EN ISO 12944 – 2007 and comply with the following requirements.

Internal coating – Food quality epoxy paint

External coating – 2 coats of epoxy

External coating color shall be Sky Blue

4-E-2-3 *Fittings and Instruments*

Flange outlets, Inspection hole, Drainage plug, Glass tube levels indictor with an isolating valve,

Pressure gauge with isolating valve, Safety valve, Air inflation plug,

Supporting legs Lifting lugs

Air Compress, Magnetic level indicators

The Surge vessel shall be designed for anchor bolting to a concrete foundation. The supports shall be designed to withstand all natural loadings, any hydraulic and pneumatic thrusts resulting from surges.

Foundation design calculation shall also be submitted to the Engineer and get approval before construction.

4-E-2-4 *Testing of material*

Manufacturing process shall comply all the material test procedures in the EN 13445 – part 2 – 2009 and the following final assessment tests described under EN 13445 pat 5- 2009.

- Test on welds
- Dimensions check
- Inspection of safety accessories

4-E-2-5 *Bladder Surge Vessel*

A bladder surge vessel has the same function with regard to surge control as the traditional compressor vessel.

In a similar way to a vessel controlled by compressors, optimum pre-charge pressure results from detailed surge analysis.

The vessel can either be horizontal or vertical. It is constituted of a steel vessel containing a rubber bladder made from butyl or polyurethane (suitable for use with drinking water) and a flanged connection pipe equipped with anti-extrusion grill.

The vessels are treated internally sand blasted and coated with food quality epoxy paint as corrosion protection.

In order to verify the level in the vessel it is normally equipped with a level indicator as well as a manometer to verify the initial precharge pressure.

If hydraulically required, the vessel will be equipped with a non-return valve with a by pass to mitigate backflow surge.

The bladder shall be made out of butyl or polyeruthane complying BS 6920-2000 and shall be easily replaceable.

It shall be suitable and approved for use in drinking water systems. The bladder shall be perfectly watertight and airtight after the installation inside the vessel.

The tank, bladder and instrumentation shall carry a warranty of one year from delivery.

4-E-3 AIR COMPRESSOR

The compressor shall be integrated units with vertical or horizontal tank and piston compressor aggregate mounted on the top and total product should be confirmed to ISO 1217 – 2009.

The compressor shall be compatible with the surge vessel specification, to create necessary Pressure requirement for the above surge vessel.

The unit shall be equipped with pressure regulator, and suction filter, automatic pressure control of start and stop of the compressor aggregate, line circuit breaker and water trap.

Maximum allowed noise pressure: 70 dB @ 1m.

4-E-3-1 Control Equipment

Control equipment to provide fully automatic control of the selected duty compressor from the water level measuring instrument of the surge vessel.

Correction of air volume is preferred to be carried out under static state with idle pumps, switching on compressor should then override pumps energizing

For continuous pumping duty, a time delay shall be incorporated to prevent operation of the compressor during water level changes under surge conditions and a push button feature shall be provided for manual test of the system.

The front side shall have a full width door hinged with a rotating handle and positive closing action. The control panel shall include:

- One lock with a key
- Meters with selectors witches, HOURMETER/VOLTMETER/ANMETER.
- One switch START/STOP.
- Status indication ON/OFF/FAULT
- Contactors - (Starter).
- One differential thermal protection.
- Control circuit protection circuit breakers.
- One connection terminal (control and power).
- One PLC.
- The required relays for transmitting safety and system regulating data.
- A three pole isolating switch, with operating handle interlocked with the enclosure door.
- A water level control module.
- A non-latching motor test push-button.
- One selection switch LOCAL/REMOTE/ZERO

4-E-3-2 Fittings & Accessories

Each compressor shall be provided with the following features:

- Outlet pressure gauge.
- Pressure relief valve on each stage of compression.
- Suction filter with high separation capacity and silencer.
- Automatic unloading valve for a no-load start under all conditions
- Non-return valve.
- Protective guard between motor and compressor.
- Oil separator filter
- Filter and dryer for holding back solid and liquid particles of 5 microns.
- Pipework

4-E-3-3 Cabling

- Between the switchboard and the control panel
- Between the control panel and the compressors
- Between the control panel and the level electrodes on the surge vessel
- Earthing of all equipment.

4-E-4 SIGHT GLASS & MAGNETIC LEVEL INDICATOR

The sight glass level indicator shall have the following characteristics:

- Operating pressure range: Vacuum - Max test pressure.
- No requirement for energy source.
- Pressure compensated floats to avoid float drowning.
- Magnetic coupling of the indicator elements.
- An excellent readability ensured by resistance against product contamination and UV rays.
- Corrosion resistant.
- Highest operational safety through separation of liquid & indicator display.
- No re-calibration required.
- High mechanical strength.

The level indicator shall be equipped with magnetic switches and a continuous control elements and transmitter allowing remote monitoring of water level alarms and controls.

4-E-5 SURGE ANTICIPATION VALVES

The valve shall be installed in a by-pass line immediately downstream of the pump(s) and the check valve. The surge anticipation valve shall be interlocked to the pump(s) via the three-way solenoid valve that shall be supplied with the valve.

The basic valve shall be a single-seated, line-pressure-operated, diaphragm - actuated, pilot controlled globe or angle valve. The valve shall seal by means of corrosion - resistant seal and resilient, rectangular seat disc. These and other parts shall be replaceable in the field; all such service and adjustments to be possible without removing the valve from the line.

The stem of the basic valve shall be guided top and bottom by integral bushings. The basic valve and its pilot control system shall contain neither packing glands nor stuffing boxes.

The diaphragm shall not be used as a seating surface nor shall pistons be used as an operating medium. All internal and external ferrous surfaces shall be coated with a high quality, two-part epoxy primer; the exterior to receive a coat of backed enamel paint.

The pilot control system of the valve shall consist of a three-way solenoid controlled pilot-valve, an accumulator, a three-way diaphragm actuated pilot valve, an adjustable needle valve for opening speed control, an adjustable needle valve for closing speed control and a “Y” strainer. To isolate the control system from the main valve, inlet and outlet ball stop valves shall be provided.

- Temperature ratings: 0 °C - 85 °C
- Maximum pressure differential across the diaphragm of the basic valve must not exceed 20 bars.
- Valve materials [Pressure Ratings]:

  Cast iron - ASTM A126/B [< 25 bars]

  Forged or Cast steel - ASTM A126/WCB [> 25 bars]

  Cast bronze - ASTM B61, B62 [16 - 35 bars]

  Cast aluminum 356 - T6 [< 20 bars]

  or equivalent International Standards.
- Stem: Stainless steel/Ductile iron
- Seat Ring: Cast bronze or stainless steel
- Electrical Power: AC, 50HZ, in 110/220 volts / DC 6, 12, 24, 120, 240 volts.

4-F AIR COMPRESSORS

4-F-1 GENERAL

Air compressor units shall include at least one duty and one standby compressor set which shall be electrically driven and capable of delivering free air against a pressure differential equivalent to the pneumatic design pressure.

Air shall be filtered on the intake side of the compressors to remove dust in order to protect the compressor from undue wear.

Air shall be cooled by means of after-coolers. Air receivers shall be provided to balance supply and demand or to provide a reserve to operate a prime mover. Air dryers shall be provided.

4-F-2 AIR INTAKE

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

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

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

Intake ducting shall be in galvanized steel and of adequate proportions to minimize pressure drop and vibration. Where necessary to suppress low frequency noise, a silencer of the multiple aerofoil or `beam splitter' type shall be installed within the duct close to the inlet point.

Where air is drawn by the compressors directly from the room, appropriate provision shall be made to protect equipment and pipework from low ambient temperatures. Where air is drawn from outside the building, then heat from the machines must be dissipated effectively at times of high ambient temperatures. The room shall be properly ventilated.

4-F-3 RECIPROCATING COMPRESSORS

The compressors shall be of the oil-free reciprocating type and shall be of cast iron construction, mounted on a cast iron or fabricated steel baseplate. The baseplate shall also accommodate the drive system.

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

Cylinder heads shall be readily removable for inspection.

Each compressor shall be driven via a Vee belt drive arrangement (in accordance with ISO 5292 & ISO 9982) by a cage induction motor which shall be rated to allow the compressor to operate at the safety valve setting without overloading. The compressor and motor shall be mounted on a combination baseplate with slide rails for belt tension adjustment. A sheet steel guard shall be bolted to the baseplate.

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

Oil lubricated compressors may be used provided that oil eliminating filters are installed on the delivery side of the compressors. Where oil mist lubrication is recommended for certain types of valve actuators then the lubricators shall be installed at each point of use of the air.

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

Each air compressor shall be fitted with a pressure relief/off loading valve to avoid excessive pressure resulting from closed valves etc., and assist starting. A fusible plug, check valve, isolating valve and a delivery pressure gauge shall be fitted.

A dry media type filter/silencer shall be fitted to each air compressor inlet.

4-F-4 <u>AFTER-COOLERS</u>

The compressed air plant shall incorporate after-cooling.

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

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

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

4-F-5 <u>AIR RECEIVERS</u>

Air receivers shall be installed wherever it is necessary to balance a variable rate of air consumption with a fixed rate of supply. The capacity shall be sufficient to limit the number of compressor starts to no more than 10 per hour.

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

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

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

4-F-6 AIR DRYERS

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

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

The vessels shall each have an electric immersion heater designed for a 230 V a.c. supply unless otherwise specified, air inlet and outlet connections and drying media filling and emptying pads.

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

The dryer shall be thermally insulated and clad with aluminum sheet.

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

The control panel shall incorporate the following features:

- a- Isolating switch for 230 V a.c. supply
- b- Circuit protection
- c- Cycle timer
- d- Heating timer
- e- Heater contactors
- f- Control relays
- g- Control transformer
- h- Indicator lamps for CELL No 1 DUTY, CELL No 2 DUTY, HEATER No 1 ON, HEATER No 2 ON
- i- Indicator lamp for DRYER FAULT, voltage-free contacts for remote transmission of same and RESET push-button
- j- LAMP TEST push-button

4-F-7 AIR PIPEWORK

Pipework up to and including 50 mm DN shall be in steel with heavy fittings in malleable iron. Screwed threaded joints shall be made with a temperature resistant jointing compound. PTFE tape shall not be used.

Pipework over 50 mm N.B. shall be in steel with flanged joints to PN10 or higher rating where applicable.

All steel pipework shall be hot dip galvanized. No other internal coating is required.

Pipework shall be arranged to minimize the transmission of vibration and where necessary, connections shall be made with anti-vibration couplings.

Particular care shall be taken at points where condensation is likely to form or to accumulate such as following compression or cooling of ambient air or discharge of reactivation air from dryers. Appropriate traps and automatic drain valves discharging to approved points shall be installed.

Thermal insulation and cladding where fitted shall be arranged in a manner which provides access to valves and other components for maintenance purposes.

4-F-8 AIR ISOLATING VALVES

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

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

4-G VALVES AND ACCESSORIES

4-G-1 VALVES

4-G-1-1 General

The valve, components and all its related parts and accessories shall comply to one of the International Standards Institutes requirements (i.e. ISO, BSS, DIN, etc…).

Manufacturer(s) must have the Label of Quality ISO 9001 to be qualified as supplier. The contractor shall not submit any materials for approval if not compatible with the required specifications and from an approved manufacture.

4-G-1-2 Ductile Iron Gate valves

The Ductile Iron Gate valves should have the following characteristics:

- Working Pressures up to 25 kg/cm2 (PN 6/10/16 and 25).
- Working Temperature: From –10 °C up to 70 °C, resilient type Soft sealing for PN10 /16 /25, metal seated for PN25 and DN>300
- Body and bonnet in spherical graphite ductile iron EN-GJS-400-15 (GGG-40), with blue Ral 5015 epoxy powder coating electrostatically applied (EN1563) with min 250 microns
- Wedge in spherical graphite ductile iron EN-GJS-400-15 (GGG-40), fully coated by EPDM, or NBR (DVGW). EN1563
- Wedge lock nut in copper alloy with high resistance to corrosion, EN 12165
- Stem in stainless steel AISI-420 (X20C13), EN 10080
- Body-bonnet gasket in EPDM or NBR (DVGW), EN681-1
- Body-bonnet bolting in steel quality 8.8, with anticorrosive coating DIN 912
- Gate valves are supplied with handwheel in stamped steel, or square cap in EN-GJS-400-15 (GGG-40) for 30x30 T-key. They can also be operated with gear-box, electric, pneumatic actuator, extensions,… EN 10088 / EN1563.
- Gate Valves should be tested according to EN 12166-1, DIN 3230, and according to EN 1074 (2.500 cycles endurance resistance) or BS 5163 part2. Seat: 1.1 x PN, Body: 1.5 x PN
- Third Party approval: product conformity certificate from Bureau VERITAS or similar in addition to a proof of suitability for drinking water
- Dimensions : as per EN558 or BS 5163 part1
- Flanges and drilling EN1092-2

The Metal Seated Gate valve for DN>300 and PN 25 should be according to BS5163 & BS5150 and having the additional following characteristics:

- Wedge in Ductile Iron, BS EN 1563 / EN-GJS 400/15.
- Wedge Face Aluminum bronze, EN1982 CC331G.

- Hydraulic test to BS 5150 / EN 1171, Seat: 1.1 x PN, Body: 1.5 x PN

For all valves types for DN>350mm., bypasses are required.

4-G-1-3 Butterfly Valves

Butterfly valves, manual or motorized, fitted with maintenance free worm gear including mechanical position indicator and hand wheel, other Combined gear type may be used for specified application if particular min number of turns is specified. Where required, valves shall be electrically actuated with a manual override.

The Ductile Iron Butterfly Valves should have the following characteristics:

- On /Off duties manufactured according to EN593, eccentric (double offset) design, tight in both flow directions according to EN 1074-2
- Possible to replace profile sealing ring without disassembling the disk
- Installation: Underground, or in chamber
- Permissible working temperature: 70 C
- Hydrostatic test 1.5 PN for body 1.1PN for seat, according to EN 1074 1 and 2, and ISO 5208:
- Working pressure classes PN10/ PN16 /PN25 /PN40
- Body in ductile iron EN-JS 1030 Former GGG40
- Disc in ductile iron EN-JS 1050 or EN-JS 1030, EN1563
- Sealing seat in 316L stainless steel
- Valve sealing in EPDM
- Shaft Bearing in zinc free bronze
- Valve shaft Stainless steel EN10088 Gr 1.4057.
- Wetted bolts in S.S A4, outside bolts S.S A2
- Face to face dimension EN558-1 , Basic series 14
- Flanges drilling to EN 1092-2
- Third Party approval: product conformity certificate from Bureau VERITAS or similar in addition to a proof of suitability for drinking water
- Epoxy coating blue electrostatically applied EN 14901 min 250 microns
- Drinking water compliance approved with third party certificate
- Handwheel in Steel

4-G-1-4 Ball Float Valves

Ball float valves which are to be installed within reservoirs shall be of the delayed action type to eliminate inflow at small valve openings. They shall comply with B.S. 1212 and shall be fitted with a stilling chamber, auxiliary float valve and inlet bellmouth with regulating valve.

The main valve shall be fitted with long actuating lever to provide a long float travel for slow valve closure.

Valves shall be of the right angle pattern type with flanged inlet and have a resilient synthetic rubber disc which forms a drop tight seal against a removable seat insert. Valves shall be free of vibration under the specified working conditions. Flanged tapers shall be provides on the inlets as necessary to suit the size of valves proposed.

Valves shall be capable of withstanding the maximum static pressure and of passing the maximum flow rate. Orifice plates shall be provided as necessary to absorb excess working pressure at the initial flow rates indicated.

The pressure rating of the valve shall be cast into the body of the valve.

4-G-1-5 Check Valves

Check valves shall be of the swing, nozzle, dual disc, titled as directed by the Engineer. When used, Swing type shall be fitted with lever and counterweight to improve the response and anti-slam feature. When the check valve is installed next to surge vessel it should be titled disc or nozzle or dual disc type. They shall be installed on horizontal or upward vertical pipes. All check valves shall be of a type that will operate without shock. Valve bodies shall be of ductile iron unless otherwise specified by the Engineer and shall be fitted with renewable type seating (resilient or similar). Covers shall be provided to allow ample access for cleaning and service and shall be supplied complete with tapped bosses.

In the case of swing gate type valves the hinge pin shall be of stainless steel, mounted in zinc free bronze bushes and extended and fitted with external levers and counter balance weights, all protected by a screen guard.

Other types of valves will be considered. In every case the non return valve shall be selected with full consideration of the system characteristics, and shall avoid valve slam, and have low maintenance requirements.

Where specified, limit switches shall be provided to operate from the external lever. The screen guard being slotted to allow the guard to be removed without disturbing the switch cabling.

4-G-1-6 Cast Steel Valves

The cast steel valves shall be used where ductile iron valves are not permissible to operate at pressure > 25 bars, and shall comply to NF E 29-328, NF E29-331. The specifications of other valve parts shall be at least the same of the ones of ductile iron valves.

4-G-2 VALVE ACCESSORIES

1. Hand wheel : in steel DIN 17100 or cast iron epoxy coated DIN 1691
2. Stem cap in cast iron DIN 1691 or ductile iron EN1563
3. Extension spindle : Mild steel ST3/ZN6
4. Operation keys: Combination prizing bar and lifting key tube, with 1.5 m vertical bar and 0.5 m horizontal bar.

4-G-3 AIR-RELEASE VALVES

Air-release valves, body and components shall comply to SG 400-15 ductile iron, and are to be installed as specified on the drawings, where needed and as directed by the Engineer.

Air-release valves are introduced into the water main in order to eliminate air collections at high spots and changes in slopes.

a) Single air-release valves are meant to discharge the trapped air automatically under normal operating conditions, (when pipes are under pressure).

b) In addition to the role mentioned in paragraph a), double air-release valves (triple function air valves) permit bulk air vent under pressure, blowing off air when filling the pipes with water, and air ingress during emptying. They are also used at steep slopes to protect against sharp pressure drop in case of accidental breakage.

Air-release valves shall be supplied with an isolating valve which permits the complete removal of the air-release valve from the main without affecting the flow of water.

Air-release valve are mounted on a vertical branch connection with at the top of the main.

Air-release valves shall operate automatically and shall be constructed in a manner that the operating mechanism will not jam in either position (open or close).

Air-release valves shall be of single orifice valves (SOV) for distribution networks, and of double orifice valves (DOV) for transmission lines, pumping lines, and inside reservoirs valve chambers.

4-G-4 PRESSURE REDUCING VALVES

The pressure reducing valves shall be of the spring loaded type and of an approved design with a single external hydraulic relay system to ensure a constant downstream pressure for a variable upstream pressure.

The main valve body, cover and internal valve shall be of meehanite cast iron. The liner shall be bronze to BS 2870. The indicator rod shall be of stainless steel to BS 970 with all other components being of appropriate non corroding materials.

The relay system body shall be in bronze as shall all control valves. All connection piping and internal fittings shall be in non corroding materials.

Each valve shall be subjected to a body pressure test in the manufacturers works and witnessed by the manufacturer accordingly.

The relay system shall be capable of being checked or replaced without breaking the supply.

4-G-5 DOWNSTREAM LEVEL CONTROL VALVE AND PRESSURE HEAD BREAKER

This valve is installed in order to fulfill both functions of:

- Adjusting the upstream pipeline flow rate with the downstream side consumed flow rate.
- Local energy dissipation.

The downstream level control and head breaker valve should be installed at the end of a pressure pipeline before discharging into a water basin. It should control the water level within the water basin, where it is installed, regardless of the flow variations. This valve should be of Self – Centering Disc Obturator type from Alstom or Hydrostec or equivalent.

The upstream pipeline is connected to a vertical orifice (nozzle) at its end, above which is placed a flat disc linked with an operating rod. When exposed to the jet of water, the disc centers itself even in the absence of any lateral guiding. Using a rocker arm, the disc is operated by a cylindrical float having a vertical axis; the float moves in a chamber communicated with the downstream reservoir.

The type of obturator to be used is the hooded disc obturator type – OBCA, where the orifice and disc are located above the water level to be controlled. The orifice is a sharp – lipped nozzle and the disc is flat. A completely watertight seal should be insured by a reinforced rubber lining on the underside of the disc. This valve should include the following accessories:

- Roker arm
- Bearing
- Swivel ring
- Self – centering disc
- Deflector hood
- Convergent nozzle
- Adjustable stop
- Float

Through the rock arm, the float controls the self – centering disc, which regulates the aperture trough the water flows. When the water level in the reservoir rises, the float is lifted thus tending to close the abturator. The float chamber communicates with the reservoir trough on orifice, which is equipped with a control valve, thus providing and adjustable damping effect.

4-G-6 FLAP VALVES

Flap valves shall be normally closed, by weight of the door only, and shall open under minimum flow conditions. They shall be capable of withstanding 1.5 times the specified maximum seating head.

Where flap valves are required for flange mounting, they shall be supplied with rubber gasket and the full number of holes to BS.4504 NP 16.

All flap valves shall be operated and painted in accordance with metal painting and protection requirements.

4-G-7 STRAINERS

Strainers shall be flange mounted type. Foot strainers shall be installed at least 0.5 m above the bottom of the water reservoirs.

The strainer basket shall be of the perforated cylinder type made from galvanized steel or stainless steel. It shall be easily accessible via a removable flange.

4-G-8 MANHOLES FOR POTABLE WATER

The construction of manholes and valve chambers shall be located as specified on the drawings and as directed by the Engineer during constructions:

- Excavation and backfilling generally shall comply with appropriate requirements of PART III-1- EARTHWORK.
- Concrete works generally shall comply with the appropriate requirements of PART III-2- CONCRETE AND MASONRY.
- Ductile iron cover shall comply to ISO 1083, EN 124, or equivalent.
- Cement to be ordinary Portland cement or PA-S cement.
- Coating: Protective bituminous coating for external surfaces of concrete manholes, valve chambers, or other equal approved.

Manholes are to be precast or cast in situ as shown on the drawings and shall be completely water-tight. Particular attention shall be given to the joints between the pipes and the walls to ensure proper tightness against any leaks into the manholes.

Where valves are directed to be fixed in a chamber, etc. the necessary frames shall be placed in position using approved expanding shell bolts or an approved proprietary resin anchor system.

For precast units the Contractor shall obtain the Engineer's approval to all details of the precast units and method statement before commencing casting units.

All manhole covers located in roads shall be brought to the final finishing level of the pavements. The covers and frames shall have accurate seating faces to prevent rocking and the ingress of sand or water, and shall be fitted tight to resist overflow conditions or any leakage from under the frame base.

4-G-9 FLANGED ANCHORING PIPE WITH PUDDLE FLANGE

Flanged anchoring pipes with puddle flange shall be used in the concrete walls of manholes, valve chambers and water tanks as specified in the drawings or as instructed by the Engineer. The puddles flange will provide additional fixation to the pipe in the wall in addition to reduce or eliminate the water leakage.

The flanged anchoring pipe with puddle flange is made of ductile iron and shall comply to the appropriate requirements.

The installation requirements and fixation in concrete shall follow the manufacturing recommendations.

4-G-10 DISMANTLING JOINTS

Self restrained dismantling joints, made from ductile iron, are used to ensure extensible connections between sections of pipe work, to be mounted next to valves to enable easy dismantling from pipe work or to permit jointing pipe work when butterfly valves is removed for maintenance.

The dismantling piece is to be flanged type composed of two parts, one sliding into the other, and a free flange to compress a trapezoidal section seal to ensure water tightness.

4-G-11 FLEXIBLE JOINTS

Flexible joints shall be flanged type, the body shall be made of rubber and the flanges of mild or stainless steel. The working pressure of the flexible joints shall be 1.2 x the maximum pressure of the pump. Flexible joints shall be fit for suction and delivery, eliminate sound & vibration and shall be able to resist the effect of heat, water and weathering.

4-G-12 FLOW STRAIGHTENER / STABILIZER

The required type of the flow straighteners / stabilizers shall be selected to stop the turbulence in the water pipes.

4-G-13 DUCTILE/CAST IRON GRATING

The cover and frame shall be manufactured to ISO 1083, EN 124, or equivalent. Use rectangular grate and frames as specified on the plans and according to the following classification: Class D400; heavy duty; for minimum test load 40 tons.

The contractor shall submit certifications of Test Load according to British Standard Institute or equivalent and Quality Assurance according to the European Standard EN 124 section 10 or equivalent. The grate shall bear the following information:

- The name of the manufacture, initials and identification mark,
- Initial and number relevant standards, example EN 124,
- Production excellency stamped by one of the known agencies Example: The French standard Institute (AFNOR) or the British Standard Institute (BSI),
- Initial of material used, example: GS for Ductile Iron,
- Load capacity. Example: D400 for minimum test load 40 tons.

4-G-14 DUCTILE IRON FRAME AND COVER

The cover and frame shall be made of ductile iron manufactured to ISO 1083, EN 124, or equivalent. For Manholes, Use only round covers and frames, minimum 600 mms for cover and 850 mms for frame, as specified on the plans and their use according to the following classifications:

Class E 600: Super heavy duty; used for industrial plants, ports, airports, etc...Minimum test load 60 tons.

Class D400: Heavy duty; for streets, roads. Minimum test load 40 tons.

Class C250: Medium duty; for sidewalks, gullies, parking areas accessible for lorries. Minimum test load 25 tons.

Class B125: Light duty; for sidewalks, parking areas only accessible to passenger cars.

The contractor shall submit certifications of Test Load according to British Standard Institute or equivalent and Quality Assurance according to the European Standard EN 124 section 10 or equivalent.

The cover shall bear the following information:

- The name of the manufacture, initials and identification mark,
- Initial and number relevant standards, example EN 124,
- Production excellency stamped by one of the known agencies Example: The French standard Institute (AFNOR) or the British Standard Institute (BSI),
- Initial of material used, example: DI for Ductile Iron,
- Nominal diameter and class designations,
- Load capacity. Example: D400 for minimum test load 40 tons.

4-G-15 GALVANIZED STEEL STEPS OR LADDERS

Every inspection chamber and manhole which height exceeds 1 meter shall be fitted with metallic steps to allow easy access to the manhole from the opening in the frame.

Manholes and pressure breaker basin shall be furnished with 1 inch galvanized steel steps: to BS 729.

The steel steps can be installed during the construction of the concerned structures or after construction in case or precast units as specified in the drawings or as directed by the Engineer.

When drilling into the concrete walls for installing the steel steps, the hole shall be cleaned thoroughly and the space between the rod and the concrete shall be filled properly with non shrink cement mortar as specified by the manufacture and provide good finishing to the surface.

4-G-16 FERRULES

Gunmetal or Bronze Swivel Ferrules / vertical tapping valve / push-fit outlet for HDPE. The ferrule shall be designed for use underground and to handle potable water at temperatures of up to 40°C.

The ferrule shall work at pressures up to 16 bars without leakage.

The ferrule stem, banjo, inner plug and top cap shall be manufactured of gunmetal/bronze to BS1400 LG2, inlet shall be a male taper thread to BS 21 (ISO 7/1)

Its design shall permit service pipe installations via conventional drilling and tapping machines, under pressure or dry, with or without service saddles.

Ferrules shall be designed with a Push-fit outlet for PE pipe with grip ring , All ferrules shall be designed as a main stem with a 360° swivel outlet at 90° with control of water flow via a threaded inner plug.

4-G-17 STOP VALVES

- Gunmetal stopcock valves /House connections/Push-fit for HDPE

Easily operated, underground Stopcock BS valve type

BS5433 gunmetal stop -valves, highly resistant to corrosion

All metallic parts in gunmetal/Bronze, Gaskets in EPDM

Supplied with crutch heads or square heads for operation by underground stopcock key 5/8 size , common design of British water authorities

Supplied with plastic guard pipe and plastic chamber base with retaining clips for valve, chamber base designed to fit 160 mm guard tube.

- Ductile iron Stop valves / house connections / Push–fit for HDPE

Gate type with female thread connection acc. to ISO 228 on both sides

Resilient seated (EPDM) in accordance with EN 1074

Face-to-face length acc. to EN 558-1

Body: Ductile cast iron EN-GJS-400-15 or EN-GJS-500-7

Wedge: Brass CuZn40 Pb2 and ductile for DN 11/2" and 2"

Stem: Stainless steel X20 Cr13 EN 10088, Fix washer in bronze

Gaskets in EPDM, EN681-1

Supplied with bare square head or with extension spindle set for buried house connections, in this case the Extension spindle is made in ST3 / ZN6 min 20*20 with guard plastic pipe appropriate to valve body

- Ductile iron Stop valves / house connections / threaded outlets

Gate type with female thread connection acc. to ISO 228 on both sides

Resilient seated (EPDM) in accordance with EN 1074

Face-to-face length EN 558-1

Body: Ductile cast iron EN-GJS-400-15 or EN-GJS-500-7

Wedge: Brass CuZn40 Pb2 and ductile for DN 11/2" and 2"

Stem: Stainless steel X20 Cr13 EN 10088, Fix washer in bronze

Gaskets in EPDM, EN681-1

Supplied with bare square head or with complete extension spindle set for deeply buried house connections, in this case the Extension spindle is made in ST3 / ZN6 min 20*20 with guard plastic pipe appropriate to valve body.

4-G-18 SURFACE BOX FOR HOUSE CONNECTIONS

Manufactured in compliance with EN124, Load class: C250

Made in ductile iron with protective coating

Base inlet clear opening dimension 160mm to receive plastic guard pipe of same diameter

Min Top Clear opening 100 mm

Base Diameter 250 mm , Min H :120 mm

Marking: Water Authority

4-G-19 SADDLES FOR HOUSE CONNECTIONS

- Saddles on Ductile Iron Pipes

Saddle body in ductile iron EN-GJS-400-15 or EN-GJS-500-7 / EN1563, Epoxy or Rilsan coated min 250 microns EN 1563. PN16

Fitted with straps in stainless steel covered with rubber Strip of min. 2 mm

Stainless Steel Strap, bolts washers and nuts A2 70 DIN 933/ DIN 125

Single strap design allowed only for pipes of DN 50mm- 250mm, 2 straps design for larger diameters

- Saddles on HDPE Pipes

Electrofusion Saddles specially designed for Plastic pipes to be welded to the distribution line and to the outlet pipe, PN16.

4-G-20 WATER METERS FOR SERVICE CONNECTIONS

Water meters shall be of the volumetric type, turbine single jet liquid filled type magnetically driven or with mechanical-transmission. The meters body shall be bronze, and meters shall withstand a service pressure of 16 bars.

The accuracy at normal flow rates shall be better than ±2%. Meters shall be calibrated in cubic meters, and shall be compatible with the pipework in which they are being incorporated. The minimum reading must be 0.1 liter with head loss lower than 0.1 bar at nominal flow (Qn). The maximum working temperature is 30°C for cold water and 90°C for hot water.

Water meters shall also be equipped with:

- Tamper proof counter,
- Five (or more) reading rolls totally immersed in a hermetically sealed casing and filled with a lubricating fluid
- The maximum reading shall be 100.000 m3 (or more),
- Index wiper,

The meter must be Class C (BS 5728/1, ISO 4064., EEC 75/33, OIML N049) for horizontal position and class B in any other position, and must have an external adjusting screw tamper proof.

4-G-21 FIRE HYDRANTS

Fire hydrants, Breakable (Reversible) Type in Ductile cast Iron GS-400, Orientale 360°.

Manufactured according to EN 1074/6.

Flanged lateral connection EN 1092-2, PN 10/16.

Fitted with an anti-freezing device.

Wedge in Ductile iron with resilient seated.

Outlet are protected by caps with pentagonal nuts.

Sealing seat in bronze; driving shaft, internal parts, nuts and bolts in stainless steel, driving shaft, extension pipe and standpipe in stainless steel

The hydrant is internally and externally powder Epoxy, red polyester RAL 3000 for the upper body and blackepoxy or Synthetic resin for the underground part.

Max working Pressure: 16 bar

Min buried height: 800mm

Outlets: 2 outlets Operational Hexagonal ø 65/70 for Hydrant DN80 mm, 2 outlets Operational Hexagon ø65/70 + 1 outlet ø 100 for Hydrant DN100.

4-H WATER CHLORINATION SYSTEM

4-H-1 GENERAL

Gas chlorination equipment for installation at pumping stations, reservoirs and water treatment works and other locations on the system generally come under one of two categories.

1- Gas chlorination feeding into pressurized and gravity lines at locations where an electricity supply is available.

2- Gas chlorination at those locations, such as water catchment works, outlets from reservoirs etc where there is no electricity supply.

This specification covers both categories.

The contractor is responsible for the safe design, provision and installation of the chlorination dosing system and associated safety equipment. The safety equipment required varies from site to site depending on site location, quantity of chlorine stored or dosed and type of equipment supplied. The contractor shall access the requirements of each installation with respects to the following points:

- ventilation system
- leakage detectors
- Audio and / or visual alarms
- automatic shut down systems
- personal protection equipment
- procedures and training.

The equipment called for in this section are nominal requirements.

The scope of works for the provision of chlorination equipment includes, as appropriate to the particular category above:

1- Supply and transport to site of all equipment including chlorinators, centrifugal booster pumps, chlorine bottles, and all other material and equipment necessary for the installation.

2- Installation of chlorination equipment and fittings, pumping equipment, metering, pipework and valves, control and protection equipment to form a safe, effective and fully operational installation.

3- All necessary civil and building works.

4- Testing, commissioning, training and putting into service full equipment.

4-H-2 VACUM CHLORINATION OF PRESSURISED WATER SYSTEM

This system is applicable at pumping stations, water catchment works etc. where the water to be treated is under pressure and electricity is available.

A centrifugal booster pump shall be provided to supply pressurized water to the chlorinators.

Where specified the rate of chlorine injection shall be controlled by flow metering and proportional to the water flow rate.

4-H-3 EQUIPMENT CHARACTERISTICS

Injection of chlorinated solution shall be by vacuum type chlorinator, the vacuum being achieved by pressurized water and ejector.

The chlorinator may be either wall mounted or mounted directly on the head of the chlorine cylinder. It shall include:

- Pressure reducing valve
- Flow control valve
- Injection device
- Pressure relief valve to act in case of surge pressure of chlorine or loss of suction
- Pressure gauges up and downstream of the booster pump
- Non return valve downstream of the chlorinator

The injection service pressure (bar) and chlorinator capacity shall be calculated by the Contractor and designed from particular information for each installation.

The contractor shall supply all necessary equipment and fittings for operation, control and maintenance in accordance with the preamble to the bill of quantities and the following list (subsections "Water Circuit & Chlorine Circuits).

The list is indicative and by no means restrictive.

4-H-4 WATER CIRCUIT

Shall include but not be limited to:

- Motor Driven Pumpset:
- An electric motor driven pumpset shall be provided to achieve the discharge rate and pressure for chlorinator operation
- The booster pump discharge rate and pressure shall be as the chlorination equipment manufacturers specification. The pump assembly shall comprise a three phase 380V electric motor with a minimum protection class IP55 and maximum speed of 3000 rpm, and a centrifugal pump mounted on a common base plate
- Non return valve downstream of the pump
- PVC or bronze valves (Upstream and downstream of the pump)
- PVC or bronze control valve downstream of the pump
- Bronze strainer (1mm) upstream and downstream of the pump
- 10 or 25 bar pressure gauges as appropriate upstream and downstream of the pump
- Piping, treated against or resistant to corrosion

4-H-5 CHLORINE CIRCUITS

Shall include but not be limited to:

- Chlorine resistant non-return valve
- Anti-siphon system
- Chlorine resistant chlorinated solution injection device
- Chlorine resistant pipework for chlorinated solution injection
- Chlorine resistant pressure relief piping for release of gaseous chlorine in the event of over pressure, to a maximum length of 8m
- Piping between chlorinator and injection device, complete with fittings, all of chlorine resistant material
- Non-return valve

4-H-6 CHLORINATION OF PRESSURISED AND GRAVITY SYSTEMS IN THE ABSENCE OF ELECTRIC POWER SUPPLY

This system is for use where there is no power supply available, for example supply and delivery lines at reservoirs, catchment areas and headworks.

The chlorination process shall cease immediately in the event of lack of water.

4-H-7 CHLORINATION UNDER LOW PRESSURE

Use of low pressure chlorinators shall only be used where use of vacuum types is impossible due to insufficient line pressure.

The chlorinator shall be either wall mounted or directly assembled to a gaseous chlorine bottle, the latter providing pressure for operation of the chlorinator. A chlorine resistant piping connection shall link the chlorinator to a diffuser. In the case of a reservoir a spring loaded check valve shall be installed at the point of chlorine injection.

A nozzle injector rather than a diffuser shall be used for injection into a pipeline.

Where injection is into the pipeline pressure in the line shall always be more than 0.1 bar (g) and shall not exceed 0.7 bar (g). Partial vacuum in the pipe must be prevented.

In the case of a reservoir the level of water in the reservoir shall always be at least 1m above the diffuser.

The size of the piping between the chlorinator and the injection point will be a function of both dose rate and distance between the points.

4-H-8 CHLORINATION BY VACUM CHLORINATOR

Chlorination under vacuum only applies to reservoir gravity supply lines, the latter associated with a minimum hydraulic pressure of 0.5 bar. A hydro ejector shall achieve the required hydraulic pressure for injection provided a pressure drop is produced downstream of the hydro ejector feed point (By a valve or diaphragm).

The contractor shall optimize the locations of feed and injection points in such a way as to achieve a minimum hydraulic pressure of 0.5 bar upstream of the hydro ejector. The capacity of the chlorinator shall not exceed 200 gr/hr at a hydraulic pressure of 0.5 bar or 300 gr/hr at a pressure of 1 bar.

Chlorination shall cease immediately in the event of lack of water in the line.

4-H-9 CHLORINATION DOSING PUMP

Disinfection shall be achieved by injection of chlorinated lime or sodium chlorite (Javel water), by means of a dosing pump proportionally to the rate of flow of water. The chlorinated solution shall be stored in corrosion proof tanks.

The operation of the dosing pump shall be controlled by a flow meter equipped with a pulse transmitter. A control system receiving the transmitted pulses, shall regulate the dosage of chlorinated solution.

Supply of power shall be by:

- A low leakage, self discharge, maintenance free battery with no water addition required.
- A battery charging solar panel complete with either a charge regulator or an electronically controlled battery charger housed in a class IP55 box equipped with LED indicator.

The contractor shall supply and install such other equipment as may be necessary for the safe operation of the system.

4-H-10 CONTROL SYSTEMS BASED ON FLOW RATE OF WATER

4-H-10-1 General

The control system shall comprise a chlorine injection regulating system. It shall include:

a. A chlorinator for use with pressurized water systems.

b. A water flow meter with an output signal proportional to the rate of flow to be treated.

c. A motorized chlorine flow control valve with feedback signal to the control system, the signal to be proportioned to the chlorine injection rate.

d. A feed back control system with signal comparator. In the case of signal discrepancy, the control valve servomotor shall be actuated to adjust the injected dose of chlorine.

e. The injection nozzle and/or hydro ejector.

f. If specified the facility to receive a signal from a residual chlorine analyzer which will adjust the chlorine/water ratio.

4-H-10-2 Requirements of the above Control Systems

a) *Chlorine Flow Control Valve*

The motorized control valve shall be functionally compatible with the chlorinator. It shall achieve automatic control of the chlorination process as a function of the rate of flow of water to be treated.

The supply voltage shall be 220V, 50 Hz with a two pole circuit breaker equipped with adjustable thermal trip.

The valve capacity shall not exceed 10 kgf (gaseous chlorine)/hr. It shall receive and transmit a 4-20 mA signal to the chlorinator. The valve can either be incorporated in the chlorinator or installed separately in the system.

b) *Water Meter*

The water flow meter which may be of the turbine, magnetic flow, diaphragm or ultrasonic type, shall control the operation of the motorized control valve. It shall have the following characteristics:

a- Be suitable for fluids with up to 80 mg/1 solids particle content. It shall be designed for a range of water velocities from 0.5 to 3.0 m/s and shall transmit a 4-20 mA signal.

b- Operate on a supply voltage of 220V or 110V - 50 Hz.

c- Be equipped with a rate of flow indicator.

4-H-11 CONTROL SYSTEMS BASED ON RESIDUAL CHLORINE METERING

4-H-11-1 General

The system shall include:

- A vacuum chlorinator injecting into a pressurized water system.
- Chlorine injector flow control valve actuated by a converter to a residual chlorine analyzer with signal transmission to the control valve of a signal proportional to residual chlorine concentration in the treated water.

The residual chlorine analyzer shall be equipped with an electronic transmitter, and shall be one of two types.

4-H-11-2 Type "A" (with reagent)

The residual chlorine analyzer shall be of the amperometric type for measurement of residual chlorine in water.

It shall include:

1- Measuring cell.

2- Suitable reagent to allow measurement of the concentration of total and/or free residual chlorine.

3- Amplifying circuit and converter with 4-20 mA output signal. The above to be incorporated in the analyzer bar.

4- Zero point and scale adjustment features with automatic temperature compensation feature, to compensate for errors due to temperature fluctuation of the sample.

5- Direct reading indicator.

6- All components to be installed in a corrosion resistant box. The characteristics shall include:

- Scale range 0-0.5, 0-2.0 mg/1
- Water sample temperature range 0-50°C.
- Output signal 4-20 mA
- Supply voltage 220v - 50 Hz with 2 pole circuit breaker with adjustable thermal trip.
- Indicator: located on front of analyzer. Direct reading in mg/1 Accuracy ±2% of scale range.

4-H-11-3 Type "B" (Dry Type)

The analyzer shall consist of a potentiometric cell fitted with three metallic electrodes that shall generate a current directly proportional to the concentration of free residual chlorine.

It shall be equipped with a potentiometric amplifier and a converter to transform the current to a 4-20 mA signal.

The circuitry shall include a zero point and scale adjustment feature as well as automatic temperature compensation feature (Thermistor) in order to compensate for errors due to temperature fluctuations of the sample.

It shall have a direct reading indicator and be installed in a corrosion resistant box.

The characteristics shall include:

- Scale ranges 0-0.5, 0-2 mg/1
- Water sample temperature range 0-50°C
- Output signal 4-20 mA
- Supply voltage: 220V - 50 Hz with 2 pole thermal magnetic circuit breaker.
- Indicator: located on front of analyzer Direct reading in mg/1 Accuracy ±2% of scale range.

4-H-12 AUXILIARY EQUIPMENT FOR CHLORINATION AND STORAGE

4-H-12-1 General

Where electric power is available the chlorination room shall be equipped with an extractor fan roof mounted cowl type top discharge (10m static pressure), suitable for chlore extraction. The fan shall be connected to a PVC pipe of the indicated diameter bracketed off the internal wall of the rooms. The pipe shall run vertically inside the rooms and be fitted with a mosquito net and weather cowl at the inlet. The fan shall give twenty air changes per hour or as indicated and shall have a control switch located outside the building, A sign shall be fixed outside on the door "Danger, Toxic Gas - Access for authorized personnel only".

These shall be available at each chlorination building 2 No gas masks consisting of an integral mouth piece and wide view visual piece covering the entire face, complete with flexible breathing tube and filter cartridge with hipstraps.

2 No additional filter cartridges shall be supplied with each mask. The masks shall be kept in a dedicated wall mounted cupboard in the control room or attendants' room. The cupboard door shall have affixed to it a label stating "Chlorine gas masks. Fit new cartridge before use" "قناع واق من غاز الكلور – بدل القارورة قبل الاستعمال"", in both Arabic and English. The filter shall be effective in neutralizing gaseous chlorine.

A emergency eye wash and shower system shall be fitted to the wall immediately outside the chlorination room for emergency use. It shall have a chain operated valve.

When specifically called or deemed necessary, the chlorination room shall be fitted with an orange windsock of airport quality mounted on the top of the building. The sock shall be made of nylon and shall be chemically treated and ultraviolet dyed to prevent fading. The sock shall be mounted on a frame specially made for this application that does not lock up and shall be visible from the entrance door of the chlorine building.

4-H-12-2 Chlorine Bottles

2 No chlorine bottles shall be supplied with each chlorinator. They shall be 50 kgf capacity each unless specified otherwise.

Each bottle shall be equipped with:

- An isolating valve, which shall be provided with a protective cap during transport.
- Where specifically called for, an automatic chlorine supply change over to a standby bottle on depletion of the duty bottle. The system shall be wall mounted and shall be functionally compatible with the chlorinators. It shall function on partial vacuum and shall be complete with all accessories and fittings. The change over switch should include an indicator showing the cylinder in service.
- A bottle rack and chain support.
- Where specifically called for, a permanent weighing device shall be provided beneath the bottle in service to continuously monitor the rate of chlorine consumption.

4-H-12-3 Chlorine Detector

Where specifically called for or deemed necessary, gaseous chlorine detector units shall be fitted. The gas leak detector shall be used in conjunction with an alarm which shall be actuated if the gas concentration arises above 1 ppm or 3 mg gas/cu.m of air.

The detector may be one of two types:

Type A (Dry Cell)

The gas detector shall consist of an independent tank and detection cell located outside the tank. The tank capacity shall be sufficient to give 6 months operation. The detection cell (sensibility 1mg/cu.m) shall be connected to an electronic measuring device located in a wall mounted box. In the presence of an oxidizing gas the detection cell shall generate a current proportional to the gas concentration.

The box shall have an electronic indicating device and shall give continuous monitoring.

When gas concentration reaches its maximum permissible limit the detector shall activate visual and acoustic alarms, and shall trigger the operation of a remote alarm, where fitted, the operation of the extractor fan and closure of the supply line valves.

A test push button shall be provided to allow the operation to be checked.

Type B (Wet Cell)

The detector shall have live electrodes under constant supply voltage, immersed in an electrolyte that shall conduct current in the presence of an oxidizing gas. The generated current shall be amplified and converted to a signal.

4-H-13 LEAK DETECTION, RESIDUAL, FREE RESIDUAL AND TOTAL RESIDUAL MEASUREMENT

A bottle of liquid ammonia for chlorine vapor leak detection purposes and a measuring kit for quick determination of the concentration of the following shall be provided with every chlorination equipment installation.

- Free residual chlorine
- Residual chlorine
- Total residual chlorine

Details of the equipment to be provided, which shall include all auxiliaries, shall be provided with the tender.

4-H-14 INSTALLATION OF EQUIPMENT

The location of the chlorine bottles in the store shall be away from direct sunlight at all times. During transportation of bottles the contractor shall ensure that gas bottles are not overturned and that safe handling procedures are adopted at all times.

Gaseous chlorine piping connections between system components shall follow the shortest and most direct route possible and shall be laid to falls.

Water and other piping shall not be laid immediately alongside gaseous chlorine piping in order to prevent cooling and condensation.

Only grease or other lubricant as recommended by the equipment manufacturer shall be applied to all removable fittings.

Where the chlorinator is installed remote from the gas bottle the distance apart shall not exceed 10 meters.

The chlorinator vapor vent pipe shall be extended to outside the building away from inhabited areas. The vent pipe outlet shall be covered with a mosquito net.

Chlorination equipment piping shall be secured to the wall by brackets with a minimum clearance of 100mm off the walls for painting and maintenance purposes.

4-H-15 SYSTEM START-UP

The procedure for putting chlorination equipment into service shall include:

- A bacteriological and physico-chemical analysis of the water to be disinfected.
- Determination of the chlorine demand of the water to be disinfected based on break point method.
- Adjustment of the chlorinator capacity to achieve, after 30 mins of chlorine to water contact a residual concentration of 0.5 mg/1. A check shall be made by measurement of the concentration of free chlorine in water at a pre-determined location in the water distribution system.

In the case of a chlorinator controlled by an automatic residual chlorine measuring device, the indicated concentration shall be checked against the result of an analysis of residual chlorine in the water sample.

4-H-16 DISINFECTION CONTROL

Following start up of the chlorination system the contractor shall take five samples of disinfected water at five different locations situated at representative distances from the chlorination point so as to achieve effective control of the quality of disinfected water. The following tests shall be undertaken.

- Measurement of free chlorine (Type b1)
- Measurement of free chlorine in water.

4-H-17 SITE PROCEDURES AND TRAINING

4-H-17-1 General

Training should be carried out with emphasis being given to safety precautions and methods of dealing with emergencies. Particular attention should be given to the following aspects:

a- the hazards and characteristics of the material

b- safe methods of plant operation, including handing of the connection to supply systems;

c- methods of maintenance;

d- special operations; for example, plant shut down and start-up, methods of isolation and preparation of equipment for periodic maintenance and inspection;

e- the location and operation of emergency shut-off valves;

f- the procedures to be followed if releases occur;

g- training in the use of all personal protective equipment supplied.

4-H-17-2 Operating Instructions

The operating instructions should cover each process operation. Written operating instructions are required, in English and Arabic, for all routine and emergency operations, ranging from guide cards for simple operations to complete manuals.

Copies of the instructions, which should include a flowsheet and indicate valves to be closed in an emergency, should be available in the working area for operators.

4-H-17-3 Emergency Arrangements

The emergency procedure should include how gas releases may be dealt with safely by site personnel. The procedure should cover various degrees of emergency and should be either supplied in written form or made available to employees so that they know the steps they are required to take. This procedure should include first aid and evacuation arrangements.

4-H-18 310.14 NEUTRALIZATION CHAMBERS

Where specifically called or deemed necessary, a neutralization chamber shall be provided. For safety considerations a chlorine leak detection and neutralization system shall be provided with a capacity to treat the chlorine fumes of the largest full chlorine container present at the site. The neutralization system shall have adequate absorption stages operating under negative pressure (vacuum) including all ducting. It shall consist of the following:

1- A fan to extract the chlorine-laden air;

2- A neutralization tower with contact rings, mist eliminator, and vent system;

3- Necessary neutralization and water recirculating pumps, nozzles, sprayers, piping, valving, etc.

4- A storage tank for the neutralization solution and requited chemicals;

5- Necessary ducting, piping, valves, fans, and miscellaneous appatenances;

6- Electric and mechanical auxiliaries for monitoring instrumentation and control.

The neutralization system shall be capable of treating chlorine gas release at a rate of 45Kg/min with an overall efficiency performance of 99.998 percent removal of the chlorine vapor in the vent discharge.

The scrubber system shall run until the gas concentration in the chlorine storage room is reduced to 1 ppm in less than an hour.

The leak detector and the extractor fan inlets shall be positioned at floor level in the storage premises. The chlorine storage units, the evaporator-chlorinator assembly, and the leak neutralization tower shall be located in separate rooms. In the event of a chlorine leak in the premises where the chlorine cylinders are located, a chlorine leak detector shall sound an alarm lock up the ventilation fans and automatically start the fan that extracts the air from the polluted places to the neutralization tower. The chlorine laden-air flows shall go through the mass of contact rings in the opposite direction to the neutralizing solution. The chlorine neutralization system shall be capable of neutralizing the volume of the largest full chlorine container present at the site.

4-I LIFTING & HANDLING EQUIPMENT

4-I-1 GENERAL

Cranes and hoists shall be of standard proven design in accordance with BS 466, rated for lifting the specified working loads, utilization and service conditions and shall be suitable for operation from the runway beams provided. Motions shall be motorized as specified with dual speed hoisting facility and controlled from a pendant push button unit via a crane control panel mounted on the gantry.

All operations, whether manual or electric, shall be controlled or performed from motor room floor level unless otherwise specified.

The lifting assembly shall be rated for the highest lift that could occur during installation and maintenance operations, including allowance for stiction.

The crane shall consist of a gantry or jib, crab and hoist assembly, ropes, block and hook together with the necessary running rails and all electrical supply requirements.

Chains used for lifting or travel shall be alloy steel and corrosion protected by an electro-deposited, zinc coated finish after manufacture. They shall not be hot-dip galvanized.

The load chain anchorage, associated fittings and framework at the slack end shall be at least equal in strength to 2.5 times the maximum tension in the load chain when the working load limit is being lifted. Any links used for connecting the load chain to a terminal fitting shall be the material specified for the chain and heat treated to provide mechanical properties and strength equivalent to those of the load chain. The hook shall be made from high grade forged steel complying with BS 2903 "C" type, and provided with a safety catch. The safe working load shall be marked.

Jibs or gantries shall be of plate or box girder design and securely attached to end mountings or carriages.

A reliable braking and locking arrangement shall be incorporated and a load chain collection box shall be incorporated with the crab.

4-I-2 CROSS TRAVEL AND LONG TRAVEL

End carriages for gantries shall be fabricated from rolled steel plates and have two, double-flanged, cast steel wheels to match the track rails. Where rails are supplied and installed under this contract, they shall be adequately supported throughout their length to carry all the dynamic and static loads imposed by the crane duty.

Crab assemblies shall be mounted on four flanged cast steel wheels to suit the jib runway beam or cross-travel rails fixed to the main crane gantry.

Each travel range shall be the maximum permitted by the building and runway constraints. Where applicable the extent of each travel motion shall be limited by electrical limit switches with mechanical end stops secured to the travel rails beyond the electrical limit switch positions, to prevent overrun and building damage from swinging loads mechanical end stops shall also be provided where travel is by manual operation.

In the case of electric motor driven travel two travel speeds shall be provided. The fast speed shall not exceed 16m/min and the slow speed not exceed 4m/min. These drives shall always start at the lower speed and incorporate smooth acceleration and deceleration controls.

4-I-3 HOIST

The hoist unit on traveling beams shall be mounted to provide the highest possible lifting facility whilst maintaining adequate clearance between the crab/hoist assembly and the building structure and fittings.

Hoist units fitted to single runway beams, fixed or jib mounted, shall be of the self-suspension type mounted on a single rigid trolley suitable for manual geared travel along the runway beam. Two end stops shall be provided on the beam suitable for the trolley provided. The trolley shall have ball or roller bearings grease packed for life.

The hook shall be fitted with a swivel and a safety catch and be capable of touching the floor and providing a minimum lifting height as specified.

In the case of electrically operated hoists the normal hoist speed shall be approximately 4 min/min and the creep speed shall be approximately 600mm/min or nearest standards. An overload device and overwind limit shall be included to prevent dangerous overloads. Raise and lower limit switches shall be provided at the maximum and minimum lift positions. Instantaneous fail safe braking in the event of power failure shall be provided.

Where operation is by electric motor a power supply shall be provided under the contract. Power shall be taken from a feed in the main distribution panel forming part of the works and a wall mounted fused isolator shall be provided at a suitable location approximately 1.5 m above floor level alongside the lifting installation.

Power transmission to the moving installation shell be by pick up shoe running along the underside of shrouded rails, suspended concertina cable running on slides or a rail or a cable from a self winding cable reeling drum. In the latter case the tension in the cable shell be controlled and supports provided to prevent the cable drooping more than one meter below the crame rail (s).

4-I-4 RATING PLATES

The SWL shall be clearly marked in Arabic and English language on the rating plate and shall be legible from the plant working level.

4-I-5 PAINT FINISH

The finish color shall be a full gloss Yellow Color No. 356 to BS 381C or equivalent reference 08 E 51 to BS 4800.

4-I-6 CRANE ACCESS

Where clearances permit, provision for safe access for maintenance shall be provided in accordance with BS 466 and shall include a walkway across the span having a height clearance of 2m and be fitted with double-tiered handrails and toe boards.

An extending, portable aluminum ladder shall be provided for access to the crane for maintenance etc.

4-I-7 CRANE CONTROLS

The electrical controls shall be designed to prevent excessive acceleration, retardation, skidding and load swinging and all motions of the crane shall be arranged to be switched through the slower speed where provided.

The control circuits for the crane/hoist shall operate at not more than 110V and be derived from a double wound, screen earthed isolating transformer with one side of the secondary winding connected to neutral/earth. The primary supply shall normally be from the phase conductors.

Fuses shall be provided on each primary and secondary supply and be clearly labeled and segregated. A link shall be fitted in the neutral/earth connection.

4-I-8 CONTROL PANELS

The crane control panels shall be constructed of sheet steel or other approved material and shall be hoseproof (IP65).

The control panel shall be mounted on the traveling crane hoist bogie in a convenient position for inspection and maintenance, and shall house all the fuses, motor protection devices, starters and control equipment for controlling the crane/hoist. All contactors shall be of the air-break, electrically operated hold-on type with all necessary auxiliary contacts. Reversing contactors shall be mechanically and electrically interlocked to prevent conflicting operations.

The panel shall be fitted with a main isolating switch interlocked with the door to allow access only when the switch is open.

The motor starters shall be provided with adjustable overload protection devices suitable for the motor load at each speed and having manual resetting facilities within the panel.

All control equipment shall be fitted with suitably rated fuses. Fuse ratings shall be rationalized as far as possible to limit spares. Where practicable, fuses shall be housed in all-insulated carriers with fully shrouded bases.

Fuse links shall be HRC cartridge type to BS 88, Class Q1, having provision for screw fixings for attachment to the carrier.

4-I-9 PENDANT CONTROLS

A heavy duty, industrial pattern pendant push-button control station shall be provided, having sets of non-maintained push-buttons for each hoist speed and function specified.

Each set of buttons shall be electrically and mechanically interlocked so that conflicting operations are prevented and only one function can be initiated at one time.

The push-button enclosure shall be of a tough neoprene rubber suitable for withstanding arduous duty and provide full electrical safety, each button being suitably labeled with its function. It shall have an IP55.

The pendant shall be divorced from the crab and capable of independent cross travel. It shall be suitable for vertical adjustment for operation from alternative levels by means of spring loaded reeling drum fitted with a ratchet device or motor driven reeling drum and have a cable guide runner to assist re-coiling.

Pendant control cables shall be designed for reeling drum application and have stranded copper flexible conductors, EPR insulated to 300/500V, multicores laid-up with an internal central textile strain carrier and heavy duty, textile braid reinforced, PCP sheath.

For non-reeling applications, the outer sheath may be flexible PVC, incorporating externally laid, galvanized steel, nylon coated strainer wires.

4-I-10 RADIO CONTROL

Where specified, the crane remote control shall be by means of radio transmitter and receiver units operating within the UHF waveband range approved by the relevant authority. The receiver shall be accommodated on the crane in a metal enclosure to IP55, having shock absorbing, rubber mountings, an external receiving aerial and incorporate an output relay for each transmitter function.

The transmitter shall be a lightweight, hand held device enclosed in a heavy duty impact resistant enclosure to IP67 complete with a bandoleer carrying strap.

The unit shall be powered by rechargeable batteries having capacity for 10 hours continuous operation on fully charged batteries. To conserve battery life, a 'time out when not in use' function shall be incorporated and the stop button shall be fitted with a key switch to prevent unauthorized use. All push buttons shall be spring returned to the 'off' position and interlocked to prevent conflicting operations. Programmable security coding shall prevent operation from unwanted signal interference.

A suitable wall mounted, metal enclosed charger shall be provided to enable the transmitter to be connected and maintained in a fully charged condition when not in use.

4-I-11 FLEXIBLE CABLE SYSTEMS

The supply to the crane for both cross travel power together with pendant cross travel connections, shall be by flexible round or flat-form cable systems suspended on trolleys sliding in galvanized track from the crane structure.

The trolleys shall be formed from stainless steel side plates and axles with nylon runners. Sufficient trolleys shall be provided to effect a maximum cable loop of 0.5m.

The cables shall be PVC insulated and flexible PVC sheathed type designed for the application, incorporating flexible stranded copper live and earth conductors, terminated in suitable junction boxes as specified with weatherproof glands designed for the cable shape.

4-I-12 BUSBAR COLLECTOR SYSTEM

The power supply and earth connection for the long travel shall be from a current collector system of fixed busbar conductors which shall each be fully shrouded with PVC covers suitable for outdoor use.

The conductors shall be suitable for the current capacity, voltage drop and temperature conditions for the installation. Current collectors shall be of the sliding contact type with insulated contact heads mounted on spring loaded trolley arms. No current carrying surfaces shall be exposed.

4-I-13 CABLE REELING DRUMS

Cable reeling drums shall be of the spring loaded type which coils the cable radially about the drum axis and arranged for direct pulling off the drum, the core diameter being not less than the minimum bending radius of the cable. The springs of the drum shall be adequately rated to reel the useable length of cable fitted with the maximum tension applied shall not exceed the cable makers recommendation. Motor driven reels shall be provided where the spring loading is excessive.

The cable shall not overheat when used with the cable fully retracted. A totally enclosed slip ring connection box suitable for glanding the incoming supply cable, shall be fitted and the slip rings shall be rated to carry the full load current continuously and be accessible for maintenance.

Where specified, anti-condensation heaters shall be provided in the slip-ring enclosure, supplied at 240V AC or less from the appropriate slip rings via a fuse and link which shall be accessible without removal of the slip ring housing.

4-I-14 TRAILING CABLE

The trailing cable shall be 450/750V grade multicore type, designed to be suitable for use with a reeling drum. The size of the cable shall be such that a maximum recommended tension that may be applied to the cable is not less than the tension produced by the reeling drum.

Conductors shall be of flexible stranded copper, vulcanized rubber insulated with numbered tapes over each core. They shall be formed in a short lay round a flexible non-conducting center core, sheathed overall with a textile covering and heavy duty PCP sheath.

Cable conductors shall be not less than 2.5mm² and sized so that they will carry the maximum full load working current involved without excessive voltage drop and take account of thermal de-rating in accordance with the IEE Regulations, as applicable to the particular drum and mode of cable winding.

In addition to any supply, control, or motor feed cores, the cable shall contain an earth core of size not less than that of the largest phase conductor.

NB. Cable material descriptions:

PVC	Polyvinyl chloride (BS 6746)
EPR	Ethylene propylene rubber (BS 6899)
CSP	Chlorosulphated polyethylene
PCP	Polychloroprene (propylene/chlorosulphated polyethylene)

4-I-15 RAIL BONDING

Each section of running rail on the side adjacent to the supply isolator shall be bonded together and the rail connected to the earth terminal on the supply isolator by a protective earth conductor having a conductivity not less than that provided by a 4mm² section copper cable. The rail bonds shall be made by either of the following methods:

1- Each section of rail is to be drilled near its end with a 7mm (9/32") hole. An 8 SWG steel wire bond, galvanized to grade GLS400 to BS 182, is to be connected across each joint and secured at each end into the hole in the rail section by means of a tinned tapered steel pin which has a semi-circular groove along its length to hold the wire. The wire is to be overlength and the excess taken up by forming the wire into a 'Z' shape to absorb the expansion.

2- For indoor locations, an overlength, 4mm² section of tinned copper braid, fitted with crimped lugs at each end shall be bolted to each rail end by means of brass bolts and washers of not less than 6mm diam.

4-J TESTING

4-J-1 TESTING OF PUMPS

All pumps shall be witness tested, with the respective drive motor provided under the Contract, at the manufacturer’s works.

The tests shall prove that the respective pump can achieve the specific duty and operating range as required.

Rotary pumps shall be performance tested using clean cold water in accordance with ISO 3555 for water supply pumps.

Site conditions shall be simulated as near as possible including the NPSH condition. Pumps shall be tested with their own prime movers. Where it is impracticable to include the full length of the connecting shaft, the Contractor shall state the allowances to be made for the losses incurred by its omission and shall demonstrate the accuracy of the allowances to the satisfaction of the Engineer.

Special pumps (i.e. those for which the impeller is specially designed) shall be tested to prove the duty/guarantee point and to develop Quantity/Head, Quantity/Power, Quantity/Efficiency curves for the pump at the stated operating speed. If the pump is multi or variable speed the above performance shall also be developed at maximum and minimum speeds.

Mass produced pumps shall be tested to prove the duty/guarantee point.

All pump casings, and other pressure components, shall be hydraulically tested before assembly to a pressure of 2 times the maximum operating head of the pump

In addition to confirming the specified hydraulic performance of the pumpset, the test shall demonstrate that vibration is within the specified limits and that the mechanical performance is satisfactory.

4-J-2 TESTING OF AIR BLOWERS AND COMPRESSORS

All air blowers and compressors shall be witness tested, with the respective drive motor provided under the Contract, at the manufacturer’s works.

The tests shall prove that the respective air blower or compressor can achieve the specific duty and operating range stated in the Detailed Specification or given, by the Bidder, in the Technical Schedules.

The performance tests shall be in accordance with:

1- ISO 1217 for positive displacement blowers and compressors.

2- ISO 5389 for centrifugal blowers.

All casings, and other pressure components, shall be hydraulically tested before assembly to a pressure of 2 times the maximum operating differential pressure of the air blower or compressor.

4-J-3 TESTING OF GATE VALVES

Gate valves shall be tested in accordance with BS 5150 or BS 5163 as relevant. In either case, valve seat tests shall be made under open-end conditions, the test pressure being applied to each face of the valve in turn.

4-J-4 TESTING OF BUTTERFLY VALVES

Butterfly valves shall be tested in accordance with BS 5155. The seat test shall be for tight shut-off and low leakage. Valves shall be tested under maximum unbalanced water test pressure in either direction.

4-J-5 TESTING OF AIR VALVES

Air valves shall be water tested for drop-tightness at all pressures from 0.2 bar in steps of 2 bar up to the specified pressure. The valve body shall be water tested at 1.5 times the specified pressure, at which pressure no damage or permanent deformation of the valve body, ball or seat shall occur.

Two valves of each type and size incorporating large orifices shall be tested for exhaust of air at a differential pressure up to 1 bar in steps of 0.1 bar and for inflow of air at a differential pressure up to 0.5 bar in steps of 0.1 bar. During the tests the airflow rates shall be measured by orifice plates in accordance with BS 1042. Pressures (positive or vacuum) shall be measured by Bourdon tube gauges or by means of mercury-in-glass manometers. The temperature of the flowing air shall be measured in accordance with BS 1041: Part 1 and Part 2. The barometric pressure shall also be measured.

If the manufacturer provides results of independently witnessed airflow tests similar to those specified and these are accepted by the Engineer, then the specified airflow tests shall be deemed to be completed.

4-J-6 TESTING OF CHECK VALVES

Check valves shall be tested in accordance with the requirements of BS 5153.

4-J-7 TESTING OF PRESSURE AND FLOW CONTROL VALVES

Pressure and flow control valves shall be tested hydrostatically as follows:

- Body strength : closed-end test, valve open, test pressure 1.5 times working pressure.
- Valve element strength : open-end test, valve closed, test pressure applied to inlet end of 1.5 times working pressure.
- Leak tightness : open-end test, valve closed, test pressure of the working pressure applied to inlet end, no visible leakage permitted.

4-J-8 TESTING OF BALL FLOAT VALVES

Ball float valves shall be tested hydrostatically in the closed position and a pressure of 1.5 times the working pressure applied to the inlet end.

Valves shall be tested for drop-tightness at the working pressure.

4-J-9 TESTING OF PLUG VALVES

Plug valves shall be subject to hydrostatic shell and seat tests in accordance with BS 5158.

4-J-10 TESTING OF PENSTOCKS

Penstocks shall be operated from fully closed to fully open positions to verify correct operation. For penstocks fitted with power-operated mechanism, the test shall be carried out to demonstrate correct manual and power operation.

A leakage test shall be carried out to prove the penstock is drop tight under seating and unseating conditions.

4-J-11 TESTING OF ELECTRIC ACTUATORS

Electric actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

4-J-12 TESTING OF PIPEWORK

Pipework shall be tested in accordance with the appropriate Reference Standards.

4-J-13 TESTING OF CASTINGS

Castings shall be tested hydrostatically to 1.5 times the maximum working pressure for a minimum period of 1 hour.

4-J-14 TESTING OF SURGE VESSELS

Surge vessels shall be tested in accordance with the Reference Standards.

4-J-15 TESTING OF THE CHLORINATION SYSTEM

The tests on completion of the chlorination system shall include the following:

1- Injection rate

2- Injection pressure

3- Absence of leaks

4- Injected concentrations

5- Compliance with specification

6- Safety criteria

7- Such other tests as the Engineer may determine.

4-J-16 TESTING OF LIFTING EQUIPMENT

Before lifting equipment is used for any purpose whatsoever it shall be tested to lift and maintain a minimum test load of 125% of the safe working load. During this overload test each movement in turn shall be maneuvered and the equipment shall sustain the load under full control.

The Contractor shall provide the necessary test loads and carry out the tests on all the equipment he has supplied.

The tests shall be carried out in the presence of the Engineer, who may require to measure deflections or make other observations during the tests. The tests may also need to be witnessed by others.

4-J-17 TESTING OF AUTOMATIC IN-LINE STRAINERS

Automatic in-line strainers shall be tested in accordance with the Reference Standards and with manufacturer's own requirements.

4-J-18 TESTS AT SITE

The Contractor shall submit to the Engineer detailed proposals for testing. The proposals shall give values of test parameters and make reference to standards and manufacturers' literature. The proposed format of test sheets shall be submitted at the same time. A separate sheet shall be used for each test. The testing shall not commence until the proposals and test sheets have been approved in writing by the Engineer.

The following inspections and tests shall be carried out as appropriate.

- Inspection to check the assembly of the Plant and conformity with the Specification.
- Rotational checking of all electric motors.
- Hydrostatic testing of all gravity flow pipework systems and penstocks at the maximum head or differential head that can occur in service. Leakage from penstocks shall be measured and recorded but shall not exceed the maximum value stated in the Contract or otherwise required for safe operation.
- Hydrostatic testing of all pressurized pipework systems at 1.5 x maximum working pressure for a period of at least one hour.
- Performance testing of each pump to prove correct operation, absence of fluid leaks, correct bearing temperatures and absence of undue vibration and noise.

- Functional testing of auxiliary items including automatic in-line strainers and valve actuators.
- Functional testing of valves to demonstrate correct operation.
- Overhead cranes shall be tested with a load of 1.25 x Safe Working Load and results recorded in accordance with the Reference Standards.

4-K EQUIPMENT DATA

The Contractor shall submit the following required information related to his proposed equipment. The Engineer reserves the right to request any further information he may need to check compliance of the proposed equipment with the Specifications.

4-K-1 PUMPSET DATA

Description	Units	Particular
Pumpset		
Type	-	
Manufacturer	-	
Manufacturer's Model Number	-	
Rising Column Diameter	mm	
Delivery Outlet Diameter	mm	
Number of Pump Stages	-	
Impeller Type		
Impeller Diameter		
Actual	mm	
Maximum	mm	
Materials		
Rising Column	-	
Pump Casing(s)	-	
Pump Impeller(s)	-	
Pump Shaft	-	
Hydraulic Performance		
Nominal Running Speed	rpm	
Guaranteed Duty (ISO 3555)		
Capacity	l/s	
Total Developed Head	mm	
Power Absorbed	kW	
NPSH Required	m	
Drive Motor		
TYPE	-	
Manufacturer	-	
Standard	-	
Frame Size	-	
Enclosure Rating	IP	
Class of Insulation	-	
Performance		
Rated Output	kW	
Rated Voltage	V	
Rated Frequency	Hz	
Power Factor at Rated Output	pu	
Efficiency at Rated Output	%	
Full Load Current	A	
Starting Current (Direct-on-Line)	A	

Speed	rpm	
Weight of Pumpset Complete	kg	

4-K-2 *PNEUMATIC VESSEL*

Description	Units	Particular
Pneumatic Vessels		
Manufacturer	-	
Material	-	
Standard	-	
Class	-	
Dimensions		
Diameter	m	
Length of Parallel section	m	
Overall height	m	
Wall thickness	mm	
Corrosion allowance	mm	
Total vessel volume	m^3	
Initial air volume at maximum pumping pressure	m^3	
Maximum air volume at minimum downsurge pressure	m^3	
Design Pressure	Bar	
Hydraulic Test Pressure	Bar	
Nozzle Flanges		
Type	-	
Rating	Bar	
Standard	-	
Protection		
Interior lining	-	
Exterior coating	-	
Rated Working Pressure	Bar	
Hydraulic Test Pressure	Bar	

4-K-3 AIR COMPRESSOR

	Units	Particular
Air Compressor		
Type	-	
Manufacturer	-	
Manufacturer's Model Number	-	
Bore	mm	
Stoke	mm	
Materials		
Cylinder	-	
Cylinder Head	-	
Piston	-	
Baseplate	-	
Rated Working Pressure	Bar	
Test Pressure	Bar	
Nominal Running Speed	rpm	
Performance		
Capacity (FAD)	m^3/hr	
Differential Pressure	bar	
Efficiency	%	
Power Absorbed	kW	
Drive Motor		
Type	-	
Manufacturer	-	
Standard	-	
Frame Size	-	
Enclosure Rating	IP	
Class of Insulation	-	
Performance		
Rated Output	kW	
Rated Voltage	V	
Rated Frequency	Hz	
Performance at Rated output		
Power Factor	pu	
Efficiency	%	
Full Load Current	A	
Starting Current (Direct-on-Line)	A	
Speed	rpm	
Weight Complete Air Compressor set	kg	

4-L MECHANICAL INSTALLATIONS FOR BUILDINGS

4-L-1 GENERAL

4-L-1-1 Scope

The mechanical work is deemed to include, but is not limited, to the followings:

- Electrical requirements for mechanical equipment.
- Supports and anchors.
- Mechanical insulation.
- Valves.
- Fire protection.
- Water distribution piping.
- Sanitary drainage and vent systems.
- Storm water systems.
- Potable water system.
- Plumbing fixtures.
- Plumbing pumps.
- Water conditioners.
- Electric Water Heaters.
- Fuel oil systems.
- Hydronic piping.
- HVAC pumps.
- Cast iron boilers and radiators.
- Breechings, chimneys, and stacks.
- Mini-Split Heat Pumps.
- Power ventilators.
- Ductwork and ductwork accessories.
- Air outlets and inlets.

4-L-1-2 Inclusive Works

The scope of works shall include, at no extra cost on the bill of quantities, but not limited to, the followings:

- Working internally, externally, in plant rooms.
- Assembling.
- Jointing.
- Expansion joints in pipes that crosses expansion joints, to be included in

- Expansion loops.
- Hangers and supports.
- Pipe and equipment fittings and connecting peaces.
- Excavation, backfilling, and trenches.
- Electrical connections and controls.
- Electrical works described in the specifications and implied necessary for the proper functioning of the mechanical system or testing it.
- Anti-vibration mountings and equipment base.
- Required modifications.
- Temporary works.
- Cleaning and painting.
- Builders work in connection with mechanical works.
- Preparing shop drawings with a scale of 1/20 and 1/50 to show clearly the installation.
- Operation, balancing, and testing of systems and equipments.

4-L-1-3 Interpretation

The tender documents, drawings, and bill of quantities shall be read as a one complete unit. Tenderers are to include all necessary items that they feel essential for the good and safe functioning of the proposed systems, and shall include within the item prices their material cost, installation cost, overhead and profit.

The rate of pipeworks shall also include hangers, supports, and protection of insulation by jacketting, as per specifications, at the support location.

The rate of ductwork shall also include hangers, supports, and protection of insulation by jacketting as required by the specifications.

The rate of air outlets shall also include the air balancing of the system.

The rate of equipments shall also include operation, testing, and balancing.

4-L-1-4 Abbreviation

The following abbreviations are used in the following bill of quantities.

m	meter
sq. m	meter square
kg	kilogram
No.	number of units
$	U.S.Dollars
item	lump sum cost

4-L-1-5 Method of Measurements

Measurements are taken along the center line of pipings or ducts, equipments are counted. Tenderers are to satisfy themselves of the proposed quantities so as not to claim additional cost.

4-L-2 MECHANICAL INSULATION

4-L-2-1 General

Composite mechanical insulating material shall be provided with flame-spread index of 25 or less, and smoke-developed index of 50 or less, as tested by ASTM E 84 (NFPA 255) method.

4-L-2-2 Piping Insulation Materials

Piping shall be insulated with fiber glass pipe insulation having a density of 96 kg/m^3 and a maximum heat transfer coefficient of 0.033 W/ m C at a mean temperature of 24 degree C.

4.L.2.2.1. Vapor Barrier Jacket of Pipe Insulation

Shall be of a minimum 0.025 mm aluminum foil, laminated to kraft paper with flame retardant adhesive, and shall be reinforced with fiber glass. The vapor barrier shall be an integral part of the insulation

4.L.2.2.2. Jacketing of Piping Insulation

Exterior and in machine room piping insulation shall be protected with aluminum jacket of a weather proof construction. The jacket shall be 0.8 mm thick embossed aluminum, provided with longitudinal Pittsburgh seams and butt joint strips with weatherproof mastic adhesive protected by release paper.

4-L-2-3 Piping System Insulation

Heating water supply and return - 15 to 50 mm pipe: 25 mm thickness

Hot water piping shall be insulated with fiberglass insulation of 25 mm thickness up to and including a pipe diameter of 150 mm.

Condensate drainage and air conditioning copper pipes shall be insulated with nitrile rubber foam.

4.L.2.3.1. Exposed Piping

Protect outdoor insulation from weather by installing outdoor protective aluminum jacket with weather-proof construction.

4-L-2-4 Insulation Protectors

Provide an insulation protector at each pipe hanger and support for insulated piping. The protectors shall be provided for all insulated pipes.

The insulation protectors for cold pipe sizes 65 mm and less and hot water 50 mm and less shall be a half round 16 gauge galvanized metal shield fitted over pipe insulation.

4-L-2-5 Pipes Running Externally, Under Tiles, Or In Wall

Heating pipes running under tiles shall be insulated with 13 mm thick flexible light weight nitrile foam and wrapped with protective tape.

Hot water pipes running in walls shall be insulated with 13 mm thick flexible light weight nitrile foam and wrapped with protective tape. Cold water pipes running in walls shall be wrapped with protective tape.

Closed cell elastomeric nitrile rubber faom insulation shall at least have the following characteristics:

Density		80 kg/m3	As per ASTM D1667
Thermal conductivity at 20 °C		0.0374 W/mK	As per ASTM C 177
Temperature limits		-40 °C to 105 °C	
Water absorption (% by weight)		3	As per ASTM D 1056
Water vapor permeability (perm – in. Max)		0.033	As per ASTM E 96
Thermal stability 7 days (% shrinkage)	94 °C	4.5	as per ASTM C 548
	105 °C	5.5	
Average spread of flame		Class 1	as per BS 476 part 7
Average time of burning		less than 5s.	as per ASTM D 635-91
Average extend of Burning		15 mm	
Flexibility		excellent	
Ultraviolet resistance		good	
Chemical resistance		good	
Odor		negligeable	
Mildew resistance		no fungal growth	

4-L-3 VALVES

4-L-3-1 Standards

Valves shall be made to the following standards:

1- Cast Iron : MSS SP-70 for valves 65mm and larger.

2- Bronze : MSS SP-80 for valves 50mm and smaller.

4.L.3.1.1. Rating

Valves less than 65 mm shall be made of bronze and shall be rated PN20, valves 65 mm and larger shall be made of cast-iron and shall be rated PN16.

4.L.3.1.2. Globe, Gate, And Double Regulating Valves

Valves less than 65 mm shall be made of bronze and trim, non rising stem and shall be rated PN20, valves 65 mm and larger shall be flanged and made of cast-iron and bronze trim, non rising stem and shall be rated PN16.

4.L.3.1.3. Check Valves

50 mm and smaller shall be flanged and made of bronze body and trim, larger than 50mm shall be made of cast-iron body and bronze trim. The valve shall be of the Y pattern swing check valve.

4.L.3.1.4. Float Valves

To be made of bronze including levers and arms with copper floater suitable for 10030 kPa cold water working pressure.

4.L.3.1.5. Automatic Air Vent

Shall be designed to vent automatically with float principle; bronze body and nonferrous internal parts; 105 m WG working pressure, 115 deg C operating temperature; and having 6 mm discharge connection and 15 mm inlet connection.

4.L.3.1.6. Water Hammer Arrestors

Shall be of the bellows type , with stainless steel casing and bellows, pressure rated for 176 m of water gauge pressure, tested and certified in accordance with PDI Standard WH-201. Water hammer arrestors shall be installed where required to prevent the damaging of the system. Water hammer arrestors can be of the spring operated type.

4-L-3-2 <u>Fire Protection</u>

4.L.3.2.1. GENERAL

Fire fighting systems and equipment shall be installed and manufactured in accordance with the recommendations of “The National Fire Protection Association of the U.S.A.”

4.L.3.2.2. Portable Fire Extinguishers-Type Fe:

4.L.3.2.2.1. Fire Extinguisher (FE-1)

5 kg ABC nitrogen operated dry chemical type. The body shall be made of steel and shall be red enamel finished. The unit shall have a brass operating valve, a large operating lever, a pressure gauge and a discharge hose.

4.L.3.2.2.2. Fire Extinguisher (FE-2)

2.5 kg carbon dioxide type. The body shall be made of steel and shall be red enamel finished. The unit shall have a pull pin, squeeze handle, a double braided hose and a discharge horn.

4.L.3.2.2.3. Automatic Ceiling Fire Extinguishers

Shall be of the ceiling hang type filled with ABC dry chemical extinguisher type.

4-L-3-3 Water Distribution Piping

4.L.3.3.1. Galvanized Steel Pipes And Fittings

4.L.3.3.1.1. Galvanized Steel Pipes

Shall be used for cold, hot and potable water pipes running indoors. Pipes shall be seamless galvanized steel, medium weight, tested and manufactured to BS 1387 Appendix A.

Pipe fittings shall be galvanized and made to match pipe wall thickness.

Hangers for horizontal steel piping shall be installed with the following maximum spacing and minimum rod sizes:

Nom. Pipe Size – mm	Steel Pipe Max. Span – m	Min. Rod Dia. - mm
Up to 20	2	10
25	2	10
32	2	10
40	2.7	10
50	3.0	10
65	3.4	13
80	3.7	13

Pipings shall be supported at each floor.

4-L-3-4 *Sanitary Drainage And Vent Systems*

4.L.3.4.1. Above Ground Drainage And Vent Pipe And Fittings

4.L.3.4.1.1. Non Pressure UPVC Pipes

Shall be used for sanitary drainage and venting systems. Pipes shall be made to EN1329-1 or to equivalent European norms; with a minimum wall thickness of 3 mm. Product shall bear certification of conformance to standards.

4.L.3.4.2. Underground Drainage And Vent Pipe And Fittings

4.L.3.4.2.1. Non Pressure UPVC Pipes

Underground drainage pipes shall be made to EN1401-1 or to equivalent European norms, with a minimum wall thickness of 3.2 mm. Product shall bear certification of conformance to standards.

4.L.3.4.3. Drainage Piping Specialties

4.L.3.4.3.1. Floor Drain Type FD-1

Shall be made of PVC material and shall be constituted of the following: the top socket takes a floor gully inlet made of two parts; a raising piece with a square top to suit standard floor tiles, together with a snap-in cover that provides a circular opening for the disposal of surface water. The trapped floor gully shall have three inlet of 50 mm diameter to accommodate a lavatory connection and an outlet of 75 mm diameter.

4.L.3.4.3.2. Floor Cleanout Type FCO

Floor cleanouts shall be made of PVC material and shall be made of a raising piece with a square top to suit standard floor tiles together with a removable circular piece to be removed when rodding through the drain line. Floor cleanouts shall have the same diameter of the pipe it serves and shall be connected to the pipe with a long radius elbow.

4.L.3.4.3.3. Roof Vent And Cap – Type RVC

Shall be made of UPVC material and shall include an extension piece to connect to the pipe with a cap.

4-L-3-5 *Storm Water Systems*

4.L.3.5.1. Pipes And Fittings

4.L.3.5.1.1. Non Pressure UPVC Pipes And Fittings

Above ground pipes shall be made to EN1329-1 or to equivalent European norms, with a minimum wall thickness of 3 mm. Product shall bear certification of conformance to standards.

4.L.3.5.1.2. Non Pressure UPVC Pipes

Underground pipes shall be made to EN1401-1 or to equivalent European norms, with a minimum wall thickness of 3.2 mm. Product shall bear certification of conformance to standards.

4.L.3.5.1.3. Condensate Drainage Pipes

Condensate drainage pipes shall be made of pressure PVC for a minimum operating pressure of 10 bars.

4.L.3.5.2. Cleanouts

Cleanouts shall be provided at all ends of pipe line runs and changes of direction of more than 45 degrees for underground and suspended lines. Cleanouts at base of stacks shall be extra heavy wye branch or tee branch cleanout with full size iron screw plug.

4.L.3.5.2.1. Floor Cleanout Type FCO

Floor cleanouts shall be made of PVC material and shall be made of a raising piece with a square top to suit standard floor tiles together with a removable circular piece to be removed when rodding through the drain line. Floor cleanouts shall have the same diameter of the pipe it serves and shall be connected to the pipe with a long radius elbow. PVC floor cleanouts shall serve UPVC pipes.

4.L.3.5.3. Drains

4.L.3.5.3.1. Roof Drains Type RD-1

Shall be made of coated cast iron, of large sump and elevated dome. It shall have a leightweight, shock resistant, aluminum elevated dome strainer, a non-puncturing flashing clamping collar with integral gravel guard and a perforated extension sleeve for up to 50 mm thickness of roof insulation. It shall be of the same size as the pipe it serves.

4.L.3.5.3.2. Roof Drain Type RD-2

Scupper drain made of dura coated cast iron body, side outlet, flush type strainer with combination frame and membrane flashing clamp. It shall be of the same size as the pipe it serves.

4.L.3.5.3.3. Roof Drain Type RD-3

Deck drain made of dura coated cast iron body, with perforated extension, flat calmp collar, and promenade frame.

4.L.3.5.3.4. Balcony Drains Type BD-1

Dura coated cast iron body with side outlet, flush grating, combination invertible membrane clamp and adjustable collar.

4.L.3.5.3.5. Cast Iron Trenches

Heavy duty cast iron trenches to take truck loading and to be installed on ramp.

4.L.3.5.3.6. Floor Drain Type FD-3

Shall be made of dura-coated cast iron body with bottom outlet, seepage pan and combination membrane, flushing clamp and frame, hinged slotted grate and suspended sediment backet.

4-L-3-6 Irrigation System

4.L.3.6.1.1. Pipes

Irrigation and water pipes running in site shall be made of high density polyethylene - HDPE - rated at 16 bars. Pipes shall bear European certification of quality.

4.L.3.6.1.2. Irrigation Valves

Quick coupling irrigation valves shall be made of red brass body and bonnet, shall have a thermoplastic cover and a locking cover, and a strong corrosion resistant stainless steel spring to prevent leakage. Cover key, valve keys, and a 25 mm hose swivel shall be provided from same valve manufacturer.

4.L.3.6.1.3. Valves

Irrigation valves shall be made of PVC material.

4-L-3-7 Plumbing Fixtures

4.L.3.7.1. Lavatory

4.L.3.7.1.1. Type Lav-

White colored, vitreous china, with overflow. Similar to Rania model from Lecico or approved equal. Unit shall be provided complete with the following trim and accessories or approved equal.

Single hole mixer, chrome plated, cast spout with mousseur, ceramic cartridge, single lever, 32 mm pop-up waste set.

32 mm chrome plated waste P-trap with adjustable inlet, and a 32 mm chrome plated pop up waste set.

Two 15 mm angle valves, chrome plated similar to model No. A2129.AA from Ideal Standard.

4.L.3.7.2. Water Closet

4.L.3.7.2.1. Type Ewc-

White colored, vitreous china, European type, floor mounted , with cistern. Similar to Gardenia model from Lecico or approved equal. Unit shall be complete with the following trim and accessories or approved equal.

Fixation set obtained from the same manufacturer.

Solid plastic seat and cover to match the chosen water closet model, complete with its fixation set. Model to be obtained from the same manufacturer.

Unit shall come with its corresponding flushing mechanism.

10 mm angle valve with 300 mm long tube, chrome plated, similar to model No. 22950 from FRIEDRICH GROHE.

Toilet paper holder

4.L.3.7.3. Shower

4.L.3.7.3.1. Type SH-

White colored, vitreous china, similar to Assi model from Lecico or approved equal with the following trim and accessories or approved equal.

Exposed shower mixer, chrome plated, wall mounted, single lever, ceramic cartridge, cast spout with mousseur, automatic inverter between spout and shower handset.

Chromium handshower, 1.5 m long hose, 810 mm chrome plated wall bar with soap holder.

40 mm plastic waste outlet and strainer.

4.L.3.7.4. Kitchen Sink

4.L.3.7.4.1. Type KS-

Stainless steel, single, single drainers. Unit shall come complete with the following trim and accessories or approved equal.

Single hole mixer, chrome plated, swivel tube spout, spout head with mousseur.

40 mm chrome plated waste P-trap with adjustable inlet.

Three 15 mm angle valves, chrome plated similar to model No. 22951 from Friedrich Grohe.

15 mm pillar trap, chrome plated, swivel tube spout with jet regulator.

4-L-3-8 Plumbing Pumps

4.L.3.8.1. Cold Water Booster Set

4.L.3.8.1.1. General

The booster set shall come as one complete set from the manufacturer. The unit shall contain: the pumps, interconnecting piping, valves, steel skid base with vibration isolators, the control panel with all relevant pressure switches.

4.L.3.8.1.2. Mode of Operation

The unit shall have one, or two pumps, as indicated, controlled by pressure switches. Pumps to start on fall of pressure in tank and to stop on rise of pressure in the system at pressure values indicated on the pump schedules. The last pump can enter into operation, in addition to the remaining ones, to supply the maximum demand when the duty pumps cannot meet the demand on their own.

4.L.3.8.1.3. Components

The unit shall comprise two or three vertical or horizontal multi-stage centrifugal pumps, as indicated, interconnecting pipes, pressure control valves, control panel, pressure gauge, pressure tank. Unit shall be complete and mounted on a common base and tested at factory

4.L.3.8.1.4. Pumps

Vertical or horizontal multi-stage in-line centrifugal pumps, of cast-iron or stainless steel casing, stainless steel impeller, sleeve and shaft. All other parts in contact with water shall be made of stainless steel.

4.L.3.8.1.5. Electric Motor

Totally enclosed, fan cooled, drip proof squirrel cage induction motor permanently lubricated and sealed ball bearings.

4.L.3.8.1.6. Tank

The pressure tank shall contain a removable butyl rubber bag and shall be precharged with air at the factory to the correct pressure. Tank shall be made of welded mild steel plate for an operating pressure of 1000 kPa, with cylindrical shell and convex dished ends, shot blasted and painted internally with bitumastic and externally with zinc primer and hammer enamel paint.

4.L.3.8.1.7. Valves

Shall be screwed gunmetal to BS 1952 class 200 or cast-iron butterfly valves to BS 3952.

4.L.3.8.1.8. Pipeworks

Interconnecting pipework shall be made of heavy gauge galvanized pipework to BS 1387 and galvanized fittings to BS 143/1256.

4.L.3.8.1.9. Electric Control Panel

Shall be manufactured to IP43 and made of heavy mild steel sheet, and shall be finished with stove enamel paint or reinforced composite material to the approval of the engineer. The panel shall be mounted on vibration isolators to minimize vibration of electrical equipment. The panel shall contain, but not necessary limited to the following:

Isolating switches, starters, overload relays, pressure switches and gauges, power on light, run and trip lights, hand/off/auto switches, duty selector switch, isolator, and line and control circuit fuses.

4.L.3.8.2. In-Line Circulator Pumps

4.L.3.8.2.1. General

Circulators shall be in-line, centrifugal, single-stage, with or without mechanical seals, and rated for 10 bars working pressure and 110 deg C continuous water temperature. Pump shall come with a control box to alternate and start the operation of each pump. The control box shall be obtained from the pump manufacturer. Particularities of each pump are indicated in the schedule of equipment.

4.L.3.8.2.2. Casing

Cast iron, bronze, or stainless steel casing with impeller, fitted with a drain plug. The suction and the discharge ports shall be identical.

4.L.3.8.2.3. Impeller

Shall be made of stainless steel, cast iron, or composite material, as indicated on drawings. The impeller shall be statically and dynamically balanced, and keyed to shaft.

4.L.3.8.2.4. Pump Shaft

Shaft and shaft sleeves shall be made of stainless steel.

4.L.3.8.2.5. Mechanical Seal

Shall be of tungsten carbide or carbon, with stainless steel spring, ceramic seat, and flexible bellows and gasket.

4.L.3.8.2.6. Motor

Totally enclosed, fan cooled, squirrel cage induction motor, or wet rotor canned type. The pump shall come with a control box for motor automatic change over operation.

4-L-3-9 Water Conditioners

4.L.3.9.1. Filters

4.L.3.9.1.1. Assembly

Pressure sand-and-gravel type consisting of filter tank, face piping with butterfly valves, and gage panel.

4.L.3.9.1.2. Filter Tank

Fabricate from ASTM A36 steel plate to ASME SEC 8D suitable for working pressure of 7 bars, and hydrostatic test pressure of 10 bars. Provide 280 x 380 mm manhole in top head and leveling jacks. Equip with 20 mm automatic air vent and tubing for connection to manual air vent on gage panel. Paint externally with primer, and epoxy coat internally.

4.L.3.9.1.3. Influent Distribution System

Schedule 80 PVC pipe consisting of head and laterals with orifices directed upwards, designed for maximum 2.44 m/s velocity of water in laterals at rated filter capacity.

4.L.3.9.1.4. Underdrain System

Schedule 80 PVC pipe, consisting of header and laterals with orifices pointed downwards, designed for maximum 3.05 m/s velocity of water in laterals at rated filter capacity. Space laterals and orifices to ensure uniform water flow through filter bed during filter and backwash operations.

4.L.3.9.1.5. Face Piping

Class 125 cast iron flanged pipe fittings and Schedule 40 flange-connected steel pipe designed for maximum 3.05 m/s velocity of water at rated filter capacity, incorporating line size butterfly valves. Provide sight glass at waste connection.

4.L.3.9.1.6. Gage Panel

Mount on tank and provide with 100 mm diameter influent and effluent pressure gages connected by tubing to nipples on tank nozzles; with NSF stainless steel name plate.

Provide Concrete fill in bottom of tank to within 25 mm of underside of effluent header.

4.L.3.9.1.7. Filter Support Media

Clean, hard rounded gravel with minimum average specific gravity of 2.5, free from shale, mica, clay sandstone, loam, and other impurities. Screen to sizes specified with maximum 2 % by weight of thin, flat, or elongated pieces. Filter support media shall be of four grades of gravel laid in level layers, each 100 mm deep as follows:

1- Coarse gravel 20-38 mm.

2- Medium gravel 13-20 mm.

3- Fine gravel 3-6 mm.

4- Buckwheat gravel 1.5-3 mm.

4.L.3.9.1.8. Filter Sand

Hard, durable grains of rounded or sub-angular silica sand, free from clay, loam, dirt and organic matter, maximum 1% by weight flat or micaceous particles, effective size of 0.44 mm and uniformity coefficient of 1.35. Place upon filter support media in level bed minimum 510 mm deep.

4.L.3.9.1.9. Cartridge Filters

Cartridge filters shall have a clear housing FDA food grade approved made of Styrene-Acrilonitrile. Acarbon activated cartridge filter shall be used to remover chlorine residues and a polypropylene cartridge rated at 5 μm shall be used on potable water line. The filters shall come with a mounting stand to allow parallel installation of filters. Pressure gages at inlet and outlets shall be installed to allow verification of degree of clogging. Filters shall be approved for potable water use.

4.L.3.9.1.10. Ultra-Violet Sterilizers

Compact unit containing the UV lamps. Unit shall be configured for TOC reduction or ozone destruction application. Stainless Steel 316 chamber.

4.L.3.9.2. Chlorine Injection System

4.L.3.9.2.1. Regulator

Continuously monitor pH and chlorine levels and control chemical feed pumps. Mount regulator in surface mounted general purpose enclosure of fiberglass construction and incorporate:

1- On/off switch.

2- Green light to indicate regulator is energized.

3- Toggle switches for chemical feed pumps, with off, manual, and automatic positions.

4- Relays for direct switching of pump motors.

5- Yellow lights to indicate pump operation.

6- Red lights for abnormal conditions.

7- Interlock to prevent chlorine feed when PH is abnormal.

8- 3 inch (80 mm) meters for continuous display of PH and chlorine levels.

9- Calibration controls for PH and chlorine.

4.L.3.9.2.2. Sensors

Electrode with coaxial cable for attachment to regulator.

4.L.3.9.2.3. Flow Switch

Shuts down controller on no flow through sampling line.

4.L.3.9.2.4. Liquid Chlorinator

System consisting of a tank with injector pumps to feed liquid chlorine (bleach) and muriatic acid.

4.L.3.9.2.5. Solution Metering Pump

Positive displacement, diaphragm pump with adjustable flow rate, thermoplastic construction, continuous-duty fully enclosed electric motor and drive, and [built-in] relief valve.

4.L.3.9.2.6. Solution Tank

114 liters capacity, polyethylene, self-supporting, graduated markings; molded fiberglass cover with recess for mounting pump and liquid level switch, and direct reading scale.

4-L-3-10 Electric Water Heaters

4.L.3.10.1. Electric Water Heater Type - Ewh-

4.L.3.10.1.1. General

Shall be of the water and heating capacities indicated on the drawings. The unit shall have a bottom inlet and outlet connection, and shall be wall mounted.

4.L.3.10.1.2. Outer Jacket

Shall be made of heavy gauge steel, finished with durable baked-on high gloss enamel paint.

4.L.3.10.1.3. Insulation

Injected polyurethane foam shall be used to isolate the outer jacket from the inner one.

4.L.3.10.1.4. Inner Tank

Shall be made of heavy gauge welded steel, hydrostatically tested to a pressure of 12 bars, and internally enameled lined.

4.L.3.10.1.5. Heating Element

Shall be removable without draining the water container and shall have a contactor and a high limit temperature control.

4.L.3.10.1.6. Safety Unit

Shall be placed at the water inlet line and shall contain the following:

a relief valve, a non-return valve, a protection cathodic element, and a drain valve. Shall be obtained according to manufacturers' of water heater recommendation.

4-L-3-11 Fuel Oil Systems

4.L.3.11.1. Above Ground Steel Storage Tanks And Accessories

4.L.3.11.1.1. General

Shall be fabricated from 6 mm thick hot-rolled carbon steel plates or sheets, as specified in UL 58, of the size and capacity as indicated on drawings. Tank shall be painted and protected on its external surface from soil material.

4.L.3.11.1.2. Connection Fittings

Tank shall have threaded pipe connection fittings on top of tanks, for fill, supply, return, vent, and gaging as shown on miscellaneous details drawings.

4.L.3.11.1.3. Supply Tube

Provide extension of suction line fitting into tank, terminating 150 mm above tank bottom and cut at 45 degree angle.

4.L.3.11.1.4. Vent Cap

Cast iron threaded tee inlet; 40 mesh brass wire cloth screen.

4.L.3.11.1.5. Fill Box

Flush heavy duty, waterproof, cast iron body and top cap, and brass inner cap with lock with key wrench.

4.L.3.11.1.6. Remote Oil Gages

Balanced hydraulic type providing a true volumetric indication. Gage volume range to suit capacity storage.

4.L.3.11.1.7. Painting

Tank and accessories shall be cleaned and shall be painted on the outside only with two coats of emulsified asphalt.

4-L-3-12 Hydronic Piping

4.L.3.12.1. Pipes and Fittings

4.L.3.12.1.1. Pipes

Shall be made of black seamless steel manufactured to ASTM A 106 Grade B, schedule 40.

4.L.3.12.1.2. Fittings for Black Steel Pipes

For 200 mm diameter and under shall be screwed malleable iron, banded type, and rated PN20. For pipes over 50 mm diameter, fittings shall be seamless butt-welded steel of the same thickness and rating of the pipes they serve.

4.L.3.12.1.3. Chemical Feeder

Shall be installed to protect the hydronic piping system. Chemical Feeder shall be of the bypass type chemical feeders of 19 liters capacity, welded steel construction; 105 m WG working pressure; complete with fill funnel and inlet, outlet, and drain valves. Chemicals shall be specially formulated to prevent accumulation of scale and corrosion in piping system and connected equipment, developed based on a water analysis of make-up water.

4.L.3.12.2. Hangers and Supports

4.L.3.12.2.1. Sizes and Spacing

Hangers shall be installed with the following minimum rod sizes and maximum spacing:

Nom. Pipe Size	Max. Span	Min. Rod Size
25 mm	2.1 m	9.5 mm
40 mm	2.7 m	9.5 mm
50 mm	3.0 m	9.5 mm
80 mm	3.7 m	12.7 mm

4-L-3-13 HVAC Pumps

4.L.3.13.1. General

4.L.3.13.1.1. Motors

Pumps shall be supplied complete with the corresponding electric motor.

4.L.3.13.1.2. Mechanical Seals

Shall be compatible with the type of pump and shall be obtained from the same pump manufacturer and according to his recommendation.

4.L.3.13.1.3. Balancing

Impellers and rotating units shall be statically and dynamically balanced at the factory.

4.L.3.13.2. In-Line Circulating Pumps

4.L.3.13.2.1. General

Circulators shall of the dry or wet motor single or twin type, as indicated, and shall be vertical in-line, centrifugal, single-stage, with mechanical seals, and rated for 10 bars working pressure and 110 deg C continuous water temperature. Pump shall come with a control box to alternate and start the operation of each pump. The control box shall be obtained from the pump manufacturer.

4.L.3.13.2.2. Casing

Cast iron casing, fitted with a drain plug. The suction and the discharge ports shall be identical.

4.L.3.13.2.3. Impeller

Shall be made of cast-iron, stainless steel, or composite material as indicated in the schedule of equipment schedule. The impeller shall be statically and dynamically balanced, and keyed to shaft.

4.L.3.13.2.4. Pump Shaft

Shaft and shaft sleeves shall be made of stainless steel. The shaft shall have an integral thrust collar and shall be supported by two oil lubricated bronze sleeve bearings.

4.L.3.13.2.5. Mechanical Seal

Shall be of tungsten carbide or carbon, with stainless steel spring, ceramic seat, and flexible bellows and gasket.

4.L.3.13.2.6. Pump Shaft Bearings

Oil-lubricated, bronze journal and thrust bearings.

4.L.3.13.2.7. Motor

Totally enclosed, fan cooled, squirrel cage induction motor, resiliently mounted of the sleeve bearing type. The pump shall come with a control box for motor automatic change over operation.

4-L-3-14 Cast Iron Boilers And Radiators

4.L.3.14.1. Cast Iron Hot Water Heating Boiler

4.L.3.14.1.1. General

Shall be provided of capacity as scheduled in the drawings.

4.L.3.14.1.2. Boiler Type

Shall be constructed of cast-iron sections with integral base, sealed with asbestos rope for gas-tight construction, with pressurized combustion chamber. It shall be factory-assembled and tested for an operating pressure of at least 4 bars at a temperature of 110 deg C. However, final operating pressure shall be checked by the contractor at the final installation of the system.

4.L.3.14.1.3. Combustion Chamber

Shall be water cooled.

4.L.3.14.1.4. Cast Iron Boiler Sections

Shall be made of high grade cast iron, shaped for the best efficiency of heat transfer. Boiler shall have integrally cast supporting leg allowing it to rest on concrete base support with a uniform weight distribution. Boiler sections shall be assembled with rod and nuts and shall be sealed for complete gas tightness.

4.L.3.14.1.5. Burner

Burner shall be provided with the boiler. Provide flame retention power burner for oil as scheduled to match the cast iron boiler selected. Provide burner mounted, factory-wired control panel. Burner mounting door shall be fitted with thick steel front plate, supplied undrilled and with internal frame to support the factory supplied refractory. Door shall have an observation port to inspect the flame condition.

4.L.3.14.1.6. Equipment And Accessories

Provide insulated flush jacket, burner mounting plate with refractory, flue collar with built-in breaching damper, front cleanout doors and plates, back access door, flue brushes and handles, close nipples and caps for washout tapings on front and back sections, and supply elbows or top outlets. Provide also, altitude gauge, thermometer, two thermostats, and a boiler drain. Fiberglass insulation sheet steel jacket to be fitted to boiler for field installation. Provide for hot water boilers relief valve, combination high- and low-limit control, and combination pressure-temperature-altitude gage. In addition to above, provide a water level controls, low water cutoff and feeder combination, and a Flow Switch.

4.L.3.14.2. Cast Iron Radiators

4.L.3.14.2.1. Radiators

shall be made of sectional, multitube type high grade cast iron with smooth finish. It shall be factory tested at 1200 kPa.

4.L.3.14.2.2. Accessories

Each radiator shall have a bronze angle regulating valve, bronze balancing valve and elbow. Cast iron wall supporting kit. Accessories to be obtained from radiator manufacturer.

4.L.3.14.2.3. Type

Radiators shall be obtained from Chappe Savane line or approved equal.

4-L-3-15 Breechings, Chimneys And Stacks

4.L.3.15.1.1. Materials

Shall be made of black, carbon, hot-rolled steel complying with ASTM A 569.

4.L.3.15.1.2. Door Cleanouts

Shall be made of the same material as the breeching.

4.L.3.15.1.3. Fabrication

Breeching and chimneys shall be fabricated in a manner to minimize field welding.

4.L.3.15.1.4. Longitudinal Seams

Shall be welded except longitudinal seams for breechings less than 600 mm of longest side, may be Acme grooved type.

4.L.3.15.1.5. End Joints

Weld, lap and bolt, or use companion flanges; except breechings less than 600 mm of longest side, may have end joints beaded and crimped.

4.L.3.15.1.6. Jacketting And Insulation

The chimney shall be insulated and insulation shall be jacketted with 1.2 mm thick aluminum sheet. Jacketing and insulation shall be submitted for approval among other materials. Insulation shall be 50 mm thick rockwool adequate for the flue gas temperature.

4-L-3-16 Power Ventilators

4.L.3.16.1. Centrifugal In Line Fans

4.L.3.16.1.1. General

Product shall conform to the following standards: performance ratings to AMCA 210, sound ratings to AMCA 301, fabrication to AMCA 99, and shall be UL listed..

4.L.3.16.1.2. Fan

Shall be of the direct or belt-drive fan as required, single stage, in line type, to fit into ducts. Unit shall be complete with flanges, flexible and installation kit according to manufacturers recommendations.

4.L.3.16.1.3. Casing

Shall be fabricated of heavy gauge steel, continuously weld, the housing shall be of square design constructed of heavy gauge galvanized steel shaft and shall include square duct mounting collars. The casing shall include removable access panels for maintenance purposes.

4.L.3.16.1.4. Fan

The fan wheel shall be centrifugally backward or forward inclined, constructed of aluminum. Wheel shall be statically and dynamically balanced.

4.L.3.16.1.5. Motor

Shall be totally enclosed, squirrel cage induction type

4.L.3.16.1.6. Accessories

The fan shall be equipped with the following accessories: vibration isolator kit, installation set, and flexible connectors.

4.L.3.16.1.7. Noise

Noise level shall not exceed the indicated loudness level in the schedule of equipment.

4.L.3.16.1.8. Filter

Roof supply fresh air fans shall have aluminum 50 mm thick filter EU2 classification as per Eurovent standard. Fresh air fans shall not have backdraft dampers.

4.L.3.16.2. Wall Mounted Propeller Fans

4.L.3.16.2.1. Fan

Shall be of the direct drive. Unit shall be complete with flanges, and installation kit according to manufacturers recommendations.

4.L.3.16.2.2. Casing

Shall be fabricated from mild steel with epoxy powder coat finish or from hot dipped galvanized steel.

4.L.3.16.2.3. Impeller

Shall be made of aluminum clad mild steel propeller blade resistance to corrosion, and shall be dynamically and statically balanced.

4.L.3.16.2.4. Motor

Shall be totally enclosed, squirrel cage induction type, lubricated motor.

4.L.3.16.2.5. Accessories

The fan shall be equipped with the following accessories: vibration isolator kit, installation set, and flexible connectors. Fans shall come with integral backdraft shutter, and speed controller.

4.L.3.16.2.6. Noise

Noise level shall not exceed the indicated loudness level in the schedule of equipment.

4.L.3.16.3. Ceiling Mounted Fan

4.L.3.16.3.1. Fan

Shall be of the direct drive. Unit shall be complete with installation kit according to manufacturers recommendations.

4.L.3.16.3.2. Casing

Shall be fabricated from injected plastic

4.L.3.16.3.3. Impeller

Shall be helicoidal type made of injected plastic.

4.L.3.16.3.4. Motor

Shall be totally enclosed, squirrel cage induction type, lubricated motor.

4.L.3.16.3.5. Accessories

The fan shall be equipped with the following accessories: installation set, flexible connectors, roof cowl, and speed controller.

4.L.3.16.3.6. Noise

Noise level shall not exceed the indicated loudness level in the schedule of equipment.

4-L-3-17 Mini-Split Air Conditioners – Heat Pumps

4.L.3.17.1. Split Room Air Conditioners - Heat Pump

4.L.3.17.1.1. Condensing Unit

To be suitable for operation in 45 ºC ambient temperature air cooled, horizontal air discharge type, comprising a compressor, condenser coil, condenser fan and motor, refrigerant receiver, charging valve and controls, assembled in a common casing. Unit to be tested at factory and supplied complete with refrigerant and dehydrated compressor oil. Unit to be of the heat pump type where required.

4.L.3.17.1.2. Compressor

Sealed, hermetic rotary type, mounted on external spring isolators, with in-built thermal overload protection.

4.L.3.17.1.3. Condenser Coil

Heavy gauge seamless copper tubes mechanically bonded to aluminum plate fins.

4.L.3.17.1.4. Condenser Fan And Motor

Axial type, weatherproofed, statically and dynamically balanced, directly driven by a totally enclosed, permanently lubricated, resiliently mounted electric motor, with Class F insulation and in-built thermal overload protection.

4.L.3.17.1.5. Condensing Unit Casing

Heavy gauge galvanized steel, zinc phosphatized and finished with baked enamel, fully weatherproofed for outdoor installation. Casing is to have openings for power and refrigerant connections and removable panels for easy access to internal components.

4.L.3.17.1.6. Condensing Unit Control

To be factory wired and tested. They are to include high and low pressure switches, compressor overload device, positive acting timer to prevent short cycling of compressor on power interruption, condenser fan contactors and circuit breakers.

4.L.3.17.1.7. Evaporator Unit

Decorative floor mounted unit, white colored. Evaporator Unit consists of DX coil, one centrifugal or tangential fans, electric motor, condensate drain pan, galvanized steel casing panels, filter, electric junction box and fan switch, and back-up electric heater.

4.L.3.17.1.8. Evaporator Coil

Staggered 12 mm O.D. heavy wall seamless copper tubes mechanically bonded to aluminum fins, with 16 mm solder joint copper tube connections and manual air vent. Coil is to be leak tested at factory to 2352 KPa minimum air pressure under water.

4.L.3.17.1.9. Evaporator Fan

Centrifugal, forward curved, non-overloading type, directly connected to fan motor, statically and dynamically balanced and designed for whisper quiet operation. Materials are to be high strength and corrosion resistant.

4.L.3.17.1.10. Evaporator Motor

Shaded pole, 3-speed type, with built in thermal overload protection and bronze sleeve type bearings with oil reservoirs. Motor to be resiliently mounted.

4.L.3.17.1.11. Evaporator Condensate Drain Pan

18 gauge galvanized steel, projecting under entire length and width of coil including headers and return bends, valves and fittings. Pan is to be treated against corrosion, insulated and pitched for positive drainage and unit installed level.

4.L.3.17.1.12. Evaporator Fan Switch

3-speed with "OFF", heat-cool, provided with each unit from factory, decorative wall plate remote type.

4.L.3.17.1.13. Control

To include the following:

- Remote control unit.
- Liquid crystal display.
- Selection of heating, cooling, heating/cooling or ventilation only.
- Automatic sweeping of supply air.
- Economy mode.
- Delayed start and stop.
- Recovery power failure.

4-L-3-18 Ductwork And Ductwork Accessories

4.L.3.18.1. Ducts

4.L.3.18.1.1. Fabrication

Shall be fabricated and supported in accordance with SMACNA Low Pressure Duct Construction Standards and ASHRAE handbooks.

4.L.3.18.1.2. Gauge

The minimum gauge and sheet metal shall not be less than:

DUCT SIZE (mm)	U.S. GALVANIZED	MINIMUM THICKNESS (mm) STEEL GAUGE
Up to 300 mm	26	0.6
325 to 750 mm	24	0.7
800 to 1350 mm	22	0.9
1400 to 2100 mm	20	1.0
2125 mm and larger	18	1.3

4.L.3.18.2. Dampers

4.L.3.18.2.1. Volume Control Dampers

Of the multi-blade type and operated from outside of the duct. Shall be made of galvanized sheet steel blade.

4.L.3.18.2.2. Fire Dampers

Shall be made of 3 mm thick black steel plate. Blades shall hung on zinc-coated hinges with loose fitting brass pins and bushings. Blades shall close tightly in case of fire. Blades shall be held open by a fusible link having a melting point not exceeding 75 deg C. Shall be of the 100% free air opening. Fire dampers shall be U.L. listed.

Part V: Electrical Works

Part V-1: ELECTRICAL EQUIPMENT

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PART 5.1 - ELECTRICAL WORKS: 1-ELECTRICAL EQUIPMENT

5-1-A GENERAL

5-1-A-1 ENVIRONMENTAL CONDITIONS

The electrical equipment shall be designed and constructed for continuous operation at full load under the climatic and environmental conditions at the Site.

5-1-A-2 ELECTRICAL TERMS

For the purpose of the following and other sections of this document the following abbreviations of electrical terms have been used.

R	red phase
Y	yellow phase
B	blue phase
N	neutral
a.c.	alternating current
d.c.	direct current
A	Ampere
mA	milli-Ampere
V	Volt
kW	kilowatt
kWh	kilowatt-hour
kVAr	kilovolt-ampere reactive
kVA	kilovolt-ampere
MVA	megavolt-ampere
Hz	hertz (cycles per second)
CT	current transformer
SP	single pole
SPN	single pole and neutral
DP	double pole
TP	triple pole
TPN	triple pole and neutral
SPSwN	single pole and switched neutral
TPSwN	triple pole and switched neutral
LSF	low smoke and fumes
MCB	miniature circuit breaker

MCCB	molded case circuit breaker
RCD	residual current device
MCC	motor control center
ICA	instrumentation , control and automation

5-1-A-3 INSTALLATION STANDARDS

All electrical works shall be carried out in accordance with the requirements of:

i- ISO, DIN, AFNOR - Mechanical equipment

ii- The institution of Electrical Engineers (I.E.E.) regulations for the electrical equipment CEI, UTE, VDE, AFNOR, BS.

iii- British Standards Institution (B.S.I.) and code of practice (C.P.) or equivalent International Electro-technical Commission (I.E.C.).

5-1-A-4 MATERIALS

All materials incorporated in the works shall be the most suitable for the duty concerned and shall be new and of first class commercial quality free from imperfection and selected for long life and minimum maintenance.

All materials and material finished shall be selected for long life under the site conditions detailed in the specification and shall be derated by the approved factors given in the British Standard Specifications.

5-1-A-5 WORKMANSHIP

Particular attention shall be paid to the appearance of the electrical installation, arrangements of which shall be agreed by the Engineer's representative before the commencement of installation. The Contractor shall ensure that the installation is completed to the highest standard of neatness with respect to the visible cable runs and the arrangement and alignment of apparatus and fittings.

Conduit shall be surface run with the exception of personnel, administration and control room where, generally, fittings shall be suitable for flush installation.

The positions of all equipment and cable routing shown on drawings are indicative. The Contractor shall submit for approval detailed shop drawings showing exact location of equipment and cable routing (trenches, cable trays…)

No structural steel, timberwork or concrete shall be drilled for the support of cables or fittings without the prior approval of the Engineer's representative.

Should the Contractor propose to use junction boxes in auxiliary control cable circuits for the purpose of marshalling a number of cables feeding to a common item of equipment full details shall be given to the Engineer, and the Contractor shall only proceed after the receipt of the Engineer's written approval. Any such junction box shall be of the wall mounting weatherproof pattern (IP55) with double terminals. All cores shall be ferruled and identified in accordance with the system schematic and cable diagrams.

The Contractor shall arrange for the switchgear and panel manufacturers to provide skilled labor for the supervision of off-loading, placing in position on prepared foundations, erection and commissioning of all switchgear and control panels.

5-1-A-6 SAFETY INTERLOCKS

A complete system of interlocks and safety devices shall be provided as necessary for the safe and continuous operation of the plant in order to provide for:

i- Safety of personnel engaged on operational and maintenance work on the plant.

ii- Correct sequence of operation of the plant during start up and shut down.

iii- Safety of the plant when operating under normal or emergency conditions.

Interlocks shall be preventive and not corrective in operation.

The Contractor shall be responsible for the preparation of interlocking schemes for the approval of the Engineer.

5-1-A-7 PLANT OPERATION

The plant’s constituent units shall be arranged to be fully automatic and maintained ready for service at all times.

In order to simplify operation and maintenance, all control schemes shall, as far as possible, follow the same operating pattern, have similar control cubicle layouts, and employ similar items to minimize spares holdings.

Electrical system design shall reflect the hydraulic system design as far as possible and shall be directed to making each major item of plant capable of running substantially independent of others. Where common equipment is employed then every effort shall be made to ensure that no single fault can affect the entire plant and particular care must be taken to protect the overall integrity of the system.

5-1-A-8 POLARITY

All cables shall be so connected between main switchboards, distribution boards, plant and accessories so that the correct sequence of phase rotation is preserved throughout the system.

All non-flexible cable cores shall be identified with phase colors, red yellow blue and black for neutral, or other approved international standard, for three phase and four wire circuits. Single-phase circuits shall be red and black.

Where more than one phase is incorporated on a common system in one room the live cores shall be red, yellow, or blue as appropriate. All fittings and switch accessories shall be permanently labeled and segregated.

Harmonized systems of phase layouts on plant and equipment, of cable and plant phase identification, and of cable core insulation coloring shall be used throughout the electrical installation.

5-1-A-9 SUPPLY INTERRUPTION

To ensure that the effects of incoming electricity supply disruptions have minimal effects on pumping capacity, main switchgear shall be fitted with overload, overcurrent and earth fault protection. The switchgear shall not require manual resetting or closing after a supply interruption. Where contactor controls are used for main and auxiliary transformer circuits, these shall be latched so that they are re-energized when the supply is restored.

Re-starting of main motor circuits under automatic control shall be staggered to reduce system disturbance.

5-1-A-10 VOLTAGE DROP

The volt drop within the installation shall not exceed a value suitable for the safe functioning of any fixed current-using equipment.

5-1-A-11 EQUIPMENT AND CABLE RATINGS

All busbars, cables, switchgear, fuses, motor starters, relays, instruments, panel wiring, etc. shall be sized and rated in accordance with normal operational requirements of the associated plant and equipment, taking into account maximum load currents, voltage drop, frequency of motor starting, maximum ambient temperature, etc.

Where specific voltage or current ratings have been included on the Drawings and in the description of individual items of equipment in the Specification and/or Bill of Quantities the values stated shall be deemed to be minimum values. It shall however be the responsibility of the Contractor to ensure that all equipment supplied is properly insulated and adequately rated to handle operational loads and, in the case of fuse gear and circuit breakers, to deal with prospective fault currents.

5-1-B LOW VOLTAGE SWITCHGEAR AND CONTROLGEAR

5-1-B-1 SWITCHBOARDS AND CONTROL BOARDS

5-1-B-1-1 Performance Requirements for Switchgear and Controlgear

All switchgear and controlgear (motor control centers) used on low voltage (LV) ac systems shall be type-tested assemblies complying with the recommendations of IEC 60439-1; 1992 for installation in a power system using protective circuits unless stated otherwise.

The rated operational voltage (Ue) shall be not less than 440 V and the rated insulation voltage (Ui) shall not be less than 660 V.

The rated current of busbars and functional units shall be not less than the indicated values.

The rated short-circuit strength shall be not less than the indicated value.

The conductors between the main busbars and the supply side of a single functional unit shall be as short as possible and of adequate cross section to provide the highest possible degree of protection to personnel in the unlikely event of a short-circuit occurring on the supply terminals of that outgoing unit.

The operating conditions require maximum continuity of supply. The Contractor shall co-operate with the Engineer to ensure complete selectivity of the entire protective system which may include equipment not stated in the Particular Specification. In the event of an internal fault in any functional unit, no other functional unit shall be affected.

Test certificates shall be supplied for the following type tests to IEC 60439-1; 1992:

- Temperature-rise limits
- Dielectric properties
- * Short-circuit withstand strength
- Effectiveness of protective circuit

  ** This test to be certified by ASTA, KEMA or PEHLA or other approved authority.*

Test certificates for short-circuit strength shall cover tests of short circuits occurring on the outgoing terminals of each type of functional unit in addition to those occurring on busbars.

5-1-B-1-2 Construction

All LV switchgear and controlgear shall be constructed in accordance with the following standards:

IEC 60439-1	LV switchgear and controlgear assemblies
IEC 60947-1	LV switchgear and controlgear
IEC 60449	Voltage bands
BS 1432	Copper for electrical purposes

Each type tested assembly shall be multi-cubicle or multi-box Form 2 to IEC 60439-1. The protective conductor shall not be exposed. Each type tested assembly shall be suitable for a stationary condition in either an indoor or outdoor installation with front and/or rear access as specified. Unless specified otherwise, the incoming units shall be withdrawable equipment and the outgoing units shall be fixed equipment.

LV switch and control boards and individual enclosures for location in purpose designed switchrooms shall have a minimum degree of protection of IP52. The protection classification for switchboards located in other indoor areas shall be IP54. For outdoor location the degree of protection shall not be less than IPW55.

The degree of protection shall apply to all faces of the enclosures except the bottom face when all removable parts are in the connected position.

The supporting structure shall be constructed from steel sheet of minimum thickness 2 mm and folded to form an enclosure except where required for covers and doors which shall be of folded construction. Over-lapping surfaces of the sheet shall be completely sealed by welding and all welds which are visible when covers are in place shall be ground flush to give a neat appearance.

Alternatively overlapping surfaces after coating may be joined by non-corrodible rivets which shall not be visible when covers are in place.

The supporting structure shall be zinc coated and covers shall have a semi-gloss paint finish to the color required. Parts of the supporting structure which are not covered by these covers shall in addition have the same paint finish to give a uniform appearance. Internal mounting panels and frames shall be either zinc coated or paint finished. All protective coating shall be approved.

Unless otherwise approved, floor mounting switchboard enclosures shall not exceed 2500mm in height.

Each transport unit shall be provided with roof eyebolts for lifting. Lifting eyes shall be removable and replaced with bolts after installation.

Wall mounted enclosures shall be mounted not less than 10 mm away from the wall. Wall fixings shall be exterior to the enclosure.

5-1-B-1-3 Detail Requirements for Switchgear and Controlgear

All switchgear and controlgear shall be complete in accordance with the following standards:

IEC 60947-1	General rules
IEC 60947-5	Control circuit devices and switching elements
IEC 60947-7	Ancillary equipment
IEC 60445	Uniform system of terminal marking
BS 5584 (EN 50 022)	Mounting rails 35 mm
BS 5585 (EN 50 023)	Mounting rails 75 mm
BS 5824 (EN 50 024)	Mounting rails with C profile
BS 3858	Binding and identification sleeves
IEC 60502	PVC insulated cables

All main circuit connections shall be provided and terminated at terminal blocks as specified herein, located within the compartment to facilitate a neat termination of the power cables on site.

All auxiliary circuit connections shall be provided including interconnections between functional units. Connections between transport units shall be fitted with terminal blocks with warning labels at the joint. Connections to external control devices shall be terminated on terminal blocks to facilitate a neat termination of the control cables on site. If these terminal blocks are located in a common compartment each functional unit group shall be contained within protruding melamine partitions, and shall be fitted with warning labels and group markers. All control connections from and to other switch and control gear and control panel enclosures shall be via interposing relays and 24 V dc signals, unless stated otherwise.

Each cubicle door shall be secured with sufficient lockable chrome plated handles to ensure even gasket pressure.

All external fittings such as door hinges and handles and cover fixing screws shall have a non-corrodible finish of a matching type to give a neat overall appearance.

Each compartment shall be provided with anti-condensation heating, controlled by an on/off/auto switch with thermostat.

Self tapping screws shall not be used.

Methods of cable tying relying on adhesives shall not be used.

5-1-B-1-4 <u>Arrangement</u>

Where two or more enclosures are fitted together they shall form a flush fronted continuous suite of uniform height. Front doors and cover dimensions shall match.

Enclosures for multi-circuit switchboards and motor control centers shall comply with IEC 60439-1 Form 2, fully segregated internally, having busbars and individual switchboard feeder or control sections fully separated by means of metallic or non-metallic rigid barriers or partitions.

Switch and motor starter enclosures shall be logically grouped to reflect, as far as possible, the process with which they are associated.

5-1-B-1-5 <u>Access</u>

The arrangement of equipment within switchgear enclosures shall permit easy access for installation and maintenance.

Access from the front of an enclosure shall be through a hinged door or, for withdrawable switchgear, by removal of the withdrawable unit. Doors and withdrawable units shall be lockable.

Each busbar compartment shall be fitted with a removable cover, the removal of which necessitates the use of a tool. A warning label shall be provided on each such cover.

Where rear access is required, bolted covers shall be provided.

Front access doors shall open at least 120° and shall be fitted with a numbered locking handle or handles.

Doors shall be secured to ensure firm pressure on the seal around the whole periphery.

5-1-B-1-6 Safety

Electrical equipment shall be designed and constructed to provide a maximum standard of safety for operational and maintenance personnel.

Mechanical interlocking shall be provided to prevent access to live equipment and to protect the equipment and the operator from mal-operation.

Each compartment containing a functional unit or group shall be fitted with a door which can be opened only after all live parts above 50 V rms ac have been disconnected from the supply. Access shall be possible to maintain all components in this compartment except the switch-disconnector, when all other main circuits are live with a degree of protection of IP2LX to IEC 60947-1. Precautions shall be taken to prevent persons from coming accidentally into contact with these live parts of 50 V and below. The requirements of IEC 60439-1; 1992 related to accessibility for inspection, shall be limited to the following:

i- Visual inspection of protective conductor and all terminals for external protective conductors.

ii- Replacement of indicating lamps.

It shall be possible to padlock the switch-disconnector in the open position to prevent operation during maintenance of external apparatus.

Where access to low voltage enclosures is necessary with equipment energized from an external source, all such equipment and terminals shall be shrouded to prevent accidental contact and warning labels shall be fitted. Shrouds shall have a minimum degree of protection IP30.

Covers fitted to enclosures in which live conductors are installed shall be fitted with a warning label.

Integral distribution boards shall permit safe access to fuse carriers and miniature circuit breakers without the need for isolation. All live connections when fuse carriers and plug-in type miniature circuit breakers are removed shall be fully shrouded.

5-1-B-1-7 Earthing

Single enclosures shall be provided with an earth stud or earth busbar. Multi-cubicle type enclosures shall be provided with a continuous earth busbar which shall extend over the full length. Each cubicle shall be bonded to the earth busbar.

The earth busbar shall be provided with two terminal assemblies for connection to the electrical system main earth terminal.

All steelwork parts shall be equipotentially bonded. A positive earth connection shall be provided to all enclosure doors on which electrical components are fitted. Earthing via the door hinge will not be accepted.

The short-time rating of the earth busbar and connections shall be not less than that of the associated equipment, or the maximum through-fault current of the supply source. The temperature rise of the busbar and connections under fault conditions shall not cause damage to the connections of any equipment to which they may be connected.

Earth terminal bolts or studs shall be brass and shall not be less than 8 mm diameter.

5-1-B-1-8 Busbars and Busbar Connections

Busbars and busbar connections shall be of hard drawn high conductivity copper and shall be suitable for the specified rated voltage, rated and short-time current, frequency and insulation level.

Low voltage switchboard and control board busbars and busbar connections shall comply with the performance criteria given in BS 5486: Part 1.

Busbar supports shall be resin monoblock moldings.

Busbars and busbar connection arrangements shall have been type tested and certified by an approved independent testing authority to verify thermal, dielectric and short-circuit withstand performance.

Busbar and busbar connection systems whose performance cannot be verified will not be accepted.

5-1-B-1-9 Wiring

Wiring other than interconnections between electronic equipment shall be carried out using 600 Volt stranded copper core PVC insulated cable. With the exception of current transformer circuits, the cable conductor size shall be not less than 1.0 mm². For current transformer circuits, the cable conductor size shall be not less than 2.5 mm². For interconnections between electronic equipment the appropriate cable shall be used.

Wiring shall be installed in a neat and systematic manner and shall be securely fixed. Wiring shall be arranged so that access to any equipment or connection point is not impeded. Wiring installed in trunking shall have a cable to free space factor not exceeding 50 percent.

Each cable shall be fitted with a full ring interlocking type identification ferrule at each end. The numbering shall read from the terminal outwards. The wiring identification shall correspond with the wiring diagram.

Unless otherwise indicated or approved, wiring shall be colored as follows:

- Phases red, yellow, blue
- Neutral black
- Control a.c. black, d.c. gray
- Earth green and yellow

Where wiring passes through metalwork the access hole shall be fitted with a suitable insulated bushing.

At enclosure break points, interposing terminal blocks shall be provided each side of the break.

Wiring onto hinged doors or plates which are subject to movement shall be run in helical binding and shall be supported securely at both ends of the moving section.

Wiring associated with instrumentation and electronic equipment which could be affected by power frequency interference shall be screened and/or physically segregated.

Crimped-on type terminal connectors shall be fitted to all cable ends.

Cable trunking, tray and other supports for accommodating and supporting switchboard and control board wiring, shall be fixed by means of screw fasteners to the board structure; fixing by adhesive will not be permitted.

5-1-B-1-10 Cable Boxes, Gland Plates and Terminations

Cable boxes, gland plates and terminations shall be arranged to facilitate easy installation and connection of cables.

For bottom entry switchboards, cable entry cover plates shall be provided and shall be complete with means of sealing to achieve a degree of protection not less than IP3LX to IEC 60947-1.

For top entry switchboards, cable entry cover plates shall be provided and shall have means of sealing to achieve a degree of protection not less than that stated in the Particular Specification.

Cable gland plates shall be manufactured from sheet steel for multi-core cables and non-ferrous material for single core cables. Gland plates shall be mounted not less than 300mm above the base of the enclosure. Cable gland plates shall be connected to the protective conductor by a copper connection of suitable cross sectional area, not less than 70 mm^2. Where cable entry cover plates also serve as gland plates, they shall meet the requirements of both.

Adequate space shall be provided satisfactory termination of cables with particular attention being given to cable bending radii and to the termination of over sized cables necessary for specific cable circuits.

Where cable glands are remote from the cable terminals, purpose made cable tray or trunking shall be provided within the enclosure for securing or accommodating the cable cores.

Terminals shall be provided for all incoming and outgoing cable conductors. The direct connection of external cable conductors onto active components will not be accepted.

Terminals for low voltage application shall be of the lug or pillar type unless otherwise approved. Pillar terminals shall be of the indirect pressure type. Screwless-type terminals will not be accepted.

Terminals in a common compartment associated with different voltages or circuit type shall be segregated into clearly labeled groups. Barriers shall be provided between each group.

Terminals shall be provided for the connection of all cable cores and, where applicable, core screen drain wires.

Not more than one core of internal or external wiring shall be connected to a terminal. Where duplication of terminals is necessary, purpose made solid bridging links shall be fitted.

Terminals which remain energized when the main equipment is isolated shall be shrouded and fitted with a warning label.

5-1-B-1-11 Finish

Enclosures shall be subjected to a comprehensive system of preparation, protective coating and stoved finish painting. The finish coat of paint shall be applied by the electrostatic process. The finish color shall be as specified.

The preparation and painting system shall be suitable for the environment in which the enclosures will be installed.

5-1-B-2 LOW VOLTAGE SWITCHES, DISCONNECTORS, SWITCH-DISCONNECTORS AND FUSE-COMBINATION UNITS

Switches, disconnectors, switch-disconnectors and fuse-combination units shall comply with IEC 60947-3 and shall be suitable for uninterrupted duty.

Switching devices shall be suitable for isolation and shall be to Overvoltage Category IV to IEC 60947-1 Table H1.

Unless otherwise specified, the Utilization Category for switching devices shall be AC-23A.

Operating mechanisms shall be of the independent manual type with provision for locking in the OFF position and shall be interlocked with the access door.

Fuse links for use in fuse-switch devices shall comply with IEC 60269.

5-1-B-3 LOW VOLTAGE CIRCUIT-BREAKERS

Circuit-breakers shall comply with IEC 60947-2, shall be of the air-break type, and shall be molded case or open metalclad construction design.

Circuit-breakers shall be Utilization Category B and shall have an ultimate short-circuit capacity not less than the prospective short-circuit current at the point of installation.

Circuit-breakers for incoming supplies shall have a service short-circuit breaking capacity equal to the ultimate short-circuit capacity.

Feeder circuit-breakers shall have a service short-circuit breaking capacity not less than 50 percent of the ultimate short-circuit capacity.

Circuit-breakers shall be suitable for isolation and shall be to Overvoltage Category IV to IEC 60947-1 Table H1.

The specified rated current shall be that with the circuit-breaker mounted within an enclosure.

Unless otherwise approved, molded case circuit breakers shall be used for circuits of maximum rated current of not greater than 630A.

Circuit breakers shall be of the withdrawable or fixed type as specified. The withdrawable type shall be padlockable in the ISOLATED position. The fixed type shall be easily removable.

The fixed part of withdrawable circuit-breakers shall be fitted with shutters over the main contact openings. The shutters shall be automatically operated by the withdrawal and engagement of the circuit-breaker. Shutters shall be padlockable in the closed position. For plug-in type circuit breakers, covers shall be provided for the fixed contacts in the plug-in base.

Circuit-breaker closing mechanisms shall be of the independent manual or power operated type as specified. It shall be possible to manually charge power operated closing mechanisms. Circuit-breakers shall be padlockable in the OFF position.

Each pole of molded-case circuit-breakers shall be fitted with a bi-metallic thermal element for inverse time delay protection and a magnetic element for short-circuit protection or electronic trips as applicable. Thermal and magnetic elements shall be adjustable. Adjustments shall be made simultaneously on all poles from a common facility. Thermal elements shall be ambient temperature compensated. Where available, thermal and magnetic elements shall be interchangeable.

Unless otherwise specified, open construction low voltage metalclad circuit-breakers shall be fitted with a solid state protection system. The protection system shall be fully self-contained, needing no separate power supply to operate the circuit-breaker tripping mechanism. Protection requirements and characteristics shall be as specified.

Circuit breakers shall be provided with shunt trips, undervoltage releases, auxiliary contacts, motor mechanisms, terminal shields and phase barriers.

5-1-B-4 THERMAL-MAGNETIC MOTOR CIRCUIT BREAKERS

Thermal-magnetic circuit breakers shall be of the quick make, quick break trip type complying with BSEN 60934 and 60947 standards and shall be complete with the following:

- An adjustable thermal overload protection with automatic temperature compensation between -20° C and +60° C for open mounting and -20° C and +40° C for closed mounting.
- An instantaneous protection against short-circuit with fixed threshold 13 times the rated current.
- A minimum of three auxiliary switches that indicate pole position and a minimum of one auxiliary switch for tripping.
- A shunt trip release for remote tripping.
- A counter that indicates the number of Open/Close or Tripping operations of the circuit breaker for maintenance purposes.
- A visual indication of Open/Close/Tripped condition.
- Circuit breakers shall be padlockable in the “OFF” position.

5-1-B-5 MINIATURE CIRCUIT-BREAKERS

Miniature circuit-breakers shall comply with IEC 60898. They shall be used only for lighting circuits in final branch circuit panelboards.

Miniature circuit-breakers shall directly indicate the true position of the contacts.

Operating mechanisms shall be mechanically trip-free from the operating handle to prevent the contacts being held closed under overload or short-circuit conditions.

The operating handle shall be of the toggle type and shall have a facility for padlocking in the OFF position.

Each pole shall be fitted with a bi-metallic element for overload protection and a magnetic element for short-circuit protection. Multiple pole circuit-breakers shall be mechanically linked such that tripping of one pole simultaneously trips all the other poles. The magnetic element tripping current classification shall be of the type suitable for the connected load. Where this is not specified, it shall be Type 3.

Miniature circuit-breakers shall be capable of accepting a full range of accessories such as auxiliary switches, terminal shrouds and inter-phase barriers.

Miniature circuit-breakers shall have a rated current and category of duty as specified. The latter shall not be less than M9.

The short-circuit rating shall be not less than that of the system to which they are connected. Where this cannot be attained, a back-up fuse link or links shall be fitted.

5-1-B-6 RESIDUAL CURRENT CIRCUIT-BREAKERS

Residual current-operated circuit-breakers shall comply with IEC 61009. They shall be double pole for single phase and four pole for three phase and neutral circuits. The rated current shall be as specified.

Unless otherwise specified, the trip settings shall be as follows:

a. Rated current up to and including 40A: 30mA

b. Rated current above 40A and up to 100A: 100mA

c. Rated current above 100A: 300mA

No intentional time-delay shall be fitted unless specified.

5-1-B-7 CONTACTORS

Contactors shall be indoor air-break electro-magnetic mechanical switching devices complying with the recommendations of the following standards:

IEC 60947-4-1	LV Switchgear and Control Gear
IEC 61095	Contactors
IEC 60445	Terminal markings

All contactors shall be rated for uninterrupted duty and intermittent duty Class 12 with on-load factor of 60%. Utilization Category shall be selected to suit the application of the motor starter, but shall be not less than AC-3.

The rated operational voltage (Ue) shall be not less than 440 V ac and the rated insulation voltage (Ui) shall be not less than 660 V ac.

The rated operational current (Ie) shall not be less than the rated operational current (Ie) of the starter and the rated breaking capacity not less than 10 times the rated operational current.

Electrical life at rated current shall be not less than 1 million cycles.

All contactors shall be of the block type designed for easy replacement of coils and contacts. In the position of rest the contactor shall be in the open position and shall give its rated performance in any mounting position. All terminals shall be accessible from the front.

Test certificates shall be supplied for the following type tests to IEC 60947-4-1:

- Temperature-rise Limits
- Dielectric properties
- Operation and operating limits
- Rated making and breaking capacities
- Performance under short-circuit conditions
- Conventional operational performance
- Ability of contactors to withstand overload current

Short-circuit tests shall be certified by ASTA, KEMA or PEHLA, or other approved authorities.

The following routine tests shall be carried out on all contactors to IEC 60947-4-1 and test certificates shall be supplied:

- Operation test
- Dielectric tests

5-1-B-8 LOW VOLTAGE A.C. MOTOR STARTERS

5-1-B-8-1 General

Motor starters shall be combination type as defined in and complying with IEC 60947-4.

Motor starters shall be of the electromagnetic non latching type.

Unless otherwise specified, motor starters shall be suitable for uninterrupted duty.

Motor starters shall comprise contactor and fused switch or molded case circuit assemblies providing Type 2 short-circuit coordination. The protective device, contactor and overload relay combination shall have undergone and passed all the tests specified for full Type 2 coordination in accordance with IEC 60947-4-1.

Coordination with the short circuit protective device (SCPD) shall be Type 2 as defined in Clause 7.2.5 of IEC 60947-4-1 for the prospective short-circuit current. For this purpose the SCPD shall be fitted with the maximum rating of motor circuit fuse.

Thermal overload relays shall be Type 3c as defined in Clause 4.7.2 of IEC 60947-4-1. Time current characteristics shall be supplied by the Manufacturer on 28 mm x 56 mm logarithmic decades. These curves shall have a tolerance not exceeding ±10%.

5-1-B-8-2 Standard Facilities For Motor Starters

Each motor starter protection, control and indicating facilities shall include but not be limited to the following.

Each motor starter shall be housed in a separate compartment and be completely isolated by means of an isolating switch interlocked with the door or cover to allow access only when the switch is open. The isolating switch shall be operated by means of an external handle and shall have provision for padlocking in the "OFF" position. When in the "ON" position, interlocks shall prevent the unit door being opened. Any components still live after this switch has been opened shall be adequately shrouded and have warning labels attached thereto.

All motors rated up to 30kW shall be protected by adjustable triple pole direct acting thermal relays providing overload and single phase protection. The relays shall be hand reset and ambient temperature compensated.

Motors in excess of 30kW shall be protected by electronic relays providing:

- Thermal overcurrent protection, providing protection against overload, repeated starting, and stalling.
- Phase unbalance/single phase protection.
- Earth fault protection.
- Undercurrent protection.

All protection relays shall be hand reset and ambient temperature compensated.

Short circuit protection shall be provided by the fully coordinated operation of the starter integral HBC fuses or molded case circuit breaker.

All fault conditions relevant to each mode of operation shall stop the drive and prevent it re-starting until the particular fault is cleared and individually reset; lock-out relays and a reset button being provided for any self-resetting devices such as excess torque switches etc.

Motor starters shall be equipped with the following controls and indications:

- Start and stop push-buttons.
- Running, stopped and fault indicator lights.
- Control selector switches providing HAND/OFF/AUTO or LOCAL/REMOTE to suit the drive control requirements.
- Indicating ammeter and hours-run meter for motors in excess of 10kW or as otherwise specified.
- Emergency stop push button.

Hours-run meters shall be of the non-resettable cyclometer type indicator having a flush fascia and driven by a synchronous motor connected to show the hours (up to 99,999.9) run by the main motor. They shall incorporate visible indication of operation but need not necessarily be of the same bezel size as the instruments.

Motor starters shall be provided with the following voltage-free changeover contacts wired to terminals:

- Run.
- Stop.
- Fault.

Additional contacts shall be provided as specified.

Provision shall be made to enable control circuits to be tested with the main circuit supply isolated.

Where control and interlock circuits are broken via plugs and sockets on withdrawable type starters, one interconnecting lead shall be provided for each size and type to facilitate testing in the withdrawn position.

Where the starter is to be remotely controlled by a remote terminal unit (RTU), interposing relays with 24 volt DC coils complete with back EMF suppression diodes shall be provided in each starter unit to facilitate remote control and watchdog capability.

5-1-B-8-3 Control Circuit

All control circuits shall operate at not more than 110V and be derived from a double wound, screen earthed isolation transformer with one side of the secondary winding connected to neutral/earth. The primary supply shall normally be from one phase to neutral if available.

Individual transformers shall be provided for each starter but sequenced groups of starters having a common isolator shall use a common control transformer.

Fuses shall be provided on each primary and secondary supply and be clearly labeled and segregated. A link shall be fitted in the neutral/earth connection.

The control circuit and the main supply must be isolated before opening the cubicle door but provision shall be made to re-energize the control circuit when the main supply to the cubicle is isolated, so that the operation of the control gear may be inspected without energizing the motor. The necessary control circuit Normal/Test switch shall be mounted within the cubicle and so arranged that it is not possible to close the door with this switch in the `Test' position.

The motors in some applications will be required to operate in a predetermined sequence and starters should include suitable auxiliary relays and contacts.

Each plant control panel shall contain a multiple cam contact timer housed in a separate clearly labeled compartment. The timer shall have sufficient contacts to provide as minimum one per starter plus 25 percent spare.

The timer shall allow drives to restart in a predetermined staggered sequence under both automatic and manual (hand) control following a failure of power supply and its restoration.

Each contact shall be fully adjustable between 0 and 30 minutes.

5-1-B-8-4 Direct-On-Line Starters

Direct-on-line (full voltage) ac starters shall be air-break electromagnetic switching devices complying with the recommendations of IEC 60947-4-1.

Direct-on-line starters shall be rated for uninterrupted duty and intermittent duty class 12 with on-load factor of 60% and utilization category AC-3.

The rated operational voltage (Ue) shall be not less than 440 V ac and the rated insulation voltage (Ui) shall be not less than 660 V ac.

The rated operational current (Ie) shall be not less than the full-load current of the motor. The rated operational power shall be entered in the Technical Schedule.

Thermal overload relays shall be Type 3c as defined in Clause 4.7.2 of IEC 60947-4-1. Time current characteristics shall be supplied by the Manufacturer on 28 mm x 56 mm logarithmic decades. These curves shall have a tolerance not exceeding ±10%.

Starters shall be suitable for both automatic and non-automatic methods of control. When opening by overload relay involves energizing an auxiliary relay from the control supply, the pick-up voltage of this auxiliary relay shall be below the drop-out voltage of the contactor.

The rated control supply voltage (Us) shall be equal to the nominal voltage of the ac system. The rated control circuit voltage (Uc), and frequency if ac, shall be entered in the Technical Schedule.

Test certificates shall be supplied for the following type and special tests to IEC 60947-4-1:

- Temperature - rise limits
- Dielectric properties
- Operation and operating limits
- Rated making and breaking capacities
- Performance under short-circuit conditions
- Conventional operational performance
- Ability of contactors to withstand overload current
- Special test to verify discrimination between the SCPD and overload relay in accordance with Clause B4 of Appendix B of IEC 60947-4-1.

Short-circuit tests shall be certified by ASTA, KEMA or PEHLA or other approved authorities.

The following routine tests shall be carried out on all starters to IEC 60947-4-1 and test certificates shall be supplied:

- Operation test
- Dielectric tests

5-1-B-8-5 *Star-Delta Starters*

Reduced voltage (star-delta) ac starters shall be air-break electro-magnetic switching devices complying with the recommendations of IEC 60947-4-1.

Star-delta starters shall be closed transition incorporating automatic change-over with adjustable time delay.

Star-delta starters shall be rated for uninterrupted duty and intermittent duty class 12 with on-load factor of 60%.

The rated operational voltage (Ue) shall be not less than 440V ac and the rated insulation voltage (Ui) shall be not less than 660 V ac.

The rated operational current (Ie) shall be not less than the full load current of the motor. The rated operational power shall be entered in the Technical Schedule. The transition current shall be not less than the motor current attained at the end of the starting period.

Thermal overload relays shall be Type 3c as defined in Clause 4.7.2 of IEC 60947-4-1. Time current characteristics shall be supplied by the manufacturer on 28 mm x 56 mm logarithmic decades. These curves shall have a tolerance not exceeding + 10%.

Starters shall be suitable for both automatic and non-automatic methods of control. When opening by overload relay involves energizing an auxiliary relay from the control supply, the pick-up voltage of this auxiliary relay shall be below the drop-out voltage of the main contactor.

The rated control supply voltage (Us) shall be equal to the nominal voltage of the ac system. The rated control circuit voltage (Uc), and frequency if ac, shall be entered in the Technical Schedule.

Test certificates shall be supplied for the following type and special tests to IEC 60947-4-1.

- Temperature - rise limits
- Dielectric properties
- Rated making and breaking capacities
- Change-over ability
- Operation and operating limits
- Performance motor short-circuit conditions
- Conventional operational performance
- Ability of contactors to withstand overload current
- Special test to verify that closed transition resistor will withstand the starting current for the transition time.
- Special test to verify discrimination between the SCPD and overload relay in accordance with Clause B4 of Appendix B of IEC 947-4-1.

Short circuit tests shall be certified by ASTA, KEMA or PEHLA or other approved authorities.

The following routine tests shall be carried out on all star-delta starters to IEC 60947-4-1 and test certificates shall be supplied:

- Operation tests
- Dielectric Tests
- Phase sequence at Motor terminals

5-1-B-8-6 Auto-Transformer Starters

Reduced voltage (two-step auto-transformers) AC starters shall be air-break electro-magnetic switching devices complying with the recommendations of IEC 60947-4-1.

Auto-transformer starters shall be series closed transition incorporating automatic change-over with adjustable time delay. A three-phase air cooled autotransformer with tappings at 65%, 75% and 85% shall be built-in to each starter.

Auto-transformer starters shall be rated for uninterrupted duty and intermittent duty class 12 with on-load factor of 60%. The rated operational voltage (Ue) shall be not less than 440V ac and the rated insulation voltage (Ui) shall be not less than 660V ac.

The rated operational current (Ie) shall be not less than the full load current of the motor. The rated operational power shall be entered in the Technical Schedule. The transition current shall be not less than the motor current attained at the end of the starting period.

Thermal overload relays shall be Type 3c as defined in Clause 4.7.2 of IEC 60947-4-1. Time current characteristics shall be supplied by the manufacturer on 28 mm x 56 mm logarithmic decades. These curves shall have a tolerance not exceeding ±10%.

Starters shall be suitable for both automatic and non-automatic methods of control. When opening by overload relay involves energizing an auxiliary relay from the control supply, the pick-up voltage of this auxiliary relay shall be below the drop-out voltage of the main contactor.

The rated control supply voltage (Us) shall be equal to the nominal voltage of the ac system. The rated control circuit voltage (Uc), and frequency if ac, shall be entered in the Technical Schedule.

Test certificates shall be supplied for the following type and special tests to IEC 60947-4-1:

- Temperature - rise limits
- Dielectric properties
- Rated making and breaking capacities
- Change-over ability
- Operation and operating limits
- Performance under short-circuit conditions
- Conventional operational performance
- Ability of contactors to withstand overload current
- Special test to verify that auto-transformer will withstand starting current for the starting time (Ts)
- Special test to verify discrimination between the SCPD and overload relay in accordance with Clause B4 of Appendix B of IEC 60947-4-1.

The following routine tests shall be carried out on all auto-transformer starters to IEC 60947-4-1 and test certificates shall be supplied:

- Operation tests
- Dielectric tests
- Voltage of tappings
- Phase sequence at motor terminals.

Short-circuit tests shall be certified by ASTA, KEMA or PEHLA, or other approved authorities.

5-1-B-8-7 Stator/Rotor Starters

Where separate stator and rotor cubicles are provided, a key interlock shall be fitted to prevent access to the rotor cubicle unless the stator isolating switch is in the Open or Earth position.

Rotor resistances shall have suitable interlocking facilities to prevent operation of the starter switch until all sections of rotor resistance are in the starting condition.

The resistor enclosure shall be ventilated to IP41 and a thermostat shall be incorporated to trip the starter if the resistance overheats due to excessive use or mal-operation.

Rotor resistances may be metal or liquid material as specified to suit the drive characteristics. Metal resistors shall consist of rustless unbreakable resistor grids which may be readily replaced. Where tiered banks of resistors are provided, it must be possible to readily remove from the front any section without disturbing any other section of the resistance bank.

Liquid or derived vapor resistors shall have the electrolyte contained in leak-proof containers and incorporate means of restricting evaporation and detecting loss of electrolyte.

5-1-B-8-8 Electronic Assisted Starting

Starters for specified squirrel-cage induction motors shall incorporate a solid state device designed to provide a smooth acceleration up to the motor's rated speed.

The acceleration time shall be adjustable by means of control settings provided to enable optimum maximum starting current and torque as well as initial threshold starting current and torque to be selected.

The starting current of the largest motor shall be limited as specified.

Where specified to reduce system shocks, provision shall also be made for motor stopping under controlled deceleration.

a- Protection:

The thyristors shall be protected by high speed semi-conductor fuses and heat sink thermal cut-outs.

The device shall shut down in the event of single phase loss or open circuited thyristors.

In the event of short circuited thyristors, the drive shall continue to run at full voltage by automatically transferring to an override condition.

b- Indications:

Alarm indications shall be provided for each of the above faults.

An auxiliary relay shall be used to control the function of the main contactor.

c- Energy Saving Facility:

For continuous running drives, an energy saving control shall be provided where the voltage applied to the motor is automatically matched to the actual power demand. The control shall be effective after run-up and a dwell time at full voltage has been allowed to enable the motor load to stabilize.

The device shall respond immediately to any sudden load changes to prevent a potential stall condition.

5-1-B-8-9 Frequency Converters

The motor speed control shall be a frequency converter of an approved type and manufacture, providing a variable frequency output of adequate capacity to drive the specified motor over the specified speed range and suitably matched to the starting torque and the speed torque characteristics of the driven plant. (Details to be determined by the Contractor from the driven plant/motor manufacturer during the Contract.)

The converter unit with the associated control electronics shall be housed in a steel, free standing, drip protected (IP21) panel, mounted in the position specified. The unit shall be suitably air-cooled by means of an integral fan and all the components within the unit shall be readily accessible for easy servicing and removal without disturbing other components. Chassis units shall be suitable for rack mounting.

The incoming supply shall be via an isolator interlocked with the panel door and have suitable fuse protection.

The drive unit shall be capable of operating with the motor disconnected for test purposes.

A current limiting circuit shall be incorporated to give short circuit and overcurrent protection in the output circuit, and undervoltage detection shall be incorporated to protect the drive against fan failure. A thermostat shall be fitted for protection against fan failure and overheating.

a- Harmonics:

The unit shall be protected from any harmonic distortion or switching surges in the power supply system and incorporate contactors to automatically isolate the input and output and to protect the unit from component damage arising from a power supply interruption which shall, if necessary, include automatic shutdown. If the converter will not perform correctly when running from a specified Standby generator an interlock shall be provided to prevent such operation.

To prevent distortion of the supply system wave form (and dependent instrumentation), harmonic voltage and current distortion introduced into the mains supply by the drive unit shall be within the limits specified in Electricity Council Engineering Recommendation G5/3. The point of common coupling shall be regarded as the output connections of the first upstream transformer.

The supplier shall list with the offer the expected harmonics generated by the drive under running conditions (worst case).

Where an input filter is used to limit the harmonic currents, the design shall minimize the possibility of resonance with any power factor correction capacitors fitted.

The supplier shall include any shielding necessary in accordance with BS 800, to prevent any interference that may affect other surrounding instruments.

b- Monitoring and Control:

The control of each variable drive unit shall normally be from a PLC outstation which will provide a start/stop facility and a 4-20mA speed control signal. Where the distance between the drive unit and PLC exceeds 20m, special care shall be taken to ensure radio frequency interference and distortion are kept to a minimum.

The following signals will be required from the drive unit and wired to clearly marked terminals:

- Common fault (motor overload, emergency stop operated etc)
- Control status indicating Hand/Off/Auto
- Control 'on'
- Motor available
- Motor running
- RS 232 Serial Interface (where required by the specification).

The following items shall be included along with other control devices and instrumentation:

- Control potentiometer for speed setting on hand control, (scaled with linear graduations over the range and arrows indicating clockwise rotation to `INCREASE SPEED' and anti-clockwise rotation to `DECREASE SPEED');
- Output ammeter;
- Frequency/speed meter;
- Test and fault diagnostic card for circuit checking, having a front of panel display and facility for serial link remote indication.
- Isolated inputs for 0-10/4-20mA auto control, start/stop, external reset, etc.
- Adjustments for ramp up/down, duration, frequency range, base/maximum speed, current limiting facility and economy mode.

The following items shall be monitored for fault conditions:

- Phase failure
- Earth fault
- Overcurrent
- Over voltage
- High temperature/fan failure
- DC link fuse failure

5-1-B-9 LOW VOLTAGE FUSE LINKS AND CARRIERS

All LV fuses for use on ac power circuits and directly connected control circuits shall be of the general purpose type rated not less than 415 V and shall comply with the following standards:

IEC 60269-1	Cartridge fuses, General
IEC 60269-2	Cartridge fuses, Supplementary
BS 88: Section 2.2	Cartridge fuses, Bolted

Motor circuit fuse links may have two current ratings: a continuous current rating, and a rating on which their time/current and cut-off characteristics are based (e.g. 100M160).

Time-current characteristics of type ‘gG’ fuse links shall lie within the relevant zone of the time/current zones in BS 88: Section 2.2: 1988 Figures 3 and 4.

Fuse link carriers and bases shall be made of molded plastic insulating material. Ceramic material will not be accepted. Accessible live connections with the carrier removed shall be effectively shrouded and it shall be possible to change fuse links with the circuit live without danger of contact with live metal.

Fuse link carrier and bases used on motor circuits shall have a breaking capacity to match the highest rating of motor circuit fuse link which can be accommodated.

Test certificates, for type tests in accordance with Clause 8 of IEC 60269-1 shall be supplied. Short-circuit tests shall be certified by ASTA, KEMA or PEHLA or other approved authority.

5-1-B-10 EARTHING AND NEUTRAL LINKS

Earthing and neutral links in main supply circuits shall be of the solid copper bolted pattern. Neutral links shall be accessible from the front.

5-1-B-11 PUSH-BUTTONS

Push-buttons shall comply with IEC 60947-5-1. Unless otherwise specified, colors of the buttons shall comply with IEC 60073.

Emergency stop push-buttons shall be of the latched type and shall have a mushroom type button. Emergency stop push-buttons shall be connected in control circuits so they are effective under all plant operating conditions. Resetting of the push-button shall not automatically re-energize the isolated plant.

Terminals shall be shrouded.

5-1-B-12 INDICATOR LIGHTS

Indicator lights shall comply with IEC 60947-5. Lens colors shall comply with IEC 60073 unless otherwise specified.

The lamps shall operate at not greater than 90 percent of their rated voltage.

Lenses and lamps shall be easily removable without the use of a tool.

Light emitting diode type indicator lights shall not be used except where they form part of proprietary equipment.

Terminals shall be shrouded.

Indicator lights shall be provided with individual or group lamp test facility.

5-1-B-13 INDICATING INSTRUMENTS

5-1-B-13-1 General Requirements

Indicating instruments shall comply with International standards, namely IEC 60051 and IEC 61010 for analogue instruments and EN 61010 for digital instruments or equivalent.

Indicating instruments shall display clearly the specified measured values in either electro-mechanical or electronic digital form, as defined in the Particular Specifications.

Instrument cases shall be made of magnetic sheet metal providing further protection against external magnetic fields. The instruments shall be termite and fungus resistant and shall be self extinguishing.

All indicating instruments shall withstand a minimum of 20% current and/or voltage overload.

All instruments and related accessories shall be suitable to operate between -25°C and +50°C at 85% maximum humidity for 60 days without condensation.

All instruments shall be shock proof and they shall not be affected by vibration. They shall have an insulation of 2 kV at 50 Hz.

Wherever possible, panel mounting indicating instruments shall be of matching size, appearance and orientation and suitably scaled, all in accordance with the general requirements for electrical panels.

All indicating instruments shall be of similar flush vertical mounting, rectangular pattern, enclosed in black colored, dust and damp proof cases, one side being not less than 90 mm long unless otherwise specified. Scaling shall be in approved metric units normally ranged from zero to 20% --40% above the system designed operating value, except where finite limits exist (e.g. power factor indicators, etc…) or where restricted ranges are specified. Adjustable set points within the instrument ranges shall be incorporated as specified.

Instruments having a mechanical movement shall provide at least a 90° scaled arc. 240° arc scales shall be employed where particularly specified.

Ammeters for motor circuits shall have an extended scale to cater for the starting current. These shall have adjustable red pointers or red markings on the scale to indicate the normal circuit current for the associated plant and shall be connected to each of the three phases of a three phase motor circuit.

5-1-B-13-2 *Analogue Indicating Instruments*

Analogue indicating instruments shall be of the moving iron or moving coil and fixed magnet type.

They shall have an accuracy of class 1.5 except for frequency instruments where it shall be 0.5.

The maximum rated voltage shall be 500 V a.c. and the instruments shall be of a low power consumption.

5-1-B-13-3 *Digital Indicating Instruments*

Digital indicating instruments shall be designed to accept the most common transmitter signals such as pressure, temperature, Pt100, etc. and similar sensors providing current or voltage output signal.

The signal wires shall be accepted by means of individual terminal blocks at the back of the instrument.

All settings shall be made by means weather proof keys arranged at the front panel of the instrument.

In addition to universal signal and display features, digital instruments shall incorporate a ‘HOLD’ key that memorizes the actual value when depressed.

The technical specifications of these indicating instruments are summarized as follows:

- Display principle: 7 segment red LED, 14 mm high at least.
- Polarity and out of range indication.
- Protection against incorrect polarity.
- Accuracy: ±0.05% of span ±2 digits, except for voltage and current digital indicators where it shall be ±0.5% of span ±1 digit.
- Error messages.

- Adjustable zero span and decimal point.
- Input signals: 0..20 or 4..20 mA 2,3 or 4 wires signal, Pt100.
- Output signals: 0..20 or 4..20 mA with a high response time.
- Two individually adjustable alarm contacts rated 8A at 250V ac.
- One serial RS232 interface, where specified in particular conditions.
- Power supply: 240 V ac, 50/60 Hz
- Ambient temperature: 0..50°C.
- Ingress protection: IP65.

5-1-B-13-4 Current and Voltage Transducers

These transducers shall be used wherever specified for display and/or control of electric parameters of electrical network. They shall have the following specifications:

- Accuracy class: 0.5
- Response time: maximum 100 ms.
- Galvanic isolation of output signal from both input signal and power supply.
- Overload: 300% nominal current and 120% nominal voltage.
- Protection against incorrect polarity.

5-1-B-13-5 Digital Metering Instrument for Electrical Network (Digital Multimeter)

This digital multimeter is an integrated range of electronic electricity meters in one compact module, and it shall allow the monitoring of the main electrical parameters of a distribution line.

It shall be a type-approved according to international standards.

The meter shall have an LED or LCD display for information display and on-site configuration.

The meter shall be in compliance with the following standards: IEC 61000, EN 61010-1, EN 50081 and EN 50082.

The range of parameters to be displayed includes, unless otherwise indicated, the following:

- Voltage, phase-neutral and between phases.
- Current.
- Power factor.
- Frequency.
- Active power, instantaneous and cumulative.
- Reactive power, instantaneous and cumulative.
- Apparent power.
- Ambient temperature.

Where applicable the above parameters shall be readout and displayed for each phase.

The multimeter shall be suitable for panel or DIN rail mounting as indicated. In case of front panel mounting, the IP rating of the relevant panel shall not be affected.

The multimeter shall have the following technical specifications:

- Power supply: 220-400V, ± 15% single phase.
- Low power consumption: 3VA for LCD and 6VA for LED display.
- Voltage input: 20 to 500 V ac, phase-phase.
- Permanent overload: 20%.
- Input impedance: 1 MΏ.
- True RMS value of phase and line voltages, and phase current.
- Measurement of THD (Total Harmonic Distortion).
- Measurement of maximum power demand.
- Accuracy:±0.5% ±1 digit, except for power factor where it shall be better than ±1% ±1 digit.
- Operating temperature: -10°C to +60°C.
- Relative humidity: 90%.
- Insulation test: 3kV for 1 minute.
- Built-in communication port, RS485 for data transmission.

5-1-B-14 CONTROL SWITCHES

Control switches shall be of the rotary type.

Control switches for ON/OFF and START/STOP application shall be of the three position type with a spring return action to a central neutral position.

Control switches for circuit breaker ON/OFF operation shall be of the pistol grip type and shall be lockable in the neutral position. Consecutive ON operations shall not be possible, the switch having to be first moved to the OFF position.

Control switches other than for circuit breaker ON/OFF operation, shall have spade, tee or other approved handles.

Terminals shall be shrouded.

5-1-B-15 CONTROL TRANSFORMERS

Control transformers shall be of the double wound, air cooled and chassis mounting type. An earthed metallic screen shall be provided between the primary and secondary windings.

The primary voltage shall be as specified. The rated secondary voltage shall be 110V unless otherwise specified. One end of the secondary winding shall be earthed.

The transformer rated output shall be not less than 20 percent greater than the total standing load. The combination of the inrush VA of the largest contactor plus the total hold-in VA of all devices shall not result in the transformer secondary voltage falling below 80 percent of its rated value.

Control transformers shall be provided with primary and secondary winding protection devices.

5-1-B-16 CURRENT TRANSFORMERS

Current transformers shall comply with IEC 60044-1 and shall be of the wound-primary or bar-primary type according to the ratio required. Current transformers shall have a short-time current rating of not less than that of the switchgear in which they are incorporated.

Unless otherwise specified, current transformers shall be of Class 1 accuracy for use with measuring instruments and Class 5P for use with protective relays.

The secondary winding(s) of each current transformer or of each set of star-connected three phase current transformers shall be earthed at one point only, via a bolted link. The link shall be located in the instrument wiring chamber.

Separate current transformers shall be used for metering and protection. An ammeter may be connected in non-unit protection circuits supplied by Class 5P current transformers.

Tappings of multi-ratio current transformers shall be wired to link-boards with labeled identification of the connection options. The link-board shall be located in the instrument wiring chamber.

Shorting links shall be provided at test blocks.

5-1-B-17 PROTECTION RELAYS

Protection relays shall comply with IEC 60255 and shall be front of panel mounted in flush draw-out pattern cases with strong and durable clear front covers. The protection enclosure classification for case and cover combination shall be not less than IP 52. Cases shall be finished in phenolic black unless otherwise approved.

Unless otherwise specified, relays shall be fitted with hand reset operation indicators. The reset mechanism shall be externally operated.

Relays shall be provided with facilities for testing in the withdrawn position.

Relay types shall be as specified.

5-1-B-18 ANTI-CONDENSATION HEATERS

Unless otherwise specified, individual switchgear enclosures shall be provided with an anti-condensation heater. Alternatively, multi-cubicle type panels may be provided with a common heater located at the base of each panel section if appropriate to the manufacturer's standard design.

Heaters shall be mounted as low as possible in enclosures and panels. Heaters shall be located to ensure free air flow over the heating element and to have no detrimental effect on temperature sensitive devices or adjacent cabling.

Heaters shall be fitted with a safety guard the surface temperature of which shall not exceed 60 °C.

Heaters shall be rated to ensure condensation does not occur under the ambient air temperature and relative humidity conditions prevailing at the location where enclosures and panels are installed.

Individual enclosure heaters shall be complete with protective device, ON/OFF switch and thermostat. Heaters provided for panel sections shall be complete with a common protective device, ON/OFF switch and thermostat.

Heater circuits not isolated by the enclosure switch-disconnector shall have all live terminals fully shrouded and a warning label fitted.

5-1-B-19 LABELS

Enclosures and associated external and internal components shall have identification labels. Identification labels shall be manufactured from white-black-white laminated plastic or photo-metal labeling on aluminum sheet plates. Unless otherwise specified, the label type shall be the manufacturer's standard.

Rear engraved plastic labels shall be clear with black engraving unless otherwise specified. Internal labels shall be inscribed with the component description given on the associated circuit diagram.

Labels for fuses shall have the fuse link rating inscribed.

Internal labels shall not be fixed to components or cable trunking covers.

Danger and warning labels shall comply with BS 5378: Part 1, and shall unless otherwise approved by the Engineer, be manufactured from rigid plastic.

Labels shall lay flat to the surface and shall be secured by non-rusting screws.

Labels shall be in English unless otherwise specified.

Label and engraving sizes, and label inscriptions shall be approved by the Engineer before manufacture.

Embossed plastic and paper labels will not be accepted.

Each item of equipment on the external face of all covers and doors shall be provided with a label to indicate its function. Each such label shall be colorless transparent plastic material not less than 3 mm thick with edges beveled to half the thickness. Each label shall be reverse engraved and filled with paint. All inscriptions shall be approved by the Engineer. Labels shall be fixed to the outside of covers and doors by clamping under equipment bezels or screws, rivets etc. (adhesives are not acceptable). Each item of equipment mounted inside the enclosure shall be provided with a label to indicate the reference number of the device as designated on the circuit diagram and the current rating of all fuse links. Each such label shall be black letters engraved on a white plastic material secured by screws or rivets (adhesives are not acceptable).

Engraved labels shall be screwed or riveted to the rear of each compartment to indicate its function.

5-1-B-20 WARNING SIGNS

Warning signs shall be provided and mounted at a location to be agreed.

Warning signs shall be made of vitreous enameled aluminum sheet or plastic, 500mm x 300mm, bearing the following inscription:

> “CAUTION
>
> PLANT UNDER AUTOMATIC CONTROL AND LIABLE TO START WITHOUT WARNING
>
> ISOLATE AT SOURCE BEFORE ATTEMPTING ANY MAINTENANCE OF MECHANICAL AND ELECTRICAL PLANT”

5-1-B-21 EMERGENCY STOP BUTTONS

Separate emergency stop push buttons of the lock-off type shall be provided adjacent to every item of auxiliary plant involving a motor drive.

5-1-B-22 LIMIT SWITCHES AND POSITION RESPONSIVE DEVICES

Limit switches and all other position responsive devices shall be of the quick break metalclad type and shall have a positive action.

Where mercury switches are used, the angle of tilt and speed of operation shall be such that the switch tube cannot rest at any intermediate point between the open and closed positions and the tube shall be of the dry type, i.e. with top entry tails.

All switch enclosures shall be watertight to IP55 with covers suitably gasketed and mounted singly, not in multiple assemblies.

Limit switches shall be automatically self-resetting with a positive mechanical drive in both directions, and shall be located in readily accessible positions for adjustment and repair. Each limit switch shall be arranged for individual adjustment of the setting position by screw bolts on the operating rod or by an alternative approved method.

Where more than one limit switch is provided at a particular location, cabling shall terminate at a suitable terminal box and the interconnection shall be completed in flexible conduit or other method as may be approved by the Engineer.

Before placing sub-orders, the Contractor shall submit for approval details manufacture, type and rating of all limit switches to be used throughout the Works.

5-1-C ELECTRIC MOTORS

5-1-C-1 TYPE

Motors shall be of the a.c. cage rotor induction type unless otherwise specified.

This section covers low and high voltage three phase cage induction motors for general use, including hazardous area installations.

All motors shall be suitable for operation in the climatic conditions detailed in the Specification and in ambient temperature up to 40°C.

The site rating, if derating applies, and normal ratings of all motors together with all performance data be provided with the offer.

5-1-C-2 STANDARDS

Standards shall apply as follows:

IEC 72	General Purpose	For LV indoor induction motors
	Induction Motors	without special requirements
BS 5000: Part 15	Type Ex 'E' Motors	As title
BS 5000: Part 16	Type Ex 'N' Motors	As title
IEC 34-1	Miscellaneous Machines	For all other induction motors
IEC 72-2	Symbols	For all induction motors
IEC 34-7	Terminal Markings	Ditto
IEC 34-8	Standard Dimensions	Ditto
	Types of Construction	Ditto
BS 4999: Part 145	Winding Terminations	Ditto except Type Ex 'N'
IEC 34-11	Built-in Thermal Protection	Ditto Type Ex 'N'
BS 292: Part 1	Dimensions of Ball	For LV motors with frame number
	and Roller Bearings	250 upward and HV motors
ISO 281/1	Dynamic Ratings of	For all motors except LV motors
	Bearings	with frame number 315 and below
ISO 15	Dimensions for Radial	For LV induction motors with
	Bearings	frame numbers 112 – 225

5-1-C-3 HV MOTOR SURGE WITHSTAND

HV motors shall be suitable for use with vacuum contactors which produce current chopping of 3A on a probability of 0.1%. The surge withstand voltage (175/2500 us) to earth of the stator winding shall be not less than 18 kV peak and 31 kV peak for 3.3 kV and 6 kV motor rated voltage respectively.

5-1-C-4 RATING AND DUTY

All cage induction motors shall be of rating class MCR. The rated output and shaft number of all LV motors up to and including frame number 315, except for Zone 1 and Zone 2 hazardous area motors, types Ex 'E' and Ex 'N', shall be in accordance with IEC 72.

Unless otherwise specified, motors shall be suitable for continuous operation at rated output at any voltage between 94 and 106 percent and any frequency between 95 and 102 percent of rated values. Motor ratings shall be determined by the Contractor according to the power requirements and the normal working environmental conditions for the plant offered in accordance with this Specification. The maximum temperature rise of any machine winding shall not exceed 80°C above a 40°C ambient when operating at the above rating. Where the insulation is rated up to 120°C only, the maximum plant loading shall not exceed 95% of the rated output of the machine.

Unless stated otherwise, the continuous maximum rating of each motor shall be in accordance with the following requirements:

Application	Up to 75 kW Drives	Above 75 kW Drives
All pump motors (excluding positive displacement type)	10% above the calculated maximum power requirements under all conditions of operation	5% above the calculated maximum power requirements under all conditions of operation
Positive displacement pumps & accessories	25% above the calculated power requirements for normal duty or 5% above the power required for maximum duty whichever is the greater	12 1/2% above the calculated requirements for normal duty or 5% above the power required for maximum duty whichever is the greater.
All other drives, including screens, tank scrapers, etc and process plant.	50% above normal duty requirements	25% above normal duty requirements.

The above percentages shall be added to the calculated power requirements for motors, prior to making the necessary adjustments (increased ratings) for high ambient temperature at site. A higher percentage shall be added to the calculated power requirements for motors, if specified in the appropriate machinery section of the specification.

All motors shall be capable of developing a minimum starting torque of 150 per cent of the full load torque. It may, however, be necessary to limit the starting torque on some drives and this shall be achieved by the form of starter and method of starting.

The site rating and normal ratings of all motors together with all performance data shall be provided at the time of tender.

All guaranteed and technical data shall be that for an ambient temperature of 40°C, although all proving tests at the manufacturer's works shall be carried out at ambient temperature. The declared site rating at 50°C shall be estimated by means of approved recognized method and the manufacturer shall provide derating curves for each motor and these shall be included in the maintenance instructions. Where identical type and size motors are being supplied one motor only shall be subjected to full tests and the remaining units to abbreviated tests.

Motors for use with variable frequency converter type speed controllers shall be rated for continuous running duty over the specified speed range. The motor design shall take in to account:

a- Increased heating, vibration and noise arising from a non-sinusoidal supply voltage waveform.

b- Reduced cooling when operating at lower than rated speed.

c- Bearing life, lubrication, radial forces and critical speeds when operated at speeds in excess of rated.

5-1-C-5 EFFICIENCY

Unless stated otherwise, the minimum efficiency of general purpose LV and weather protected LV induction motors with frame numbers 112-225 shall be in accordance with the following:

Rated Output (kW)	Minimum Efficiency (%) at Rated Output			
	3000 r/m	1500 r/m	1000 r/m	750 r/m
4.0	85	86	83	82
5.5	87	86	84	83
7.5	89	87	86	83
11.0	89	89	86	86
15.0	89	90	88	87
18.0	90	90	89	89
22	90	90	90	90
30	91	91	90	-
37	92	92	-	-
45	92	92	-	-

All motor efficiencies shall be determined in accordance with IEC 34-2 and for all motors with frame numbers 250 and above may be used for capitalization of running energy costs.

5-1-C-6 STARTING

General purpose and weather protected LV motors of frame number 100 and below shall be suitable for direct-on-line starting within the transient voltage range of 330-460 V. Other motors shall be suitable for direct-on-line starting within the transient voltage range of 80-110% of rated voltage. All motors shall be capable of withstanding the acceleration period of the driven machinery. Unless otherwise specified, cage induction motors shall be full voltage direct-on-line, or reduced voltage auto-transformer or star-delta started.

Pump motors shall have thermal capability of 12 starts per hour, under normal pump start-up conditions with a supply voltage during starting of 80% of rated voltage. Pump motors shall be designed for not less than 50,000 starts during the life of the motor.

Unless otherwise specified, the starting performance of cage induction motors shall comply with BS 4999: Part 112 design "N", "NY" or "D" as appropriate for the starting method specified. Specific attention shall be given the power system characteristics under starting conditions to ensue that adequate voltage is available during starting to ensure satisfactory starting and acceleration under all driven plant load conditions.

The direct starting current (Is) of electric motors shall not exceed 7 times the nominal rated current (In). The torque available during starting of each motor shall be at least 20% in excess of the maximum required at any speed to satisfactorily start and accelerate the mechanical plant load under all service conditions.

5-1-C-7 WINDINGS AND INSULATION

Winding insulation shall be Class F or better. The maximum temperature shall not exceed that permitted for Class B.

Windings shall be supported, braced, wedged and blocked to provide adequate rigidity under all conditions of service. Special attention shall be given to the windings of direct-on-line started motors and the support of windings of vertical motors to prevent any permanent displacement during the service life. The coil overhang of rotor windings shall be tension banded.

Cage type rotors shall be designed to provide an adequate factor of safety against mechanical failure due to fatigue during the service life of the motor. Special attention shall be given to the design of cage rotors fitted to motors which are subject to operation at speeds in excess of rated speed, and where flywheels or large inertia loads are involved.

Electrical joints and connections shall withstand the mechanical and thermal stresses under normal and abnormal operating conditions. Stator end windings shall be blocked and braced to provide high rigidity.

Completed windings, including connections, shall be subjected to a minimum of two cycles of vacuum impregnation with solvent-free resin varnish followed by curing, to effectively fill gaps between individual conductors, to enhance mechanical strength and to provide a high resistance to moisture, oil and chemical contamination.

The insulation of flexible cables connecting stator windings to terminal boxes shall be of the chlorosulphonated polyethylene (CPS) or ethylene propylene rubber (EPR). Natural rubber insulated cables shall not be used. Cables shall be securely fixed to the stator frame.

5-1-C-8 DEGREE OF PROTECTION FOR MOTOR ENCLOSURES

The winding insulation materials and cable insulation shall be resistant to flame propagation.

Unless otherwise specified the following minimum degrees of protection shall apply:

Motors located in indoor dry areas	:	IP52
Motors located indoors in damp or wet areas	:	IP54
Motors located indoors subject to water jets	:	IP55

Motors located outdoors	:	IPW55
Submersible motors	:	IP58

Fans and blades external to the enclosure shall be protected against contact by means of guards.

Totally enclosed motors shall be provided with suitable means for breathing and for drainage to prevent the accumulation of water.

All outdoor motors shall be provided with suitable covers to protect them from direct sunlight. Motor cowls shall not be fabricated in fiberglass or plastic.

5-1-C-9 HAZARDOUS AREAS

Electric motors in hazardous areas shall be as follows:

Zone 1	Type Ex ‘e’
Zone 2	Type Ex ‘N’

Duty type shall be S1.

Certification by BASEEFA or other recognized authority shall be provided for Type Ex ‘e’ and Ex ‘N’ electric motors.

For Type Ex ‘e’ motors, type test certificates shall be supplied for starting current ratio IA/IN and time Te in accordance with IEC 79-7 and impact tests to IEC 79-7.

For Type Ex ‘N’ motors, type test certificates shall be supplied for impact tests to IEC 79-7.

Temperature class of hazardous area shall be suitable for the installation.

5-1-C-10 COOLING

All motors shall be fan cooled by direct shaft driven fans.

5-1-C-11 GENERAL CONSTRUCTIONAL FEATURES

Motor frames shall be cast iron, fabricated from steel plate or aluminum as appropriate. Frames shall incorporate substantial internal ribbing to provide high structural strength.

End covers, end shields, external fan cowls and other external components shall be of adequate strength and robustness, and shall be constructed of metal.

External surfaces shall be finished to manufacturer’s highest quality to a color agreed with the Engineer.

5-1-C-12 NOISE LEVEL

The motors shall be commercially silent in operation and run free from vibration. The rotors shall be balanced both statically and dynamically and shall be tested and adjusted, in an approved manner.

5-1-C-13 BEARINGS

5-1-C-13-1 General

Bearings shall be capable of accepting:

a. The mechanical and electrical forces imposed on them by the rotor.

b. The forces imposed by the motor attitude.

c. External forces due to the drive method.

Bearings shall be of the rolling or plain type as determined by consideration of motor rating and speed, shaft system, duty, method of drive and the type of bearing of the driven equipment.

Unless otherwise specified or approved by the Engineer, motors rated up to and including 750kW at 1000 rpm, 530kW at 1500 rpm and 375kW at above 1500 rpm shall be fitted with rolling type bearings.

Where bearings are insulated from the main frame to suppress shaft circulating currents, they shall be connected to earth at one point via a link. The link shall be removable to permit testing of the bearing insulation. Oil and water pipes, direct driven oil pumps and any other ancillary equipment shall be insulated as necessary to maintain the integrity of the bearing insulation. The insulation shall not be short-circuited by the application of electrically conducting paint.

5-1-C-13-2 Rolling Type

Rolling bearings shall comply with the relevant British and International Standards and the assembly shall be designed to exclude the ingress of dirt and water. The bearings shall be grease lubricated or oil lubricated where the shaft speed is in excess of that permitted by the former. The bearing assembly shall be sealed to prevent leakage of the lubricant along the shaft and shall be designed to permit the easy removal of bearings. Oil lubricated bearings shall be fitted with a breather.

Rolling type bearings shall be selected to meet the following requirements:

a. A minimum life of 40,000 hours when the forces on the bearing are from the motor only and 32,000 hours when the forces include those from the motor and the driven unit.

b. A re-lubrication interval preferably of 8,000 hours but not less than 4,000 hours.

c. A maximum outer race temperature of 80 °C.

Rolling bearings of the "sealed for life" type shall operate for a minimum of 18,000 running hours, or for a period of 5 years if the latter occurs sooner.

Grease lubricated bearings shall be packed with lithium based grease at the time of assembly.

A separate grease nipple shall be provided for each lubricating point. Grease nipples shall be manufactured from steel. Bearings shall be provided with facilities to eject surplus grease.

Oil lubricated bearings shall be provided with an oil reservoir, breather and, if appropriate, an external make-up reservoir. The reservoir shall have a filler plug and an oil level indicator.

Where there is a danger of vibration from other plant being transmitted to a stationary motor, provision shall be made to prevent fretting damage to the bearings.

It shall be possible for lubrication to be carried out with the motor stationary or running and without the need to remove guards.

5-1-C-13-3 Plain Type

Plain bearings shall be self-lubricated by oil rings or discs, or alternatively, shall be forced lubricated. The bearings shall be designed to exclude the ingress of dust and water, shall have provision for breathing and shall be sealed to prevent leakage of oil. Bearings shall be fitted with an accessible drain plug, provision to permit the cleaning of the oil sump, and a transparent window or other approved facility for observing the oil feed.

The two bearing shell parts shall have white-metal linings and shall be self-aligning. The two bearing shells shall be located to each other by dowels.

The temperature of the oil leaving the bearing shall not exceed 70 deg C. Bearings shall incorporate thermometer pockets or shall be fitted with a dial type thermometer as specified. Dial type thermometers shall incorporate two sets of adjustable contacts for alarm and motor trip initiation. The contacts shall be wired to a terminal box.

The oil rings or discs of self-lubricating bearings shall run in an oil-bath. Bearings shall have provision for filling and a clearly visible oil level indicator. The oil level indicator may be fitted externally to the bearing.

Forced lubricated bearings shall be supplied from a self-priming oil pump driven from the main shaft system or from a separate pump. An oil flow indicator shall be provided for each bearing together with oil cooler, oil tank filter valves and all interconnecting pipework. Unless otherwise specified, the oil feed system shall be fitted with a pressure gauge and flow switch. The pressure gauge shall incorporate two sets of adjustable contacts for alarm and motor trip initiation. The contacts shall be wired to a terminal box.

5-1-C-14 BALANCING

Rotors shall be dynamically balanced with full key. The rotors of motors fitted with an external fan shall be initially balanced without the fan and then with the previously statically balanced fan fitted. Any additional weights shall be fitted to the fan balance rings.

5-1-C-15 VIBRATION LEVELS

Unless otherwise specified, the maximum limits of vibration severity for horizontally mounted motors shall be quality grade "N" (normal) as given in BS 4999: Part 142. For vertical motors the same limits shall apply to the lower bearings and 1.5 times these limits for top bearings unless otherwise agreed with the Engineer.

5-1-C-16 LIFTING FACILITIES

All heavy parts of motors shall be provided with facilities for lifting.

5-1-C-17 PROTECTION OF MOTORS

For motors rated less than 2 kW, a three pole, thermal overloads with single phasing protection, shall be provided.

For motors rated above 2 kW and up to and including 30 kW shall be protected by three pole adjustable thermal magnetic overloads and single phasing protection.

Motors above 30 kW, unless otherwise specified, should be protected by an electronic protection relay (motor manager).

The trip characteristic shall be adjustable, so that it can protect motors having differing maximum locked rotor times and currents therefore shall protect motors with long run-up times.

In addition, pump drive motors shall be provided with protection devices in order to stop the motors in case of:

- Reverse rotation
- High pressure in the pumping line
- Failure to start
- Frequent starts

5-1-C-18 MOTOR MANAGER

All LV motors for pumping units shall be provided with electronic motor managers. The device shall be a self monitoring unit with the following operating features:

- select and change operating parameters.
- select and modify setting values.
- display values and modifications.
- indicate faults.
- test, e.g. verify the unit operation.
- reset: Enable the unit after a trip.

Technical data:

- Operating temperature : -5°C to 60°C
- Storage temperature: -40°C to 60°C
- Climatic sensitivity: as per IEC 68-2-3 and IEC 68-2-30
- Degree of protection: IP65
- Resistance to vibration: as per IEC 68-2-6
- Resistance to shock: as per IEC 68-2-27
- Noise emission and noise proof as per EMC standard.
- Power supply module shall be self-protected against short circuits.
- Data shall be retained in case of voltage supply failure.

- Fail-safe operation.
- Output relays (contacts) galvanically separated.

Protective functions

- Thermal overload.
- Asymmetry.
- Overload.
- Rotor stalling during running and starting period.
- Underload
- Earth fault.
- Long starting (Monitoring of starting time).
- Limited starts per hour.
- short circuit.
- Thermistor (PTC) input.
- Phase sequence.
- Phase failure.
- Pt 100 input (up to six No.)

This unit shall be equipped as well with a communication interface to enable data exchange with logic controllers or PLCs.

5-1-C-19 TEMPERATURE MONITORING DEVICES

Monitoring devices for motor winding temperature indication and thermal protection shall be of the resistance or thermocouple type as specified. For thermal protection application only, positive temperature coefficient (PTC) type thermistors shall be used unless otherwise specified.

Resistance and thermocouple monitoring devices shall be distributed evenly around the stator periphery and installed at the hottest points. The devices shall not be directly exposed to the cooling air.

Thermistors shall be installed in the stator end winding and shall be distributed evenly over the winding periphery. The thermistors shall be as follows:

LV Motors	Class II to IEC 34-11
HV Motors	Type TP11 to IEC 34-11
Hazardous Area Motors Type Ex ‘e’ and Ex ‘N’	Class I to IEC 34-11

Type test certificates shall be made available on request.

Monitoring devices shall be wired to an insulated terminal strip within a dedicated terminal box fitted with an identification label.

Devices for bearing and cooling air temperature monitoring shall be of the thermocouple type.

The requirements for temperature monitoring devices shall be as specified.

5-1-C-20 ANTI-CONDENSATION HEATERS

Anti-condensation heaters shall be fitted to all medium voltage motors and all low voltage motors located outdoors. The requirement for anti-condensation heaters for low voltage motors located in other areas shall be specified.

The heaters shall be of a size to maintain the temperature of the windings 5°C above ambient. Each heater shall be provided with a switch and also an automatic control, within the respective starters, to disconnect it when its motor is in operation.

All motors without heaters shall be fitted with drain holes with removable plugs.

Heaters shall be connected to an insulated terminal strip within a dedicated terminal box by means of flexible butyl rubber insulated leads. The terminal box cover shall be fitted with a warning label advising the need to isolate the supply before removing.

Heaters shall be of the embedded element type having a low surface temperature and be impervious to moisture. They shall be arranged to operate on a 220V supply from the associated control unit when the motor winding is de-energized.

5-1-C-21 TESTING

Motors up to Frame Number 225	Test certificates shall be made available on request for all basic tests listed in Table 1 of BS 4999: Part 143
Motors with Frame Numbers 100– 25	Routine check tests as listed in Table 1 of BS 4999: Part 143 shall be performed on all motors and certificates provided
LV Motors with Frame Numbers 250 – 315	Duplicate tests as listed in Table 1 of BS 4999: Part 143 shall be performed on the first machine of any batch. Routine check tests shall be performed on all machines in the remainder of the batch. Test certificates shall be provided for all basic duplicate and routine check tests listed in Table 1 of BS 4999: Part 143.
LV Motors with Frame Numbers 355 and above	Basic tests as listed in Table 1 of BS 4999: Part 143 shall be performed on the first machine of any batch.
HV Motors Type Ex 'N' Motors	Duplicate tests shall be performed on all machines in the remainder of the batch. Test certificates shall be provided for all tests.
Type Ex 'e' motors	Basic tests as listed in Table 1 of BS 4999: Part 143 shall be performed on all machines and test certificates shall be provided.

5-1-C-22 ELECTRICAL TERMINATIONS

Windings of LV motors except for Type Ex 'N' shall be brought out to studs mounted on a terminal board inside an air-insulated metal terminal box with a degree of protection of IP54 for indoor locations and IPW55 for weather protected motors. Ex 'N' motors shall have terminations in accordance with BS 5000: Part 16.

HV motor windings shall be brought out to studs mounted in an air insulated metal terminal box of the pressure containing type with a degree of protection IP54 for indoor locations and IPW55 for weather protected motors. This terminal box shall be suitable for operation on a fuse protected system with the prospective fault current present at the motor starter. The terminal box shall be suitable for making off and sealing the cable(s) to be connected. HV motors shall have a separate terminal box for heaters and thermistors.

A protective earth terminal shall be provided on the frame and in the terminal box of all motors.

Terminal boxes shall have a neoprene bonded gasket fitted between the box and motor frame and between the box and cover.

Terminal boxes shall be dimensioned to permit external cables to be satisfactorily connected. The cable box design shall take in to account the need to connect oversized cables required for volt drop or short-circuit considerations.

Terminal boxes shall be provided with a removable cable gland plate. Unless otherwise specified, gland plates fitted to motors for use with variable frequency converter type speed controllers shall be insulated from the cable box with facilities for shorting out.

Terminations, associated leads and terminal boxes shall withstand the effects of a short circuit at the motor terminals without damage. Winding terminations and terminal markings shall comply with BS 4999: Parts 145 and 108 respectively.

5-1-D DIESEL GENERATING SETS

Generator sets shall be installed in separate buildings complete with ventilation louvers for air intake for engine combustion and cooling.

5-1-D-1 DIESEL ENGINE

5-1-D-1-1 General

The engine type shall have proven service in commercial operation, for an approved period.

The engine shall be of the 4 stroke, water cooled direct injection compression ignition type with an in-line or “V” cylinder configuration. The engine may be naturally aspirated or turbo-charged. The nominal speed shall not exceed 1500 rpm for 50Hz.

The engine shall be rated in accordance with BS 5514 and shall be capable of continuous operation at rated output plus a 10% overload for 1 hour in any 12 consecutive hours running.

Fuel oil shall be Class A2 distillate.

All chain and gear drives shall be located in oil-tight cases and shall be pressure lubricated.

The engine shall be capable of accepting full rated load within 20 seconds from initiation of the starting sequence when starting from cold at the minimum specified ambient air temperature. The initial step load shall be not less than 40 percent of the full load value unless otherwise specified.

5-1-D-1-2 Lubrication

The engine shall have a forced lubricating system throughout using an integral gear-driven pump with a coarse strainer on the suction side. A full flow filter of nominal micron rating not greater than 10 and having a pressure operated by-pass valve shall be provided on the delivery side. Manual lubrication of any part of the engine shall not be accepted. The lubrication system shall not require priming prior to starting the engine.

The engine lubricating oil dipstick shall be easily accessible and minimum and maximum levels shall be clearly marked.

The engine sump shall have an easily accessible drain point or drain pipe, fitted with a BSP plug.

5-1-D-1-3 Cooling

Unless otherwise specified cooling shall be by means of a sealed or pressurized radiator of the air blast type, which shall be mounted on the generating set base frame with the fan driven by vee belts from the engine crankshaft. Remote radiators, when approved shall be floor mounting and shall be complete with motor driven fan or fans. Remote radiators shall be suitable for indoor or outdoor location as specified.

Engine mounted radiators shall be provide with a flange for the fitting of flexible ducting.

Engine driven pump(s) shall circulate the jacket water and lubricating oil if appropriate through the radiator sections.

A thermostatically controlled diverter or by-pass valve shall be fitted in the engine cooling water discharge pipework, with a return to the circulating pump suction, to maintain the circulating water at the optimum temperature irrespective of load.

The cooling system shall be provided with plugged valves as necessary to enable all parts to be drained.

5-1-D-1-4 Drive Belts

Drive belts shall be of the multiple endless vee type which shall be resistant to fuel and lubricating oils. The number of belts fitted to each drive shall be one more than is necessary to transmit the maximum power requirement.

An accessible belt tensioning device shall be fitted to each drive and it shall be possible to change the belt(s) without major dismantling and reassembly.

5-1-D-1-5 Safety Guards

All exposed hot or moving parts and in particular, fans, belt drives, couplings and flywheels, shall be fully guarded to ensure safe operation.

To permit the adjustment and inspection of drives, apertures with secured cover plates shall be provided in the guards at appropriate points.

5-1-D-1-6 Protection Devices

Devices shall be fitted and arranged to stop the engine under the following conditions:

- Oil pressure low
- Oil temperature high
- Coolant temperature high
- Overspeed
- Fuel low

A voltage-free set of changeover contacts shall be provided for each of the above conditions for the initiation of a remote alarm. The contacts shall be wired to a terminal box.

5-1-D-1-7 Wiring

Wiring shall be insulated with heat resistant insulation of approved type suitable for use at temperatures of up to 85°C. Conductors shall be multi-stranded copper of minimum cross sectional area 1.5 mm² except special types such as screened cables.

All wiring, excluding starter cables, shall be shall be connected to a terminal box or terminal boxes mounted on the base frame. Starter cables may be directly connected.

5-1-D-1-8 Pipework

Fuel pipework shall be produced from seamless steel tubing with welded or compression type steel fittings. All other pipework shall be either seamless copper tubing with brazed or compression type gunmetal fittings, or seamless steel tubing with welded or compression type steel fittings.

Flexible sections of pipework shall be synthetic rubber with stainless steel braided sheaths. Flexible fuel and lubricating oil connections shall additionally have flame resistant sleeves.

5-1-D-1-9 Heaters

Engines shall incorporate thermostatically controlled oil and water heaters to facilitate cold starting. The surface loading of oil heaters shall not exceed 7.5kW/sqm.

5-1-D-1-10 Instrumentation

Instruments as follows shall be provided:

- Lubricating oil pressure gauge
- Lubricating oil temperature gauge
- Cooling water temperature gauge
- Turbo-charger air pressure gauge (if applicable)
- Running hours indicator
- Tachometer
- Battery charge ammeter for electric start engines
- Engine stop pushbutton
- Other instruments as considered necessary by the engine manufacturer

The instruments shall be fitted on an engine mounted panel supported on anti-vibration mountings. The panel shall be mounted at a convenient height and position for observation and operation.

5-1-D-1-11 Governing

Engine governing shall be of the electronic type having a droop characteristic adjustable over the range 0 to 5%. The governor shall be Type 1 to BS 5514 and shall be Accuracy Class A1 or better. The maximum transient speed change shall not exceed 5 percent with the maximum step load application.

5-1-D-1-12 Exhaust System

Engines shall be provided with a complete exhaust system comprising rigid and flexible pipework, stainless steel bellows, silencer(s) and all necessary brackets, hangers, wall sleeves and plates and sundries for a complete installation. Pipe wall thickness shall not be less than 3mm.

Unless otherwise specified, silencers shall be of the residential type.

The first section of exhaust from the engine manifold shall include a flexible bellows unit. The next section of pipe shall be supported to allow movement without imposing forces on the manifold.

Exhaust support brackets shall be designed to allow for pipe expansion and contraction movement.

Bends in the exhaust pipework shall be kept to a minimum and shall be of the long radius type.

Where the exhaust pipe passes through a wall, a wall sleeve and plates shall be fitted. The space between the pipe and sleeve shall be filled with heat resistant material.

Exhaust terminations shall be located away from building air inlet grills or opening windows to prevent ingress of exhaust gasses.

The exhaust outlet shall be fitted with weather proofing flap valve.

For long exhaust runs, a water drain point or condensation trap shall be fitted near to the engine.

Exhaust silencers and pipes, flanges, clips and fixings shall be sprayed with an approved heat resistant metallic aluminum paint.

Internal sections of the exhaust system shall be effectively lagged. The lagging shall be clad with aluminum sheet secured by stainless steel band clips.

Where it is not practical to lag any part of the internal section of the exhaust system with which personnel can come into contact, guards shall be fitted.

5-1-D-1-13 Electrical starting systems

Engines shall be electrically started from a battery.

The starting battery shall be of the nickel-cadmium or lead acid type as specified, installed on a non-corrodible tray or rack and shall have a cover of insulating material. The battery shall have sufficient capacity for three consecutive start attempts each of 10 seconds duration. In addition, the battery shall have sufficient capacity after the three start attempts to supply the maximum demand of the control panel for a minimum period of 24 hours.

The battery charger shall be of the solid state design and shall incorporate "Float" and "Boost" charging facilities. In the "Float" charge mode the charger shall automatically maintain the battery in a fully charged condition whilst supplying standing loads. In the "Boost" charge mode the charger shall be capable of fully charging the battery from a fully discharged condition in a period not exceeding 7 hours.

The charging characteristics for the nickel-cadmium vented type battery shall minimize electrolyte gassing.

The charger shall be complete with:

- Incoming supply On/Off switch
- Supply On indication
- Output voltmeter

- Output ammeter
- Float/Boost Charge selector switch
- Charger Failed relay with voltage free changeover set of contacts wired to terminals
- Charger Failed indication

The minimum requirement for the "Charger Failed" alarm shall be the detection of a.c. supply and d.c. output failure. The relay shall not operate under a transient a.c. supply failure condition.

5-1-D-1-14 Fuel System

The fuel system shall comprise an engine driven feed pump with duplex filters, daily service tank with supporting structure and drip tray and all interconnecting pipework including flexible engine connection pipe.

Daily service tanks shall be fitted with the following:

- High, intermediate and low-level float switches for the control of a fuel oil transfer pump and/or alarm initiation.
- A jettison connection fitted with fire valve. The connection shall be sized to drain the contents of the tank in a period not exceeding 5 minutes.

Unless otherwise specified, the capacity of daily service tanks shall be sufficient for eight hours full load operation of its associated generating set.

Fire valves shall be activated from a generator room fire detection system.

5-1-D-2 GENERATORS

The generator shall be of the salient pole brushless type. The generator shall be flange and foot mounted or foot mounted with open coupling, with single or twin end-shield bearings. A single bearing machine shall be directly coupled to the engine crankshaft. A two bearing machine shall be coupled through an intermediate flexible coupling.

The generator shall be capable of continuous operation at rated output plus 10 percent overload for 1 hour in any period of 12 hours without exceeding the temperature rise limits of the insulation system.

The generator's windings shall be of the 2/3 pitch design to eliminate triple harmonics on the voltage waveform and fully interconnected damper windings for stable operation during paralleling.

Bearings shall have a minimum life of 40,000 hours and shall have a re-lubrication interval preferably 8,000 hours and not less than 4,000 hours. The bearing speed rating shall not exceed 80 percent and the bearing outer race temperature shall not exceed 70 deg C.

Oil lubricated bearings shall be fitted with a clearly visible and protected oil level gauge.

Generators shall be fitted with an anti-condensation heater.

5-1-D-2-1 Excitation System

A permanent magnet pilot exciter shall provide power to the main exciter via the automatic voltage regulator. The main exciter output shall be fed to the main rotor winding through a 3 phase full wave bridge rectifier. The diode bridge shall be protected against surges and voltage transients.

The excitation system shall sustain a short-circuit current of not less than 300% rated current for a minimum period of 5 seconds to allow external protection to operate.

5-1-D-2-2 Electrical Insulation System

The electrical insulation system shall be Class F or better the temperature rise shall not exceed the preceding thermal class.

The generator and exciter stator windings shall be impregnated with a moisture, oil and acid resistant polyester varnish with a final coat of anti-tracking varnish. The generator and exciter rotor windings shall be impregnated with a high strength thermo-setting epoxy resin to withstand rotational forces.

5-1-D-2-3 Automatic Voltage Regulator

Automatic voltage regulators shall be of the solid state three-phase sensing type with in-built protection against sustained over-excitation. Unless otherwise specified the voltage regulation shall be not less than Grade VR2.21 to BS 4999: Part 140.

With the application of the maximum step load at any power factor between 0.2 and 0.8 lagging, appropriate to the associated pumping station at peak output duty, the initial voltage shall not drop below 85 percent of the nominal value recovering to 97 percent within 1.5 seconds. The transient voltage rise when the rated load is thrown off shall not exceed 25%.

Provision shall be made for remote adjustment.

5-1-D-3 CONTROL

5-1-D-3-1 General Requirements

The controls shall be designed to provide the following facilities:

- Automatic starting and stopping of the engine.
- Manual starting and stopping of the engine.
- Simulated mains failure for testing the automatic starting and stopping of the engine.

5-1-D-3-2 Control Panel

The control panel shall be base frame, wall or floor mounted as specified and the construction and components shall generally comply with related section of this Specifications.

Unless otherwise specified the control panel shall be equipped as detailed below:

a. Generator outgoing unit:

A three pole and neutral molded case circuit breaker with overload and short-circuit protection for control of the generator output. The overload setting range shall be 0.7 to 1.0. The short-circuit setting range shall be 2 to 4 times the generator rated current.

b. Indicating instruments:

- Phase ammeters or ammeter with phase selector switch
- Voltmeter with phase selector switch.
- Wattmeter
- Frequency meter

c. Control switches:

- Hand/Auto/Off
- Test(Simulate mains failure)/Normal
- Engine heater(s) supply On/Off
- Generator anti-condensation heater supply On/Off

d. Push-buttons:

- Engine Start/Stop
- Engine Emergency Stop

e. Hand regulating controls:

- Engine speed
- Generator voltage

f. Indicator lights:

- Main supply available
- Standby supply available

g. Alarm annunciators:

- Engine failed to start
- Engine high cooling water temperature
- Engine low lubricating oil pressure
- Engine overspeed
- Engine underspeed
- Generator voltage high
- Generator voltage low
- Generator circuit-breaker auto trip
- Fire detection system operated
- Emergency stop operated

- Battery charger failed
- Daily service tank low level
- Daily service tank low overflow
- Fuel transfer pump fault

5-1-D-3-3 *Automatic Mains Failure Control System*

The control system shall initiate the automatic generating set start-up and shut-down sequences as described below. The controls shall be designed to operate on an "energize to run and "de-energize to stop" basis.

5-1-D-3-4 *Automatic Startup and Shutdown*

With the engine control selection switch in the AUTO position, the control system shall operate as follows:

- On loss of main supply and after a preset adjustable time delay of 0-10 seconds, engine starting shall be initiated via a mains failure relay located in the incomer unit of the associate switchboard. Concurrent with the starting of the engine the inlet and outlet air louvers shall be opened.
- The engine cranking sequence shall comprise a maximum of three 10 second periods. The control system shall provide facilities for adjusting both the number and duration of the cranking sequence.
- On the generating set reaching full speed and voltage, and after a preset adjustable time delay of 0-5 seconds, automatic switchgear changeover from mains to generator supply shall be initiated.
- Upon restoration of mains power supply, a minimum period of 10 seconds shall elapse before a signal is given to initiate the automatic switchgear changeover back to mains supply and to stop the generator. Delayed stop timer setting to be adjustable 0 - 3 min.

5-1-D-3-5 *Simulated Mains Failure Test Facility*

The facility shall permit the testing of the generating set automatic start-up sequence under a simulated main supply failure condition. With the test facility switch in the SIMULATE MAINS FAILURE position the automatic start-up sequence shall be initiated. The engine shall be stopped by returning the switch to the OFF position.

5-1-D-3-6 *Engine Lock-Out*

The engine shall automatically stop and lock-out under the following conditions:

- Engine failed to start
- Engine high cooling water temperature
- Engine low lubricating oil pressure

- Engine overspeed
- Engine underspeed
- Generator voltage high
- Generator voltage low
- Generator circuit breaker auto trip
- Fire detection system operated
- Emergency stop operated
- Daily service tank low level

Alarm and lock-out systems shall be inhibited during normal starting and stopping operations.

Restarting of the engine shall be prevented until the alarm has been reset.

5-1-D-3-7 Emergency Stop

The emergency stop shall operate in all control modes.

5-1-D-3-8 Auxiliary Contacts

Voltage free changeover contacts shall be provided for remote indication of the operational status and fault alarm indications.

5-1-D-3-9 Fire Detection System

Unless otherwise specified a fire detection system shall be installed above the generating set. The system shall comprise fusible links and tensioned operating wires.

Link fusing shall initiate the operation of the engine fuel supply fire valve, daily service tank jettison fire valve when fitted and switches for initiating engine lock-out, remote alarm and, when installed, fuel transfer pump stop.

5-1-D-4 FUEL OIL SYSTEM

A complete fuel oil system shall be provided. It shall comprise steel storage tanks.

A single line scheme diagram of the system shall be submitted and of a form suitable for permanent display in the generator building.

An accurate fuel oil meter shall be inserted in feed from the tanks to the engines. Meters shall be in such a position to be readily readable.

Two filters shall be provided in the main fuel oil supply line with by-passes enabling one filter to be taken out and cleaned without interrupting the supply of oil through the other filter.

The whole of the fuel system shall comply with the requirements of painting and metal protection, finished color as instructed by the Engineer.

5-1-D-4-1 Storage Tanks

Each engine shall be provided with a free standing tank with capacity as specified and shall be provided with the following fittings:

a. Air vent of not less than 50 mm diameter.

b. Overflow piping of not less than 150% percent diameter of the fuel delivery line.

c. Cleaning handhole and cover of not less than 300 mm diameter.

d. Contents gauge graduated in Arabic and English to read "Full - 1/2 full - empty". The gauge shall be of the magnetically operated type and shall be complete with low and high level control contracts.

e. Outlet connection to engine not less than 50 mm above tank base.

f. Fuel outlet isolating valve lockable in open position.

g. Drain plug.

h. Excess fuel return connection if necessary.

i. Inlet connection from bulk fuel supply system including pipework and connections.

There shall be allowed a minimum of 10% percent of the volume of the tank contents as ullage. The top oil level of the tank shall not be less than 75 mm from the top of the tank.

Tanks prior to dispatch from manufacturers works shall be tested hydraulically to a pressure 0.5 bars.

Tanks shall be complete with all supports and fixing bolts for mounting remote from engine base or skid mounted tanks will not be accepted.

There shall be provided all necessary fuel oil pipework, unions and valves between the day tank and the engine.

Fuel connecting pipework to engine shall be seamless steel and all pipes shall incorporate flexible section, if not less than 250 mm long (plastic pipes or fittings are not acceptable).

5-1-D-4-2 Warning and Safety Devices

The following warning notice shall be supplied and fixed in a prominent position in the vicinity of each bulk fuel tank with 50 mm plain block black letters on a yellow background, printed in Arabic and English.

NO SMOKING

DIESEL FUEL - HIGHLY INFLAMMABLE

Additional notices shall be provided in accordance with the labels signs and notices requirements. The wording of the notices shall be subject to the Engineer's approval.

5-1-D-4-3 Fire Cut-off Valves

Fire cut-off valves shall be incorporated in the fuel delivery pipe to each engine from the daily service tank and be located in an accessible horizontal position, coil uppermost, close to the tank.

The valves shall be manually operated and solenoid maintained in accordance with BS 799 Part 7, the solenoid will be arranged to release in the event of a fire signal. The emergency handle shall be labeled with a conspicuous permanent notice reading:

"FIRE VALVE-PULL LEVER DOWN TO ISOLATE FUEL SUPPLY.

LIFT TO RESET".

Where specified, a dump valve shall be fitted in the pipeline immediately beneath the daily service tank so that the tank contents can be returned by gravity head to the bulk storage tank or a suitable external dump tank in the event of a fire signal. Electrically operated valves shall open when the operating solenoid is de-energized.

5-1-D-4-4 *Steelworks*

The following steelwork shall be provided and fixed in accordance with metal protection and painting requirements.

a- Support frames and access platforms for fuel storage tanks.

b- All necessary pipe supports.

c- All ancillary brackets, clamps, etc.

5-1-D-4-5 *Pipework*

All fuel pipes and fittings shall be of seamless stainless steel, all valves shall be cast steel, and designed for the duty they are required to perform. Galvanized pipework and fittings shall not be used for any line handling fuel. All pipework shall be fully supported and complete with all brackets and fixings.

Pipework installations shall be carried out for the various items of plant, equipment and shall include:

a. All pipework and valves from the bulk storage tanks to the daily storage tanks and filling point.
b. For the bulk storage tanks.
    i. 1No. easily cleaned filter.
    ii. 2 No. shut off hand operated valves (one each side of filter).
c. The main fuel line from the bulk storage tank installation shall be fitted with fail safe quick closing emergency valve with replaceable fusible link arrangement to shut fuel off in event of fire. The operating temperature of the heat sensitivity element shall be 93°C.
d. One complete set valves for each set of fuel transfer pumps comprising suction and delivery isolating valves, non-return valves and pressure relief valve with return pipe.
e. Overflow pipework and fittings from each daily tank to the bulk storage tanks.
f. The pipework installation shall comply with the general protection requirements. Finish color shall be as instructed by the Engineer.

5-1-D-4-6 Stop Push Button Stations

Local "Emergency Stop" push button stations shall be provided.

Each generator set shall be provided with 1 No. emergency stop push button station, suitably positioned at the end of the generator set assembly.

5-1-D-5 WEATHERPROOF AND SOUNDPROOF ENCLOSURE

The enclosure shall be removable pre-fabricated type designed to reduce the noise level by approximately 20 dB(A).

The enclosure shall be of weatherproof construction suitable for unprotected outdoor installation.

The enclosure shall incorporate access doors or panels such that routine maintenance can be carried out without removing the entire enclosure. It shall be possible to remove the enclosure without disconnection of the silencer mounted outside the enclosure. The operating sound pressure level of the set, measured in accordance with BS 4196 at a distance of 3 meters, with the exhaust silencer and the noise attenuating enclosure in position, shall be as elsewhere specified.

The Tenderer shall state, the predicted sound pressure level of the plant under the specified operating conditions, with and without the noise attenuating enclosure fitted.

5-1-E OUTDOOR POLE-MOUNTED POWER TRANSFORMERS

5-1-E-1 POLE AND PLATFORM

Mounting pole and platform shall strictly conform to EDL requirements and standards. The Contractor shall submit shop drawings for pole and platform to EDL for approval.

5-1-E-2 FLUID FILLED TRANSFORMERS

5-1-E-2-1 General

Outdoor pole-mounted transformer shall be to EDL specification and subject to EDL approval.

5-1-E-2-2 Standards

Fluid filled power transformers shall comply with IEC 76, 354, 404-2-and 606.

5-1-E-2-3 Characteristics:

– Rated power (net without fans)	:	As indicated
– Frequency	:	50 Hz
– Rated voltage		
MV side (primary)	:	As indicated
LV side (secondary)	:	400 V
– Impedance voltage al rated current	:	5%
– Rated power frequency withstand voltage	:	50 kV
– Lightning impulse withstand voltage	:	125 kV
– Short-circuit apparent power of the system at location	:	500 MVA
– Duration of short-circuit withstand	:	two seconds

5-1-E-2-4 Service Conditions

Transformers shall be designed for continuous load duty at full rated output under maximum site ambient conditions.

5-1-E-2-5 Dielectric Fluids

Unless otherwise specified, the dielectric fluid shall be mineral oil, non-PCB type.

Low-flammability fluid shall be synthetic silicone or ester based as specified.

5-1-E-2-6 Cooling Method

Unless otherwise specified the cooling method shall be natural oil and air circulation.

5-1-E-2-7 Tanks and Radiators

Tanks shall be fabricated from mild steel sheet and shall be provided with a skid type base. The tank shall be constructed to prevent distortion when the complete transformer is lifted, jacked or transported.

Unless otherwise specified, mineral oil filled transformers shall be of the free breathing type and shall be fitted with a dehydrating breather. Synthetic fluid filled transformers shall be of the sealed type.

Tank covers shall be designed and constructed to prevent the accumulation of water.

Cooling radiators shall be of the detachable pressed steel panel type or corrugations on the tank side as dictated by the transformer rating and design. Tanks with corrugated sides shall have strengthening bars to provide rigidity and mechanical strength.

Surfaces shall be grit blasted, caustic washed and phosphatized, primed with waterproof primer and finished with weather-resistant enamel and final coat of air-drying enamel. Alternative finish may be used subject to approval.

5-1-E-2-8 Cores

Cores shall be manufactured from laminations of cold rolled, low loss and grain orientated electrical sheet steel.

Each lamination shall be coated on both sides with insulation which shall be unaffected by mineral oil or other dielectric fluid and continuous operation at the design temperature of the transformer.

The core shall be of interleaved construction with mitred or step-lap mitred construction, and shall be designed to provide uniform flux distribution throughout the magnetic circuit and minimize flux saturation at corner joints.

The core limb laminations shall be held in compression by heavy-duty cotton tape, bands or bolts depending on core size.

Top and bottom yoke laminations shall be clamped between steel channel sections, plates or folded steel clamps. The top and bottom channels, plates or clamps shall be secured to each other by means of steel tie rods to eliminate tensile stress in the core limbs when the core and windings are lifted.

5-1-E-2-9 Windings

High and low voltage windings shall be manufactured from high conductivity copper. Conductors shall be insulated with high quality paper or synthetic varnish according to design requirements. Insulation levels shall comply with BS 171 Table II List 1 unless otherwise specified.

High voltage windings shall be of the layer or disc type depending on voltage and application. Low voltage windings shall be of the helical layer type. Windings shall be constructed and braced to withstand the forces arising under short circuit conditions without deformation or movement.

Tapping and phase leads shall be insulated and shall be rigidly braced and supported to prevent movement under short-circuit conditions. Barriers shall be provided between phase and tapping leads.

Three-phase distribution transformers shall be connected delta-star, connection symbol DYn11, unless otherwise specified.

5-1-E-2-10 Tappings

Tappings shall be positioned to minimize voltage stress and to maintain electromagnetic balance of the windings as far as possible over the tapping range.

5-1-E-2-11 Off-Circuit Tap Changing

Unless otherwise specified, transformers shall be fitted with an off-circuit tap changing facility having a tapping range plus and minus 2.5% and 5% of nominal supply voltage. Tap selection shall be by means of an externally operated self-positioning switch.

Provision shall be made for the locking of the tapping switch handle in each position by means of a padlock having a 7mm diameter shackle.

The tap position shall be clearly marked.

5-1-E-2-12 Cable Bushings

Bushings shall be porcelain, mounted on tank cover, with arcing horns on MV side (if not enclosed). Side bushings-for flanged and enclosed connections or plug-in bushings shall be provided for terminal connections as required or as shown on the Drawings.

5-1-E-2-13 Conservators

Mineral oil filled transformers for rated voltages above 11 kV shall be fitted with an oil conservator. Transformers of rated voltage 11 kV and below shall be fitted with a conservator when specified.

Conservators shall be manufactured from sheet steel and shall be positioned above the highest point of the oil circulating system. Connections into the main tank shall be at the highest point to prevent air or gas becoming trapped under the main tank cover.

The capacity of conservators shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservators shall be complete with filling point, drain valve with captive cap, oil level gauge, silica-gel type dehydrating breather and provision for access for cleaning. The breather shall be mounted at a height of approximately 1.5 m above ground level. The pipe between the conservator and main tank shall be fitted with a valve.

All valves shall be of the gate type, and have provision for locking in the closed and open positions.

5-1-E-2-14 MV Switch Disconnector

Pole-mounted transformer shall be equipped with an MV switch-disconnector.

MV switch-disconnector is to be of the general purpose, 3-pole, load break, short-circuit make, Category B to IECC 265.

– rated normal current: to EDL requirements

– rated short circuit making capacity (peak): equal to rated peak withstand current

5-1-E-2-15 Standard Fittings

The following standard fittings shall be provided:

a. Diagram and connection plate.

b. Lifting lugs.

c. Earthing terminal.

d. Liquid level indicator.

a- Pressure relief device with N.C. trip contact.

e. Drain valve.

f. Thermometer pocket.

g. Padlocks.

The following fittings shall be provided as applicable:

a. Filling hole and cover.

b. Plain breathing device of weatherproof design.

c. Pressure bleed device.

5-1-E-2-16 Optional Fittings

One or more of the following optional fittings shall be provided when specified:

a. Gas and oil surge (Buchholz) relay.

b. Winding temperature indicator.

c. Dielectric fluid temperature indicator.

d. Dehydrating breather.

5-1-E-2-17 Gas and Oil Surge (Buchholz) Relay

Gas and oil actuated (Buchholz) relays shall be located in the pipework interconnecting the main and conservator tanks. The pipe shall be inclined at an angle recommended by the relay manufacturer.

Relays shall be provided with a test cock suitable for the attachment of a flexible pipe for checking operation and main tank side isolating valve. The valve type shall be as specified for the conservator.

Relays shall be fitted with contacts which close on collection of gas or low oil level for alarm initiation and contacts which close on oil surge for circuit breaker trip initiation.

5-1-E-2-18 Winding Temperature Indicator

Winding temperature indicators shall be of the dial type and shall incorporate two sets of adjustable voltage-free changeover contacts for the initiation of remote alarm and trip signals.

5-1-E-2-19 Dielectric Fluid Temperature Indicator

Dielectric fluid temperature indicators shall be of the dial type and shall incorporate two sets of adjustable voltage-free changeover contacts for the initiation of remote alarm and trip signals.

5-1-E-2-20 Dehydrating Breathers

Dehydrating breathers shall be of the silica-gel cartridge type constructed from heat resistant glass tubing with strong metal shield. The whole assembly shall be constructed to form a robust and durable unit.

5-1-E-2-21 Pressure Relief Device

Pressure relief devices shall incorporate a color coded mechanical indicator pin and a sealed, weatherproof changeover switch assembly.

5-1-E-2-22 Drain Valves

Drain valves shall be of the gate type with non-rising spindle. Provision shall be made for padlocking the valve in the fully closed position.

Drain valves fitted to mineral oil filled transformers shall be fitted with a plug.

5-1-E-2-23 Padlocks

Padlocks for all valves and tapping switch handles shall be provided.

Padlocks shall be of the brass cylinder type with non-rusting hardened shackle. Each padlock shall have a different key number.

Two keys shall be supplied with each padlock.

5-1-E-2-24 Rating and Connection Plates

Rating and connection plates shall be securely fitted to the transformer. The plates shall be of non-corrodible and durable material.

5-1-E-2-25 Painting

As soon as practical after shot blasting or zinc spray treatment, the exterior of steel tanks, radiators and conservators shall be given one coat of high build priming paint. Two coats of durable and weather resistant paint, of contrasting color, shall be subsequently applied. The paint shall be resistant to the dielectric fluid.

The paint coats shall be applied by a combination of spraying and flood coating to ensure complete coverage of all external areas.

Unless otherwise specified, the finish color shall be the manufacturer's standard.

5-1-E-2-26 Noise Level

Noise level in general shall be less than 76 dB at 0.3 m for ratings up to 1600 kVA and 69 dB for ratings up to 630 kVA, and in accordance with IEC 551.

5-1-F ELECTRIC ACTUATORS

5-1-F-1 GENERAL

Electric actuators shall be suitable for outside installation and all components shall be housed in waterproof enclosures to IP67 or better, which shall incorporate an anti-condensation heater.

The whole actuator shall be of easily maintained, robust construction and shall be sized to guarantee the penstock or valve opening or closing at the maximum differential pressure specified herein. The operating speed shall be approximately 300mm/minute unless otherwise specified.

All actuator component items shall be coupled via flanged mating faces secured by stainless steel bolts, except valve mounting fixings subject to thrust forces which shall be by means of suitably sized, high tensile steel bolts.

The gearbox shall be of the worm gear totally enclosed, oil bath lubricated type, having a cast iron enclosure suitable for operating at any angle and provided with the appropriate filling and drain plugs. The actuator drive bushing shall be easily detachable for machining to suit the valve stem or gearbox input shaft and the length of the drive nut shall not be less than 1.25 x the spindle diameter.

The drive shall incorporate a lost motion feature to provide the additional torque required to unseat the valve from the “Open” or “Closed” position in the event of the valve being in either position for an extended period. This movement shall give a hammer blow of sufficient force to free the valve.

The output shaft shall be hollow to accept a rising spindle where appropriate, and incorporate thrust bearings of the ball or roller type. The design shall preferably permit the gear case to be opened for inspection without releasing the spindle thrust or taking the penstock/valve out of service.

5-1-F-2 MOTORS

All motors fitted to actuators shall be specially designed for the application and of the squirrel cage induction type for operation from the Power supply system of 220 VAC $\pm$ 5%, 50 Hz.

The rated output of the motors shall be determined by the tenderer in relation to the requirements of the mechanical plant described elsewhere in this specification, and starting torque shall be at least 10% in excess of maximum service requirements. The intermittent running load factor shall be 25% in accordance with VDE 530.

The motors shall preferably be 4 pole 1440 revs/minute machines designed with adequate thermal capacity to ensure that the actuator and starter can adequately perform, without overheating, the number of successive opening and closing operations, in no case shall this number be less than three.

Each motor shall be fitted with a thermostat or thermistor per phase arranged to stop the motor in the event of dangerously high temperature in the motor windings due to overcurrent or an abnormally high number of starts per hour.

5-1-F-3 MANUAL OPERATION INTERLOCK

The actuator shall have a handwheel for manual operation which will be at standstill during motor operation. A lever shall be provided for engaging the handwheel drive, and this shall be interlocked so that when starting the motor the handwheel is automatically uncoupled without danger to the operator. Provision shall be made for the lever to be padlocked in either position to prevent hand or motor operation as required.

5-1-F-4 POSITION MONITORING

A mechanical position indicator, showing the open, closed or intermediate positions of the valve on a visible dial, shall be incorporated in the actuator housing. Alternatively, where specified, a continuous position indicator shall be provided.

Remote position indicators, where specified, shall be controlled from a suitable potentiometric drive arranged to provide a continuous proportional signal from “Open” to “Closed” positions.

5-1-F-5 POSITION CONTROL

Where specified for control purposes, a current position transmitter shall be provided to give a positive 4-20mA signal proportional to the valve position, and shall incorporate zero and span adjustments to suit the actual valve travel.

5-1-F-6 TORQUE AND LIMIT SWITCHES

All switches shall be accommodated within the actuator housing and all contacts and mechanism shall be of sealed, rustproof and robust construction and have a self-cleaning wiping action. Adjustable torque limiting devices and switches shall be provided to trip the starter in the event of mechanism overload due to obstructions or jamming etc. They shall be mechanically latched to prevent torque tripping during unseating.

Adjustable limit switches shall be arranged to trip the starters when the `fully open' or `fully closed' positions are reached. Should the manufacturer consider it desirable (to ensure proper seating) the travel may be stopped in the “fully closed” position by the torque limit switches, but in this case the `fully closed' limit switches shall still be provided, although they will be adjusted to be inoperative.

The actuator shall be equipped with two independent torque limit switches operating in both rotational directions.

5-1-F-7 AUXILIARY SWITCHES

Two adjustable auxiliary switches shall be provided. They may be used for remote controls or indications monitoring the “Open” and “Closed” positions.

5-1-F-8 TERMINAL FACILITIES

All electrical components shall be wired out to terminal blocks in a common terminal chamber incorporated in the actuator housing but separated from all actuator components by means of a watertight seal.

Each terminal shall be labeled to correspond with the diagram of connections and shall be capable of accommodating not less than $2.5mm^2$ copper conductors. AC and DC terminals shall be clearly segregated.

Terminal blocks shall comprise shrouded anti-tracking moldings of melamine phenolic or comparable material with provision for securing conductors by screw clamp connectors or other approved vibration-proof devices.

The terminal chamber shall be provided with three tapped conduit entries, 1 x 32mm ET and 2 x 25mm ET or as otherwise specified. These holes shall be plugged with suitable plugs during transit and storage to prevent ingress of moisture or foreign matter.

Any conduit entries not used after cabling is completed shall be plugged with threaded aluminum blanks and the threaded joints made watertight by using suitable tape or jointing compound.

5-1-F-9 STARTERS AND CONTROL GEAR

Where motorized valves are installed far from pumping stations or reservoirs and the provision of a control panel is impractical, the actuator motor shall be controlled through integrally mounted electrically and mechanically interlocked contactors rated for switching the motor direct-on-line, adequate for the duty requirements and complete with all necessary auxiliary contacts for the functions specified herein.

The control circuit shall operate at 24V DC derived from a suitably rated transformer/rectifier with one side of the secondary winding connected to earth or as otherwise specified. Primary and secondary windings shall be protected by cartridge type fuses.

The method of control and operation shall be as called for in the PS and the actuator shall be provided with any facilities called for therein to suit the method of control, whether this be automatic or by hand. Local controls integrally mounted on the actuator shall consist of push buttons for `Open', `Close' and `Stop' functions, together with a Remote/Off/Local selector, lockable in all positions. The "Stop" button shall be effective in both local and remote settings and operate directly in the contactor control circuit.

Local and remote status indications (ON, OFF, FAULT, CLOSE, OPEN) shall also be provided.

Facilities by means of volt-free contacts shall be provided for remotely monitoring:

a. motor running
b. actuator is available for remote operation
c. actuator opened and actuator closed.

Wherever motorized penstocks and valves are specified, they shall be provided with adequately rated starters. The starter shall be integrally housed within the actuator in a robustly constructed, totally enclosed weatherproof housing. The motor starter shall be capable of starting the motor under the most severe conditions.

The starter housing shall be fitted with contacts and terminals for power supply, remote control and positional indication, and shall also be fitted with internal heaters to provide protection against damage due to condensation. Heaters shall be suitable for single phase operation. The heaters shall be switched to "ON" when the starters are "OFF" and shall be switched "OFF" when the starters are "ON".

Starters for motorized actuators shall be equipped with a thermal overload relay and unless otherwise specified, starters shall include an integrated controller (PLC) with an RS 422/485 output allowing remote operation and data acquisition through a twisted pair bus.

5-1-F-10 PAINT FINISH

The finish color shall be full gloss, Crimson, Color No. 540 to BS 381C (or 04 D 45 to BS 4800).

5-1-F-11 ACTUATOR ISOLATORS

Unless otherwise specified, motorized actuators shall have an isolator switch. The switch shall have a slow make and break mechanism of the two position rotary pattern arranged to isolate the 3 phase supply and all other control circuit supplies to the actuator. The isolator rating shall be based on the actuator average load current being switched normally off-load, but emergency on-load.

Each switch shall be incorporated in a heavy duty, hose-proof, cast aluminum enclosure to IP65, having external fixing lugs and adequate seals and drip shields on the operating shaft and cover. Austinlite rotary type EXO 190 or equal.

Switch positions shall be 90° apart, clearly and permanently inscribed or embossed as `OFF' and `ON' on the cover, and the switch handle shall incorporate provision for the switch to be padlocked in both the `OFF' and `ON' position. The `OFF' position to be to the left of center or vertical, the `ON' position to the right or horizontal.

It shall be possible to remove the switch cover for access to the terminal without disturbing the switch or its mounting base. The enclosure shall be suitable for mounting on, or adjacent to, the penstock pedestal. If mounted on the penstock pedestal, cabling between the isolator and the actuator above may be arranged through conduit connections, suitable for disconnection should it be necessary to remove the actuator assembly complete.

(This item preferably to be provided by the contractor who is responsible for the cabling.)

5-1-G LOCKS & KEYS

5-1-G-1 GENERAL

Lockable selector switches or panel doors in a multi-unit installation shall employ a common interchangeable operating key but keys for each function may be non-interchangeable, subject to the approval of the Engineer.

For each key pattern employed, three keys shall be provided; each having a permanently attached brass identification label, embossed with the following:

a. key number
b. location of lock/item of equipment ref.

Loose padlocks and keys for security locking switchgear, isolators, shutters etc. shall not be included but will be provided by the Client to suit their master key suite for permit locking. Hasps shall have not less than 9mm diameter holes suitable for 6mm diameter shackles.

5-1-G-2 Padlocks

Padlocks shall be provided for independently securing busbars and circuit shutters in the closed position and also for locking each circuit breaker or switch in the open position. A padlock and key, or similar device, shall be provided to lock each circuit breaker closed when in the earth position. Padlocks and keys shall also be provided to lock any isolator and earthing device handles in either the open or closed position, such that the mechanism is inoperative unless the locks have been removed. All padlocks in any station shall take the same key.

Glass fronted lockable key boxes, with labeled hooks, shall be provided for each switchboard.

5-1-G-3 Key Cabinets

Key cabinets shall be provided to accommodate, on suitably numbered/colored, adjustable hook bars, one set of all the above keys and padlocks. The keys shall be fitted with corresponding number/color coded tabs. The cabinets shall be of stove enameled sheet steel material, suitable for surface wall mounting and be fitted with lockable hinged cover doors.

5-1-H TESTING

5-1-H-1 POWER TRANSFORMERS

5-1-H-1-1 Tests at Manufacturers' Works

Tests shall be carried out to demonstrate compliance with the specified functional and performance criteria.

Unless otherwise specified, the tests shall be Routine Tests in accordance with the Reference Standards.

Type or other special tests shall be carried out when specified.

5-1-H-1-2 Tests at Site

Transformers shall be inspected prior to testing for:

a. Damage sustained during transportation and erection, particularly damage which might have caused moisture ingress into the tank of a liquid immersed transformer.

b. Oil leaks.

c. Satisfactory condition of dehydrating breather silica-gel charge.

d. Tightness of HV and LV connections.

e. Continuity and tightness of earthing conductors.

f. Contamination of bushings.

Unless otherwise specified, the following tests shall be carried out before energization:

a. Insulation resistance between core and tank or enclosure, HV to LV , HV to earth and LV to earth using a megger. The duration of the tests shall be not less than one minute from the time the megger reading becomes constant.

b. Measurement of magnetizing current.

c. Correct calibration of temperature measuring instruments and operation of alarm and trip initiating contacts.

d. Electric strength of the insulating oil.

e. Correct operation of Buchholz relay floats and operation of alarm and trip initiating contacts.

5-1-H-2 SWITCHGEAR AND CONTROLGEAR

5-1-H-2-1 Tests at Manufacturers' Works

Tests shall be carried out to demonstrate compliance with the Reference Standards and the specified functional and performance criteria.

Unless otherwise specified, the tests shall be Routine Tests in accordance with the Reference Standards and the following additional tests as appropriate to demonstrate:

a. The interchangeability of withdrawable equipment.

b. The correct operation of electrical and mechanical interlocks.

c. The correct functioning of current and voltage operated protection relays by primary and secondary current injection and voltage application.

d. The correct polarity between current and voltage elements of power operated protective devices, instruments and metering.

e. Meters do not creep with the removal of either the current or voltage supply.

f. The correct operation of control circuits, indications and alarms. Where necessary a suitable test panel shall be provided for simulation of external controls and signals during such tests.

g. The calibration of ammeters at 0.25, 0.5 and full scale deflection by secondary current injection.

h. The calibration of voltmeters.

Type and special tests shall be carried out when specified.

5-1-H-2-2 Tests at Site

The following tests shall be carried out as appropriate:

a. Insulation resistance of main connections and secondary wiring using an approved insulation tester. The test shall be carried out between phases and phase to earth. All circuit-breakers, switches and contactors shall be in circuit and closed.

b. The correct operation of electrical and mechanical interlocks shall be demonstrated.

c. The correct operation of current and voltage operated protection relays shall be demonstrated by primary and secondary current injection and voltage application.

d. The stability of unit protection systems shall be demonstrated by primary current injection.

e. The correct operation of control circuits, indications and alarms shall be demonstrated.

f. The continuity of all protective conductors shall be checked.

g. The correct operation of intertripping circuits shall be demonstrated.

h. Any tests required by the electricity supply company.

5-1-H-3 ELECTRIC MOTORS

5-1-H-3-1 Tests at Manufacturers' Works

Motors shall be inspected and tested to show that they are fully compliant with the specification and approved drawings.

Tests shall be carried out in accordance with BS 4999:Part 143. For low voltage standard production motors for general use, the tests shall be routine check. For high voltage and low voltage motors for main drive application, the tests shall be duplicate.

If the test to determine the locked rotor current of cage induction motors is carried out at reduced voltage, allowance shall be made for the effect of saturation when adjusting for rated voltage. The estimated value of locked rotor current at rated voltage shall be stated on the test certificate.

A Polarization Index test shall be carried out for high voltage motors.

The requirement for "basic" or "special" tests shall be as specified.

5-1-H-3-2 Tests at Site

Each motor shall be inspected prior to testing for:

a. Absence of damage during transportation and erection.
b. Absence of moisture or other contamination.
c. Ventilation openings and drain holes are free of debris.
d. Cable glanding and core terminations for tightness and identification.
e. Free rotor rotation.

Unless otherwise specified the following tests shall be carried out on each motor before energization:

a. Winding insulation resistance.
b. Polarization Index for medium voltage motors.
c. Insulation resistance between windings and ancillary devices.
d. Calibration of winding and bearing temperature monitoring devices and the operation of alarm and trip initiating contacts.
e. Continuity and resistance of winding thermistors.
f. Bearing insulation integrity.
g. Any other tests recommended by the manufacturer or stipulated in the Reference Standards.

On the satisfactory completion of the inspection and tests listed above, motors shall be energized to check for correct direction of rotation and that vibration levels are within the specified limits. The tests shall be carried out with the motor uncoupled from the driven plant.

5-1-H-4 DIESEL GENERATING SETS

5-1-H-4-1 Tests at Manufacturers' Works

The following tests shall be carried out:

a. Routine tests as stipulated in the Reference Standards.
b. Tests to verify the specified governor and automatic voltage regulator performance. For (b) the Contractor shall record the tests on an oscillograph.

5-1-H-4-2 Tests at Site

The generating set and ancillary equipment shall be inspected prior to testing for:

a. Compliance with the Specification.
b. Damage during transportation, off-loading, storage and erection.
c. The presence of lubricating oil, fuel oil and cooling system leaks.
d. The fitting of all protective safety guards and warning labels.
e. The correct termination of power and auxiliary cables.
f. Continuity and tightness of earthing connections.

The following tests shall be carried out:

a. Generator winding insulation resistance between phases and earth.
b. Generator phase rotation to check that it is the same as the main supply.
c. Functional to prove the correct operation of all protection devices, alarms, status indications and controls.
d. A simulated mains failure. This test shall not use the control panel mounted test facility.
e. Load test, which unless otherwise specified, shall be carried out using the available site load. The duration of the load test shall be:
   - Rating up to and including 100kW : 1 hour
   - Rating from 101kW and up to 750kW : 2 hours
   - Rating above 750kW : 4 hours

Should the available site load be less than 25 percent of the generating set rating, the duration of the test shall be reduced to a period to be agreed with the Engineer.

Part IV: Mechanical Works

Part V-2: CABLING & EARTHING INSTALLATIONS

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PART 5.2 - ELECTRICAL WORKS: CABLING

5-2-A CABLES AND WIRES

The electrical installation shall comply with the current edition of the Regulations for Electrical Installations published by the Institution of Electrical Engineers (IEE Wiring Regulations) and the requirements specified herein where these differ from the IEE Wiring Regulations.

Cables and wires shall be supplied from an approved manufacturer and where possible the same manufacturer shall be used for all cables and wires. Each drum or coil of cable shall be accompanied by a certificate stating the manufacturer's name, rating of cable, result and date of tests.

All cables shall be delivered with cable ends effectively sealed. When a cable is cut from a drum, both ends shall be immediately sealed to prevent ingress of moisture.

Cables and wires shall be adequately rated for current carrying capacity under normal and short time fault conditions at the specified voltage.

Assessing the rating and cross section of any cable or wire shall be in accordance with IEC 287 and shall take into account, the following factors:

a. Maximum voltage drop permissible.

b. Type and magnitude of load.

c. Fault level and duration related to circuit protection.

d. Overcurrent setting of relays.

e. Route length and disposition of cables.

f. Ambient temperature.

g. Method of laying.

Cable sizing with respect to system voltage depression shall be based on the following parameters, unless otherwise specified.

Cable sizes in conjunction with electrical plant operating characteristics shall ensure the maximum circuit volt drops are not greater than:

a. Main feeder cables to and between system switchboards at rated circuit current: - 1%

b. Feeder circuits from control switchgear and panels to terminal equipment at rated load current: - 2%

c. The transient voltage depression at the started motor terminals is not greater than: 10%

d. The transient voltage depression at the busbars of any power system switchboard does not exceed: 5%.

Transient voltage drops for motor starting conditions shall include the dynamic loading of all running plant.

Cable schedules shall be submitted for approval detailing ratings, sizes, lengths, method of installation and function of all individual cables and wires.

5-2-B CABLE CONDUCTORS

Cable conductors shall be plain annealed copper.

Low voltage three phase and neutral power cables shall not incorporate a reduced neutral conductor.

5-2-C CABLE TYPES

5-2-C-1 GENERAL

The following specified standards indicate the types of cables which shall be used; if a Contractor wishes to use cables to an alternative standard then such cables shall be of equivalent standard and details of the cables their construction, current carrying capacity, derating factors, etc, shall be submitted approval.

5-2-C-2 POWER CABLES

Power cables shall comply with the following:

a. XLPE/SWA/PVC type comprising, semi-conducting conductor screen, cross linked polyethylene insulation, stranded copper conductors, core screen of semi-conducting compound, semi-conducting tape, and metallic layer, extruded PVC bedding, galvanized steel wire armored, red polyethylene sheathed overall, suitable for use on medium voltage earthed systems up to 11.5/20kV or as otherwise specified. Cables shall comply with BS 6622, IEC 502 and IEC 504.

b. XLPE/SWA/PVC type comprising, cross linked low density, polyethylene insulated, stranded copper conductors, extruded PVC bedding, galvanized steel wire armored, black PVC sheathed overall, suitable for use on earthed systems at a rated voltage of 0.6/1kV or1.9/3.3kV. Cables shall comply with BS 5467.

c. PVC/SWA/PVC type comprising, PVC insulation, extruded PVC bedding, galvanized steel wire armored, black PVC sheathed overall, stranded copper conductors suitable for operation on a system at a rated voltage of 0.6/1kV. Cables shall comply with BS 6346. Non-magnetic armor of hard drawn aluminum wire shall be used on single core cables. Installation of the above cables shall be direct in the ground, in underground ducts or clipped direct to a surface or cable tray.

d. PVC/PVC type comprising PVC insulated, extruded PVC bedding, PVC sheathed overall, stranded copper conductors suitable for operation on a system at a rated voltage of 0.6/1kV. Cables shall comply with BS 6346. Installation of unarmored cables shall be in enclosed floor ducts or conduits.

e. PVC type comprising, PVC insulated single core copper conductor rated at 450/750 V. Cables shall comply with BS 6004. Insulation shall be phase colored. Installation shall be in conduit or trunking.

f. Flame retardant cables shall be EP rubber insulated, tinned copper conductors in a CSP sheath, braided with galvanized steel wire (single cores having phosphor bronze wire) and protected with a CSP sheath overall, generally in accordance with BS 6883. The sheathing shall have heat and oil resisting characteristics to BS 6899 with an oxygen index value not less than 35 (HOFR type).

5-2-C-3 CONTROL CABLES

Multicore control cables shall be of the PVC insulated type having a rated voltage 600/1000V. PVC type cables shall comply with BS 6346.

The above control cables shall be used for general plant control, protection, and monitoring signal functions.

Control cables shall be armored for installation direct in the ground, in underground ducts or clipped direct to a surface or cable tray.

Unarmored control cables may be used where installed in enclosed floor ducts or in conduit.

Control cables for analogue and digital signal measurement, control, and monitoring systems shall be as detailed in the related section.

5-2-D CABLE INSTALLATION

5-2-D-1 GENERAL

To avoid the risk of damage, cables having PVC insulation and/or sheathing shall not be handled or installed if both they and the ambient temperature is below 0°C.

Care shall be taken to prevent damage to the cable oversheath during installation. Minor sheath damage may be repaired subject to the approval of the Engineer. In the case of major oversheath, damage the whole section of the cable should be replaced.

Cables shall not be bent during installation to a radius less than that recommended by the cable manufacturer. Where practical, larger radii shall be used.

Where cables are run together in the same tray, trench or conduit they shall be suitably derated or spaced to maintain current rating. Crossovers shall be avoided where possible. Power and signal cables shall be run separately to minimize interference.

Cables of up to 40 mm diameter may be fixed with cable ties or PVC coated aluminum strip formed to shape on site.

Cables above 40 mm diameter shall be fixed using correctly sized proprietary cleats. The Contractor shall allow for the best quality components and must ensure adequate supplies are available before commencing installation.

All saddles, cleats, hangers, brackets, trays, ladders, ties, nuts, bolts, screws, washers, ducts, concrete covers, marker tape necessary for a complete installation shall be provided.

Marker tape shall be 150 mm wide, yellow with black printing "DANGER – ELECTRIC CABLES," in languages as specified.

Power Cables shall be installed without tees or through joints unless approved by the Engineer. Cables shall not be installed in areas of direct sunlight. Where this is unavoidable, approved sunshields shall be supplied and installed.

Cable runs with one or more cables exceeding 40 mm in overall diameter shall be supported on galvanized ladders of suitable configuration, width, radius and strength.

Alternatively, cable racking systems may be used, provided unsupported horizontal or vertical spans between rack arms or channels do not exceed those recommended by the cable manufacturer. All steelwork shall be galvanized.

Trays, ladders and rack channels shall be fixed using galvanized steel or heavy duty aluminum alloy brackets. All steel brackets shall be galvanized after forming and drilling. Brackets shall be fixed to concrete or masonry using stainless steel wood screws and plugs for up to 150 mm width tray. All other brackets for wider trays, ladders, racks and channels shall be fixed by expanding concrete anchors.

Fixings to metalwork, where approved shall be by stainless steel machine screws, nuts and washers (up to 4 mm diameter). Larger bolts may be zinc coated or stainless steel. Self-tapping screws shall not be used.

All trays, ladders and racking shall have 20% spare width.

5-2-D-2 ARRANGEMENT OF SINGLE CORE CABLES IN THREE PHASE SYSTEMS

Three phase cable systems comprising two or more single core cables per phase shall be arranged in three phase, that is red, yellow and blue, groups. This is to equalize, as far as practicable, mutual inductance. The three phase groups may be in trefoil or flat formation as dictated by the cable system design. Cables shall not be arranged in groups comprising the same phase.

5-2-D-3 CABLE SPACING

Unless otherwise specified, the minimum space between cables shall be as follows:

Medium voltage	:	50 mm
Low voltage	:	Touching unless current rating considerations dictate otherwise.
Medium and low voltage	:	300 mm
Medium voltage and control	:	300 mm
Low voltage and control	:	150 mm
Medium voltage and instrumentation	:	300 mm
Low voltage and instrumentation	:	150 mm
Control	:	nil

5-2-D-4 DESIGN SUBMISSIONS

Design submissions which should be provided in relation to the cable installation shall include the following:

5-2-D-4-1 Drawings and Schedules

a. Block diagrams to show control cabling systems with each cable and terminal equipment being identified as in the cable schedules.
b. Cable route and layout drawings. For those items which are underground these drawings shall include the following:
   - Route plans for all cables, cable ducts, and cable trenches.
   - Sectional views of all cable ducts, trenches etc. for each different section throughout the route.
   - The position joints, draw pits etc.
c. Route plans and section views for all cable trays and cable runs.
d. Cable schedules, which shall detail the cable number type, voltage, size, route, length, number of cores. Control cable schedules shall detail the connected and spare core numbers, diagram numbers of connected equipment, core ferrule and terminal reference numbers.

5-2-D-4-2 Calculations

Sizing calculations for all power cables.

5-2-D-5 INSTALLATION DIRECT IN THE GROUND

Unless otherwise specified the minimum cover for cables shall be as follows:

Low voltage (up to and including 1000V)	:	600mm
Control and instrumentation	:	600mm
Medium voltage (above 1000V)	:	1000mm

Cables shall be laid on a minimum thickness of 75mm soft fill or sand extending the full width of the trench. After laying cables shall be covered with a further layer of soft fill or sand of minimum thickness 75mm and then protected with concrete tiles extending at least 60 mm over the outer edges of the cables. All cable bedding shall be well compacted.

Where more than one horizontal layer of cables is laid, the level of the upper layer shall be gauged from the bottom of the trench and marked on the side of the trench at regular intervals to ensure the correct vertical separation is maintained.

Where medium voltage and low voltage cables are laid in the same trench, the former shall be laid at the bottom and covered with bedding material and protective tiles. The low voltage cables shall be then laid on a further layer of bedding material at the required separation distance.

Cables shall only cross other cables at junctions at which point clearances between the cables shall be maintained.

Cable laying shall only be undertaken in firm ground conditions.

No cable joints shall be made without the written permission of the Engineer. Joints will normally only be allowed where it is impracticable to obtain a continuous cable of sufficient length. Joint boxes shall be of the best quality, manufactured by the cable manufacturer.

Cables laid underground shall be tested in accordance with the appropriate specification for insulation resistance, continuity and continuity of earth circuit in the presence of the Engineer before the cable trenches are backfilled. All joints made during the installation of the cables which prove faulty when tested shall be re-made and re-tested to the satisfaction of the Engineer at the Contractor’s expense.

5-2-D-6 INSTALLATION IN UNDERGROUND DUCTS

Where cables pass through walls or under roads or hard-surfaced areas, continuous PVC ducts surrounded in concrete and arranged in suitable formation, with one spare duct will be provided by the Employer, (unless stated otherwise in the Detailed Specification). The ducts will be 100 mm diameter for cables up to 50 mm diameter and 150 mm diameter for larger cables. Only one power cable shall be drawn into each duct.

Underground ducts shall be constructed of impact resistant uPVC or double-wall corrugated polyethylene pipes, and laid at a minimum depth of 600 mm (to the duct center), surrounded by at least 75 mm of sieved sand. At road crossings, ducts of minimum diameter 100 mm shall be laid at a minimum depth of 1000 mm (to the duct center). The duct shall be encased by 150 mm concrete on all sides.

When installing cables in ducts the following measures shall be observed:

- Cables shall be pulled in a straight line.

- Rollers shall be positioned at the edges of draw pits both at the drawing in and drawing out points over which the cables shall be drawn.
- uPVC pipes and cable sheaths shall be coated with an approved lubricant.
- Sufficient draw-in points shall be provided and adequate room allowed for installation of cables.
- The pulling rope shall be guided by rollers.
- Measures shall be employed to ensure that the manufacturer's recommended maximum pulling force is not exceeded for the cable being installed.

Only one power cable shall be drawn into one duct.

Whenever a duct is laid in the ground, a draw wire shall be pulled through with at least 1000 mm excess at each end and the draw wire left if the duct is not be used immediately.

5-2-D-7 SEALING CABLE ENTRY INTO BUILDINGS

Where cables pass through walls below ground level, the point of entry shall be sealed against the ingress of water. This shall be achieved with petrolatum tape and mastic, a silicon foam or proprietary cable transits.

Where cables pass in or out of any duct entries into or within buildings such entries, together with any spare ducts shall be sealed against the ingress of moisture by an approved method.

5-2-D-8 INSTALLATION IN BUILDING TROUGHS AND TRENCHES

Power distribution cables may be laid on the floor of the trench. Control and instrumentation cables shall be segregated and installed on supporting steelwork or cable trays secured to the walls of the trench.

Where cables are run in concrete troughs or trenches, they shall be run on the floor of trenches less than 300mm deep. In trenches deeper than 300mm, cables shall be supported along the side of the trench on galvanized mild steel hangers, racking, cleats or on a suitable tray run supported from the side of the trench, whichever is specified.

Where the building general service trenches containing pipework, chemical lines and other services, all cabling shall be segregated from other services and run on the trench walls.

Crossovers shall be kept to a minimum and cabling shall be taken above wet service pipework.

5-2-D-9 INSTALLATION ON CABLE TRAY

Cable trays for indoor installations shall be of hot dip galvanized (after fabrication) to an approved standard with formed flanges and of minimum thickness not less than 1 mm for trays up to 100 mm width, not less than 1.25 mm for trays from 100 mm to 150 mm width not less than 1.5 mm for trays from 150 mm to 300 mm width, and not less than 2mm for trays 300 mm to 600 mm width.

All bends, elbows, tees and reducers shall be factory formed before galvanizing. Minimum radii shall be 300 mm. Trays in outdoor, damp or corrosive locations shall be UPVC, GRP or stainless steel. Elsewhere trays shall be galvanized after forming and punching.

Cable tray supports shall be of ample strength to maintain rigid support to the fully laden cable tray along its entire length. All brackets and traywork shall be suitable for withstanding a temporary weight of 125 kg.

Wherever possible, cable trays shall be installed in full lengths without cutting. Should it be necessary to cut or drill a length of tray, the bared ends shall be dressed and immediately be given a coat of zinc rich cold galvanizing paint (type ZN25 or Zinga, or equivalent).

All cables shall be firmly secured to the tray using purpose made saddles, as approved by the Engineer, together with proprietary cable cleats.

5-2-D-10 INSTALLATION ON LADDER RACKS

Ladder racking shall be heavy duty type, fabricated from mild steel not less than 2mm thick and galvanized after manufacture. They shall be secured to walls or ceilings by preformed galvanized interlocking channel, cast into the structure.

The side rails shall be at least 120mm deep with rungs set towards one edge, spaced at regular intervals of approximately 300mm and having elongated slots to accommodate the cable fixings.

Lengths of ladder shall be coupled and changes in direction, level and width shall be achieved by means of standard accessories designed for the system, such as radiussed risers and gusseted intersections. Cable tray shall be accommodated on the ladder system for cables less than 15mm overall diameter.

Cables shall be located between 50 mm pegs spaced at 40 mm centers across a rung so that a 40 mm or 80 mm space is maintained between cable centers. Cleats shall be used where the ladder racking is vertical.

Wherever ladder sections are cut and shaped on site, cut edges shall be dressed and immediately painted with a coat of cold galvanizing compound.

5-2-D-11 INSTALLATION IN BUILDINGS

Cables required to be run on walls, ceilings, or other structures shall be carried on substantial cleats, either in groups or simply at spacings determined by rating requirements, supported on tray or ladder racks or enclosed in conduit or trunking.

All cables shall be neatly run vertically or parallel to adjacent walls, beams or other structural members.

The spacing of clips, saddles and cleats shall be such as to prevent the sagging of the cables during their installed life. The method of fixing clips, etc shall be by means of non-corrodible screws inserted into approved wall fixings.

Cable hangers, cleats, saddles, brackets and similar supporting devices shall be of an approved type and of adequate strength for the cables they are supporting. They shall be treated to withstand site conditions without corroding. Self-locking plastic buckle clips and strapping shall not be used.

Cables shall be run at least 150 mm clear of plumbing and below heating and hot water pipework.

5-2-D-12 CABLE INSTALLED IN CONDUIT

Conduit wiring systems shall be used for building electrical services installations.

Conduit may be PVC or heavy duty galvanized steel type.

Wiring within conduit shall be by the loop-in system with wiring terminations and joints made only at switches, isolators, and appliance fittings.

A space factor of 40% shall not be exceeded. Conduit size of less than 20mm will not be permitted.

5-2-E Conduit

5-2-E-1 PVC CONDUIT

PVC conduit shall be round high impact non-flame propagating type to an approved standard.

Jointing shall be carried out using a PVC solvent and socketed accessories. Expansion couplers shall be fitted in straight surface rings every 12 m. The free end shall be sealed with non-setting mastic to form a waterproof seal.

Purpose made bends may be used providing that the cable bending radius is maintained. Cracked or crinkled conduit will be rejected.

The conduit shall be suitable for use in ambient temperatures of between –5°C and 60°C and shall not be installed in areas that receive direct sunlight. A separate protective conductor (earth continuity conductor) shall be installed.

Adaptable boxes and accessories shall be made from heat resistant insulating material. The minimum wall thickness of boxes having a nominal internal depth of 16 mm or less shall be 1.5 mm. For deeper boxes, the minimum wall thickness shall be 2 mm. All boxes which are intended to support luminaries or other heat sources shall have either external fixing lugs riveted to the metal fixing inserts or utilize steel insert clips.

5-2-E-2 DOUBLE-WALL CORRUGATED POLYETHYLENE CONDUITS

Double-wall corrugated polyethylene conduits shall only be used for underground ducting.

They shall comply with EN 50086-2-4.

Conduits to be made of halogen-free polyethylene.

Crushing resistance shall be less than 5% at 450 N under 23°C.

5-2-E-3 STEEL CONDUIT

Conduit shall be galvanized heavy gauge steel screwed type.

Accessories shall either be malleable cast iron or pressed steel.

Conduit of less than 20 mm diameter will not be permitted. The tubing shall be perfectly smooth inside and out and free from imperfections. Both ends of every length of tubing shall be reamed with all sharp edges removed before erection.

Where conduits converge, adaptor boxes shall be used. Conduits shall be connected by means of male brass bushes and couplings. Where conduits are greater than 25 mm, straight through joint boxes shall be of the trough type. Where conduit or fittings are attached to equipment casings, the material of the casing shall be tapped for a depth of not less than 10 mm or male bushes and flanged couplings may be used.

Hexagonal lock nuts shall be used at running joints. They shall seat firmly and evenly on to mating faces. All junction boxes, draw-in boxes, and inspection fittings shall be placed so that the cables can be inspected, withdrawn and re-wired during the life of the installation.

Generally not more than two bends or offsets or one coupling will be permitted without a suitable inspection accessory.

Generally, conduits shall not cross expansion joints of buildings. Where they cannot be installed in any other manner, a galvanized flexible conduit shall be used across the expansion joint. A total of 150 mm movement shall be allowed.

5-2-E-4 SURFACE INSTALLATION OF CONDUIT

Surface conduits shall be secured and fixed by means of distance spacing saddles or clips which allow the conduits to be taken directly into accessories without sets or bends. Conduits shall be run in a square and symmetrical manner. Runs shall be properly ventilated and allow for drainage of condensation. Where large multiple parallel conduit runs occur, trunking may be used instead.

Conduits installed on structural steelwork shall be secured by girder clips, drilled and tapped to the metalwork.

Steel conduit shall form a continuous electrical enclosure throughout. Smooth bore bushes and couplings shall be used with plain boxes or alternatively spouted boxes may be used. Exposed threads of galvanized steel conduit shall be cleaned and then painted with two coats of an approved metallic zinc based paint.

Non-metallic conduit shall not be used in areas classified as hazardous areas in accordance with BS 5345.

With non-metallic conduit only fittings approved by the conduit makers shall be used. Jointing may be screwed or by an adhesive as approved by the manufacturer. A continuous earth conductor shall be provided through non-metallic conduit systems.

Draw-in boxes or inspection fittings shall be provided at every 2 right angled bends and in every 10 m of length of conduit.

Boxes to which lighting or other fittings are to be attached shall be fixed independently of the conduit by non-ferrous screws in PVC plugs.

Except for those installations located in areas classified as hazardous areas in accordance with BS 5345, drain holes 4 mm in diam. shall be provided at low points of all conduit runs to allow condensate to escape.

5-2-E-5 CONCEALED INSTALLATION OF CONDUIT

Concealed conduits shall be securely fixed to prevent movement before laying of screed, floating of plaster, casting of columns or other building operations necessary after the conduit installation.

At least 15 mm shall be allowed for finishes over the conduit. Where this cover cannot be maintained then expanded metal shall be fitted over the conduit. Conduit cast into reinforced concrete floors shall be fixed to the steel reinforcing. Concrete shall be prevented from entering conduit boxes when being poured.

5-2-E-6 FLEXIBLE CONDUIT

Flexible armored conduit shall be used to motors or other units subject to vibration and elsewhere where required. A through box shall be provided at the joint between the rigid and flexible conduit which shall be adequately glanded at both ends.

Flexible conduit shall be of the waterproof galvanized type or PVC wire-wound type with cadmium plated mild steel couplings. Lengths of flexible conduit shall be sufficient to permit withdrawal, adjustment or movement of the equipment to which it is attached and shall have a minimum length of 300 mm. Flexible conduit shall not be used as a means of providing earth continuity. A single earth conductor of adequate size shall be installed external to the conduit complete with earth terminations.

5-2-E-7 TRUNKS

Metal trunkings and fittings shall be galvanized steel not less than 1.2mm thick. Copper earth bonding straps shall be fitted at the junction of adjacent lengths of trunking and fittings.

PVC trunkings and fittings shall be of high impact heavy duty rigid PVC.

5-2-F Cable Terminations And Joints

5-2-F-1 POWER CABLE TERMINATIONS

Power cables shall be terminated in totally enclosed boxes mounted on switchgear, power transformers, motor starters and motors.

Cable boxes shall be of adequate proportions to accommodate all cable fittings including stress cones or other means of insulation grading. Boxes shall be openable for inspection without disturbing the gland plate, cable or termination.

Where air insulated terminations are used for medium voltage cables, the cable crutch shall be protected by a heat-shrink trifurcating sleeve.

Cores shall have either crimped lugs or sleeves to match either post terminals or bolted clamp terminals.

Aluminum cores of power cables shall be terminated using approved bimetallic connectors.

Each cable entry into a terminal box shall be made through a suitable gland.

All glands shall be provided with an earthing tag. Glands shall seal the inner and outer cable sheaths against ingress of dirt and moisture and provide mechanical support.

Where cable glands are exposed to the weather these shall be protected by heat shrink plastic tape or purpose molded sleeves covering the gland continuously from overall sheath to the gland neck.

Where the apparatus enclosure classification requires sealed cable gland entries, sealing shall be achieved by using threaded cable gland holes and polytetrafluoroethylene (PTFE) tape.

Glands for armored cables shall provide a positive armor clamp to the box and terminal plant. The clamp shall provide earth continuity and be of adequate size to withstand the full fault current of the system for one second.

Single core glands shall be non-magnetic. The gland plate shall also be of a non-magnetic material.

5-2-F-2 MULTICORE OR CONTROL CABLE TERMINATIONS

Terminal blocks for terminating up to and including 35 mm² cables shall securely clamp the conductor, without damage, between two plates by means of a captive screw; pinch screw type terminal blocks shall not be used.

For cables above 35 mm5, stud or bolted terminals shall be used, each cable core being fitted with a suitable lug.

Not more than one core of internal or external wiring shall be connected on any one terminal. Where duplication of terminal blocks is necessary, purpose made solid links shall be incorporated in the design of the terminal blocks.

Terminals which remain energized when the main equipment is isolated shall be suitably screened and labeled.

5-2-F-3 JOINTS

Through joints should only be used on long cable runs outside buildings.

Joints in thermoplastic and elastomeric cables shall be shall be epoxy or acrylic resin cold setting compound type. Joint boxes shall be split, molded plastic type with filling vents for compound. Continuity of cable armor shall be by armor clamps and cross bonding straps.

Conductor cores shall be jointed number-to-number or color-to-color.

5-2-G CABLE LABELING

Every cable shall be permanently identified at each end and at entry and exit points of ducts, buildings, with positively attached indelible non-corrodible means.

Power cable cores shall be color-coded to an approved standard. Three-phase power circuit core identification shall preserve the correct phase sequence throughout the system.

On rotating plant where, to achieve the required direction of rotation, it is not possible to connect the phase cores to the appropriately identified terminals, additional core ferrules shall be fitted to identify each core with the terminal to which it is finally connected.

Control cables shall have individual cores identified by means of suitable permanent ferrules bearing the same number at both ends. Core identification shall occur at every point of termination using an approved system of ferrule markers. The size of the ferrule markers shall be such as to match the overall diameter of conductor plus insulation. Numbering shall read away from the termination on all cores.

Each cable and core shall bear the same number at both ends of the cable and core respectively.

Cable schedules shall be prepared giving all cable details, including core references and origin/destination terminal numbers.

5-2-H Testing

5-2-H-1 TESTS AT MANUFACTURERS' WORKS

Unless otherwise specified cables shall be subject to Routine Tests in accordance with the Reference Standards.

5-2-H-2 TESTS AT SITE

The following inspection and tests shall be carried out on the completed cable installation as appropriate:

a. Insulation resistance between cores and core to earth using an approved insulation tester compatible with the voltage grade of the cable under test. For high voltage cables, the test shall be carried out at the highest voltage compatible with the voltage grade of the cable under test. Where cables are jointed, the test shall be repeated after each joint has been completed.

b. For multicore and multipair cables, continuity of each core and correct identification and ferruling.

c. Supports and cleating arrangements are fitted.

d. For power cables, correct phasing and phase coloring.

e. Correct bonding and earthing of cable metallic sheaths, core screens and armoring.

f. Sealing of cable entries against water and vermin ingress.

g. Mechanical glands have been correctly fitted.

h. For high voltage cables pressure tests shall be carried out in accordance with the Reference Standards using high voltage d.c. Wherever possible cables shall be energized after the satisfactory completion of the pressure test.

i. For high voltage cables, additional checks and tests to the manufacturers' specific instructions shall be carried out.

j. For low voltage cables, additional tests as required by the Reference Standard.

k. Loop resistance test for each pair of conductors in multipair instrumentation and telephone distribution cables.

l. Attenuation test for each pair of conductors in telephone distribution cables.

m. Measurement of cross talk across pairs of conductors in telephone distribution cables over a minimum frequency band of 0.5 to 20 kHz. The conductors connected to a resistive load equal to that of their characteristic impedance. The injected signal shall have a sinusoidal waveform at a level equivalent to the intended operating level of the modems to be connected (-3dBm).

Part IV: Mechanical Works

Part V-3: LIGHTNING PROTECTION & EARTHING SYSTEMS

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PART 5-3 - ELECTRICAL WORKS: LIGHTNING PROTECTION & EARTHING SYSTEMS

5-3-A GENERAL

Lightning protection systems shall be designed to withstand direct and indirect lightning strikes.

Lightning protection systems shall consist of the following:

- Air termination network or rod-type lightning conductor.
- Down conductors.
- Earth termination network.

Earth termination shall be achieved by installing electrode rods (in pits) connected to the bottom of the down conductors using tape tails.

5-3-A-1 JOINTS

Any joint other than welded represents a discontinuity in the current conducting system. The lightning protection system must have as few joints as possible.

Joints should be mechanically and electrically effective, e.g. clamped, screwed, bolted, riveted or welded with overlapping joints, the overlap should not be less than 60 mm for all types of conductors. Contact surfaces should first be cleaned and then inhibited from oxidation with a suitable non-corrosive compound. Bi-metallic joints should be thoroughly cleaned using a separate abrasive for each type of material.

All joints should be protected against corrosion or erosion from the elements of the environment.

5-3-A-2 BONDS

Bonding shall be used to prevent side flashing.

Careful attention shall be given to the metals and items being bonded.

A bond should be mechanically and electrically effective and protected from corrosion and erosion either by selection of material or by protective measures.

5-3-B LIGHTNING PROTECTION SYSTEMS

5-3-B-1 GENERAL REQUIREMENTS

5-3-B-1-1 Down Conductors

Down conductors shall be copper flat strip and have a minimum 25x3 mm² c.s.a. They shall be fixed with leaded gunmetal clamps, secured by phosphor bronze screws or bolts. Each down conductor shall take the most direct route from the air termination network to the earth termination and be provided with a bolted test joint in such a position that, whilst not inviting unauthorized interference, it is convenient for testing purposes.

Plates indicating the position, number and type of earth electrodes should be fitted above each test point.

Down conductors shall be protected with galvanized steel covers between the control junction and the ground up to 2 m above ground.

5-3-B-1-2 Equipotential Bonding System

Buildings with a lightning protection system must be included into the main equipotential equalization by means of the main earthing bar or equipotential bonding bar. Lightning protection equipotential bonding for the conductors of the energy network must be accomplished as close as possible to the point of entry of the mains into the building.

5-3-B-1-3 Earth Termination Network

Earth electrodes of 16 mm² copper bonded, steel cored rods shall be deep driven into the ground as close as practical to the structure. The rods shall be installed in sections connected by screwed couplers and driven to a sufficient depth to achieve a combined resistance to earth not greater than 3 ohms.

The screwed couplers shall be long length aluminum bronze material, counterbored to protect the threaded ends from damage and corrosion.

The earth termination network shall be able to carry high currents repeatedly.

Electrodes may be one of the following types:

- Deep driven rods
- Radial strip
- Solid plate or mat.

Step and touch voltages on the surface of the earth in the vicinity of earth electrodes must be restricted to a maximum value of 5% the voltage gradient.

5-3-B-2 SYSTEM USING AIR TERMINATION NETWORK

The protection system shall be designed and installed in accordance with BS 6651. No part of the roof should be more than 5 m from the nearest horizontal conductor. For large flat roofs, this will be achieved typically by an air termination network mesh which dimensions are adequately chosen. On a reinforced concrete structure, the air termination network should be connected to the reinforcing bars in all positions required for down conductors.

All metalwork on or very close to the structure shall be bonded to the lightning protection system. Where connections between dissimilar metals are made, precautions shall be taken to prevent corrosion.

If portions of a structure vary considerably in height, any necessary air termination networks for the lower portions, should be joined to the down conductors of the taller portions in addition to being joined to their own down conductors.

It must be noted that at all times adequate conductor fixings must be used in conjunction with the recommended fixing centers.

5-3-B-2-1 Lightning Protection Zones

The zone concept of integrating external and internal lightning protection systems through equipotential equalization shall be followed to ensure an effective and complete protection system of all sensitive equipment susceptible to damage and failure from switching operations in power networks, or from the effects of lightning, together with overvoltage hazards due to electrostatic discharges.

All the cables entering the building must be incorporated into the protective equipotential bonding system at the interfaces between lightning protection zones.

The active conductors of power supply and computer networks shall be integrated into the protective equipotential bonding system via special lightning arresters.

Local equipotential bonding must additionally be ensured at every other interface between zones within the building. Equipotential bonding of active conductors is realized with the aid of overvoltage arresters at these points.

The local equipotential bonding bars are to be connected to each other and to the main lightning protection equipotential bonding bar.

5-3-B-3 SYSTEMS USING ROD LIGHTNING CONDUCTOR

5-3-B-3-1 Franklin Type

This type of protection consists of a lightning conductor inert rod mounted on a mast and connected to a ground post by down conductors.

Location and height shall be determined by the Contractor and approved by the Engineer to ensure that the protection of the entire plant is in accordance with NF C 17-100.

The lightning conductor shall be tied with galvanized steel clamps on the mast to withstand vibrations and mechanical stresses.

5-3-B-3-2 Early Streamer Emission Type

The same installation rules of the Franklin type apply for the early streamer emission type with the following additions:

- No radioactive sources shall be used.

- The high voltage/frequency emission components shall be inaccessible.
- No external electrical or mechanical energy supply shall be needed: The system shall be self-contained, drawing its energy from the ambient electric field existing at the time of the storm (5 to 20 KV/m).
- The radius of protection and installation height shall be determined in accordance with NF C 17-102.
- A test report from a high voltage laboratory shall be submitted to the approval of the Engineer as well, confirming the initiation advance ΔT of the lightning conductor and the efficiency of the self-contained electronics in the lightning conductor.

5-3-B-4 <u>OVERVOLTAGE PROTECTION</u>

Electrical and electronic equipment shall be protected against surges or transients generated by switching operations, electrostatic discharges and induction, etc. by the use of graded lightning and overvoltage arresters.

Other earthing systems such as that for building, plumbing, power supplies, information processing etc. shall be taken into consideration upon designing the complete protection system.

Compatible overvoltage devices for ‘line-side’ protection, that includes basic, medium level and detailed protection, shall be installed and shall be of the same brand.

These overvoltage devices shall be installed according to BS EN 60099 and to the manufacturer’s recommendations and shall have the following characteristics:

- Modular design
- Visual fault indication
- Remote signaling module
- Replacement of active module (varistor) without interrupting the power supply
- Negligible leakage current
- High discharge capacity
- No follow current when the surge voltage has died down
- Short response time

Telecommunication systems, data interfaces, electronic networks, etc. shall be protected with adequate overvoltage protection devices.

5-3-C EARTHING SYSTEM

5-3-C-1 SCOPE

Earthing system shall consist of the following:

- Earth points and underground connections (main earthing network)
- Electrode inspection pits
- Collector pits
- Protective conductors

5-3-C-2 DESIGN

All non-current-carrying metal parts of the electrical installation and other services shall be properly bonded together and connected by means of a protective conductor to an efficient earthing system in accordance with IEE Wiring Regulations.

The earthing system shall be designed and installed in accordance with BS 7430 and BS 7671.

The materials used and the method of installation shall be such as to ensure effective and reliable operation over a prolonged period under the conditions appertaining to the Site.

The earthing installation shall comprise earthing terminal, earth electrode(s) where specified, and earthing and equipotential bonding conductors. The earthing and equipotential bonding conductors shall be of the radial, grid or ring form as dictated by the plant layout.

The metalwork of all items of electrical plant, electrical system neutral points, power and auxiliary cable armoring and screens and extraneous metalwork including structural steelwork, pipework, fences and gates, shall unless otherwise specified, be connected to the earthing installation.

Protective conductors shall provide earth continuity either through the conduit, armoring, lead sheathing, copper sheathing, steel trunking or by independent earth tapes or PVC sheathed wires, according to the system of wiring employed. Where PVC conduits or trunking systems are employed, the protective conductor shall be routed within the conduit or trunking.

Wherever cable armoring is used as a protective conductor, care must be taken to ensure an adequate earth bond and additional bonds to the metalwork shall be provided as required.

5-3-C-3 EARTH ELECTRODES

Earth electrodes shall normally comprise copper or copperclad high tensile low carbon steel cored rods. Copperclad type rods shall have a minimum copper thickness of 0.25 mm which shall be molecularly bonded to the steel core. Rods shall have hardened tips and driving caps to prevent damage during installation.

Earth rods shall have a minimum diameter of 16mm and a driven length of 2.5m. Spacing between rods shall not to be less than the depth of the rod. Inspection pits shall be provided for each electrode to allow subsequent access for testing.

Couplings shall be manufactured from aluminum bronze and shall have completely enclosed threads to prevent damage and corrosion.

Where soil conditions are very aggressive, solid copper earth rods shall be used.

Earth rods shall penetrate a minimum of one meter below ground water level.

Where multiple rods are installed, they should be separated by a distance of not less than their driven length. Bare copper tape or multi-stranded cable, buried at a minimum depth of 400 mm, shall be used for the interconnection of rods.

Each rod shall be provided with a non-ferrous clamp for the connection of the earthing conductor. The connection shall be made in a concrete or other approved material inspection chamber set flush with the finished ground level. The inspection chamber shall be permanently marked ELECTRICAL EARTH.

Where soil conditions make the use of rod type electrodes impractical or uneconomical, a grid configuration shall be used. The grid shall comprise horizontally buried bare copper tape or multi-stranded cable.

The resistance to earth of the earth electrode system shall be not greater than 1 ohm unless otherwise specified.

5-3-C-4 ELECTRODE INSPECTION PITS

Connections with rings, links and other auxiliary earthing systems shall be done exclusively inside standard inspection pits.

These inspection pits shall allow location of main earthing points, verification of electrical continuity and measurement of resistivities.

5-3-C-5 COLLECTOR PITS

Collector pits shall be erected as required in the earthing system. They shall contain a earthing collector made of a tinplated copper frame of appropriate c.s.a. allowing the connection of all protective cable ends.

The earthing collector shall ensure at least a double connection with the earthing network.

5-3-C-6 EARTHING TERMINAL

An earthing terminal shall be mounted in an accessible location and shall provide facilities for connecting:

a. the earthing conductor(s) between the earthing terminal and electrode(s) or electricity supply company earth terminal;
b. circuit protection conductors between the earthing terminal and exposed conductive parts;
c. the main equipotential bonding conductors between the earthing terminal and extraneous conductive parts; and
d. the system neutral earthing conductor (where specified).

Facilities (a) and (d) shall be removable with a tool to permit measurement and testing.

The earthing terminal shall comprise a terminal block or busbar on an insulated frame as appropriate. A label shall be provided inscribed MAIN EARTH TERMINAL.

5-3-C-7 CONDUCTORS

Earthing and equipotential bonding conductors shall be high conductivity copper tape or 1000V grade PVC insulated multi-stranded cable. The conductors shall be sized in accordance with the Reference Standard. PVC cable insulation shall be green and yellow. Cable lengths shall be continuous.

Cable armoring and screens shall be bonded to earth at both ends unless otherwise specified. Earthing of instrumentation cable screens shall be as specified elsewhere. Cable armoring shall not be used as the only earth protective conductor.

The conductors shall constitute with the earthing collectors a radial network. Series earthing connections are strictly prohibited.

Protective conductors shall be laid exposed in gutters or in a sleeve built-in in masonry or concrete works.

Radius of curvature of the protective conductors shall not exceed 8 times its overall outside diameter.

Protective conductors rising from the floor, shall be protected by a sleeve protruding 50 cm above ground level.

5-3-C-8 INSTALLATION

The earthing installation shall comprise an earth terminal, earth busbars, circuit earthing conductors, equipotential bonding conductors, main earthing conductor and earth electrodes. The circuit earthing and equipotential bonding conductors shall be of the radial, grid or ring form as dictated by the plant layout.

The earthing installation shall be protected from mechanical damage and corrosion.

Joints in tape conductors shall be riveted and soldered, brazed, clamped, bolted or exothermically welded. Non-corrosive flux shall be used for soldered joints. Clamped and bolted type joints shall be tinned and shall be used only above ground.

The interconnection of conductors below ground shall be by means of exothermic welding or brazing. Compression type lugs shall be provided for the termination of cables.

Earthing conductors shall be buried directly in the ground or secured to building structures, cable racks and trays using propriety fixings.

Where the soil is aggressive to copper, buried earthing conductors shall be protected by an approved serving.

An equipotential bond shall be provided to all buried metal pipework at the point of entry into a building or chamber where electrical apparatus is installed. Electrical continuity across all pipe joints within the structure shall be ensured. Where pipework incorporates a compression coupling a bond shall be provided to any isolated section.

Cable armoring and screens shall be bonded to earth at both ends unless otherwise specified. Cable armor shall not be used as the sole earth protective conductor.

5-3-C-9 TESTING

On completion of the earthing installation tests shall be carried out in accordance with the Reference Standards.

Part IV: Mechanical Works

Part V-4: INSTRUMENTATION, CONTROL & AUTOMATION

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PART 5.4 - ELECTRICAL WORKS: INSTRUMENTATION, CONTROL & AUTOMATION

5.4-A GENERAL

5.4-A-1 FOREWORD AND SCOPE

This standard covers general schemes of instrumentation and control systems relevant to water and waste water applications.

The following clauses specify general requirements and standards of workmanship for the equipment and installations. These clauses shall apply where appropriate except where particularly redefined in the particular specification clauses.

5.4-A-2 NORMATIVE REFERENCES

This section has been developed in accordance to the following standards:

IEC	International Electrotechnical Commission
BSI	British Standards Institution
IEEE	Institute of Electrical and Electronic Engineers

5.4-A-3 SYSTEM OF UNITS

Unless otherwise indicated, the International System (SI) of units shall be used.

5.4-A-4 ABBREVIATIONS AND DEFINITIONS

The following abbreviations and definitions are used throughout this section:

A/D or A to D	: Analog to Digital
BSI	: British Standards Institution
CP	: Control Panel
CPU	: Central Processing Unit
DCS	: Digital Control System
DPSK	: Differential Phase Shift Keying
EMC	: Electromagnetic Compatibility
FSK	: Frequency Shift Keying
I/O	: Input/Output
LED	: Light Emitting Diode
PID	: Proportional Integral Derivative
PLC	: Programmable Logic Controller
PTT	: Poste de Téléphone et de Télégraphe

RAM	: Random Access Memory
RTU	: Remote Terminal Unit
SCADA	: Supervisory Control and Data Acquisition
SSU	: System Supervisory Unit
TDM	: Time Division Multiplex
UHF	: Ultra High Frequency
UPS	: Uninterruptible Power Supply
VDU	: Video Display Unit
VGA	: Video Graphics Array
VHF	: Very High Frequency

5.4-A-5 DESIGN BASICS

All circuits and equipments shall be designed in accordance with good engineering practice and particular care shall be taken to ensure that no component shall exceed its maximum voltage/current/power ratings at any time, including during transient surges.

5.4-A-6 ELECTROMAGNETIC COMPATIBILITY

All instrumentation equipment shall be protected from interference emanating from radio frequency transmissions, either radiated or cable borne, such that it shall not cause malfunction of the system or damage to the components.

Where excessive electromagnetic interference (EMI) and/or radio frequency interference (RFI) is anticipated, special screening and grounding arrangements shall be implemented.

Moreover, operational use of UHF hand-held transceivers to troubleshoot field wiring can induce excessive RFI interference and maintenance technicians should be aware of this problem and provide adequate shielding, where necessary.

All equipment supplied shall not radiate any form of electromagnetic energy in amounts that might interfere with external equipment or instrumentation.

The latest standards on interference and the principles of electromagnetic compatibility (EMC) IEC 61000-4-2 to IEC 61000-4-5 shall be followed. The electrostatic discharge (ESD) and surge immunity shall be applied to the design of the plant and applications.

5.4-A-7 INTERRELATION WITH OTHER SECTIONS

Requirements given in other sections shall be applicable wherever relevant to equipment or materials specified in this section.

5.4-A-8 CLIMATIC CONDITIONS

All supplied equipment shall function without error and shall be constructed of such materials or so treated as to prevent the formation of mould, fungus or any corrosion over the ranges of temperature and relative humidity relevant to the specified site.

5.4-A-9 INGRESS PROTECTION

Instrumentation and hardware mounted in the field shall be housed or contained in suitable enclosures to provide an ingress protection (IP) to IEC 60529 rating indoors dry and wet locations IP55 and IP65 outdoors as a minimum. Sensors installed below water level or liable to submersion shall be rated to IP68. Where items are fitted in a panel or other enclosure, they shall preserve the design IP rating of that enclosure.

5.4-A-10 VOLTAGE AND FREQUENCY TOLERANCE

Equipment shall be capable of working from a supply whose voltage may vary +/- 15%, and tolerate any transients that could be experienced in such an environment without program corruption or system failure.

5.4-A-11 DISCRETE AND ANALOG SIGNALS PROTECTION

Opto-isolation shall be provided on all input and output interfaces to cards.

Digital signals shall be 24VDC with the power supply from either the associated power pack or the external instrument. Relays shall be used where more than one instrument including I/O are fed from a single signal.

Analogue signals shall be continuous linear scaled signals with a 4-20 mA operating range. Loops with instruments wired in series shall have adequate semi-conductor components (Zener diodes) fitted across each subsequent leg to ensure loop integrity.

5.4-A-12 TERMINALS

Signal terminals shall be disconnect type. Power supply terminals shall be shrouded and clearly marked with the appropriate warning tags. LED's shall be provided for fault tracing, if not supplied on the I/O cards. LED's in either case must be clearly visible from the front, with only the enclosure door open.

For each incoming screened cable, a separate earth terminal shall be provided for screen termination to earth.

All equipment, isolators, terminals and cables shall be clearly marked. 20% spare terminals shall be provided.

5.4-A-13 PROGRAMMING AND MONITORING UNIT

Hand-held portable devices shall be provided for each item allowing user configurable operation and to enable the downloading or uploading of data or software and the local running of diagnostic software.

5.4-A-14 INTEGRATED CIRCUITS

All integrated circuits shall be of a proven design and shall be clearly marked with the original manufacturer's identity and device number.

5.4-A-15 SUB-MINIATURE SWITCHES

Where DIP or other sub-miniature switches are used, they shall be provided with a cover, or other means of protection, to prevent accidental switching during handling.

5.4-A-16 SOCKETS AND CONNECTORS

The use of plug-in connectors for electronic equipment shall be kept to a minimum, and all circuit components including integrated circuit chips shall have soldered connections where this is allowed by the chip manufacturer.

Where sockets and connectors are incorporated in the design, they shall have self-cleaning, hard gold alloy plated, wiping action contact faces, and incorporate polarizing keys or similar means to prevent incorrect mating. Insulation displacement type connectors shall not be used.

All light current wiring having a cross-section of 1 mm^2 or less, shall have tinned copper (TC) conductors.

5.4-A-17 SELF TEST FACILITIES

The electronic equipment is to include built-in test facilities to permit the detection and replacement of faulty modules without the use of sophisticated test equipment such as oscilloscopes, signal generators, or others.

5.4-A-18 SURGE PROTECTION

All telecommunications lines, data and signal cables and other items of equipment external to the building environment prone to damage resulting from induced surges due to lightning discharges, shall be fitted with lightning surge protection barrier devices at each end of the line to suppress and divert any transients likely to cause damage to the connected equipment.

All surge diverters/lightning arresters fitted to telecommunication lines shall be of a design approved by the telecommunication authority.

Surge protection units shall be un-fused, solid state devices, designed to limit the transient over-voltages to not more than twice the normal working voltage of the line. They shall have low in-line resistance and automatically return to normal operation after diverting a surge.

The units shall have provision for either DIN rail or individual panel mounting or direct bolted connection to a suitable copper earth bar.

The location of the units shall be arranged such that the earth connection shall be routed clear of the protected signal cables and have short, straight connections without sharp bends to the main earth points, using copper conductors not less than 16mm² c.s.a. and not greater than five meters in length to provide a low impedance path.

Surge suppression devices providing protection from mains switching or other supply network disturbances, shall be incorporated or fitted to all sensitive monitoring or control devices. They shall be designed to filter un-wanted transients and limit the 'let-through' voltage to less than twice the working mains voltage, between all conductors and each conductor and earth.

Protection monitoring status indication shall be fitted.

5.4-B INSTRUMENTATION

5.4-B-1 PRESSURE MEASUREMENT

5.4-B-1-1 Pressure Gauge

Pressure gauge shall be of the Bourdon tube or diaphragm type. Each gauge shall incorporate a surge-damping device and be fitted with its own stainless steel isolating cock.

Pressure gauge shall be constructed with stainless steel case and bezel.

Case shall be equipped with rear blowout plates to protect the operator in the event of the Bourdon tube rupturing due to overpressure.

The case shall be liquid (glycerin 99.7%) filled, and its diameter shall be as specified in particular requirements. It shall be scaled in metric units according to EN 837-1/5 and normally ranged over a 240° arc from zero to 20% - 40% above the system designed operating value for full load conditions.

The gauge shall have a degree of protection equivalent to IP65 according to IEC 60529, and shall be able to operate safely for temperature values ranging from -20°C up to +60°C with the same accuracy.

The accuracy class shall be according to EN 837-1/6.

Labels shall be securely attached on or adjacent to each gauge; and groups of any such instruments shall be of matching appearance and approved layout.

Pumping station water pressure gauges shall have a dial diameter of not less than 100mm. Pump delivery and station delivery pressure gauges shall be mounted at a convenient height for reading. Suction and delivery gauges and their isolating cocks may be mounted direct on the tapping bosses and shall be adequately supported.

Pressure gauges incorporating transducers for remote monitoring shall be damped to provide a steady output. The pressure at the tapping point shall give a direct indication on the gauge as well as driving the transducer. Any alarm contact settings shall be independent of the transducer function and neither shall interfere with the direct gauge indication.

5.4-B-1-2 Differential Pressure Switch

It consists mainly of an electro-mechanical switch which is generally used as a protective device for high discharge pressure but also for low-pressure protection.

Pressure switches shall be selected for optimum performance and operation considering basic functional and environmental parameters such as: working range, setpoint, deadband, tolerance, sensitivity, switch setting, corrosion protection, and safety considerations.

Location of these devices should be that no turbulence shall interfere with the measurement of pressure either side of the device.

Differential pressure switches shall have the following characteristics:

- Two adjustable micro-switches, SPDT type, hermetically sealed.
- High repeatability of the switch points.
- Differential pressure range nominal settings, adjustable over the whole range of the instrument.

- Setpoint value indicated by means of a scale and pointer.
- Overload pressure protection up to 1.5 times the maximum line pressure.
- Stainless steel, cast zinc or aluminum alloy casing.
- IP54 for indoor installations, IP65 for outdoor installations and IP67 in locations liable to flooding.
- Operating temperature: -10 °C to +70 °C.
- Adjustment of switchpoint is made by setpoint screws accessible from the front.
- Switching point repeatability accuracy: < 1.6 %.

5.4-B-1-3 Pressure Transducer

Pressure monitoring shall be by a transducer/transmitter suitable for the medium and pressure/level range specified herein.

Each transducer shall be ranged to provide adequate sensitivity over the working range and be capable of sustaining a 400% overpressure (burst pressure) without damage.

They shall be rugged and waterproof design, employing a pressure sensitive element within a stainless steel enclosure having an isolation diaphragm, suitable for either free wire suspension in the medium or fitted with a BSP thread for external connection to the relevant pipe tapping.

Suspended sensors shall be mounted in accordance with the manufacturer's instructions within a UPVC 'stilling tube' of sufficient nominal bore to enable easy withdrawal of the sensor.

Sensors shall be enclosed to IP67, offer a long life and shall be supplied complete with a suitable signal cable of enough length to reach the approved point of termination indicator – control system without intermediate joints.

The position of the equipment shall be such that withdrawal and installation can be achieved easily.

Cable entry shall be by integral sealed assembly.

The pressure transmitter shall be integrated in the same casing of the transducer, and shall be suitable for operation from a DC source not greater than 30V dc; and converting the signals received from the transducer to an analogue 4-20mA signal proportional to the range specified.

The pressure sensor shall be internally compensated for zero and thermal drifts, and shall be able for safe operation under temperature conditions ranging from -30°C to +80°C.

For use in hazardous areas as specified, the units shall be certified intrinsically safe Ex.

5.4-B-2 LEVEL DETECTION AND MEASUREMENT

5.4-B-2-1 Level Electrode

It shall be of the single pole electrode type, comprising mainly an AISI 304 stainless steel probe, a noryl holder and a cable gland.

Special arrangements of seal rings and cable glands shall be available to prevent water from entering the cable terminal connector.

The maximum operating temperature of the fluid shall not be less than 75°C.

Electrode Holder:

This device shall be installed whenever a standard multi-probe arrangement is foreseen.

It consists mainly of a thermo-set resin or ceramic holder suitable for three electrodes. The electrode holder mounting is either flanged or on a threaded coupling.

For each set of three electrodes, or less, a holder shall be supplied and shall be of the same brand of the electrodes.

5.4-B-2-2 Level Control Relay

Level control relays shall be installed to convert the relative impedance of level electrodes into dry contacts suitable for automatic control sequences.

They shall comply with IEC/EN 60255-6 and have the following technical data:

- Modular DIN (43880) housing.
- Relay – electrode cable length not less than 500 meters when using single core, double insulated cables.
- ‘Power On’ indicator LED.
- ‘Relay State’ indicator LED.
- One changeover output contact.
- Adjustable sensitivity from 2 to 12 kOhms.
- Automatic reset.
- Dual supply voltage, one of which shall be 220 V a.c.
- Wiring terminals for three probes.

5.4-B-2-3 Float-Type Level Switch

The float type level switch is a standard tank level switch used to provide alarms on low or high levels and to initiate automatic control sequences or alarm conditions.

When the fluid level reaches the float mechanism, it lifts the float and operating shaft. The operating shaft is pivoted inside the level switch and its movement operates an integrated dry contact switch that shall be rated 10 A @ 220 V a.c.

5.4-B-2-4 Magnetic Level Indicator

It shall be made of a vertical mounted stainless steel tube, suitable for measuring fluid levels up to 6 meters.

This device shall be used where it is unadvisable rather difficult to install level sensors inside the fluid itself, or where indicated specifically.

The operating principle of this level indicator, called also bypass tube, is based on the vertical movement, inside the measuring tube, of a floating device with integrated magnet, which follows the liquid level and transmit it, without physical contact with the fluid, for local display and remote signaling.

The local display shall be through bi-stable magnetic blind plates having different high contrast colors on opposite sides.

The blind plates shall toggle face (color) according to upward or downward movement of floating device.

The fluid level shall be permanently indicated in case of power failure.

The level indicator shall have an integrated transmitter drawing a standard output analogue signal 4-20 mA with an overall precision better than 0.3 %.

The level indicator shall have provision for the installation of two dry contacts for triggering alarm conditions.

The level indicator shall operate safely for fluid temperatures ranging up to 100°C and its overall degree of protection, including the transmitter and contact blocs, shall be equal or better than IP65.

5.4-B-2-5 Ultrasonic Level Sensor

Level monitoring by non-contact ultrasonic measuring devices shall incorporate ambient temperature compensation and adjustable datum setting facilities.

Transducer:

The sensor head shall be protected to IP67, mounted to provide an unhindered beam path, prevent unwanted reflections, within easy reach of maintenance personnel and, where possible, be clear of flood conditions.

Transmitter:

The transmitter shall be suitable for operation from the specified power supply and convert the signals received from the sensor head to a 4-20 mA signal proportional to the range specified, to be used as indicated in the particular requirements.

The transmitter shall comprise a base unit and a programming device, all in a weatherproof enclosure to IP65, in case it is mounted separate from the transducer, and to same IP value of transducer in case of compact version.

A minimum of 4 digit LCD shall be used to indicate key programming features, settings and output conditions.

Accuracy of transmitter shall be better than +/- 0.25% of reading and shall have the following programmable outputs:

- Analogue signal 4-20 mA proportional to user defined engineering units.
- SPDT relay contact output closing upon failure of the signal transmitter, lost echo or multiple echoes.

5.4-B-2-6 Gauge Glass Level Indicator

Gauge glass level measuring systems shall be provided with a protective housing, borosilicate glass tubes and isolating valves. The range of any gauge glass shall be the same as that of any other level meter installed on the same vessel, including any high and low level sensor. Multi-section gauges shall have an overlap of at least 25 mm between sections.

Where necessary the level indicator shall be provided with flushing and drain points with valves and hose connections.

5.4-B-3 FLOW DETECTION AND MEASUREMENT

5.4-B-3-1 Flow Switch

This flow control device shall be mounted on the process piping, and shall be supplied with 'T' connection to fit the required pipe size.

It shall have the following characteristics:

- Stainless steel body 316L.
- IP65 class of protection.
- 85°C maximum ambient temperature and 120°C maximum fluid temperature.
- Adjustable stainless steel paddle sensing element.
- Two switch contacts, 8A @ 240 Vac.
- Mounting in all directions.

5.4-B-3-2 Flowmeters

All liquid flow measurements shall be performed in accordance with accepted practices defined by International standards.

Reliable and accurate flow measurement is of paramount importance and requires special attention in the following implementation phases that shall be strictly followed by the contractor:

- Selection of the flow measuring element and its associated instrumentation.
- Accurate calibration and operational checkout of the flow measuring system before installation.
- Precise and accurate installation and checkout in the field.
- Correct operational procedures applied to ensure that accurate metering data is generated in accordance with the design capabilities of the metering system.

5.4-B-3-3 Mechanical Flowmeters

Mechanical flowmeters shall be of the helix type and incorporated into a flanged section of pipe.

Tapers shall be provided, or non-standard bearings and propellers, if required, to obtain the specified degree of accuracy at the specified flow rates.

The meters shall be suitable for working pressures up to 16 bar unless otherwise stated.

An extension drive and extended head shall be fitted to meters as required. The drive shaft bearings and gears shall be designed for long life under continuous operation, and normal wear shall not significantly affect the accuracy of the meter.

Mechanical flowmeters shall not require any constraints on the piping downstream and upstream the meter, nor any additional flow stabilizing sections.

Meters shall have a circular dial and rate of flow indicator registering flow in units as specified in particular requirements. A flow totalizer having at least six digits shall be incorporated in the head. The totalizer shall have a capacity of at least one year‘s flow at maximum flow rate. A multiplying factor in multiples of ten may be used in conjunction with the totalizer if required, however if this is the case, the factor shall be clearly marked alongside the register.

The meter bodies shall be in cast iron with a high quality epoxy coatings minimum 150 microns, inside and outside.

Meters shall be individually flow calibrated at the manufacturer’s works and shall be guaranteed to within +/-2% of true flow within the rated range of the meter. Each meter shall be supplied with a calibration certificate.

The coupling between the wet and dry part (totalizer mechanism) shall be magnetic, fully tamperproof against any external non-destructive actions. The totalizer mechanism shall be located in a non-plastic housing, preferably copper, and with a solid glass window. It shall be totally condensation free and waterproof if submerged under 2 meters of water.

It shall be possible to remove all moving parts from the meter without the necessity to remove the meter body from the pipeline. A blanking plate shall be provided for each meter, if necessary, to allow flow to pass through the meter body when the operating mechanism has been removed.

The spare parts shall include as a minimum spare gearing and bearings for each size of flowmeter used.

Where specified, meters shall incorporate a pulsed output unit and data logger connection to enable flow rates to be monitored and logged at a remote data center. However, the totalizer mechanism of all meters shall be pre-equipped to receive a pulse output unit in the future which can be added on site without destroying the seal and without removing the meter or the measuring mechanism. The pulse unit and data module shall be self-supporting using dry cell batteries.

5.4-B-3-4 Ultrasonic In-line Flowmeters

The flowmeters shall have flanged steel bodies and be without probes or pressure tappings which can foul or create a disturbance to the flow. The meter performance shall not be affected by emptying the pipeline, and servicing shall be possible without the need to remove the meter from the pipeline.

Ultrasonic flowmeters measuring the fluid level upstream of a flume or weir shall employ a microprocessor-based system to compute flow in accordance with BS 3680 against a range of user programmable primary device characteristics. Combined system accuracy shall be within 1% of span over 5-100% flow. Displays of flow, programming details and operating parameters shall be provided by LCD device. For outdoor use the whole system shall be in an IP65 enclosure.

The sensor tube and associated equipment shall be capable of withstanding occasional submergence in the flow metering chambers. The contract shall include for the provision of a 230V, 50Hz power supply from the nearest distribution panel, and a power pack unit if required for flowmeter operation.

The transmitter unit and the power pack unit shall be housed in a G.R.P. lockable cabinet which may be either pedestal or wall mounted as appropriate to the meter location. The cabinets shall have heaters and thermostats if required to prevent condensation.

The contract shall include for all internal wiring, and for cabling between the flowmeter and cabinet. Where necessary, cabling shall be screened to prevent interference.

The transmitter shall give an output signal of 4-20mA.

The span of the instrument shall be adjustable and the range of each instrument shall be chosen to unit the particular flow range. Means shall be provided for check calibrating the meter on site.

The outputs signals from the flowmeters shall be wired back for display and control, with provision for wiring to a telemetry outstation.

Meters on gravity lines will normally have flow, and although this could be low at some times of the day, in practice flow is unlikely to drop below approximately 20% of maximum.

The meters on the pumping mains will have flow dependent on the operation of the pumps.

5.4-B-3-5 Electromagnetic Flowmeters

The flow meter shall be of the electro-magnetic inductive type having a DC pulsed field with automatic zero error averaging and low power consumption. It shall have no moving or protruding parts nor cause any restriction in the flow path and be capable of setting adjustments without the need to stop the flow.

Each metering system shall be in accordance with ISO 4064/1 and comply with EN29104 and comprise a flow sensor mounted in pipe work line and a transmitter which degree of protection is equal or better than IP65, either integrally mounted or remotely located; preferably within the main control panel.

The flowmeter shall be approved and certified for hygienic and sterile requirements when used for potable water, and it shall be capable of accurate reading for a fluid conductivity equal or higher than 5 µS/cm; and a fluid temperature range between -20°C and 130°C.

The system accuracy shall be independent of the range which has been selected for the analogue signal and shall be better than 0.25% of the actual measurement, for a fluid velocity equal or higher than 0.5m/sec.

For a velocity < 0.5m/s, the accuracy shall be better than +/- 1.25 mm/s of actual flow.

The repeatability of the system shall be better than 0.1% for flow ranges from 0.03 up to 10m/s.

Flow Sensors:

These shall comprise electrodes located in a meter tube which shall be of watertight construction, suitable for operation without loss of accuracy when totally submerged to a depth of three meters or even buried into the ground together with the water pipe. Its degree of protection shall be IP68. They will not contain any active components such as amplifiers or memory modules.

The meter tubes shall be made from a non-magnetic material lined with an inert material suitable for the medium. The flowmeter may be flanged or welded ends type. On flanged type the lining shall cover the external parts of both flanges.

The measuring electrodes shall be continuously cleaned by means which do not interrupt the process flow or the measurement.

The flowmeter shall have an automatic pipe detection feature.

The flowmeter body shall be effectively bonded by non-corrodible, tinned copper braid links at each end, to the adjacent pipework to ensure a good connection between the body and the metered liquid, an earthing flange being inserted where non-conducting pipework is employed.

Transmitter:

The transmitter shall provide the following minimum functions:

- Conversion of its supply voltage (85 to 240VAC or 11 to 40 VDC) in a pulsed signal which feeds the coils in the flow sensor. This method allows the transmitter to compensate for a zero drift of the flowmeter and shall give the flowmeter a perfect zero stability.
- Supervision of the flow sensor: The transmitter shall be able to generate an alarm signal when the following conditions occur:
    - Flowmeter empty.
    - Reverse flow direction.
- Output signals to inform the control/display equipment. Thus, the transmitter shall have as a minimum the following independent output signals:
    - Standard analogue current signal 4-20mA, where the zero and full-scale mA values are configurable as well as the measuring range. The range adjustment shall be continuous, and the units shall be configurable in flow engineering units.
    - This analogue signal shall represent forward flow, reverse flow or both depending on the configuration.
    - In case the analogue signal represents both flows, then an output digital signal shall be provided to indicate flow direction.
    - A serial port for downloading data.
    - Two pulse signals, fully configurable in volume and length. The pulse signals shall be open collector transistors or voltage free contacts.
    - Two alarm signals, fully configurable and representing the following fault signals (each fault signal can be assigned through configuration to the first, the second or none of the two alarm contacts):

* Empty pipe.
* No signal from electrodes.
* Coils broken (open circuit).
* Flow above or below selected alarm level.
* Reverse flow direction.
* Output pulse frequency above maximum selected rate.

The alarm signals shall be open collector transistors or voltage free contacts.

- Local, user-friendly indicator, used to inform the operator about the measurement. The indicator shall provide at least the following information and functions:
  - Actual flow with direction, in selected units.
  - Alarm indication with full description.
  - Selection of total positive, negative and net flow as well as velocity in the pipe and actual flow in percentage of full scale.
- Configuration tool: It consists of a password protected menu from which the operator shall be able to access and set all configurable parameters grouped by function: measuring range, totalizers, alarms... A test function shall be available as well to test the wiring and the complete configurations.

Flowmeter Cabling:

Where remote mounted converters are specified, cables shall be provided, installed and terminated between the sensor and converter unit for the following purposes:

- Flow signal.
- Reference signal.
- Coil supply.

Such cables and sealing glands shall be suitable for submersible operation (IP68) of the sensor to the depth specified. The length of each cable shall be as specified.

Spool Piece:

A flanged steel pipe spool piece shall be provided of the same diameter and length as the respective flowmeter and flanged for insertion in the pipe; should it be necessary to remove the flowmeter.

Isolating gate valves shall be provided on either side of the flowmeter.

Calibration Certificate:

The flowmeter shall be supplied with a calibration certificate mentioning also the pressure at which the meter has been factory tested. The flow test shall be made on a recognized test bench which is traceable to international standards.

5.4-B-3-6 Differential Pressure Flowmeters

Flowmeters of the differential pressure type shall be designed and installed in compliance with BS 1042, ISO 5167-1 or equivalent. Primary devices shall be a stainless steel carrier-ring type orifice assembly with a stainless steel orifice plate, a dall or a Venturi tube, and which shall include two sets of gaskets, fixing bolts and isolating valves for each primary device. All materials shall be appropriate to the metered fluid and service conditions. Full details of the calculations of the differential pressure flowmeter shall be supplied to the Engineer.

Orifices shall be square-edged and concentric. The upstream edges of orifices shall be sufficiently sharp that the reflection of a beam of light from the edge cannot be seen without magnification. Drain holes shall be provided. The diameter ratio shall be between 0.20 and 0.70. Orifice assemblies shall have identification tags showing the direction of flow, orifice diameter and position of drain hole.

Differential pressure transmitters shall have over-range protection up to 1.5 times the maximum line pressure.

Interconnecting pipework between the primary isolating element valves and the transmitter shall be supplied and installed with a suitable 3-valve manifold and blowdown legs.

Provision shall be made for easy connection of a U-tube manometer or portable instrument for the purpose of calibration.

The differential pressure produced by each primary element shall be converted to a dc current by an output signal transmitter mounted adjacent to the primary element. Power supply units for transmitters, if required, shall be mounted close to the transmitter in a weatherproof housing unless they are mounted in a control panel.

Square root extraction shall be provided to give a linear 4 to 20 mA dc output signal proportional to flow.

After installation the calibration of each flowmeter system shall be proved to the satisfaction of the Engineer by applying fixed measured differential pressures to the input of the converters.

5.4-B-3-7 Water Meter Counter

Water meter shall be equipped with a 7 figure counter indicating water flowing through in m^3 and shall be confirmed to NFE 17-002 and NFE 17-004.

It will be a Woltmann type with diameter and pressure equivalent to the pipe's diameter and pressure.

To avoid water turbulence, straight pipes shall be installed before and after the water meter counter (10 d pipe size before water meter counter and 5 d pipe size after water meter counter or as recommended by the manufacturer).

If required, a straightener shall be installed at the entrance of the water meter counter.

Where required, water meters shall be provided with a 4..20 mA signal transmiter.

5.4-C INSTRUMENTATION CABLING AND EARTHING

5.4-C-1 INSTRUMENTATION CABLING

Instrumentation cables shall be polyethylene or PVC insulated with stranded conductors and laid up as twisted pairs, individually screened, polyethylene bedded, steel wire-armored with light blue colored PVC sheath overall, all in accordance with BS 5308 Part 1 Type 3. Conductors shall be Class 5 or Class 2 (PE /IS/SWA/PVC type). Pairs shall be twisted with one twist per 300mm approximately. Screens shall be of braided copper or mylar-backed aluminum foil giving a minimum coverage of 85%. Cables for intrinsically safe circuits shall additionally comply with the certificate of the apparatus concerned and the Contractor shall submit calculations verifying compliance.

Cables for high level signals, low level signals, resistance thermometers and thermocouples shall be segregated from each other and each shall be separated from cables for power, communications and other electrical services. Other cables run in the vicinity of instrumentation cables shall be twisted at the rate of one twist per 50mm approximately and shall be separated from instrumentation cables by a distance of not less than 300mm.

Initiating devices for plant protection and personnel safety shall be connected by individual cables direct to the tripping or safety device and shall not be routed via any intermediate junction, marshalling box, cabinet, relay etc. The outer sheaths of such cables shall be colored orange.

Telemetry cabling between a master station and an outstation, unless specified otherwise, shall consist of a minimum of 6 signal pairs, of which two pairs shall be allocated to the telemetry system, one pair shall be allocated to a speech circuit and three pairs shall be spare. Each conductor shall be multi-stranded with an equivalent diameter of not less than 0.9mm. Conductors shall be laid up in star-quad formation. The dc resistance of any pair of conductors shall not exceed 88 ohms per loop mile at 10EC and the difference between the resistances of the conductors of any pair shall not exceed 0.5 % of the loop resistance of that pair.

Telemetry cables shall be designed for burying in water-logged ground. Conductors shall be plain annealed copper with aluminum/polythene laminate sheath moisture barrier, copper or brass tape pest barrier, single galvanized steel wire armor and overall polythene sheath. The cable shall have a solid filling of petroleum jelly.

The characteristic impedance of each signal circuit shall have a nominal value of 600 ohms at 800HZ and the circuits shall be suitable for signal input levels of between –30dbm and +4dbm (0dbm - 1mW into a load of 600 ohms). The overall attenuation between the terminations of any circuit at the mean frequency of the and width specified elsewhere shall not exceed 20dbm and the attenuation at any two frequencies within this band width shall not differ by more than 6dbm. The transmission time for any two frequencies within the bandwidth specified elsewhere shall not differ by more than: 1/4 B seconds, where B is the transmission speed in bauds.

The signal-to-noise ratio within the bandwidth specified elsewhere shall be better than 12db. The frequency of any received signal shall not differ from the frequency by more than 1% of the transmission speed in bauds specified elsewhere.

Loading coils as necessary to meet the performance requirements detailed herein shall be supplied and installed at equally spaced points as shown on the Engineer’s Drawings.

Cable termination boxes shall have double-ended screw terminals with removable links to facilitate core isolation during testing. Each box shall contain sufficient terminals for every conductor plus 20 % spare terminals. Gable termination boxes shall have cable sealing chambers and insulated glands with earthing terminals so that the armoring may be earthed or isolated from earth, as circumstances dictate. Termination boxes for use within buildings shall be of sheet steel with hinged or removable front covers. All other termination boxes shall be cast steel or heavy gauge sheet steel construction giving protection to IP55. All termination boxes shall be hot-dip galvanized or approved equivalent finish. Each terminal box shall have a removable, un-drilled gland plate and the Contractor shall supply and fit the requisite number of cable glands.

At each cable termination box, each cable core (including spares) shall be identified by a numbered slip-over type collet. The numbering for a particular cable core shall be the same throughout its length.

Cable joints shall be subject to Engineer’s approval.

Each cable joint shall be of the straight-through type. The conductors shall be ferrule-jointed with the insulation maintained by heat-shrink sleeving. Joint closure shall be made with epoxy resin and the completed joint shall be impervious to water if submerged or in waterloged ground. If cast iron joint boxes be used, they shall be provided with cable glands and, after installation and testing, shall be covered with Densomastic HD compound or equal ; so that all sharp corners, bolts and projections are molded to a smooth surface. Two lappings of Densopol grade ZN 50mm tape, or equal, shall then be applied overall. Jointing shall be carried out on each conductor, including any provided in excess of the minimum quantity specified. All materials and things of every kind required for the cabling jointing shall be provided by the Contractor.

5.4-C-2 INSTRUMENTATION EARTHING SYSTEM

An instrumentation earthing system shall be provided throughout. The instrument earthing system shall be isolated from the main electrical earthing system except at their point of connection which shall be at the main earth terminal in the relevant process area.

Instrumentation earth cables shall be segregated from other power and earth system cables in order to reduce electrical interference on the instrument earthing system.

The instrument earthing system shall be used for the connection of any signal system zero volt point and all communications and instrumentation cable screens. Cable screens shall be earthed at one end only. Instrument cable armors shall not be used as protective screens. Instrument cable armors shall be earthed to the electrical earth system at one end only.

Avoidance of earth loops shall be paramount in the design of the instrument earthing system.

Each instrumentation, control, communications and telemetry panel shall be provided with an:

- electrical system earth bar bonded to the metalwork of the panel and providing earth connections for all cable armors and power circuit protective conductors.
- instrumentation earth bar insulated from the panel metalwork for connection of signal system zero volt connections and connection of all signal cable screens.

The design of the instrument earthing system shall be incorporated as part of design of the overall earthing system for the works.

5.4-D CONTROL SYSTEM

5.4-D-1 OVERVIEW

The control of the pumping stations shall be designed in such a way to allow future connection to a remote centralized monitoring and control center that would eventually contain the *system supervisory unit* (central computer for SCADA system).

In this respect, control of the pumping units shall be done by the means of PLCs and/or RTUs with necessary digital and analog inputs and outputs, totally compatible with a SCADA system. Future connection to the SCADA system should be done without any changes in the control hardware; only limited additional communication modules will be permitted.

Based on his proposed control system, the Contractor shall submit a list of all equipment necessary for the communication with a SCADA system. Provisional space shall be provided inside the control section of motor control centers for such equipment.

Each PLC or RTU shall be capable of autonomous operation without reference to the central computer, but shall be capable to collect and transfer plant and process data and to accept control or programming information from the central computer. Data is collected by sensors connected to the RTU's, and commands are dispatched to controlling elements also connected to the RTU's.

All processes shall be Software controlled through PLC's.

All plant shall be monitored through local telemetry units to display status/alarms at the SSU.

Safety, emergency and high priority signals must be independent of the software based control system. The contractor shall review the control system at each stage of the design and provide all required inhibits.

All inhibit status shall be indicated visually, on the panel sections and SSU database/mimics and all alarm signals shall be hard-wired to annunciators.

The control system shall be designed for automatic and manual operation.

5.4-D-2 CONTROL SYSTEM HARDWARE

5.4-D-2-1 Programmable Logic Controllers (PLC)

They shall be microprocessor based controllers designed to suit various application needs such as controlling, regulating, monitoring, etc.

They shall be of a proven technology, shall have robust enclosures and shall provide reliable functioning even in locations near sources of electromagnetic interferences.

PLC units shall be compliant with the latest editions of IEC 61131 standards.

The PLC units could be of an expandable compact or a modular type. They shall cater for analog and digital inputs/outputs and have serial ports for communication with computer equipment. They shall be capable to accommodate special modules such as intelligent peripherals cards or functional units that operate autonomously.

PLC units shall be capable of processing complex data at high speed. For large programs, CPUs shall be added to maintain a high processing speed.

PLC shall support hierarchical configurations of control system networks with central operator station.

Power Supplies:

Instrument signals shall operate at 24 Vdc, derived from a suitably rated power supply to each PLC or instrument panel section and connected to the I/O terminals as necessary. The power supply units shall be sized such that the total demand does not exceed 75% of the power supply's maximum rating.

The power supply functions inside the PLC shall provide for conversion and isolation of the PLC system

CPU:

The CPU function consists of the application program storage, the data storage, the operating system, and the execution of the application program functions.

The CPU shall process signals obtained from sensors as well as internal data storage and generates signals to actuators as well as internal data storage in accordance with the application program.

The interface function to sensors and actuators shall convert:

- The input signals and/or data obtained from the machine/process to appropriate signal levels for processing;
- The output signals and/or data from the signal processing function to appropriate signal levels for commands and/or display.

Input/Output Modules:

The I/O modules shall accept standard analog and digital signals. These modules shall accept also signals coming from special modules which pre-process external sensor signals according to the defined functions contained in the special modules themselves. Examples of such special modules include PID controllers, fuzzy control module, motion modules and others.

The number of I/O points shall be determined according to the relevant control scheme. Spare I/O points shall be provided to allow for system expansion or enhancement. Unless otherwise specified, 30% overall spare I/O points shall be provided at least, while ensuring a minimum of 20% spare of each type of I/O points.

PLC Programming Languages:

The PLC programming language shall comply with IEC 61131-3 which specifies the syntax and semantics of a unified suite of programming languages for PLCs. These consist of two textual languages:

- IL (Instruction List).
- ST (Structured Test).

and two graphical languages:

- LD (Ladder Diagram).
- FBD (Function Block Diagram).

The programming language shall include for programming, debugging, testing and documentation functions. These functions shall provide for application program generation and loading, monitoring, testing and debugging as well as for application program documentation and archiving.

The programming language shall be user-friendly, open and manufacturer – independent.

Communication Ports:

PLC shall have a communication function which provides the data exchange with other systems such as other PLC-systems, controllers, computers, etc.

PLC's shall have as many communication ports as necessary to achieve the specified control scheme.

Unless otherwise specified, each PLC shall have as a minimum one RS485 communication port.

Watchdog:

All PLC's shall be self monitoring and any system failure, whether hardware or software derived, shall cause the watchdog relay(s) to de-energize / fail-safe and un-inhibit back-up control operation and/or carry out any function as detailed in the functional design specification.

Watchdog status shall be indicated visually on the panel sections and the SSU mimics.

Failure of PLC's shall not leave the associated plant in an unsafe condition or allow a process failure.

Physical Installation:

The installation of PLC based units shall be as per relevant standards and manufacturer recommendations.

PLC equipment shall be mounted in secure lockable panels, which may be housed within an instrument panel.

PLC cabling shall be separately routed and segregated from other cabling services.

5.4-D-2-2 RTU (Remote Terminal Unit)

RTU is a PLC based control device, installed at a remote site for control and tele-transmission functions.

The RTU shall transmit a digital report whenever a nominated alarm or analog change-of-state condition occurs unless a periodic interrogation/polling is taking place.

The RTU receiver shall support acknowledgment messages and periodic interrogation/polling from the SSU. The transceiver equipment shall be specifically designed for use in digital networks and incorporate the following features:

- Ultra low power consumption.
- Sleep and standby modes.

- Hardware and bit synchronization.

Intercommunication between RTU's will be necessary if they are used as signal repeaters, or if the message handling of the radio network requires the RTU transmissions to be synchronized.

A watchdog system is required at each RTU / process area or group.

RTU Power Supply:

RTU equipment shall operate from the specified site UPS.

120 minutes full function battery backup including continuous battery charging equipment shall be provided for each RTU unit and the signals required for monitoring and control at 24 V dc, 110 V ac and any other voltage used for instrumentation.

RTU Memory:

The RTU unit shall have sufficient memory capacity such that in the event of a communications failure, information shall be retained for a minimum of two weeks with normal digital event/alarm density and all analogues at 15 minutes sample rate.

5.4-D-2-3 System Supervisory Unit (SSU)

The System Supervisory Unit shall incorporate microprocessor based units (or a computer) of suitable operating and storage capacity to provide the specified data handling, processing and graphics performance and having non volatile or on-board battery supported RAM and hard disk data storage capacity together with dual drive 3.5" 1.4 megabyte floppy disk drive, dual CD read/write drive, 2 serial, 2 parallel and 2 USB ports.

The disk operating system shall be provided with full documentation and spare copy. Full auto restart after power failure is required, without manual intervention.

Hard disk data archive capacity shall be sufficient for one year on line availability at least.

Both RAM and hard disk shall have 100% spare capacity in excess of maximum working load to allow for system development in the future.

The screen shall be of the flat type, latest technology, 21 inch.

The keyboard shall be a low profile standard QWERTY patter, complete with special function keys if necessary. The keyboard shall have an ergonomic form design.

A color graphics printer and a monochrome A4 laser printer shall be supplied with the SSU. The color printer shall be a thermal inkjet having a graphics resolution of 1200*800 dpi and having A3 media size capability.

5.4-D-2-4 Man Machine Interface (MMI)

This device shall be directly compatible with PLC product. It shall allow the supervisor to have an interactive global view of the installation configuration and the states of the various parameters as well as the possibility to issue some essential commands.

The MMI shall be directly connected to the field network (RS485) of the process area and shall have a communication protocol fully compatible with PLC devices.

It shall have a high resolution graphics display showing the process area main components.

The MMI shall be directly configurable from the SSU or any other computer.

5.4-E COMMUNICATIONS

5.4-E-1 CONTROL AND COMMUNICATIONS

The control system shall communicate with plant via one or more Remote Terminal Units (RTU). The RTU's shall be linked by a common communications link so designed that failure of any RTU connected to it or failure of the computer system shall not cause the link or data highway to malfunction.

The configuration, communications speed and number of data highways shall be determined considering the response times, distribution and number of signals presented by the Plant requirements.

The communications network for the SCADA system shall accommodate both continuous real time and timed polling acquisition of data throughout the system. The RTU's/Outstations may be polled on a pre-determined rate but shall have a real time responses to alarms.

The means of communication shall be in accordance with the Particular Specification and the following clauses relevant to the selected medium.

5.4-E-2 LINE TRANSMISSION MODES

The telemetry system is to transmit in the Time Division Multiplex mode (TDM) with Frequency Shift Keying (FSK) or Differential Phase Shift Keying (DPSK) modulation and shall employ an interrogation/response or an indeterministic (random acquisition) system.

Suitable modems shall be provided to match the system characteristics which shall have a transmission rate to meet the system performance requirements.

The system is to detect at least 98% of all and 100% of 1, 2 and 3 bit transmission errors.

The equipment shall be suitable for the future installation of UHF radio links as an alternative to transmission over public or dedicated private lines.

5.4-E-2-1 Private Lines/Dedicated Lines

Where communications between sites is to be over 2 wire private circuits rented from the local communications authority or laid along the pipeline, by the Contractor, they shall be speech band circuits (2 wire, half duplex).

Where communication links between sites are specified to comprise two independent circuits, each circuit shall use separate routes where possible. Automatic changeover to the standby line shall occur in the event of duty line failure on the links between the specified sites. The standby lines shall be continually monitored and an alarm raised in the event of failure. Adequate provisions shall be made to allow testing, debugging and servicing a faulty cable while the alternate one is in use.

It shall be the Contractor's responsibility to negotiate and agree on behalf of the Purchaser with the local communications authority for the supply of all lines which must be suitable for the proper operation of the system. Any connection charges arising shall be submitted for payment by the Purchaser.

5.4-E-3 RADIO LINKS

Where it is envisaged that communication between outlying locations and the works will be by radio, the Contractor shall be responsible for carrying out a site radio survey to confirm that this method is suitable.

The results and conclusions of the survey shall be collated into a report which shall contain all documents including correspondence, calculations, etc with any statutory bodies, landowners, etc.

It shall be the Contractor's responsibility to obtain licenses from the relevant licensing authority to operate the required frequencies on behalf of the Purchaser.

The Contractor shall minimize the number of frequencies he intends to use and shall justify the use of all proposed frequencies.

The Contractor shall restrict the data transmission rates over the radio links to the minimum number required for the effective operation of the system. Calculations shall be provided justifying the signaling rates.

5.4-E-4 LOW POWER RADIO

Transmission between individual or small groups of instruments to local stations for monitoring purposes should be considered wherever hardwiring would be more costly. However, control functions should be hardwired or via approved PLC units and not performed within the radio station units.

The above individual or small groups of instruments should form 'cells' within the 'cells' transmitting to a master station via a radio data network.

All systems using low powered radio must be approved to the appropriate local communications authority and shall be installed in a manner which ensures operation within the allowable frequency and power restrictions.

Antenna shall be appropriately sized, orientated and safely installed. All systems shall be of a robust nature with a full consideration given to location, access and vandal interference.

Where radio networks are proposed, available network systems shall be used which optimize the available bandwidth in each channel. The network architecture shall utilize a well established protocol designed for the radio environment operating in real time and able to guarantee data security. In addition the network shall utilize an open architecture to allow for inclusion of a wide variety of devices either existing or in the future.

It may be necessary for more than one radio channel to be utilized to guarantee performance and response. Multiple channels may be used in a cell structure providing this can be demonstrated to be a well proven network facility and does not require custom software design.

5.4-F UNINTERRUPTIBLE POWER SYSTEMS

5.4-F-1 UNINTERRUPTIBLE POWER SUPPLY

Any uninterruptible power system (UPS) which provides a power supply to instrumentation, control or automation equipment and/or any part of a SCADA system should comply with the requirements of this clause.

The UPS shall include, but not be limited to, the following major components:

- rectifier
- battery charger
- static switch with by-pass
- battery

The UPS shall be capable of operation in any of the following modes:

(a) Normal mode:

In normal operation the UPS shall supply precisely-regulated and disturbance-free power to its load. The input power to the UPS shall be supplied from the primary ac source. The rectifier shall by the inverter and battery charger with regulated dc power and the inverter shall convert the dc power to closely-regulated ac power for the load.

(b) Emergency mode:

On failure of the primary ac power source, the battery shall become automatically the source of power until restoration of the primary power source is achieved, whereupon, the rectifier shall restore automatically the normal power supply to the inverter. If the ac power is not restored before the discharge limit of the battery (as defined by the battery manufacturer) is approached, the UPS shall automatically revert to the by-pass mode (see (c) below) leaving the battery with sufficient power for the operation of all protective and monitoring devices. On restoration of the primary supply, the battery shall fully recharge within twenty-four hours.

(c) By-pass mode:

On failure of the inverter output or if the battery approaches its discharge limit, as described in (b) above, the static switch shall transfer the load automatically without interruption to an alternative source of ac power. This facility shall also be capable of manual initiation to enable the remainder of the UPS to be taken out of service for maintenance. Circuit breakers shall be provided so that during maintenance the complete UPS, including the static switch, may be completely isolated from the load and all sources of mains power.

On restoration of the inverter output, or on manual initiation, retransfer of the load back to the inverter shall be accomplished automatically, synchronising the UPS output to the alternative source, paralleling the UPS to ramp into the load and finally disconnecting the alternative source .

(d) Downgraded mode:

Facilities shall be provided to take battery out of service, e.g. for maintenance, whilst the UPS continues to operate in all other respects in the normal mode.

Each power semi-conductor circuit shall be fused to prevent cascaded or sequential semi-conductor failures. Indicating lamps or LEDs shall be provided to show blown fuses. All active electronic devices shall be solid-state. Each semi-conductor device shall be sealed. The design of the UPS shall ensure that electromagnetic effects are minimised and harmless to the operation of any computer, SCADA system or instrument.

The UPS shall have build-in protection against undervoltage, overcurrent and overvoltage including lighting surges on the primary ac source and voltage and current surges on the output including those caused by load transfer between itself and external synchronised source. The complete UPS shall be capable of being started up by the operation of a single switch whose action shall initiate an automatic start-up sequence.

The primary and secondary ac sources shall be a single phase or a three or four wire, three-phase supply, as specified elsewhere. The output ac neutral shall be electrically isolated from the UPS chassis.

Any multi-cabinet UPS shall be housed in free-standing cabinets of equal height capable of being butted end-to-end. Each cabinet shall have forced-air cooling to ensure that every component operates within its environmental ratings. Blower motor shall have sealed bearings and shall be fitted in such a way as to facilitate their replacement. Each cabinet shall have redundant blowers and the failure of any blower shall cause the operation of the appropriate alarms . Each air inlet shall have a standard filter which may be replaced from outside the cabinet. Air inlets and exhaust openings shall have expanded metal guards so that removal of blowers or filters does not give access to live parts. Any blower mounted at the top of a cabinet shall have a removable horizontal baffle-plate fitted above the blower inlet to prevent dirt and drips from entering the cabinet with the blower not operating. The locations of parts, test points and terminals shall be such that they are readily and safely available for circuit checking, adjustment and maintenance without removal of any adjacent or component.

A UPS shall meet the following minimum performance requirements:

(a) Sound radiation:

The UPS shall not generate noise in excess of a sound pressure level of 75 dB measured 2m from the enclosure surface, under any mode of operation and at any load up to the maximum rating. The decibel reference pressure shall be 5x10-5 N/m2.

(b) Electrical noise:

Common mode rejection	120dB
Series mode rejection	60dB
Power line voltage spike attenuation	2000:1
Maximum input to output circuit capacitance	2pF

(c) Efficiency:

The overall efficiency, input to output, shall not be less than 85% with the fully charged and with the inverter supplying the full rated load.

(d) Rectifier:

The rectifier shall be capable of supplying an overload of up to 125% of full load current and shall have current limiting above this value. On removal of the overload , the rectifier shall return to normal without any degrading of performance or components. An isolating transformer shall be provided between the mains terminals of the UPS and the rectifier . The initial magnetising inrush surge shall be limited to 600% of the full load current. The harmonic feedback to the source supply shall not exceed 10% total harmonic distortion and the power factor shall not be less than 0.85 with the nominal input voltage and frequency and with the inverter operating at its rated load.

(e) Inverter:

The inverter steady state voltage shall not deviate by more than 2% due to the following conditions:

- 0 to 100% load;
- ambient temperature variations;
- minimum to maximum dc bus voltage.

The inverter transient voltage shall not exceed 10% with the following system disturbances:

- 50% step load application and removal with zero, 50% and 100% initial loads;
- transfer of load to alternative source following UPS output failure .

The output voltage shall return to within 5% of the steady-state value within 25ms and to within 2% of the steady-state value within 50 ms.

The inverter output voltage shall remain within the steady-state band for:

- inverter drop on to battery with full rated load on its output;
- retransfer of the rated load from the alternative source.

The inverter steady-state free-running output frequency shall not deviate by more than 1% due to the following conditions:

- 0 to 100 % load
- ambient temperature variations
- minimum to maximum de bus voltage.

The inverter shall have harmonic neutralisation and filtering which shall limit the total harmonic distortion in the output voltage to 5%, and for any single frequency to 3%, over the entire load range.

A manual adjustment facility shall be provided to give an output voltage variation of 5% from the rated value.

The output frequency shall be capable of operation as a free-running unit, or as a slave for synchronized operation from an external source or a similar, redundant UPS. The inverter shall track the synchronising source to within 1 Hz, the inverter shall automatically revert to free-running.

For any three-phase inverter, the inverter phase-to-neutral output voltages shall not differ by more than 2% from the arithmetic mean of the three voltage values for a 20% load unbalance. The inverter output voltage shall have a phase displacement within 120 ±1° between adjacent phases for any balanced load and a phase displacement within 120 ±4° between phases for a 20% load unbalance .

The Contractor shall submit details of his proposed installation to the Engineer for approval and obtain this approval before starting any installation work.

5.4-F-2 LOAD CONDITIONER

Any group of ICA equipment using an ac power supply, which is not supplied from an uninterruptible power system, shall be fed from a load conditioner (power conditioner), which has the capability of maintaining a constant voltage output under all specified variations of the site public and stand-by power supplies. The conditioner shall filter high and low frequency transient fluctuations in the power supply.

5.4-G TESTING

5.4-G-1 INSPECTION TESTING AND SETTING TO WORK

Each item of plant shall be subjected to the manufacturer's own tests which shall be certified.

Each item of plant shall be subject to inspection and testing at the place of manufacture.

The Contractor shall be responsible for the provision of all necessary test equipment.

The Contractor shall demonstrate the correct operation of any item of plant and the Engineer may witness any test. Tests which in the opinion of the Engineer, were failed or not performed correctly shall be repeated.

Before any test is made, the Contractor shall submit to the Engineer, a full list of test equipment to be used. Each item of test equipment shall have a standard of accuracy better than that stated by the manufacturer of the item to be tested. The Contractor shall provide evidence of the condition and performance of any item of test equipment, in the form of test certificates issued by an appropriate authority independent of the Contractor and manufacturer, or as otherwise directed by the Engineer. Test equipment shall be checked frequently during the period of the tests.

The Contractor's staff responsible for supervising and carrying out tests shall be fully conversant with the various items of equipment of other manufacturers and if necessary the Contractor shall arrange for his personnel to attend suitable training courses.

Any fault or shortcoming found during any inspection or test shall be rectified to the satisfaction of the Engineer before proceeding with further inspection or testing of that item. Any circuit previously tested, which may have been affected by the rectification work, shall be re-tested.

5.4-G-2 PRELIMINARY WORKS TESTING – PLANT-MOUNTED INSTRUMENTS

After the successful completion of the manufacturer's own inspection and testing of instruments supplied under the Contract similar tests shall be carried out in the presence of the Engineer and the Contractor, if requested. Such tests shall include a demonstration that an increase or decrease of the measured value at several points over the full range of the instrument produces a corresponding increase or decrease in the instrument output signal. These tests shall include checks on the specified accuracy of the instrument at all points.

All magnetic flowmeters shall be calibrated and wet-tested on a permanent test rig specially designed and installed for the testing of flowmeters. The test shall be performed at an agreed number of flow rates over the range of the flowmeter and shall be subject to witness by the engineer and the contractor shall demonstrate that the output of the associated flow converter or signal amplifier is linear to flow throughout the flowmeter range and is within the accuracy specified for the flowmeter.

5.4-G-3 PRELIMINARY WORKS TESTING – INSTRUMENT PANELS PLCS AND SCADA SYSTEMS

The manufacturer shall not present instrument panels, enclosures and mounting boards (assemblies) for inspection and testing until the manufacturer's own tests and inspection has been completed. A preliminary inspection and test of these assemblies may then be witnessed by the Engineer. The Contractor shall give not less than 7 days notice in writing that he has completed his tests and inspection and is ready for the witnessed tests and inspection.

The witnessed inspection and testing shall include the following:

- a visual inspection of the panel assembly to show that the design, construction and finish are satisfactory and in accordance with the Specification and Specification Drawings.
- a check that equipment is securely mounted, accessible for removal, or calibration without damage to or undue disturbance of other components, wiring or piping.
- that all engraving and labels are correctly positioned fixed and designated in accordance with the Specification or later documents provided under the Contract.
- panel power distribution circuits have the correct breaker/fuse rating co-ordination and designation.
- power isolation facilities meet the Specification.
- the main incoming supply voltage, frequency and/or pneumatic supply pressure is within the required limits. These shall be checked at the beginning and end of the test and the results recorded on test certificates.
- the output of all power supply units again at the beginning and end of the testing with results being recorded.
- the power supply voltage or air pressure of all component instruments of the assembly(s). These voltages/pressures shall be recorded on the test certificate.
- the insulation resistance of all circuits except sensitive electronic equipment which is liable to damage by application of the test voltage. Such circuits shall be disconnected before making the insulation resistance tests. These tests shall be carried out in accordance with BS 7671 (IEE Wiring Regulations).
- for leaks in each pneumatic signal and supply line by brushing the joints with soap solution whilst the lines are at maximum pressure.
- that the clean earth bar is isolated from main frame of the panel.

Internal lighting and anti-condensation heaters and associated thermostats, isolators, limit switches and wiring shall be checked for compliance with the Specification.

Spare capacity within the panel(s) shall be checked to see that it complies with the Specification. This shall include future equipment space, spare terminals, space in wiring trunkings and provision for additional cable entry.

5.4-G-4 FUNCTIONAL WORKS TESTING

Once the Preliminary Inspection and Testing is complete to the satisfaction of the Engineer. Functional testing shall commence. The purpose of the functional tests is to demonstrate that instrument panels enclosures and mounting boards (assemblies) conform with requirements of the Specification.

Not less than 30 days before the commencement of functional tests the Contractor shall submit to the Engineer, for approval, two copies of comprehensive test procedural documents detailing each test to be carried out. The document shall include results forms on which the results of each test will be entered. The forms shall include spaces for numerical values, where necessary, and witness signatures. This document shall be used as the basis for the functional testing procedure.

All applicable drawings and data shall be provided at the place of inspection by the Contractor.

The Contractor shall provide all test instruments and equipment necessary to test the assembly(s) in their entirety. The following is typical of the equipment required.

- switch boxes
- indicator light boxes
- analogue signal sources
- dummy loads
- meters
- simulators
- desk top computers
- programmers for programmable logic controllers (PLCs) or outstations
- insulation test equipment

The equipment shall remain energized throughout the period of the functional tests. If equipment proves to be unreliable the Engineer may require a re-test. The aim of this particular test is to check for faults in major components such as PLC's. Video display units (VDU's), power supplies, transformers, ventilation systems etc. Failures of small components such as relays, switches, indicator lights or pushbuttons will not be deemed to cause a failure of the test unless a number of such components fail.

Panels and enclosures shall be tested, with all the doors closed and any forced ventilation in operation, for 12 hours and with as many circuits as possible energized. Dummy loads shall be used where applicable. Temperature levels, at agreed points within the panel or enclosure, shall then be checked and recorded.

Each item of equipment within a particular loop, and included within the panel, shall be tested together as a system. Test equipment shall be connected to the panel outgoing terminals.

Testing shall be carried out loop-by-loop but all equipment within the panel shall remain energized, as far as possible, throughout the period of the functional testing.

Indicators and recorders shall be checked by varying the analogue signal to the panel at the panel analogue input terminals or if this is not possible connecting directly into the loop wiring within the panel.

PID controllers shall be checked by varying the analogue signal to the panel at the analogue input terminals to ensure:

- correct control action
- the auto/manual switch functions correctly
- correct operation of the cascade system (where applicable)

Other control algorithms shall be checked in a similar way. These checks apply to discrete stand alone controllers as well as control systems within PLCs or outstations.

Alarms derived from transmitters analyzers or trip amplifiers, mounted within the panel, shall be tested by varying the associated analogue signal. Testing by adjusting the alarm setpoint will not be acceptable.

Signal isolators within the panel(s) shall be injected with a current source and the calibration checked.

The purpose of the tests is not to allow calibration of the electro mechanical analogue display instruments but to ensure they are operating within the correct range and that their zero and scan points are approximately correct. Final calibration of these display instruments shall be carried out on site. The exception to this are the instruments fed from electrical transducers mounted in the switchgear part of a combined instrumentation/electrical panel. The electrical circuits shall be injected and the zeros and spans adjusted on the transducers to provide the correct range on the indicating instruments or to the PLC/outstation.

All digital input and output signals to and from the panel shall be verified to show that (where applicable) they:

- provide the correct alarm indications
- are received at the PLC or outstation
- are received at the panel output terminals in the case of output signals.
- the correct sequence control is provided

These signals shall be wired, for test purposes, to switch boxes and indicator light boxes. In the case of panels with a large number of digital signals the box(s) may be moved from one set of digitals to another however the boxes must be large enough to cover a whole control scheme so that it is possible to check any problems of interaction with the circuitry/software.

The operation of conductivity probe control units shall be checked by short circuitry the appropriate input terminals. Confirmation is required that the output is received at the correct point within the panel or that the appropriate alarm is given.

Where digital or analogue signals within a combined switchgear and instrument panel assembly start and stop starters, or vary the speed of a drive or control other power devices these circuits shall be proved such that they operate the switchgear or inverters themselves.

All logic, sequence, and timer functions shall be verified whether they are "hard wired" or part of a PLC or outstation. This verification shall follow the requirements of the FDS and the Test Documentation.

Other tests which the Engineer deems necessary for particular applications shall also be carried out.

5.4-G-5 INSPECTION AND TESTING AFTER DELIVERY

As soon as possible after delivery and before installation the Contractor shall check the operation of every instrument and sensor under clean conditions in a workshop which shall be provided and equipped by the Contractor to the approval of the Engineer. Each shipping stop and all packing shall be removed. Any component removed for shipment or consumable stores such as recorder charts, ink, oil, etc. shall be fitted or filled. If any defect is found which cannot be rectified or if any instrument cannot be calibrated, the Contractor shall give the Engineer written notice to this effect, without delay. Each test shall simulate process conditions as closely as possible by the use of manometers, potentiometers, resistance bridges, dead-weight testers, test pressure gauges etc. Calibration and check lists shall be completed for transmitters, receivers, direct-reading instruments, switches for pressure, differential pressure, flow, temperature and level, solenoid valves, control valves etc, and the calibration of each shall be checked against the test certificate issued for the works tests, to the satisfaction of the Engineer.

The calibration of thermocouples shall be checked with a potentiometer against the values given in the IEC standard for the particular thermocouple. The calibration of resistance thermometers shall be checked with a bridge circuit or decade resistance box with accuracy " 0.1%. Ph and reference electrodes shall be calibrated by measuring the emf produced in solution of known composition and strength. Glass Ph electrodes shall be given a minimum of 12 hours equilibration before calibration. Ph monitors shall be checked by the use of not less than three buffer solutions. Conductivity and dissolved oxygen monitors shall be checked using prepared solutions.

No test shall be carried out on electronic equipment before an adequate warm-up period (preferably 24 hours) has been completed.

5.4-G-6 INSPECTION AFTER INSTALLATION

During erection of the plant the installation will be inspected from time to time in the presence of the Contractor's supervisor to establish conformity with the requirements of the Specification. The Engineer reserves the right to make additional un-scheduled inspections at any time and may attend, observe and take note of any activity of the Contractor or those within his employ including his sub-contractors. In the event of any plant or work failing to meet the requirements of the Specification, or the workmanship being defective, the Contractor shall take immediate steps to remedy the deficiency to the satisfaction of the Engineer.

5.4-G-7 INDIVIDUAL TESTS

The Contractor shall carry out pre-commissioning tests to demonstrate the accuracy and correct operation of all instruments, plant monitoring and plant control systems (including control loops, control sequences and safety systems). Pre-commissioning tests shall be carried out after installation and connections to equipment have been completed, but before main plant commissioning trials commence.

The Contractor shall submit detailed test schedules and program of testing to the engineer 30 days prior to testing and the schedules shall be approved by the Engineer before testing is allowed to commence. The test schedules shall identify each item of plant to be tested including test title and purpose, item tag numbers, locations, instrument/circuit type and the test to be carried out. Spaces shall be provided on the Schedules for recording tests results, date and signatures from the Contractor and Engineer.

Pre-commissioning activities may be carried out as a single activity or as a number of separate activities depending upon the size of the plant concerned and the Contractors overall program of works.

The Contractor shall give seven days notice to the engineer of his intension to carry out pre-commissioning testing. If the testing has deviated from the test program, then the Contractor shall give notice within seven days of the change. Pre-commissioning tests shall be programmed and resourced by the Contractor such that the Engineer or Engineer's representatives are able to witness each test.

The Contractor shall ensure that any defects, omissions and deficiencies recorded during inspections have been corrected to the satisfaction of the Engineer before the pre-commissioning tests commence.

The Contractor's personnel conducting tests shall be in teams of at least two test engineers per team and each team shall be provided with efficient remote communication equipment, e.g. field telephones or radios, to the satisfaction of the Engineer, for use during the tests.

The Contractor shall provide all necessary equipment, tools, measuring instruments, calibrators, injectors, data loggers, etc to carry out the tests.

Unless otherwise agreed with the Engineer, the pre-commissioning tests on the various main categories of plant shall be as listed below and incorporated into the detailed test schedules:

- all lines, vessels and connections shall be pressure tested for continuity and freedom from leakage.
- all cables shall be tested for continuity and insulation resistance
- all power supplies shall be available to equipment at the appropriate voltage.
- all gas/liquid supply pressures are available to pneumatically/hydraulically operated instruments and control equipment.
- recorders shall be fitted with the correct charts and drives set in operation, pens inked and checked for clear marking.
- electronic equipment shall have been energized for at least twenty-four hours before testing begins.
- the zero setting of each display instrument including any local indicator on or associated with a transmitter shall be checked.
- the correct calibration of each item in each control or monitoring loop, including the calibration of the whole loop, shall be checked by the introduction of appropriate signals at each source at five cardinal points of the range for increasing and decreasing input signals.
- the correct operation of each automatic control loop, including its regulating device. Each control loop shall be calibrated to its optimum tuned set of control parameters (term, time delays, deadband etc) prior to the pre-commissioning tests and the control loop response shall be demonstrated by simulation of step input and ramped input to the control system for both increasing and decreasing measured variable inputs.

- the correct calibration of all instruments by exercising the transducer using an appropriate measured medium, e.g. tank displacement for flow and level instruments, pressure injection for pressure instruments, use of standard samples for analytical instruments, calibrators for temperature and vibration instruments.

Where instruments require a period of time after calibration to reach an equilibrium state, the instrument shall be set up for the period required to reach equilibrium before the tests commence.

- correct operation of all actuating devices, including electrical, pneumatic and hydraulically controlled actuators on valves, penstocks metering pumps etc, including manual and automatic operation from each operating location (e.g. local at the equipment, remote at the switchgear, remote at a central control room etc)
- correct operation of all control circuits and sequences (hardwired and software).
- "fail safe" operation of all systems shall be checked against the intended design "fail safe" modes.
- correct operation of all alarm devices, alarm displays, alarm messages and alarm accept and reset facilities.

Each calibrated item of equipment shall be labeled after successful testing with the date, name and signature of the Contractors test engineer. The test schedules shall be completed and signed by the test engineer at the time of the tests.

The completed test schedules shall be copied to the Engineer within 14 days of completion of the pre-commissioning tests and prior to overall plant commissioning and the original test schedules shall be included in the operating and maintenance manuals.

Tests shall be carried out on all instruments, actuators, instrument panels and control panels to demonstrate compliance with the functional and performance criteria specified and with relevant standards.

5.4-G-7-1 Field-Mounted Instruments

These shall be subjected to the manufacturers' own inspection and testing procedures together with a demonstration that an increase or decrease of the measured value at several points over the range of the instrument produces a corresponding increase or decrease in the instrument output signal or reading within the accuracy specified or otherwise required for the application.

Flowmeters shall be calibrated and tested on a certified wet test rig.

5.4-G-7-2 Instrument and Control Panels

Inspection and testing shall be carried out to determine that:

- From visual inspection, design and construction are in accordance with the Specification. The engraving, position and fixing of all labels shall be shown to be satisfactory and in accordance with the consent to drawings.

- Power distribution circuits are correctly rated, coordinated and identified.
- Insulation resistance of circuits normally energized at potentials exceeding 50V to earth shall be not less than 10 megohms between conductors and between conductors and earth using a 500V insulation tester. Any equipment liable to be damaged by the application of the test voltage shall be disconnected prior to testing.
- Each item of equipment within a particular loop and the complete loop function correctly. Each indicator, recorder and controller shall be checked over the whole scale range and there shall be no interaction with any other circuit. Controllers shall be checked for correct operation of control action, auto-manual circuits, cascade circuits, proportional, integral and derivative actions and any special features.
- Alarms function as required. Those initiated from remote contacts shall be tested by opening and closing the circuit at the panel outgoing terminals. Those operated from analogue signals shall be tested by use of a variable simulated signal. Each test shall verify that the correct alarm circuit is operated, the alarm sequence is correct and that there is no interaction with any other circuit.
- Sequence programs operate as required and that all input and output responses are correct.

5.4-G-7-3 Programmable Logic Controllers

Testing shall include, but not be limited to, demonstration that any of the following events cannot cause a potentially unsafe condition nor mask the existence of any alarm:

- Output device or driving element failing in a conducting state.
- Failure of the central-processor, memory, input circuit or output circuit.
- Removal and, after a short period, restoration of the power supply.
- Disconnection of any component.
- Unplugging and reinserting any module, filter, printed circuit board, etc.

The demonstration shall also include testing of the PLC input and output responses while exercising all sequence programs.

5.4-G-7-4 Tests at Site

The following inspections and tests shall be carried out after installation at site.

- All instrument piping shall be tested for continuity and freedom from leakage.
- All cables shall be tested for continuity and insulation resistance.
- Electrical supply voltages shall be checked.
- Instrument air supply pressure shall be checked.
- The common mode d.c. voltage at each signal input terminal shall be measured and recorded.

- The zero setting of each display instrument shall be checked.
- The correct calibration of each item in each loop shall be checked by introduction of appropriate signals at each source at five cardinal points of the range for increasing and decreasing signals.
- Recorders shall be fitted with the correct charts and drives set in motion, pens inked and check for clear marking. Multi-point recorders shall be checked to ensure they print at the correct stations.
- Every item shall be visually inspected and any damaged part or deficiency made good.
- All safety devices shall be tested for correct operation.
- Control sequences shall be checked with control inputs activated but outputs initially in a monitoring mode.

The test methods to be used shall be as follows unless otherwise agreed with the Engineer.

- Pressure operated devices shall be tested with dead weight testers or portable calibrators.
- Level operated devices shall be tested by actual level variation or simulation thereof. Zero readings shall be checked against a benchmark where applicable.
- Flow devices of the differential type shall be tested by application of differential pressures. Flow devices of the magnetic type shall be tested with a flow simulator. Where practicable, each flow device shall be checked by an actual displacement test.
- pH electrodes and monitors shall be calibrated by measuring the emf produced in solutions of known composition and strength. Glass pH electrodes shall be given at least 12 hours to stabilize before calibration. pH monitors shall be checked by use of at least three buffer solutions.
- Water quality analyzers shall be calibrated using prepared solutions.
- Each control valve shall be checked by operation of the manual output control on the associated controller. Automatic controllers shall be set to the appropriate estimated values of the control terms.
- All systems shall be checked for fail-safe operation as appropriate by simulated failure, open circuiting, disconnection and so forth.

Part VI: Geotechnical Investigation

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PART 6 – GEOTECHNICAL INVESTIGATION

6.A. SCOPE

The purpose of the work specified herein is to determine the type, nature and characteristics of subsurface materials and the extent and conditions of the various materials of foundation soils and conclusion of soils bearing capacity and to identify any potential geotechnical problem (sliding, instability, settlement,…). This is to be accomplished by means of core drilling, field testing sampling and analysis, laboratory testing. The Contractor will provide access roads as he deems necessary for the execution of work. The Contractor will also provide a report summarizing and interpreting field and laboratory results.

6.B. QUANTITIES AND LOCATIONS OF HOLES

The locations of the drill holes to be executed by the Contractor are distributed on all the project sites (pumping stations, reservoirs, pipelines, access roads, treatment plant, springs,…) and wherever requested by the Engineer. The approximate number and location of drill holes and test pits shall be proposed by the Contractor and approved by the Engineer. The Engineer reserves the right to increase or decrease the quantity of work for the Contract items to such an extent that the total contract amount would be increased or decreased by 50 percent with no change in Contract unit prices. In case of test pits required by the Engineer, these will be paid as unclassified excavations.

6.C. MOBILISATION AND DEMOBILISATION

a. Mobilization: mobilization shall consist of the delivery to the site of all plant, equipment, materials, and supplies to be furnished by the Contractor; the complete assembly in satisfactory working order of all such plant and equipment on the job; and the satisfactory storage at the site of all such materials and supplies.

b. Demobilization: demobilization shall consist of the removal from the site of all plant and equipment after completion of the work and shall include restoration of the area as requested and approved by the Engineer.

6.D. INSPECTION

No work shall be performed in the absence of the Engineer unless authorized by him. The Contractor shall not remove casing or equipment from any completed boring or test pit except with the express permission of the Engineer and not until the Engineer has had the opportunity to obtain all relevant data prior to removal.

6.E. RECORDS

The Contractor shall keep accurate driller's logs and records of all work accomplished under this Contract and shall deliver complete, legible copies of these logs and records to the Engineer on completion of the work in each hole or pit, or at other times as he may be directed. All such records shall be preserved in good condition and order by the Contractor until they are delivered and accepted. The Engineer shall have the right to examine such records at any time prior to their delivery to him. Separate logs shall be made for each hole and test pit. The following information shall be included on the logs or in the records for each hole:

1. Full information on the location, type of boring, diameter, ground elevation, inclination.
2. Location, elevation, depth, type, and number of each sample taken.
3. Driving energy and blow count data for each 15 centimeter penetration of drive sampler and 30 centimeter penetration of casing where the casing is driven.
4. Average rpm and hydraulic advance pressure of drill rig on undisturbed samples, cores, and casing, where the casing is advanced by drilling.
5. Length in centimeters of sampling or coring drive or run.
6. Length and percent of recovery for all samples and cores.
7. Driller's classification or description by depths of the materials sampled, cored, or penetrated, including a description of thickness of zones, moisture conditions, and of conditions of compactness or stiffness of soils materials encountered. This classification or description shall be made immediately following the taking of the samples or cores.
8. Size and lengths of casing used in each bore hole and where added.
9. Elevation of rock if encountered.
10. Elevation of depth of water in holes, daily, at the start of work and after completion of the bore hole until true water table conditions have been established as approved by the Engineer.
11. Elevations and depths of seepage tests and artesian measurements.
12. Elevations and depths at which drill water is lost and regained, and amounts and color of return water.
13. Elevation and depth of bottom of hole.
14. Dates and time by depths when test-pitting, drilling, sampling, seepage testing, and artesian measuring operations were performed.
15. Time required for drilling each run.
16. Time required for seepage tests and artesian measurements.
17. Pressure employed in seepage tests and artesian measurements.
18. Any changes in the drilling action which would be supplemental information to the sampling or coring.
19. Any information or data that the driller may deem pertinent or that may be requested by the Engineer.

The presence of the Engineer or the keeping of separate drilling records by the Engineer shall not relieve the Contractor of the responsibility for the work specified in this paragraph.

6.F. CONTAINERS

a. General The Contractor shall furnish litter size wide mouth jars, 10kg capacity moisture proof bags, undisturbed sample and core boxes, and accessories meeting the specified requirements, or approved as equal by the Engineer. The Contractor shall furnish as many containers as may be required. All such containers will become the property of the Engineer and the cost thereof shall be included in the Contract price for the applicable item for which payment is provided.

b. Core Boxes. Longitudinally partitioned core boxes constructed of lumber or other approved materials, shall be used for all rock cores, selected cores of soil, and selected cores of weathered zones taken from within the rock. Where the Contractor elects to advance a hole by coring in overburden, such core as may be designated by the Engineer shall also be placed in core boxes. The soil and weathered zones shall be preserved in undisturbed boxes or core boxes as directed by the Engineer. As many core boxes as may be required shall be used in submitting each core or group of cores. Core boxes shall be completely equipped with all necessary partitions, covers, hinges, screws for holding down the cover, identification plates, tags and other accessories.

6.G. LABELS

Each bag and core box shall have printed or typewritten labels shall be identified with water-proof and wear-proof labels or markings indicating the following:

Project
Hole No. ______________________________ Location ________________________

Hole No. ______________________________ of____________________________Jars

Jar No. ______________________________ of__________________________ Bags

Top Elev. of Hole ____

Depth of Sample __________________________ to ______________________________

Description of Material ____

6.H. BORINGS

a. General. The Contractor shall make vertical borings of minimum 101 mm in bedrock and 200 mm in overburden. Coring will be continuous from the top of rock to the bottom of hole.

b. Equipment and Supplies. The Contractor shall furnish and use sufficient numbers of drill rigs and associated equipment to successfully complete the project within the designated time scheduler. The drill rigs shall be capable of drilling vertical holes to a depth of 30 meters. Some rigs shall be provided with whirling capability but all rigs shall be provided with hydraulic feed mechanic lams and catheads, and capable of taking drive samples and double tube core barrel rock cores to the depths required. The Contractor shall supply such equipment or accessories necessary for proper positioning of vertical borings.

All borings may be drilled with minimum 101 mm. Drilling mud will not be allowed because of permeability testing requirements.

The Contractor shall provide sufficient heavy-duty casing of such a type to be driven or drilled through the overburden to sound rock. The Contractor shall furnish drill rods, piping, pumps, water, tools, power and all other supplies required to execute the borings to the required depths by the procedure described. Prior to mobilization, the Contractor shall submit to the Engineer for approval a list of equipment he will use.

c. Additional Equipment. If it appears during the course of the work that the Contractor will not complete the contract work within the specified contract period, he shall be required to obtain additional equipment, as deemed adequate by the Engineer, to insure completion of the work as specified. When the Contractor is ordered by the Engineer to use additional equipment or rigs to complete the work on schedule, he shall employ the most expeditious measures and act with the utmost promptness to comply with the Engineer's instructions.

d. Advancing and/or Cleaning the Drill Hole. Samples taken above the water table shall be taken from a dry hole. Advancing and/or cleaning the dry hole to the sampling depth shall be accomplished using a clean out auger or approved equivalent so as to keep the hole dry and not disturb the virgin material at the depth to be sampled. Below the water table any method of cleaning the hole to the sampling depth that does not disturb the virgin material shall be used. If jetting is used, upward or baffled jets shall be required. Below the water table, a head of water greater or equal to the water table, shall be kept in the boring at all times, including the duration of the withdrawal of tools. Where seepage tests or double tube core barrel has introduced water into the hole above the water table, methods other than those required in a dry hole may be used at the convenience of the Contractor where approved by the Engineer. When core drilling through a boulder or ledge rock has been accomplished the cored portion of the hole shall be reamed out as required to advance the casing. If blasting is done, the Contractor shall obtain all necessary permits and shall comply with all laws, rules, regulations and ordinances governing blasting operations. Recirculated or clean water shall be used in overburden below the water table, in holes where seepage tests are designated or requested, and in rock coring. The holes shall be flushed out with clean water prior to testing in accordance with the appropriate Technical provision.

The Contractor shall be responsible for keeping the hole open at all times during the drilling and until all tests or other work in connection with the hole has been completed and the Contractor has been authorized by the Engineer to backfill the hole. In the event of collapse of the hole prior to receipt of authorization to backfill, the hole shall be reopened, in a manner specified by the Engineer, at the Contractor's expense.

e. Artesian Flow. Artesian flow may be encountered when drilling. Each time such flow is encountered, the advancement of the bore hole shall be immediately interrupted and the artesian rise in water or pressure in the casing measured.

f. Advancing the Casing. The casing shall be advanced by hammer, rotary drill, or any method approved by the Engineer, in such a manner to keep the hole open, and insure a tight seal in sound rock. The casing shall be advanced at a sufficient distance behind the sampling operation so as not to disturb the material to be sampled.

6.I. SAMPLING AND CORING IN BORINGS

a. General. Samples and cores shall be taken at designated elevations, with the designated sampler or core barrel as directed by the Engineer. The hole shall be properly advanced and cleaned in accordance with Subparagraph 7-H-d, Advancing and/or Cleaning Drill Hole, prior to sampling. Sampling shall be done by such means as to prevent the inclusion of wash in the sampler. The depths of starting and stopping drives or runs shall be accurately established to the nearest 10 cm.

b. Coring in Overburden. Where specifically requested by the Engineer, double tube core barrels with or without liners will be used to core overburden, generally in dense materials, boulders, and highly weathered rock. The speed of rotation, rate of hydraulic advance, and length of run shall be adjusted so as to provide minimum soil disturbance and maximum recovery. The speed of rotation shall not exceed 200 RPM unless otherwise approved by the Engineer and the maximum length of run shall be such as to provide a 150 cm long sample within the liner, when approved by the Engineer.

c. Rock Core Drilling. The casing through overburden or weathered rock shall be sealed tightly in sound rock prior to commencement of rock coring. The coring of rock with double tube core barrels 101 mm shall be in accordance with Subparagraph b, except that the maximum length of run may be increased to 3 meters when approved by the Engineer. The Contractor shall exercise particular care in recording water losses, rod jerks, and other unusual coring experiences that, supplementing the core record, will indicate the nature and the extent of any fracturing.

6.J. CASING

a. General. The advancing of casing shall be as mentioned in Subparagraph 7-H-f.

b. Removal of Casing. Except as otherwise authorized by the Engineer, all casing shall be removed on completion of the work, and it shall remain the property of the Contractor. Casing shall not be removed until authorized by the Engineer.

6.K. TEST PITS

a. General. A test pit shall be any excavation in soil, cinders, hardpan, decomposed rock or other unconsolidated or partially consolidated overburden which has an open cross-sectional area large enough to permit safe, efficient engineering inspection in situ density testing and undisturbed bag sampling. Bag samples totaling 450 kg or more may be required. The Contractor shall comply with all safety regulations governing this work.

b. Equipment and Supplies. The Contractor shall furnish all equipment and supplies necessary to perform the work.

c. Excavation. The test pits shall be excavated to the required depths.

d. Sampling. All sampling shall be performed by the Contractor as requested by the Engineer and labeled and preserved as specified in 7-G and 7-M, respectively.

e. Barricades. Immediately upon completion of excavation operations for each pit the Contractor shall construct an enclosure guard around each pit, set back about 1 meter from the edge of the pit. The enclosure shall be constructed of materials selected by the Contractor. The enclosure shall be constructed in such a manner that no person or animal can fall into the test pit. Barricades will not be measured for payment, and all costs in connection therewith shall be considered a subsidiary obligation of the Contractor. In addition, it is the Contractor's responsibility to ensure that the barricades are placed; the liability associated with the failure to do so shall lie with the Contractor.

f. Refilling of Test Pits and Test Trends. The test pits shall be refilled when directed by the Engineer. The refilling of test pits will not be measured for payment and all costs in connection therewith shall be considered a subsidiary obligation of the Contractor.

6.L. ABANDONED BORINGS AND FALSE STARTS

No measurement or payment will be made for borings abandoned or lost before reaching the required depths. Except with the specific permission of the Engineer, the Contractor shall not abandon or complete any boring, or remove any casing or drilling equipment, without first affording the Engineer the opportunity of obtaining the position and depth of the boring prior to abandonment or completion, and any other information which the Engineer may require. The Contractor shall furnish the Engineer with complete records and samples for the depth penetrated in the manner hereinafter prescribed for completed borings.

6.M. PRESERVING SAMPLES AND CORES

a. General. The Contractor shall provide all material, equipment and labor necessary for preserving soil samples and rock cores. Wax for sealing sample containers shall be Socony Vacuum Oil Company Product 2300, or approved equal. The preserving and storage of samples and cores shall be a subsidiary obligation of the Contractor in connection with obtaining the samples or cores and no extra payment shall be made for preservation or storage of samples and cores.

b. Test pit Samples. Bulk samples selected by the Engineer from test pits shall be preserved in waterproof bags and shall be clearly marked with two (2) waterproof labels, one wired to the bag and one placed inside the bag. Jar samples taken as directed by the Engineer shall be scaled by double dipping the cap and threads into wax immediately after capping. Undisturbed samples requested by the Engineer shall be moisture proofed and handled accordingly and as requested by the Engineer.

c. Undisturbed Samples in Liners. After inspection by the Engineer, the ends of the sample tubes shall be cleaned out to a depth of 2 inches and a seal provided of micro crystalline wax, such as Socony Product 2300 or equal. A metal disc, having a diameter slightly less than the inner diameter of the tube shall be inserted into the wax at a distance of 2.5 cm from the end of the soil sample. The wax plug shall be flush with the ends of the tube and a metal cap shall be placed over the ends, taped and sealed with two coats of wax. Liners which are only partially full should be filled with wax before capping. Special care shall be made to mark the top and bottom of liner. Material taken from the shoe and the top shall be placed in separate litter jars and marked accordingly and sealed in accordance with the requirements of Subparagraph b.

d. Undisturbed Double Tube Core Samples Without Liners. After inspection by the Engineer, the undisturbed core sample shall be wrapped in polyethylene, coated with wax twice, and wrapped in cardboard, or other stiff material approved by the Engineer. Special care should be taken not to break or disturb the sample during the handling.

e. Soil and Rock Cores. All rock cores and all soil cores such as undisturbed samples shall be arranged neatly in the partitioned boxes constructed and marked in the same sequence in which they occurred before removal from the hole. Facing the open box with the hinged cover above the open box below, cores shall be arranged neatly in descending sequence beginning at the left end of the partition nearest the hinges and continuing in the other partitions from left to right. The highest core shall be placed in box 1 and the lowest portions of the core shall be placed in the other boxes in consecutive order. The runs shall be sectionalized by wood Spacers showing depth, length of run, fractures and their estimated width, and recovery. Core loss blocks shall be used to indicate areas in which no core is recovered. Core sections as designated by the Engineer, shall be wrapped in polyethylene sheets, coated with wax twice, and wrapped in cardboard or other stiff material approved by the Engineer.

6.N. STORAGE AND DELIVERY OF SAMPLES AND ROCK CORES

a. General. The Contractor shall be solely responsible for preserving all samples in good condition. He shall keep samples from undue exposure to the weather. The Contractor shall keep all descriptive labels and designations on sample jars and boxes clean and legible until final acceptance by the Engineer. The Contractor shall comply with all requests of the Engineer concerning the care and protection of samples.

b. Storage. Upon completion of drilling and sampling operations in each hole, or as necessary to protect samples, all boxes containing samples and cores shall be delivered to a structure provided by the Contractor near the work site. Undisturbed samples shall be transported with the tubes in a vertical position, top down, to prevent consolidation and segregation of pore water. Boxes containing disturbed samples and core boxes shall be so arranged in the storage area that the samples and cores can be conveniently and readily examined by the Engineer. Undisturbed samples shall also be stored in an orderly method. Upon request of the Engineer, the Contractor shall furnish a laborer to assist the Engineer in inspecting the samples and cores. The Contractor shall provide all transportation and labor required for storage of the samples and cores at the desired location.

c. Shipment of Selected Samples. Upon request by the Engineer, soil samples and cores shall be boxed by the Contractor as described below and shipped to the Laboratory approved by the Engineer. Samples not directed to be shipped to the above address shall remain at the core storage area at the site. Every precaution shall be taken to avoid damage to samples and cores, especially to undisturbed samples, as a result of careless handling and undue delay in shipping. Undisturbed samples shall be shipped in partitioned wooden boxes made from lumber 6cm, or heavier lumber. The sample tube shall be placed vertically top down, in the box and well-packed in excelsior or other equal material to protect the sample against vibration. The undisturbed sample and core boxes shall be marked "Do Not Jar or Vibrate" and "Handle, Haul and Ship in a Vertical Position". Containers containing glass jars shall be marked as such.

6.O. SEEPAGE TESTS

a. General. Seepage tests shall be performed in bore holes and at depths designated by the Engineer. Prior to performing the seepage tests, the bore hole shall be cleaned out and flushed with clean water to the bottom of the hole by means of a shielded jet or deflected jet as approved by the Engineer, so that all material is removed from inside the bore hole and a clean surface of undisturbed material exists at the bottom of the hole. The rate of seepage shall be determined by one of two methods described below. After performing the above tests the bore hole may be advanced without advancing casing, cleaned as described above and the rate of seepage again determined. Ground water table shall be determined for each seepage test. The data to be recorded for each test which are common to each of the two test methods are as follows:

1. Inside diameter of casing.
2. Height of top of casing above ground surface.
3. Length of casing during test.
4. Diameter of bore hole below casing.
5. Depth to bottom of boring from top of casing.
6. Depth to standing water level from top of casing.
7. Description of exposed material tested.

b. Falling Water Level Method. The casing shall be filled with water and the rate of drop in the water level in the casing determined by observing the depth of the water surface below the top of the casing at 1, 2 and 5 minutes after the start of the test, and at 5 minute intervals thereafter. The record of measurements shall include the depth of the water surface below the top of casing before and after filling of the casing, the time, and tile amount of the drop measured from the start of testing for each observation. Observations shall be continued until the rate of drop in water level becomes negligible or until stopped by the Engineer. If the drop in water level, as described above, is too rapid to permit accurate observations to be made, then the method described below shall be used.

c. Constant Water Level. Water shall be added in accurately measured quantities by pouring from calibrated containers or by pumping through a water meter at a rate of flow sufficient to maintain a constant water level at or near the top of the casing for a period of not less than 20 minutes, until stopped by the Engineer. The record of measurements shall include the depth of the water surface below the top of casing before filling and during the test period, the length of time during which the water in the casing was maintained at constant level, and the amount of water necessary to be added to maintain the constant water level in the casing at 1, 2, and 5 minutes, and at 5 minute intervals thereafter, as directed by the Engineer.

6.P. PRESSURE TESTING IN ROCK

a. General. Pressure testing of weathered and sound rock shall be performed as directed. The apparatus used shall consist of a single pneumatic or mechanical expanding packer to seal off a section of the bore hole for testing. The packer and drill rods shall be calibrated to determine friction losses in the system. The length of the packer when expanded shall be about five (5) times the diameter of the hole. It is the Contractor's responsibility that the packers used are compatible with the size casing used in each borehole. Water lines shall be arranged so that water may be pumped below the packer. The system shall include a pressure gage, water meter, a manually adjusted automatic pressure relief valve, and a pressure pump. After each three (3) meter depth of hole is drilled, the packer shall be seated so that the entire three (3) meter length of hole can be pressure tested. Water under pressure shall be pumped into the test section and the readings recorded. Upon completion of the test, the packer shall be removed, the hole drilled deeper, and the packer reinserted after an additional three (3) meters of hole have been drilled. The packer shall be seated each time at an elevation that will allow the full three (3) meter length of newly drilled hole to be tested.

b. Water Pressures, Duration of Tests, Data to be Recorded The pressure testing shall be performed in five (5) steps for each complete pressure test with the maximum pressure (P_3) based upon the vertical depth to the mid-point of the test section. The value of P_3 will be determined by the Engineer but will be in the range of 0.35 to 10 Kg/cm^2. In no case will the pressure at the test section exceed 0.23 Kg/cm^2 per meter of depth. The following table shows "specified ratios" of pressure and times specified for each step of pressure test.

Step No.	Pressure (P)	Time(minutes)
1	$P_1 = 1/3\ P_3$	5
2	$P_2 = 2/3\ P_3$	5
3	P_3 (determined by test depth)	10
4	P4 = 2/3 P3	5
5	P5 = 1/3 P3	5

Additional data to be recorded in each test are as follows:

1. Elevation of bottom of hole at time of each test.
2. Elevation of packer.
3. Elevation of ground water table at the time of the test.
4. Elevation of piezometric level in artesian strata.
5. Length of test section.
6. Radius of hole.
7. Length of packer.
8. Height of pressure gauge above ground surface.

6.Q. ARTESIAN MEASUREMENTS

a. General. Where artesian flow is encountered the Contractor shall measure its pressure as directed by the Engineer.

b. Equipment. The Contractor shall supply all necessary equipment for performing these measurements, including two Bourbon Gages, a watertight casing cap with "Y" connection and bleeder valve, and expansion plugs to seal off a portion of the hole for testing. The expansion plugs shall be expandable rubber packer having a length about 5 times the diameter of the hole. The Bourbon Gages shall be calibrated in meters of water relative to atmospheric pressure. One gage shall have a range of 0 to 6 meters and the other a range of 0 to 30 meters.

c. Procedure. Where the artesian pressure is of such magnitude that the water in the borehole does not rise above the top of the casing, the pressure shall be measured and recorded as the number of meters and tenths of a meter between the natural ground water level and the level of the water in the casing. Where the artesian pressure is of such a magnitude that the water rises above the highest elevation to which the casing can be practicably extended, the pressure shall be measured by means of a Bourbon Gage fitted to a watertight casing cap by means of a "Y" connection equipped with a bleeder valve.

After each measurement of artesian pressure, the bottom of the borehole shall be advanced at least 0.3 meters but not more than 1.5 meters below the elevation at which the artesian pressure is encountered. If the artisan condition persists after advancing and cleaning out the borehole, additional measurements shall be made.

Records shall be kept of the gage readings and the vertical distances in meters and tenths of meters between the center of the gage, the natural ground surface and the natural ground water level.

6.R. SURVEYING AND HOLE MARKERS

Upon completion, each test boring, test pit, and well shall be surveyed to determine its exact location and elevation. A piece of plastic pipe filled with neat cement shall be installed by the Contractor to mark the hole. A suitable rust proof metal tag shall be attached to each marker showing the whole number, depth, and surface elevation. No separate payment will be made for whole markers, and all costs in connection therewith shall be considered a subsidiary obligation of the Contractor.

6.S. LABORATORY TESTING OF SOIL SAMPLES AND ROCK CORES

a. General. Laboratory testing will be completed on disturbed and undisturbed samples of soil and on lengths of rock core selected by the Engineer and shipped to a laboratory proposed by the Contractor and approved by the Engineer, as described in subparagraph 7-N, Storage and Delivery of Samples and Rock Cores.

b. Testing Laboratory. The laboratory testing shall be performed by an approved laboratory.

c. Type and Approximate Number of Tests. The complete laboratory testing program cannot be determined until the field exploration has been completed and the number and condition of all the samples known.

d. Submittal of a final report. A written detailed report containing the results of the laboratory testing program shall be submitted following the completion of the work in 5 copies to the Engineer for review , then the Contractor will issue the finalized report (5 copies also). The report should identify also the soil strata of the site. The report shall contain the summary of the results and the procedures used. The report shall contain the results of the field testing and the summary of the results as well as the results of the laboratory tests and all conclusions.