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**Section – 5b**

**Technical Specifications for Civil Works**

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## **1 Site Surveys**

### **1.1 Topographical Surveys**

Where a topographical survey is called for, or is otherwise necessary for the execution of the works, the survey shall establish the following information:

- a. Site location relative to existing developments
- b. Location of reference points (temporary benchmarks etc) and datum levels for setting out and levelling
- c. Site boundaries
- d. Contoured plan showing existing site levels
- e. Drainage patterns
- f. Features of engineering significance, e.g, unstable ground, vegetation, contaminated lands, previous use for landfill etc
- g. Means of access to site
- h. Positions of utility service mains, pipelines, cables etc, if any.

### **1.2 Soil Investigations**

Reports of sub-surface examinations made by the Employer will be made available to the Contractor on request, including reports of studies, where available, of the normal ground water level fluctuations. This information is being supplied in good faith but any conclusions drawn from them will be at the Contractor's responsibility.

Prior to designing the foundations for structures that will impose a significant load, the Contractor shall carry out a geotechnical survey in sufficient detail to confirm the validity of the existing geotechnical data. The survey shall include boreholes under every structure that will impose a significant load, including:

- a. pumping stations;
- b. water retaining structures;
- c. dewatering facilities; and
- d. all other tanks, silos etc which will hold liquids or solids in bulk.

Where geotechnical data is unavailable for the area in which a foundation is to be constructed, the Contractor shall carry out a full geotechnical survey and shall establish the following information:

- a. the sequence, thickness and lateral extent of the soil strata and level of bedrock (if appropriate);
- b. the soil parameters and soil chemistry, including identification and classification, contamination and toxic substances determined from tests on representative samples of the soils and rock;
- c. the groundwater conditions, variations and fluctuations; and
- d. the in-situ load bearing capacity of the soil matrix.

Where off-site materials have to be used on the project, the Contractor shall, if the Employer's Representative so desires, make available certified soil test reports including information regarding sieve analyses, plastic limits, liquid limits, maximum density, optimum moisture contents and the credentials of the testing laboratory. The Contractor shall also submit a testing schedule to ensure uniformity of materials supplied. Certificates, when required, shall be submitted in triplicate.

### **1.3 Survey of Existing Underground Services**

The Contractor is wholly responsible for the verification of information regarding existing utilities and their location.

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The Contractor shall conduct a detailed survey to accurately define the line location and depth of existing buried pipes, ducts, cables and other services affected by the works and where required update the drawings.

The Contractor shall establish the location and identify the function of all existing services which:

- a. pass under the proposed location or within 1.5 metres of any proposed new structure or extension to an existing structure
- b. cross the proposed route of any new road, footpath, buried pipe, duct, cable or other service
- c. run within 1 metre of the proposed route of any new road, footpath, buried pipe, duct, cable or other service.

#### **1.4 Survey of Structures to be Modified or Demolished**

##### **1.4.1 Surveys to Establish Strength**

The Contractor shall survey each existing structure for which:

- a. the structure is to be maintained and incorporated into the new works;
- b. the loads to which the structure will be subjected will be increased by more than 10% of the current worst case load conditions; or
- c. the structure itself will be modified in such a way as to affect its ability to withstand loads

For each such structure, the Contractor shall measure structural components on site, expose parts of the foundations, examine the materials of construction etc to an extent which, in conjunction with any available drawings and design calculations for the structure, is sufficient for the strength of the structure to be confirmed.

Where drawings for the structure are available, the Contractor shall check the key dimensions on site. The Contractor shall check all existing structural design calculations made available to him prior to using the results of such calculations.

##### **1.4.2 Structural Condition Survey**

Prior to modifying any existing structure, the Contractor shall carry out a structural condition survey to establish the extent of any of the following parameters:

- settlement and differential settlement
- corrosion
- distortion, abnormal deflections and cracking
- damage to and deterioration of surface finishes
- damage to and deterioration of doors, windows etc

##### **1.4.3 Survey to Identify Hazards**

For each structure which is to be modified or demolished under the Contract, in addition to reviewing any available information about the materials used in constructing the structure or which have been handled in the structure, the Contractor shall survey the structure to identify any potentially hazardous materials such as asbestos. Where appropriate, the Contractor shall carry out chemical or other appropriate tests to verify the identity of any materials that it is believed may be hazardous.

The Contractor shall also identify other features, e.g. fragile roofs, flammable materials etc, which could give rise to a hazard during the modification or demolition work.

#### **1.5 Setting Out**

Setting out and measurement shall comply with the methods and values of accuracy given in ISO 1134: 'Setting Out Buildings'.

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## **2 Relocation, Abandonment and Protection of Existing Utilities, Services and Structures**

The buried services survey must be reconfirmed by the Contractor with the utility authorities involved.

The Contractor is responsible for liaison with the relevant authorities responsible for the utilities, services and structures and establishing the authority's technical requirements and the protocols and planning requirements for their relocation, abandonment and protection and incorporating these requirements into the Contractor's programme.

Unless specifically required by the authority responsible for a particular service, the Contractor is responsible for the relocation (permanent or temporary), abandonment and protection of existing utilities, services and structures required to complete the works.

All utility lines and structures, whether indicated on any drawings or not, which remain in service shall be protected by the Contractor from any damage likely to result from his operations. The Contractor shall be solely responsible for any damage to other utilities as well as any consequential damage/loss as a result of such damage.

The Contractor is responsible for the design of any temporary or permanent works required to temporarily or permanently support or relocate services and structures during the works and demonstrate the adequacy of his designs. Any relocation of services and structures during the works shall be shown on the as-constructed drawings.

Before starting any section of the works, the Contractor shall disconnect or arrange for the disconnection of any utility services designated to be removed, performing such work in accordance with the requirements of the utility company.

The Contractor shall preserve in operational condition any active utilities traversing the site that are designated to remain in operation until the new facilities have been constructed and commissioned.

Where damage is likely to result from his operations, the Contractor shall relocate the utility to the approval of the Employer's Representative and the utility authority.

In the case of any utility whose location or existence is unknown, but which is encountered during the course of the work, the Contractor shall immediately inform the Employer's Representative of such discovery and the Contractor shall either relocate the utility or undertake to have it relocated.

## **3 Demolition**

### **3.1 General**

Demolition work includes, but is not necessarily limited to, the following tasks:

- a. Demolition, removal and disposal of existing structures, mechanical and electrical installations, pipelines and other buried structures and services described in the Employer's Requirements at the project sites or included within the project working areas.
  - b. Demolition, removal and disposal of those structures, mechanical and electrical installations, pipelines and other buried services encountered during excavation which are not required to be retained for future use.
  - c. Temporary and/or permanent relocation of existing utilities and other buried services to be retained for future use which are either encountered or affected by demolition works.
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- d. Temporary and permanent support and protection of existing utilities and other buried services affected by or encountered during demolition works which are to be retained for future use.
- e. Temporary and permanent support for existing above ground and buried structures affected by or encountered during demolition works.
- f. Filling, backfilling and compaction to grade level further to demolition and removal.

The Contractor shall complete, at a minimum, the tasks included in the following paragraphs in the execution of dismantling, demolition and removal of the required items and shall submit a detailed execution and safety plan to the Employer's Representative for inspection prior to commencing his activities.

### **3.2 Existing Services, Utilities and Structures**

Work shall be carried out in such a way that no damage is caused to the adjoining utilities, work or property and precautions shall be taken to minimise dust- nuisance.

### **3.3 Temporary Fencing and Hoarding**

The Contractor shall erect a fence around the perimeter of the safe working area required for demolition and shall demonstrate to the Employer's Representative that the extent of this area fulfils safety requirements.

The Contractor shall provide hoarding as required and to the satisfaction of the Employer's Representative, to protect all those who may be affected by those works.

### **3.4 Demolition and Reinstatement**

The Contractor shall demolish the required structures in accordance with the detailed execution plan submitted to the Employer's Representative.

Dismantling shall be commenced in a systematic manner. All materials which are to be dismantled at height, such as during the demolishing of roofs, shall be carefully lowered to the ground and not dropped.

The Contractor shall remove and dispose of demolition waste off-site, in accordance with the regulatory requirements.

The Contractor shall backfill excavated areas and voids due to demolition or the removal of materials, immediately. Backfilling and compaction shall be suitable for the final requirements at that location. As a minimum, backfilling shall include compacted hardcore to 300mm below grade level and granular fill or topsoil to grade as appropriate.

### **3.5 Removal of Debris**

Any serviceable material obtained during dismantling or demolition shall be separated out and stacked properly. All unserviceable materials shall be disposed of from the site and the site left in a neat and orderly condition, to the satisfaction of the Employer's Representative and in accordance with prevailing regulations.

### **3.6 Treatment**

All the demolition areas shall be rendered clean of all debris. After the removal of any doors, windows chowkhats etc and unless otherwise required, the sides of jambs, sills, soffits etc shall be plastered in 1:3 cement mortar with neeru finish to render sides, corners, edges etc. true and square.

### **3.7 Asbestos Based Materials:**

Asbestos based materials may be present in buildings to be demolished under this contract.

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If any suspected asbestos based materials are discovered during demolition work this shall be reported immediately to the Employer's Representative.

Removal of asbestos based materials shall be carried out by a specialist, licensed sub-contractor prior to any other works starting in the location.

#### **4 Landscaping**

**4.1** The site shall be landscaped once the Works are substantially complete. Landscaping area shall be marked in the layout plan of STP site. The area of landscaping shall not be less than 33% of the proposed plant layout area.

**4.2** Landscaping shall include planting of suitable trees and development of lawn/grassed areas. Landscaping in general shall meet ecological and environmental conditions of the site. Road widths shall determine the size of the tree height and spread to be selected for planting. Trees suitable for local conditions shall be selected as approved by the Engineer. Medicinal and fruit trees shall be avoided. Landscaping shall be maintained in good condition till the completion of the contract.

#### **4.3 Clearance of Large Trees, Structures etc**

Clearance of large trees and structures shall include the removal of large trees, stumps and structures or parts thereof lying within the site of the works as demarcated at the site.

#### **4.4 Removal of Top Soil**

All shrubs, vegetation and other plants shall be removed and cleared from the site and disposed of.

Topsoil shall be carefully stripped and stored at a suitable location on the site, separate from other excavated material. Excess topsoil and topsoil unsuitable for landscaping and grassing shall be removed from the site and disposed of.

All debris and material unsuitable for re-use at the site shall be excavated to a depth of 30 cm shall be removed from the site.

#### **4.5 Grading**

Areas of exposed soil shall be graded, landscaped and planted to produce a neat and attractive environment not subject to ponding.

Where required, areas shall be refilled to correct grade with selected suitable excavated material from the site, or suitable material imported to the site. The quality and compaction of such fill or embankments shall be in accordance with the requirements of Section 5.

Backfilling and compaction shall be suitable for the final requirements at the given location. As a minimum, backfilling shall include compacted hardcore to 300mm below grade level and granular fill or topsoil to grade as appropriate.

The Contractor shall, where necessary, refill and compact any existing pits, wells, existing dry-wells or other areas where the levels are below the general finished grade.

#### **4.6 Grassing and Landscaping**

##### **Landscaping:**

- 1 In addition to top soiling, landscaping includes the supply, installation, laying-out and stocking of flower beds and rockeries, planting of trees and shrubs and for the seeding or turfing of lawns.
  - 2 All parts of the site not covered by buildings or paving shall, as soon as practicable after the completion of the earthworks, be covered with topsoil and sown with grass, all as specified hereafter.
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**Top Soiling:**

- 1 As far as practicable topsoil shall be obtained from material generated from excavations and separately stored in temporary spoil tips as approved.
- 2 If, in the Employer's Representative's opinion the Contractor cannot reasonably obtain sufficient topsoil of acceptable quality in this way, the Contractor shall if so approved by the Employer's Representative provide extra material from an approved source off the site.
- 3 Topsoil shall be evenly spread and trimmed over embankments and other areas to appropriate slopes and grades. The depth after spreading and trimming shall be 300 mm, measured perpendicular to the surface. All clods and lumps shall be broken up and any rubbish large stones, roots and weeds shall be removed.

**Grassing:**

- 1 Areas to be grassed and which have been covered with 300 mm of topsoil shall be sown with an approved species of grass seed suitable for local conditions.

The Contractor shall be responsible for maintaining all landscaped areas including grassed areas, flower beds, rockeries, trees and shrubs in good condition throughout the Contract including all watering, rolling, fertilizing, weeding, cutting and re-sowing as necessary.

**4.7 Fencing****4.7.1 Mild Steel Posts and Struts**

Mild steel posts and struts shall be free from rust, scale, cracks, twists and other defects and shall be fabricated to the required shape and size out of the suitably sized sections. The posts and struts shall have split ends for proper fixing and shall be embedded in cement concrete of mix 1:3:6. The exposed surfaces of the posts and struts shall be painted with two coats of synthetic enamel paint of approved make and shade over a coat of approved primer.

**4.7.2 Reinforced Concrete Posts and Struts**

Reinforced concrete posts and struts shall be of a standard size and be cast in suitable bases in cement concrete 1:2:4 mix and shall have appropriate reinforcement and dimensions. The posts and struts shall be free from honeycombing, cracks and other defects.

After casting, the posts/struts shall be cured for a minimum period of 7 days without being moved. After 7 days curing the posts/struts shall be moved to a levelled area and stacked for 14 days of further curing. After 21 days of curing, the posts/struts may be transported for fixing in position.

**4.7.3 Spacing of the Posts and Struts**

Posts shall be installed at 3 m. centres unless otherwise specified or as approved by the Employer's Representative, to suit the dimensions of the area to be fenced. Every 10th post, last but one end posts, corner posts and posts where the level of fencing changes in steps and end post when the fencing changes its direction shall be strutted on both sides, or as approved by the Employer's Representative. End posts where barbed wire fencing is discontinued shall be strutted on one side only.

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#### **4.7.4 Fixing of Mild Steel/Reinforced Concrete Posts and Struts**

Pits of size 45 x 45 x 45 cm. deep, shall first be excavated centrally in the direction of the proposed fencing work, true to line and level to receive the posts. For struts, the pits shall be excavated to receive a minimum of 15 cm concrete cover at any point to suit its inclination.

The pits shall be filled with a 15 cm layer of cement concrete of 1:2:4 mix. The posts and struts shall then be placed in the pits to the required height above ground level and held true to line, plumb and position by providing adequate temporary supports and then filled with cement concrete so that the posts are embedded. The concrete in foundation shall be watered for at least seven days to ensure proper curing.

#### **4.7.5 Barbed Wire**

Barbed wire shall conform to IS 278-1978.

#### **4.7.6 Chain Link**

The chain link shall be plastic coated galvanised mild steel of approved manufacture and colour and of appropriate size, gauge etc. The base materials of the wire shall be of good commercial quality mild steel. The wire shall be circular in section, free from rust, scale, cuts, welds and other defects and shall be uniformly galvanised.

#### **4.7.7 Fixing of the Chain Link Fencing to Mild Steel/Reinforced Concrete Post**

The chain link fencing shall be fixed first to the end post with the approved GI U type clamps threaded at both ends and GI nuts, bolts and washers and with a 6 mm diameter full height galvanised anchor bar. After fixing the chain link at the end post, it shall be stretched tightly and fixed to the next posts sequentially using the clamps and bars etc leaving 50 mm ground clearance, if soil, or 20 mm if surfaced. At points of change in the level of the fencing, the necessary links shall be adjusted suitably as per the manufacturers' recommendations.

#### **4.7.8 Mild Steel Crimpnet Gate**

All steel work, pipe frame work and crimpnet shall be galvanised and of suitable sizes and sections and shall conform to relevant IS specifications. The crimpnet shall be minimum 25 x 25 mm x 8 g unless otherwise stated and of approved manufacturer.

For each leaf of the gate, the crimpnet shall be welded to an internal angle iron frame of suitable size. The iron frame shall then be fixed to the 50 mm dia seamless pipe outer frame of by means of 65 mm long angle iron lugs welded together. Suitable cleats for the locking arrangement shall be welded at a convenient height. Both the leaves of the gates shall be fitted with suitable hinges provided on the galvanised mild steel channel posts. The side post shall be welded with mild steel plates 250 x 150 x 5 mm at the bottom. These posts shall be properly embedded in cement concrete foundations of suitable sizes and be allowed to set properly. All the assembly shall be properly erected correct to line, level, plumb and allow easy and proper movement of the gates.

The steel parts shall be thoroughly cleaned and painted with red oxide primer of approved make and shade. Final painting with two coats of synthetic enamel paints of approved shade and make shall be carried out to the approval of the Employer's Representative.

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## **5 Earthwork and Excavation**

### **5.1 Site Clearance**

Before the earthwork is started, the areas coming under cutting and filling shall be cleared of all obstructions, loose stones, shrubs, vegetation, grass, brush-wood, trees and saplings of a girth up to 30 cm. measured at a height of one metre above ground and rubbish removed from of the area under clearance. The roots of trees shall be removed to a minimum depth of 60 cm below ground level, or a minimum of 30cm below formation level whichever is lower and the hollows filled up with compacted earth.

The trees with a girth above 30 cm at a height of one metre above ground shall only be cut after permission of the Employer's Representative is obtained in writing.

Any useful materials obtained from the site will remain the property of the Employer and shall be properly protected and stored. The Contractor shall dispose of other materials off site.

### **5.2 Setting Out and Making Profiles**

The Contractor shall erect masonry or concrete pillars at suitable points in the area to serve as bench marks for the execution of the work. These bench marks shall be connected with GTS or any other permanent bench mark approved by the Employer's Representative. Necessary profiles with pegs, bamboos and strings shall be made to show the correct formation levels before the work is started.

### **5.3 Excavation**

Excavations shall be prepared with shallow side slopes to minimise the risk of slope failure. Where this is not possible and the depth exceeds 0.6m then the trench slopes must be stabilised. Prior to man entry into the excavation the Contractor must ensure the excavation is stable. Further checks should be made following periods of rainfall or when excessive loadings occur within close proximity to the excavation.

No excavated material shall be placed, even temporarily, nearer than three metres to the outer edge of an excavation.

The removal of obstructions that would interfere with the proper execution and completion of the work shall conform to the correct lines and grades or be limited generally to 60 cm beyond the outer limit of the structure. It shall be the Contractor's responsibility to provide all required pumping, ditching or other approved measures for the removal or exclusion of water from excavations.

The Contractor shall notify the Employer's Representative before any ground is disturbed and shall conduct a ground level survey. The ground levels shall be taken at 5 to 15 metres intervals in uniformly sloping ground and at closer distances where local mounds, pits or undulations occur. The ground levels shall be recorded in field books and plotted on plans, which shall be signed by the Contractor and the Employer's Representative, before the earth work commences.

When excavating to the required levels for the foundation of any structure or to the required limits for the face of any structure abutting undisturbed ground, the Contractor shall not excavate the last 150 mm until immediately before commencing the constructional work. Should the Contractor have excavated to within 150mm above these specified levels or to within 150 mm of these specified limits before he is ready or able to commence the construction work, he shall excavate further to remove not less than 150mm of material immediately before commencing the construction work.

The excavations shall be carried out systematically. No under-pining or undercutting will be allowed. The bottom and sides of excavation shall be dressed to proper levels, slopes, steps, cambers etc by removing high spots and filling and thoroughly as necessary.

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The width of excavations shall generally be of the width of the mudmat concrete and depth as required by the design and according to availability of the desired bearing capacity of soil below. The minimum depth of foundations for all structures, equipment, buildings and frame foundations and load bearing walls shall be 1.50 m below average ground level, whether the foundation is in soil or in murrum. For any excavation, if taken below the required depth and level, the Contractor shall fill such over-cut to the specified level with 1:4:8 cement concrete in the case of all types of soils and with 1:2:4 cement concrete in the case of soft or hard rock.

The Contractor shall provide adequate ventilation and efficient apparatus to keep all excavation trenches, tunnels and heading structures, sewers and manholes free from all noxious gases and he shall take precautions to ascertain that they are in a safe condition before allowing workmen to proceed.

After the excavation is completed, the Contractor shall notify the Employer's Representative to that effect and no further work shall be taken up until the Employer's Representative has approved the depth and dimensions and also the nature of the foundation material. Levels and measurements of the excavation shall also be recorded prior to taking up any further work.

#### **5.4 Classification of Earthwork**

The earthwork shall be classified under the following main categories:

- 1 All types of soils, murrum, boulders.
- 2 Soft rock.
- 3 Hard rock.

##### **5.4.1 All types of Soils, Murrum, Boulders**

This includes earth, murrum, top deposits of agricultural soil, reclaimed soil, clay, sand or any combination thereof and soft and hard murrum, shingle etc which is loose enough to be removed with spades, shovels and pick axes. Boulders of not more than 0.03 m<sup>3</sup> in volume found during the course of excavation shall also fall under this classification.

##### **5.4.2 Excavation in Soft Rock**

This shall include all materials which are rock or hard conglomerate, all decomposed weathered rock, highly fissured rock, old masonry, boulders bigger than 0.03 m<sup>3</sup> in volume but not bigger than 0.5 m<sup>3</sup> and other varieties of soft rock which can be removed only with pick axes, crow bars, wedges and hammers with some difficulty.

##### **5.4.3 Excavation in Hard Rock**

This includes all rock other than that stated in Sections 5.4.1 and 5.4.2, occurring in masses, boulders having approximate volume of more than 0.5 m<sup>3</sup> plain or reinforced cement concrete, which can best be removed by chiselling and wedging.

The excavation of hard rock shall be done by chiselling and wedging or any other agreed method. Blasting shall not be allowed on this project.

All the excavated hard rock obtained shall be stacked properly and neatly by the Contractor as approved by the Employer's Representative.

#### **5.5 Excavation Side Slopes**

Loose soil or boulders shall be removed from the sides of the trenches before workmen shall be allowed into the excavation and the trench sides shall be stabilized with screening or other methods approved by the Employer's Representative.

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## **5.6 Undercutting of Adjacent Works**

In no case shall the Contractor undercut the foundations of adjacent facilities. Should such a situation be envisaged or develop the Contractor shall provide protection measures as necessary to ensure the safety of the adjacent facility.

The Employer's Representative shall be given every opportunity to review the methods adopted by the Contractor and where he requires, Contractor shall satisfy the Employer's Representative of the adequacy of the methods employed.

## **5.7 Shoring**

The Contractor shall be responsible for the design of shoring for the proper retaining of the sides of trenches, pits etc with due consideration to any traffic or other superimposed loads. Shoring shall be of sufficient strength to resist the pressure and ensure safety from slips and to prevent damage to work and property and injury to persons. Any shoring shall be removed after the items for which it is required are completed. Should slips occur, the slipped material shall be removed and slope dressed to a modified stable slope.

## **5.8 Trench Excavation**

The Contractor shall not keep trenches open for unduly long periods, creating public hazards, such that laying and jointing of pipes can reasonably be expected to be completed and the trench refilled not later than three days after excavation of the trench, except by special permission of the Employer's Representative.

Loose soil or boulders shall be removed from the sides of the trenches before workmen shall be allowed into the excavation and the trench sides shall be stabilized with screening or other methods approved by the Employer's Representative.

Excavation for pipe trenches in hard rock shall be carried out so that the clearance between the pipe, when laid in position and the sides and trench bottom shall be kept to the minimum limits necessary to provide for the thickness of bedding and surround to the pipe.

The minimum width of trenches measured at the crown of the pipe shall permit adequate working space. The trenches may be widened at sockets and other structures as may be necessary.

Care should be taken to avoid excessive trench widths and thereby increasing the load on the pipes. Where this is the case the Contractor shall provide either special bedding or stronger pipes.

### **Over-excavation of Trench Bottoms:**

- 1 All pipeline trenches shall be excavated to a depth of 150 mm below the bottom of the outside of the pipe and backfilled with the appropriate bedding.
- 2 All excavation below the required level shall be refilled with compacted bedding material.

## **5.9 Trenchless Excavation**

### **5.9.1 General**

The Contractor shall submit his proposals for excavating and constructing sewers and pipe lines in tunnel and obtain the approval of the Employer's Representative before any work may commence.

The Contractor shall be responsible for the security of any timbering or other temporary tunnel supports. The Contractor shall submit for approval full details of the support and timbering he proposes to use.

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The excavation for the tunnel shall be of sufficient size for the proper execution of the construction work, all timbering must be driven and fixed in close contact with the ground to be supported.

Unless otherwise approved by the Employer's Representative, the tunnel shall be closed timbered and the timber shall be left in place on completion of the work. During excavation, securely fixed running boards shall be provided to the floor of the tunnel. On completion and after the formation has been cleaned and dried out, a concrete sealing coat shall be provided. The tunnel shall be driven complete between access points before the permanent work may commence and the work shall, at all times, be carried out as quickly as possible so that the excavation remains open for the shortest possible time.

The working face of the tunnel excavation shall be supported as necessary and shall be fixed up at the end of each point when continuous working is not in progress or whenever required by the Employer's Representative.

When work is in progress, proper access ladders shall be fixed and maintained at the tunnel access points and the tunnel lit by electricity of not more than 110 volts. Lamps shall be provided at not more than 9m intervals and no flame or other naked light shall be used. Proper and adequate ventilation fans and ducts must be provided, maintained and operated at all times.

## **5.9.2 Method for Trenchless Excavation**

### **(i) General**

The Contractor is required to take full cognisance of the physical site condition and available working space and select his method with due regard to the same in addition to other requirements for the method proposed.

There is a high likelihood of heavy seepage of water into the excavation.

If required, the Contractor may use sleeve pipes of a bigger diameter than necessary and lay the carrier pipe inside the sleeve pipe at the required grade and alignment.

The Contractor shall take into account the existing manholes to which the proposed pipeline is to be connected and take every precaution to avoid damage to the manholes and any existing sewers.

Where a connection is to be made to a functioning trunk sewer, the Contractor shall take all necessary steps for plugging the sewer and diverting the flows and restoration of the same after completion of the work.

### **(ii) Jacking and Receiving Shafts**

The Contractor shall take due cognisance of the available working space and provide jacking and receiving shafts at appropriate locations so not to cause any harm or danger to adjoining structures, as well as to not occupy additional space.

The Contractor must shore the sides of shafts securely as approved by the Employer's Representative.

### **(iii) Jacking/Boring/Ramming**

The jacking pipe and or carrier pipe should be of suitable length joined by properly designed leak proof joints as required for the method adopted by the Contractor.

The jacking pipe may be provided with arrangements for circulating bentonite solution for stabilization of the surrounding ground.

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The grade and alignment of jacking shall be periodically checked by suitable instruments after jacking of individual units and correct grade and level will have to be ensured.

If the jacking pipe is other than the carrier pipe, the annular space shall be grouted with 1:3 cement sand grout.

**(iv) Tolerance**

The pipes shall be installed in place, true to line and level. The maximum tolerance allowable in the displacement of the centreline of the laid pipe from the design centreline is 50mm per 30 metres in the horizontal plane and 50mm per 100 metres in the vertical plane. There shall be no back fall at any point.

**5.10 Dewatering**

The Contractor shall keep excavations clear of water.

**5.11 Clean Up**

Upon completion of the work in this section, all rubbish and debris shall be removed from the site. All construction equipment and implements shall be removed and the entire area shall be left in a neat, clean and acceptable condition.

**5.12 Disposal of Excavated Material**

Materials suitable for re-use obtained from the excavation shall be properly stored, as approved by the Employer's Representative, and shall remain the property of the Employer.

Materials shall be stored in a convenient place that will not obstruct the free movement of materials, workers and vehicles or encroach on the area required for constructional purposes. Materials shall be used to the extent required to completely backfill excavations to the finished ground level.

Surplus and unsuitable materials shall be disposed of off-site to an approved location.

**5.13 Surface Reinstatement**

**5.13.1 Surface Reinstatement Outside Roads and Footpaths**

In areas outside roads and footpaths, after backfilling trenches, the Contractor shall replace all top soil previously removed, spreading it evenly over the full stripped area. Areas grassed before commencement of work shall be suitably prepared and sown with grass seed of equivalent quality and maintained.

**5.13.2 Road and Footpath Reinstatement**

**(i) Unclassified Roads**

Backfilling shall be carried out in accordance with this specification to within 300 mm of the finished ground level. The last 300 mm shall be backfilled with material, approved by the Employer's Representative, and which shall, as far as practicable, match the existing surface both in quality and level.

**(ii) Macadamized and Premixed Roads**

Backfill, compaction and finishing of macadamized and premixed roads shall be reinstated in accordance with road and pavement Section of this specification. The finished surface shall match the undamaged sections in quality and level.

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## **6 Excavation Dewatering**

### **6.1 General**

Continuous operation of dewatering systems shall be required to complete all portions of the works where dewatering is necessary to prevent inflow and collection of surface water or groundwater, or to protect adjacent properties or constructions from damage resulting from a rise or fall in groundwater levels.

Dewatering systems shall effectively intercept and remove water from the strata and thus enable the excavations to be kept dry when necessary.

The Contractors shall provide and operate all pumps, engines and machinery necessary to keep excavations clear of water. The pumping shall be continued until after the execution of any portion of the work and continued afterwards as necessary.

Where ground water is encountered or anticipated the Contractor shall provide sufficient pumps to handle the ingress of water and shall provide, and maintain in working order, standby pumping units to be available and employed in the event of mechanical failure. The Contractor shall also arrange for night and day management and operation of the pumps as necessary to ensure that at all times and weather the works may proceed.

The Contractor shall furnish for the Employer's Representative review, the proposed drawings and method statements giving the intended plan for dewatering and re- charging operations. These should include locations and capacities of dewatering wells, well point, pumps, sumps, collection and discharge lines, standby units, recharge system (if any), water disposal methods, monitoring and settlement, measuring equipment and data collection.

### **6.2 Components of Dewatering Systems**

Units of standard manufacture and in good working order shall be used. Unserviceable equipment shall be removed from the site. Major items of equipment for which spare parts are not available from local suppliers shall not be used. Adequate arrangements shall be made for the provision of under drain systems below grade slabs to give relief from hydrostatic pressure during construction activities.

### **6.3 Execution**

#### **6.3.1 Preparation**

Coordination: The dewatering installation shall be laid out and installed outside the limits of the permanent works, without interfering with access or other activities.

Barricades, Shelters and Safety: Vital sections of the works shall be protected from accidental damage and barricades and suitable prominent signs shall be provided to indicate and where necessary, isolate hazardous areas.

#### **6.3.2 Performance**

Dewatering arrangements shall be adequate to enable underground and below-grade work to be performed in the dry except where sections of the work have been specified to be done in the wet. Dewatering shall, wherever required or approved, be continuous from commencement to completion, including placing and compaction of back-fill.

When and where approved by the Employer's Representative, the Contractor shall provide an approved monitoring system to measure groundwater levels and settlement.

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### **6.3.3 Maintenance of Existing Water Table**

Where deep pits and heavy, continuous dewatering have to be maintained for long periods in developed areas, the possible effects of groundwater depletion beyond the range of usual fluctuations shall be given due consideration before commencement. Special methods shall be adopted, as necessary, to avoid such dangers. Any observations or complaints of subsidence in the vicinity shall be promptly brought to the notice of the Employer's Representative and corrective measures adopted immediately.

### **6.3.4 Protection of Existing facilities**

Adequate standby units and spares shall be provided by the Contractor to ensure uninterrupted dewatering. Where any sloped excavation potentially endangers any existing facilities or structures, the Contractor shall provide shoring, sheeting and bracing to the satisfaction of the Employer's Representative.

### **6.3.5 Drainage**

During the entire course of operations at any site, the Contractor shall provide and maintain an effective drainage system to prevent inundation of the site. The effluent from the drainage system shall be disposed of as approved by the Employer's Representative.

Grading in the vicinity of excavations shall be such as to exclude rain/surface water from draining into the excavations. The excavation shall be kept clear of rain or such other water by suitably pumping out.

Care shall be taken to ensure that the water is discharged sufficiently away from existing foundations to keep it free from nuisance to other works.

### **6.3.6 Removal**

When no longer needed for dewatering or control operations, the equipment used for such purposes shall be removed from the site. This shall be done after monitoring and settlement measuring operations, if any, are completed and the removal of the equipment is approved. Any underground components such as well-points may be abandoned in place only to the extent of the approval of the Employer's Representative.

The Contractor shall not allow any accumulation of water either from the discharge of their dewatering pumps or their water connections on the site. If an accumulation is unavoidable, it shall be treated with insecticides to the satisfaction of the Employer's Representative.

## **7 Backfilling and Filling**

### **7.1 Materials**

Fill material shall be free of rubbish, roots or debris of any sort. Boulders, rock or concrete fragments over 100 mm in size shall not be present in backfill material. The fill material shall be subject to the approval of the Employer's Representative.

Approved fill shall consist of suitable earth or granular material that has been retained from excavations, taken from designated borrow areas or been hauled from an approved off-site source. This material will be acceptably dry, free from roots, large stones, boulders or large broken rocks, refuse, vegetable matter, topsoil, silt or debris.

Pea gravel shall be washed, rounded durable stone, 9.5 mm to 4.74 mm in size with no more than 2% passing a 75 micrometer sieve.

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Rip-rap material shall be durable stone with a mass of a single stone being between 25 and 50 kg. Stones smaller than 25 kg mass are unsuitable.

All other materials, not specifically described but required for proper completion of the work of this section, will be subject to the approval of the Employer's Representative.

The Contractor shall reserve, separate and stockpile suitable excavated materials for use in backfilling later.

If the Employer's Representative deems the native material to be unsound for the purpose of backfill and an adequate amount of suitable material cannot be so collected, or if the Contractor fails to collect and preserve the requisite quantity, the Contractor shall furnish the additional quantity required. The additional material shall be natural sand, gravel or crushed murrum and shall be readily incorporated in a 100 mm lift and containing not more than 25% by weight of material passing a No. 200 sieve.

If a portion of the excavated materials is found to be unsuitable for use as backfill, the Contractor shall provide suitable material from another source.

## **7.2 Execution**

### **7.2.1 General**

The use of stones, rocks or concrete fragments of more than 100 mm in their greatest dimension shall not be permitted in any trench backfill and stones, rock or concrete fragments larger than 60 mm shall not be permitted in the backfill within 300 mm of the pavement sub grade or within 300 mm of any utilities.

Some backfilling may have to be carried with sand, as approved by the Employer's Representative. The sand used shall be medium grain, clean, sharp, angular, hard and durable, free from clay, mica and soft flaky pieces and free from other impurities. Sea sand shall not be used except under special circumstances. All sands must be well washed and cleaned before use.

Sand fill shall be kept flooded with water for 24 hours to ensure maximum consolidation. The surface of the consolidated sand shall be dressed to the required level or slope. Construction of floors or other structures on sand fill shall not be started until the Employer's Representative has approved the fill.

Backfilling work shall be suspended at any time when satisfactory compaction results cannot be obtained due to rain, or other adverse conditions in the field. The surfaces of any fill shall be maintained with a slope at all times to provide proper surface drainage.

Materials shall be compacted in maximum 300 mm layers and shall be of the proper moisture content before compacting to facilitate obtaining the required compaction.

Temporary planking and formwork etc, shall be removed as backfilling progresses to avoid the formation of voids.

Excavated foundations shall be inspected and approved by the Employer's Representative before proceeding with further work, including placing of any mudmat, reinforcing steel etc.

Complete final grading at grassed or seeded areas shall be to within 50 mm.

The Contractor shall repair damage and correct deficiencies that may result from the settlement of backfilled areas.

### **7.2.2 Foundation Bedding**

Unless otherwise specified, new concrete foundation floors and base slabs shall be constructed on a suitably prepared formation and 100mm PCC mudmat.

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Bedding material, except for clear crushed stone, shall be compacted by mechanical means at optimum moisture content to a value of 95% standard Proctor maximum dry density (SPD).

### 7.2.3 Backfill around Structures

Backfill under this item shall be considered as all replaced excavation or new embankments adjacent to structures. No backfill shall be placed against any structural elements until they have been approved by the Employer's Representative. Backfilling shall be done as soon as practicable after the required conditions are satisfied. Backfill against waterproofed surfaces shall be carefully placed to avoid any damage to the waterproofing material.

The scope of work for filling and backfilling shall include filling for all the buildings covered under the contract.

Mechanical tampers or other approved compactors shall be used to compact all backfill and embankments within 1.2m of a structure and heavy compaction equipment beyond 1.2m of this area. The backfill shall be placed in 200 mm un-compacted depth lifts.

Backfilling shall only be carried out after the concrete or masonry has fully set and shall be done in such a way as not to cause under-thrust on any part of the structure.

All timber shoring and formwork left in excavations shall be removed after use and waste materials shall be cleared out from the excavation.

All the space between foundation masonry or concrete and the sides of excavations shall be backfilled to the original surface level with approved materials in layers not exceeding 300 mm in thickness, watered and well consolidated by means of rammers to at least 90% of the consolidation obtainable at optimum moisture content (Proctor density). Flooding with water for consolidation will not be allowed.

Areas inaccessible to mechanical equipment such as areas adjacent to walls and columns etc shall be tamped by hand rammer or by hand held power rammers to the required density.

Tests to establish proper consolidation as required will be carried out by the Contractor. Two tests per 50 m<sup>2</sup> will be taken to ascertain the proper consolidation.

Unless otherwise specified or approved by the Employer's Representative, the period of time after which the Contractor may place backfill against or on top of any cast-in-place structures is greater than or equal to the time periods as shown in the table below:

Operation	Location			
	Against structures	sides	of	On top of structures
Placement of loose backfill	5 days			21 days
Compaction of backfill	7 days			28 days

The Contractor shall observe any special backfilling requirements or materials, such as those for sub-drains and perimeter drain filters and insulation/expansion material where required.

Where walls are waterproofed on the exterior, or where insulation/expansion material has been placed, backfill shall be placed by hand to prevent damage to the waterproofing membrane. Should any damage to waterproofing occur, such areas shall be re-excavated and the membrane or coatings repaired or replaced to the satisfaction of the Employer's Representative.

Where fill is required on both sides of a wall, foundation or culvert, it shall be deposited layer by layer at each side alternately.

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#### **7.2.4 Filling Beneath Plinths and Floors**

Construction of floors or other structures on fill shall not be started until the Employer's Representative has inspected and approved the fill.

Suitable fill material shall be placed in 15 cm layers, each layer being well watered and consolidated by approved hand or mechanical tampers or other suitable means to achieve the required density.

Gravel if required to be filled under floors, shall be single washed gravel of approved quality and of size varying from 12 mm to 20 mm it shall be uniformly blinded with approved type of soil and/or sand to obtain full compaction. Gravel shall be placed in 15 cm layers and shall be well watered and rammed entirely to the satisfaction of the Employer's Representative.

#### **7.2.5 Slab Base (Rubble Hard Core)**

The rubble shall be of the best variety of black trap/granite/basalt or other approved stone available locally. The stone shall be hard, durable, free from defects and of the required size and shall be approved by the Employer's Representative before incorporation in the work.

The stone used for the work shall be broken rubble of fairly regular shape and free from weathered, soft or decayed pieces.

#### **7.2.6 Workmanship**

The bed on which rubble soling is to be laid shall be cleared of all loose materials, levelled, watered and compacted and approved by the Employer's Representative before laying the rubble soling. Cable or pipe trenches shall be completed before the soling is started.

Over the prepared surface, the stone shall be set as closely as possible and well packed and firmly set. The stones shall be of full height and shall be laid so as to have their bases of the largest area resting on the sub-grade. Soling shall be laid in one layer of 230 mm or 150 mm or other specified thickness and no stones shall be less than 230 mm or 150 mm depth or specified thickness of soling with a tolerance of 25mm

After packing the stones properly in position, the interstices between them shall be carefully filled with quarry spoils or stone chips, to obtain a hard, compact surface.

The entire surface shall be examined for any protrusions and the same shall be knocked off by a hammer and all interstices shall be filled with approved murrum. Excess murrum over the surfaces shall be removed. The surfaces shall then be watered and consolidated with mechanical or sufficiently heavy wooden tampers and log-rammers, as approved by the Employer's Representative, to give the required slope or level and density of sub-base. After compaction, the surface shall present a clean look.

Adequate care shall be taken by the contractor while laying and compacting the rubble soling to see that concrete surfaces in contact with soling are not damaged.

### **7.3 Trench Backfilling**

#### **7.3.1 General**

Backfilling over pipes shall not take place until after the pipes have been successfully tested except for bracing purposes.

Trench backfilling shall start at the top of the pipe or conduit bedding. All materials below this elevation are considered as bedding.

Filling in trenches for pipes and drains shall be commenced as soon as the joints of pipes and drains have been tested and passed.

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The bedding between the bottom of the trench and up to a level of 300 mm above the top of the pipe shall consist of granular material or murum. The maximum size of coarse material or stone shall not exceed 20 mm. The bedding shall be placed in layers not exceeding 150 mm watered and consolidated, taking care that no damage is caused to the pipe. Placing the bedding around thin-walled pipes shall receive special consideration.

The backfill materials shall be suitable excavated material, gravel, crushed stone or murrum or sand, free from any boulders and lumps of hard earth larger than 100 mm in size. Backfill material shall be spread evenly in 225 mm horizontal layers, brought to approximately the optimum moisture content and then tamped or rolled until 95 percent of the maximum dry density is achieved as determined by the standard proctor Test as per IS 2720 (Part VII) or a higher value if one is required in particular circumstances.

Backfill for cast-in-place piping, appurtenances or structures such as manholes shall start at the sub-grade for the structure. Backfill shall be brought up simultaneously and equally on all sides of the structure.

Care shall be exercised during backfill operations to prevent damage or dislodging of the pipes or conduits. Any damage or dislodging of pipes or conduits shall be repaired to the satisfaction of the Employer's Representative.

#### **7.4 Site Grading**

Generally site grading shall include the grading of un-surfaced areas to the final landscape profile with due allowance for topsoil and turfing or as approved by the Employer's Representative. The grading shall ensure that the ground profile slopes away from the structures and does not create ponding.

The site grading shall be subject to the approved by the Employer's Representative before any landscaping is commenced.

Fill for site grading shall be placed in 300 mm layers and compacted to 90% SPD.

Imported fill material shall be used if there is insufficient excavated material on the site.

Ditches and swales shall include trim, grade and slope ditches and swales, to the satisfaction of the Employer's Representative.

#### **7.5 Roads and Parking Areas**

The backfill in areas under roads and parking areas shall be filled to the underside of the sub-base using approved granular fill and compacted in layers of 150 mm to 95% SPD. In areas adjacent to structures thinner layers may be required to suit lighter compaction equipment.

In road cut sections, unsuitable material (silt, humus, topsoil etc) shall be excavated and replaced to the level of the sub-base with approved granular fill, ensuring that the minimum excavation in cut sections extends to the depth of the road base.

### **8 Embankments**

#### **8.1 General**

This work shall include the clearing of the site, setting out and preparing the ground and forming the embankments required for the roads, paths etc with approved excavated or imported material, spread in maximum 200 mm layers, watered and compacted to the 95% SPD, to line, curve, grade, camber and cross section and dimensions as approved by the Employer's Representative.

Embankments shall be set out by fixing batten pegs at regular intervals before commencing the earthwork. The pegs shall be fixed 0.5 metres back from the limits of the fill and painted in a distinctive colour.

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The size of the coarse material in the fill shall not exceed 50mm unless approved by the Employer's Representative. Such material shall be free of logs, brush, stumps, roots rubbish, organic matter, humus, or any other unsuitable material.

The Contractor shall carry out the tests to determine the maximum density of the material to be used by the proctor method before starting the work.

If the cross slopes are steeper than 1 in 3, steps with reverse slope shall be cut into the slopes to give proper hold and seating to the bank as approved by the Employer's Representative. The top 15 cm. of soil shall be scarified and watered and compacted to 95% SPD density before any embankment material placed.

Fill shall be placed extending to the full width of the embankment, including the slopes at the level of the particular layer, and 300 mm. more on both sides to allow for compaction of the full section. The extra loose earth at the edges shall be trimmed after completion of the embankment leaving the correct section fully compacted.

Each layer of the embankment shall be watered, levelled and compacted as specified before the succeeding layer is placed. The surface of the embankment shall, at all times during construction, be maintained in such a manner to prevent ponding. Water to be used shall be free from all harmful contaminants and approved by the Employer's Representative.

If the material for the embankment contains less than the optimum moisture content, water shall be added to the 100 mm embankment layers to bring moisture uniformly up to the optimum. If the excavated material contain more than required moisture, it shall be allowed to dry until the moisture is reduced to required extent. If due to the wetness, the moisture content of the soil cannot be reduced to the appropriate amount by exposure, embankment work shall be suspended until suitable conditions prevail.

When loose layer is placed, levelled and appropriately moistened or dried, it shall be compacted by 8 to 10 tonne power roller, sheep's foot rollers or heavy hauling or dozing equipment until 95 percent of the maximum dry density is achieved, as determined by the standard proctor Test as per IS 2720 (Part VII) or a higher. If on testing, the density is found to be less than 95% of the proctor density, the Contractor shall carry out additional compaction as necessary to get the specified density. If the density cannot be improved by such reasonable efforts, the work may be accepted as substandard work by the Employer's Representative, if he thinks it is not harmful for the purpose.

Embankments not accessible to rollers, such as those adjoining bridges, culverts and other works shall be carried out independently of the main embankments and shall have the layers placed in 150 mm height and each layer shall be moistened and thoroughly compacted with mechanical or manual tampers. Before placing the next layer, the surface of the under layer shall be moistened and scarified to provide a satisfactory bond with the next layer.

Embankments shall be finished and dressed to a smooth and even finish, in conformity with the alignment levels and cross sections and dimensions required. On curves, sections shall be provided with super elevations and increased widths as approved by the Employer's Representative.

The joining of old and new embankments shall be done by stepping in an overall slope of 1 to 5.

The surface of the embankment shall, at all times during construction, be maintained at such a cross-fall to shed water and prevent flooding. All rain water shall be drained away from the toe of the embankment. The Contractor shall maintain the embankment in an approved manner throughout the Contract.

Tests on the embankments shall include the following:

Sr. No.	Test	Frequency
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1.	Plasticity	As directed by the Employer's Representative
2.	Density	Each soil type to be tested. 1 test per 8000 m <sup>3</sup> of soil
3.	Deleterious content	As directed by the Employer's Representative
4.	Moisture content	1 test for every 250 m <sup>3</sup> of soil
5.	CBR test	As required by the Employer's Representative

Density tests shall be carried out for the embankment work during the progress of the work. One set of three core samples for every 1,000 m<sup>2</sup> area of each layer of embankment work shall be taken and tested. The average density shall not be less than 90% of the proctor density, obtained in the laboratory.

The arrangements for obtaining the samples and transporting to a laboratory shall be made by the Contractor.

## **9 Sheeting Shoring and Bracing**

### **9.1 General**

#### **9.1.1 Description**

The Contractor shall supply and install piling, diaphragm walls, bracing, underpinning shoring and dewatering systems to adequately protect existing buildings and facilities and to maintain the excavations required for the construction of facilities.

The Contractor shall be solely responsible for the adequacy of the piling, diaphragm walls, bracing and shoring on the site to maintain safety and prevent damage to existing buildings, facilities, excavation and new construction. The configuration of the proposed shoring and bracing shall be approved by the Employer's Representative.

To obtain the approval of the Employer's Representative, the Contractor shall, if so required, provide drawings of the proposed sheeting and bracing including sheeting sizes, waling, rakers, anchor systems, struts, earth anchors, anchor piles, tie rods and other components pertinent to the effectiveness and adequacy of the shoring and bracing.

### **9.2 Existing Conditions**

#### **9.2.1 Soils**

Any information provided by the Employer relating to boring logs and soil tests carried out are supplied in good faith. Any conclusions drawn from them, however, shall be the responsibility of the Contractor.

Where slopes steeper than the natural angle of repose or other conditions inconsistent with the safety of personnel required to work within an excavated area are encountered such excavations shall be sheeted or shored as may be needed to provide adequate safety.

The Contractor's attention is specially drawn to the necessity for a thorough study of the site and soil conditions, groundwater levels and other relevant factors, particularly in the case of any wet wells, incoming sewer connections and force mains at great depths, before deciding on the necessity or otherwise of sheeting, shoring and bracing and if provided, the adequacy of same.

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### **9.2.2 Obstructions**

Prior to driving sheeting etc, the Contractor shall locate existing facilities in service, if any, and avoid sections that may interfere with such. If such avoidance is not possible the Contractor shall relocate the facility or arrange for its relocation as required to clear the interference. Any action proposed in such circumstances shall be subject to the prior approval of the Employer's Representative.

## **9.3 Products and Materials**

### **9.3.1 Steel Piling and Shoring**

Steel sheet piles shall conform to the requirements of IS 2314 and the steel for walls, struts braces and tie rods shall comply with IS 226. Any materials to be incorporated into the permanent works shall be new.

Piles shall be of the types and sizes indicated in the approved shop drawings or as specified herein and shall be of a design that provides continuous interlocking throughout their entire lengths. Standard handling holes shall generally be provided located approximately 100 mm below the top of each pile.

### **9.3.2 Timber Shoring**

Where the Contractor elects to use timber shoring for trench and structure excavations he shall provide details of the shoring he proposes to adopt, taking into consideration the nature and condition of the soil to be excavated and the depths to which the excavations are to be carried. The quality and strength of the timber and the cross-sectional details and spacing of the shoring, walling and struts together with the calculations, where required or requested by the Employer's Representative, demonstrating the structural adequacy of the proposed shoring and timbering shall be included in the submittals.

Approval of the submittals shall however not relieve the Contractor in any way from his sole responsibility for the stability of the works and the safety of the employees engaged on the work and of the general public.

### **9.3.3 Dimensions**

Piles and ancillary structural members shall be as shown on the approved shop drawings. All procedures shall be subject to the approval of the Employer's Representative approval.

## **9.4 Execution**

### **9.4.1 General**

Piling shall be accurately located and driven to the required depths, plumb and true to line with each pile interlocking with the adjacent pile throughout its entire length. Frames, temporary walls templates, guide-frames and bracing as are necessary shall be installed to guide and support the sheet piling in the correct position and alignment.

The choice of specific construction procedure appropriate for any works or phase thereof shall be the Contractor's responsibility. The procedure adopted shall meet the requirement of the works and specific procedures adopted such as construction methods, shoring, sheet piling, bracing, dewatering etc are at the option of the Contractor. He shall however submit to the Employer's Representative a detailed construction procedure prior to commencement of work.

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#### **9.4.2 Driving**

Piling shall be driven by approved methods in such a manner as not to subject the piles to damage and to ensure interlocking throughout the length of each pile.

Pile hammers shall be of the size and type needed to achieve the required penetration with the minimum damage to the piles. Hammers shall be maintained in a proper alignment with the piles during driving by use of suitable leads or guides. A protective driving cap of approved design shall be used, as required, to minimize the damage to tops of piles. Unless otherwise approved by the Employer's Representative, pile driving shall be done without jetting.

The piles shall be driven plumb and if the sheet piling goes progressively out of plumb, corrective steps shall be taken. If necessary, the piles shall be withdrawn and re-driven so that no part of any pile is more than 75 mm from the design location of the alignment on completion of the work.

Piling shall be driven in stages. No sheet pile, or pair of piles if driven in pairs, shall be driven more than one-third of its length before the adjacent sheet pile is set. Piling that is damaged or driven without interlocking shall be withdrawn and re-placed. The Employer's Representative is empowered to order withdrawal if he has reasonable grounds to suspect damage. Any encroachment of piles upon concrete piles shall be sufficient grounds for withdrawal and replacement.

If obstructions are encountered during driving, the piles in question shall be driven at least to the specified refusal driving resistance after adjacent piles have been set and driven. However, the number of sheet piles permitted to be driven short of the required depths shall be limited in the field by the Employer's Representative and if so approved, the Contractor shall remove obstructions encountered by whatever means necessary.

#### **9.4.3 Splices**

Splices shall be avoided if practicable, but where unavoidable shall be designed to develop the full strength of the piling. Drawings of the proposed splices shall be approved prior to execution. Extreme care shall be exercised to align the spliced sections so that the axis of the pile will be straight and that the interlocks of the piles shall form a straight, smooth and continuous groove.

#### **9.4.4 Driving Resistance**

Steam, air or diesel hammers shall be provided with a rated energy not less than the hammer manufacturer's recommendation for the total weight of pile and the type of subsurface material to be encountered. The Employer's Representative may require the Contractor to change the hammer in use to obtain the required minimum penetration.

Piling shall be driven to such depth as required to provide the degree of protection needed.

#### **9.4.5 Stressing Rods**

All tie rods shall be stressed to minimum of 10 percent of their design load. The Contractor shall submit to the Employer's Representative for his approval the proposed procedure for pre-stressing tie rods.

### **10 Anchors to Resist Uplift**

Based on the site condition (if required) the use of rock anchors to resist uplift shall be permitted with the prior permission of the client with proper justification and design submission.

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## **11 Anti Termite Treatment and Pesticides**

### **11.1 General**

Anti-termite treatment shall be applied to structures during the early stages of construction in the foundation trenches for columns, plinth beams, pile caps, brick walls, service trenches, lift pits, steps, ramps, in the top surfaces of plinth filling, at junction of walls and floor, in expansion joints etc in stages as detailed in this specification. Unless otherwise stipulated, the anti-termite treatment will be carried out as per IS6313 (part II) 1981 and/or as per direction of the Employer's Representative.

Soil treatment shall be applied during the construction stages of the sub-structure up to plinth level.

### **11.2 Products**

Pesticide and/or termiticide emulsions, recommended by the Indian Pest Control Association (IPCA) and approved by the Employer's Representative, shall be used uniformly over the area to be treated. The Contractor shall comply with the requirements on Contractor's licensing, certification and record keeping.

The Contractor shall submit certification for the chemicals purchased and obtain verification that the containers of the chemicals are sealed from the Employer's Representative before preparing the emulsion for the treatment.

The pesticide shall be dispersed uniformly in the soil and to the required strength to form an effective chemical barrier.

### **11.3 Delivery, Storage and Handling**

Pesticides shall be delivered to the site in sealed and labelled containers in good condition as supplied by the manufacturer or formulator. The pesticides shall be stored, handled and used in accordance with manufacturer's instructions. Labels shall bear evidence of registration as per the IS or appropriate regulations.

### **11.4 Site Preparation**

In order to ensure uniform distribution of the chemical emulsion and to assist penetration, the following site preparation shall be carried out:

- 1 Remove all felled trees, stumps, logs or roots from the site.
  - 2 Remove any concrete formwork, levelling pegs, timber off-cuts and other builder's debris from the area to be treated.
  - 3 If the soil to be treated is sandy or porous, preliminary moistening will be required to fill capillary spaces in the soil to prevent the loss of emulsion through piping or excessive percolation.
  - 4 In the event of water logging of foundation, the water shall be pumped out before application of the chemical emulsion and it should be applied only when the soil is absorbent.
  - 5 On clays and other heavy soils where penetration is likely to be slow and on sloping sites, where the treating solution is likely to run-off, the surface of the soil should be scarified to a minimum depth of 75 mm.
  - 6 All sub-floor levelling and grading shall be completed, all cuttings, trenches and excavations shall be completed with backfilling in place. If this is not done, supplementary treatments shall be carried out to complete the barrier.
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At the time of application, the soil shall have sufficiently low moisture content to allow uniform distribution of the treatment solution throughout the soil. Application of the chemicals shall not be made during or immediately following heavy rains or when conditions may cause runoff and create an environmental hazard.

### **11.5 Application**

The Contractor shall apply termiticide to the soil material which will be covered by or lie immediately adjacent to the buildings and structures to provide a protective barrier against subterranean termites.

The termiticide shall be applied as a coarse spray and in such manner as to provide uniform distribution onto the soil surface. This treatment shall be applied prior to placement of a vapour barrier or waterproof membrane and prior to concrete pouring. Where treated soil or fill material is not to be covered with a vapour barrier or waterproof membrane, the Contractor shall exercise adequate precautions to prevent its disturbance.

The chemical emulsion will be applied uniformly by sprayers at the prescribed rates as detailed below in all the stages of the treatment.

#### **11.5.1 Treatment in Foundation Trenches**

In case of normal wall load bearing structures, column pits, wall trenches and basements, the treatment shall be at 5 l/m<sup>2</sup> of surface area of the bottom and sides to a height of at least 300 mm. After the foundation work, the sides shall be treated at 7.5 l/m<sup>2</sup> of vertical surface of substructure on each side. After the earth filling is completed, treatment shall be by rodding the earth at 150 mm centres close to the wall surface and spraying the chemical at a rate of 7.5 l/m<sup>2</sup>.

In the case of framed structures, the treatment shall start at a depth of 500 mm below ground level. From this depth the backfill around the columns, beams and RCC basement walls shall be treated at a rate of 7.5 l/m<sup>2</sup> for the vertical surface and at 5 l/m<sup>2</sup> for horizontal surfaces at the bottom of trenches/pits.

#### **11.5.2 Treatment on Top Surfaces of Plinth Filling**

The top surface of filled earth within plinth walls shall be treated with chemical emulsion at the rate of 5 l/m<sup>2</sup> of the surface area before sub-base to floor is laid. If filled earth has been well rammed and the surface does not allow the emulsion to seep through, holes up to 50 to 75mm deep at 150 mm centres both ways shall be made with crow bars on the surface to facilitate saturation of the soil with the emulsion.

#### **11.5.3 Treatment at Junction of Walls and Floors**

Special care shall be taken to establish continuity of the vertical chemical barrier on the inner wall surfaces from the finished ground level (or from level where the treatment has stopped) up to the level of the filled earth surface. To achieved this, a small channel 30 x 30 mm shall be made at all the junctions of wall/column with the floor (before laying sub-grade) and rod holes made in the channel up to the finished ground level at 150 mm spacings and the iron rod moved backward and forward to break the earth and the chemical emulsion shall be poured along the channel at 7.5 l/m<sup>2</sup> of the vertical wall/column surfaces to soak the soil right up to the bottom. The soil shall be tamped back into place after this operation.

#### **11.5.4 Treatment for Expansion Joints**

The soil beneath expansion joints shall be supplemented by treating through the expansion joint after sub-grade has been laid at the rate of 2 l/m length of expansion joint.

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### **11.5.5 Precautions during Treatment**

Utmost care shall be taken to ensure that the chemical barrier is complete and continuous. Each part of the area shall receive the prescribed dosage of chemical emulsion.

The treatment should not be carried out when it is raining or when the soil is wet with rain or sub-soil water.

The Contractor shall ensure that these chemicals do not enter water supply systems or potable water supplies or aquifers and that they do not endanger plants and animals. The Contractor shall notify the Employer's Representative at least 48 hours prior to the beginning of treatment and perform any formulating, mixing and application.

Once formed, the treated soil barrier shall not be disturbed. If treated soil barriers are disturbed, immediate steps shall be taken to restore the continuity and completeness of the barrier system.

If soil or fill material has been disturbed after treatment, the Contractor shall provide further treatment before placement of slabs or other covering structures. Treatment of the soil on the exterior sides of foundation walls, grade beams and similar structures shall be coordinated with final grading and planting operations to avoid disturbance of the treated barriers by such operations.

### **11.6 Safety Requirements**

The manufacturer's warnings and precautions in the handling and use of materials and the manufacturer's method of application shall be followed by the Contractor. Where the manufacturer's method differs from this document then the Contractor shall submit his method statement to the Employer's Representative for approval.

The Contractor shall formulate, treat and dispose of termiticides and their containers in accordance with the manufacturer's instructions. The Contractor shall draw water for formulating only from sites as approved by the Employer's Representative and fit the filling hose with a backflow preventer meeting local plumbing codes or standards. The filling operation shall be under the direct and continuous observation of a Contractor's representative to prevent overflow. Pesticides and related materials shall be kept secure under lock and key when unattended. Proper protective clothing and equipment shall be worn and used during all phases of termiticide application. Used pesticide containers shall be disposed of in accordance with guidelines and to the satisfaction of the Employer's Representative.

All the chemicals are poisonous and hazardous to health. These chemicals can have an adverse effect upon health when absorbed through the skin, inhaled as vapours or spray mist or swallowed. Persons handling or using these chemicals shall be instructed of these dangers and advised that absorption through the skin is the most likely source of accidental poisoning and cautioned to observe carefully, as a minimum, the safety precautions given in this document and as recommended by the supplier, particularly when handling these chemicals in the form of concentrates.

These chemicals are usually brought to the site in the form of emulsifiable concentrates. The containers shall be clearly labelled and kept securely closed.

Particular care shall be taken to prevent skin contact with concentrates. Prolonged exposure to dilute emulsions shall also be avoided. Workers shall wear clean clothing and wash thoroughly with soap and water especially before eating and smoking. In the event of severe contamination, clothing shall be removed at once and the skin washed with soap and water. If chemicals splash into the eyes they shall be flushed with plenty of soap and water and immediate medical attention sought.

The concentrates are oil solutions and present a fire hazard owing to the use of petroleum solvents. There shall be no naked flames in the proximity during mixing.

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Care should be taken in the application of chemicals/soil-toxicants to ensure that they are not allowed to contaminate wells or springs.

### **11.7 Inspections**

For the duration of the Contract, following the treatment, the Contractor shall perform annual inspections of all buildings treated.

If during the inspections, or at any other time, live subterranean termite infestation or subterranean termite damage is discovered and the soil and building conditions have not been altered in the interim, the Contractor shall:

- 1 Excavate the soil and perform other treatment as may be necessary for elimination of subterranean termite infestation;
- 2 Repair damage caused by termite infestation; and
- 3 Re-inspect the building approximately 180 days after the additional treatment.

In the event of a reappearance of termites within the building area due to defective materials or workmanship or due to any other reason, the Contractor will carry out the necessary post construction treatment to keep the entire area free from termites once again.

The Contractor shall maintain a Pest Management Maintenance Record, identifying target pest, type of operation, brand name and manufacturer of pesticide, formulation, concentration or rate of application used and submit copies of records when requested by the Employer's Representative.

## **12 Roads and Pavements**

### **12.1 General**

The construction and reinstatement of roads and parking areas shall be carried out in accordance with the specifications for road works of the related areas.

**12.2** A comprehensive network of roadways shall be provided around the treatment plant to link in with the existing road network and permit access to the plant for necessary maintenance, delivery of consumables and personnel access. All roads shall be of asphalt macadam/concrete and internal roads minimum 4.50 metres wide. Approach road and main road shall be minimum 6.0m wide. Vehicular access shall be provided for all Plant structures and buildings. All roads shall be provided with drainage and shall be constructed to prevent standing water.

**12.3** Paved pedestrian access ways shall be constructed to provide a network of logical routes interlinking plant areas. Damage to any existing roads on account of their use by the Contractor shall be made good to the satisfaction of the Engineer.

**12.4** Hard standing areas with shading facility shall be provided to permit the parking of vehicles involved in the delivery of consumables from blocking site roadways during unloading or loading. The road system shall be designed such that vehicles involved in the delivery of consumables can follow a continuous route through the works and out again.

### **12.5 Materials**

#### **12.5.1 General**

All materials shall be obtained from local sources and shall be subject to approval by the Employer's Representative prior to use.

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Substitution of material shall be on an approved equivalent basis as determined by the Employer's Representative and shall result in finished roads as designated in this specification.

Material aggregates shall consist of natural or crushed stone, gravel or sands, shall be of reasonably uniform quality throughout and shall be clean and free from soft or decomposed particles, excess clay, foreign, organic or other deleterious matter.

### 12.5.2 Coarse Aggregate for Sub-Base, Base and Semi-grout

Coarse aggregate shall be crushed or broken stone and shall conform to the physical requirement given in the following table.

#### Physical requirements of Crushed Stone for Road Work

Sr. No.	Test	Limiting Value	
		For aggregates to be used for Road base and surfacing	For aggregate to be used for sub-grade
1.	Specific Gravity	Not less than 2.6	Not less than 2.0
2.	Water Absorption	Not more than 2%	Not more than 5%
3.	Flakiness Index	Maximum 25%	----
4.	Elongation Index	Maximum 40%	----
5.	Aggregate Impact Value or Aggregate Crushing Value	Not more than 30%	Not more than 40%
6.	Los Angeles Abrasion Value	Not more than 30%	Not more than 50%
7.	Stripping Test	Maximum 15%	----

Crushed or broken stone shall be hard, durable and free from an excess of flat, elongated, soft and disintegrated particles, dirt and other objectionable matter.

Crushed or broken stone shall conform to the grading given in the following table.

#### Grading Requirements of Coarse Aggregates

Grading No.	Size Range	IS. Sieve Designations	Percent by Weight passing the sieve
1.	90 mm to 40 mm	100 mm 80 mm 63 mm 40 mm 20 mm	100 65 - 85 25 - 60 0 - 15 0 - 5
2.	63 mm to 40 mm	80 mm 63 mm 50 mm 40 mm 20 mm	100 90 - 100 35 - 70 0 - 15 0 - 5
3.	50 mm to 20 mm	63 mm 50 mm 40 mm 20 mm	100 95 - 100 35 - 70 0 - 10

		10 mm	0 - 5
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### 12.5.3 Screenings

Screenings shall consist of predominantly non-plastic materials such as sandy gravelly murrum or gravel (other than rounded river borne material) with Liquid Limit and Plasticity Index below 20 and 6 respectively and the fraction passing 75 micron sieve not exceeding 10%. The materials shall be sound and hard, of a quality not affected by weather and shall be screened at the quarry and shall be free from all impurities. Any large lumps of murrum shall be broken to pass gradation given in the above table. Gravel shall be composed of large, coarse, silicious grains, sharp and gritty to the touch, thoroughly free from dirt and impurities.

Screenings shall conform to the grading indicated in the following table.

#### Grading for Screenings

Grading Classification	Size of Screenings	IS Sieve Designations	Percent by Weight passing the sieve
A	12.5 mm	12.5 mm 10.0 mm 4.75 mm 150 microns	100 90 - 100 10 - 30 0 - 8
B	10.0 mm	10.00 mm 4.75 mm 150 microns 75 microns	100 85 - 100 10 - 30 0 - 10

### 12.5.4 Blinding Material

To fill in the voids in the coarse aggregates, any non-plastic material such as gravel/ grit/ sand/ brick powder may be used. The plasticity index of the material shall not exceed six.

### 12.5.5 Binder

The binder shall be straight run bitumen of grade S35 or S65 and shall conform to the requirements specified in IS 73 and the following table.

#### Requirements of Bitumen Binder

Sr. No.	Characteristic	Requirement for Grade		Method of Test Reference to
		S 35	S 65	
1.	Specific gravity at 27°C, Min.	0.99	0.99	IS : 1202
2.	Water prevent by weight, Max.	0.2	0.2	IS : 1211
3.	Flash point, Pensky Martens closed type °C, Min.	175	175	IS : 1209 (Method A)
4.	Softening point, °C	50 - 65	40 - 55	IS : 1205
5.	Penetration, at 25°C, 100 g, 5 sec in 1/100 cm	30 - 40	60 - 70	IS : 1203
6.	Ductility at 20 °C in cm, Min	50	75	IS : 1208
7.(a)	Loss on beating, percent by weight,	1	1	IS : 1212

	Max.			
7.(b)	Penetration of residue (expressed as percentage of item 5), Min	60	60	IS : 1203
8.	Matter soluble in carbon disulphide, percent by weight, Min.	99	99	IS : 1216

## **12.6 Setting Out**

The Contractor shall provide all labour and materials such as lines, strings, pegs, nails, bamboo, stones, mortar, concrete etc, required for setting out, establishing benchmarks and giving profiles. The Contractor shall be responsible for maintaining the benchmarks, profiles, alignments and other stakes and marks as long as they are required for the works.

The surface of the installed layers will be parallel and have the same grade as the designed asphalt surface and all subsequent layers.

## **12.7 Earthworks for Roads**

Profiles of road excavation shall be laid at 25 m intervals to conform to the required alignment, sections, grades and side slopes and the lines of cuts shall be clearly marked.

The Contractor shall, on no account, excavate beyond the slopes or below the specified grade on the drawings unless so directed by the Employer's Representative in writing.

### **12.7.1 Preparation of Sub-grade**

Immediately prior to the laying of the sub-base metal, the sub-grade shall be cleaned of all foreign substances and vegetation etc. Any ruts or soft yielding patches that appear shall be corrected and the sub-grade dressed off parallel to the finished profile. The camber of sub-grade shall conform in shape to that of the finished road surface. Camber boards shall be used to get the required section.

The prepared sub-grade shall be lightly sprinkled with water, if necessary, and rolled with a power roller of 10-12 tonnes. The roller shall pass over the same area of the sub-grade a minimum of five runs. Any undulations in the surface that develop due to rolling shall be made good with approved earth and sub-grade re-rolled.

### **12.7.2 Sub-base**

#### **(i) General**

The sub-base shall not be constructed on a wet sub-grade.

The width of the sub-base course shall be 150 mm more on either side than that of the water-bound macadam wearing course. The finished thickness of the sub-base course shall be 160 mm. The sub-base metal course shall be laid in two layers, each of thickness 120mm and compacted to 80mm

#### **(ii) Spreading and Rolling**

The metal shall be spread uniformly and evenly upon the prepared base to a thickness of 120 mm. The spreading shall be done from stockpiles along the side of the roadway. In no case shall the aggregates be dumped in heaps directly on the surface prepared to receive the metal nor shall hauling over an un-compacted or partially compacted base be permitted. The surface of the aggregate shall be carefully checked, with templates and all high or low spots remedied by removing or adding aggregate as may be required. No segregation of large or fine particles shall be allowed and the coarse aggregates as spread shall be of uniform gradations with no pockets of fine material.



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Immediately following the spreading of the metal, rolling shall be started with three wheeled power rollers of 10 to 12 tonnes capacity or tandem or vibratory rollers of approved type. Rolling shall begin from the edges gradually progressing towards the centre. First the edges shall be firmly compacted with roller running forward and backward. The roller shall then move inwards in successive passes uniformly lapping preceding tracks by at least one half width.

Rolling shall be continued until the road metal has been thoroughly keyed and the forward movement of stones ahead of the roller is no longer visible. A slight sprinkling of water may be applied if necessary.

**(iii) Application of Screening**

After the metal has been thoroughly keyed and set by rolling, screening to completely fill the interstices shall be applied gradually over the surface. These shall be dry at the time of application. Dry rolling shall be carried out while the screening is being spread so that vibrations of the roller cause them to settle in the voids. The screenings shall not be dumped in piles but be spread uniformly by spreading motion of hand shovels.

The dry rolling shall be accompanied with brooming with hand brooms, wire brushes or both. In no case shall the screenings be applied so fast and thick as to form cakes or ridges on the surface in such a manner as would prevent tilling of voids or prevent the direct bearing of the roller on the metal. These operations shall continue until no more screenings can be forced into the voids in the metal.

**(iv) Sprinkling and Grouting**

The surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the screenings into voids and to distribute them evenly. The sprinkling, sweeping and rolling operations shall be continued with additional screenings applied as necessary, until the coarse aggregate has become well bonded and firmly set in its full depth and a grout has been formed of the screenings. Care shall be taken to see that the underlying layers do not get damaged due to the addition of excessive quantities of water during construction. After the first layer of the sub-base has fully set, to the satisfaction of the Employer's Representative, the second layer shall be laid. The construction operation for the second layer will be the same as that specified herein for the first.

**12.7.3 Water-bound Macadam Course**

**(i) Preparation of Base**

The base to receive the water bound macadam course shall be prepared to the specified grade and camber and made free of dust and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm.

**(ii) Spreading Coarse Aggregate**

The coarse aggregates shall be spread uniformly upon the prepared base and compacted to 80 mm

The spreading shall be from stockpiles along the side of the roadway or directly from vehicles. In no case shall the aggregate be dumped in heaps directly on the surface prepared to receive the aggregate nor shall hauling over un-compacted or partially compacted base be permitted.

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The surface of the aggregates spread shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. No segregation of large or fine particles shall be allowed and the coarse aggregate, as spread, shall be of uniform gradation with no pockets of fine material.

The coarse aggregate shall not normally be spread over more than three days in advance of the subsequent construction operations.

### **(iii) Rolling**

Immediately following the spreading of the coarse aggregate, rolling shall be started with three wheeled power roller of 10 to 12 tonne capacity of tandem or vibratory rollers of approved types. The weight of the roller shall depend upon the type of aggregate and shall be subject to the approval of the Employer's Representative.

Except on super elevated portions where the rolling shall proceed from inner edge to the outer, rolling shall begin from the edges gradually progressing towards the centre. First the edge/edges shall be compacted with roller running forward and backward. The roller shall then move inwards parallel to the centre line of the road, in successive passes uniformly lapping the preceding tracks by at least one half width.

Rolling shall be discontinued when the aggregates are partially compacted with sufficient void space in them to permit application of blinding. A slight sprinkling of water may be applied if necessary. Rolling shall not be carried out when the sub-grade or sub-base is soft or yielding or when it causes a wave-like motion in the sub-grade or base course.

The rolled surface shall be checked transversely and longitudinally with templates and any irregularities corrected by loosening the surface, adding or removing necessary amounts of aggregate and re-rolling until the entire surface conforms to the desired camber and grade. In no case shall the use of blinding be permitted to make up depressions.

### **(iv) Application of Blinding**

After the coarse aggregate has been rolled, blinding to completely fill the interstices shall be gradually applied over the surface. These shall be dry at the time of application. Dry rolling shall be done while the blinding is being spread so that vibrations of the roller cause them to settle into the voids of the coarse aggregate. The blinding shall not be dumped in piles but be spread uniformly in successive thin layers either by the spreading motion of hand shovels or by mechanical spreaders or directly from trucks. Trucks operating for spreading the blinding shall be so driven as not to disturb the coarse aggregate.

The blinding shall be applied at a slow and uniform rate (in three or more applications) to ensure filling of all voids. The rate of spreading blinding shall not be less than  $3.00 \text{ m}^3$  or more than  $4.50 \text{ m}^3$  per  $100 \text{ m}^2$ . This shall be accompanied by dry rolling and brooming with mechanical brooms, hand brooms or both. In no case shall the blinding be applied so fast and thick as to form cakes or ridges on the surface in such a manner as would prevent filling of voids or prevent the direct bearing of the roller on the coarse aggregate. The operations shall continue until no more blinding can be forced into the voids of the coarse aggregate.

The spreading, rolling and brooming of blinding shall be carried out on only such lengths of the road which could be completed within one day's operation.

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**(v) Sprinkling and Grouting**

After the blinding has been applied, the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet blinding into voids and to distribute it evenly. The sprinkling, sweeping and rolling operations shall be continued with additional blinding applied as necessary until the coarse aggregate has been thoroughly keyed, well bonded and firmly set in its full depth and a grout has been formed of blinding. Care shall be taken to ensure that the base or sub-grade does not get damaged due to the addition of excessive quantities of water during construction.

**(vi) Setting and Drying**

After the final compaction of water bound macadam course, the road shall be allowed to dry overnight. Next morning, areas missing blinding shall be filled with blinding as directed, lightly sprinkled with water if necessary and rolled. No traffic shall be allowed on the road until the macadam has set. The Employer's Representative shall have the discretion to stop hauling traffic from using the completed water bound macadam course if in his opinion it would cause excessive damage to the surface.

Should the sub-grade at any time become soft or churned up with the sub-base material or the water bound macadam course, the Contractor shall remove the mixture from the affected portion, reshape and compact the sub-grade and replace the removed section in accordance with the foregoing requirements.

**12.7.4 Tack Coat**

**(i) Preparation of Base**

The base on which a tack coat is to be applied shall be prepared, shaped and conditioned to the specific line, grade and cross section by repairing all potholes or patches and ruts. The potholes shall be drained of water and cut to regular shape with vertical sides. All loose and disintegrated materials shall be removed. The potholes shall then be filled either with (i) coarse aggregate and screenings and compacted with heavy hand rammers or approved mechanical tampers or (ii) premixed chippings binders (bitumen grade S 35/ S 65) content of 3 percent by weight of total mix, after painting the sides and bottom of the holes with a thin application of bitumen, or a combination of both (i) and (ii) as approved by the Employer's Representative. The surface shall be thoroughly swept and scraped clean and free of dust and other foreign matter.

**(ii) Application**

The binder used for tack coat shall be bitumen of suitable penetration grade within S35 to S65 conforming to IS: 73. The binder shall be heated to the temperature appropriate to its grade and as approved by the Employer's Representative. The binder shall be sprayed on the prepared base at the rate of 1.0 kg/m<sup>2</sup>. The binder shall be applied uniformly with the aid of either self propelled or towed bitumen pressure sprayer with self heating arrangement and spraying nozzle arrangement capable of spraying bitumen at the above specified rate and temperature to provide a uniform unbroken spread of bitumen. The tack coat shall be applied just ahead of laying asphalt macadam.

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### 12.7.5 Asphalt Macadam

#### (i) Brushing

Prior to spreading of the asphalt surface, the water bound surface shall be swept clean to remove blinding to expose the metal surface.

#### (ii) Application of Macadam

The bituminous macadam shall be laid by mechanical compactor and finisher, the final consolidation being by means of power roller weighing not less than 10 tonnes. The finished surface shall not vary by more than 12.5mm above or below the designed level and the average thickness shall not be less than 65 mm after consolidation.

The grading, composition and characteristics of the bituminous macadam shall be as follows:

##### Aggregate Grading

IS Sieve Designation	Percentage passing
50 mm	100
40 mm	60 - 100
25 mm	30 – 70
20 mm	20 - 70
6.3 mm	10 - 20
2.36 mm	0 – 5

Bitumen (Grade S 65) Content: 3.7% to 4.3% by weight of total mix.

The bituminous macadam may be prepared in a hot mix plant or the bitumen may be cut back with a suitable solvent so that the heated cut back bitumen may be mixed with the aggregate. In either case mixing shall be carried out in a power driven pugmill mixer and shall be continued until all the aggregate is coated.

The Contractor shall ensure that the installation temperature is adequate during the rolling / compaction of asphalt.

#### (iii) Protection of Pavement

During the period between initial compaction of the coarse aggregate and completion of the seal coat, the surface shall be protected from all traffic other than that which is absolutely essential to its construction.

#### (iv) Premixed Seal Coat

After the full grout has been rolled, the interstices shall be completely filled with pre-coated grit of the following composition.

##### Aggregate Grading

IS Sieve Designation	Percentage passing
6.3 mm	100
2.36 mm	70 - 100
600 micron	25 – 50
300 micron	0 - 10

Bitumen (Grade S 65) Content : 7% to 8% by weight of total mix.

The premixed seal coat may be prepared in a hot mix plant or the bitumen may be cut back with a suitable solvent so that the heated cut back bitumen may be mixed with the aggregate. In either case, mixing shall be carried out in a power driven pugmill mixer and shall be continued until all the aggregate is coated.

The premixed seal must be brushed to fill in the interstices, additional material being applied during rolling if found necessary. The quantity of premixed seal required for this purpose shall be approximately 1.22 m<sup>3</sup> per 100 m<sup>2</sup>.

#### (v) Liquid Seal

On the completion of consolidation, which may be assisted by opening the road to traffic, a liquid seal coat of Grade 565 bitumen shall be applied at a temperature of between 163°C to 191°C (325°F to 375°F) at the rate of 1.25 kg/m<sup>2</sup>. The application of bitumen shall be immediately followed with a cover coat of clean dry ¼ cubical chippings at the rate of 1.22 m<sup>3</sup> per 100 m<sup>2</sup>. The surface shall then be rolled with a power roller weighing not less than 10 tonnes. The composition of this seal coat shall be as follows :

##### Aggregate Grading

IS Sieve Designation	Percentage passing
12.5 mm	100
10 mm	70 - 100
4.75 mm	20 - 40
2.36 mm	7 - 20
75 micron	0 - 4

Bitumen (Grade S 65) Content : 4.5% to 5% by weight of total mix.

#### 12.8 Quality Control

##### 12.8.1 General

All works performed shall conform to the lines, grades, cross sections and dimensions as specified or as approved by the Employer's Representative subject to the permitted tolerances described hereinafter.

##### 12.8.2 Horizontal Alignments

These shall be reckoned with respect to the centreline of the carriageway as specified. The edges of the carriageway as constructed and all other parallel alignments shall be corrected within a tolerance of ± 20 mm.

##### 12.8.3 Longitudinal Profile

The level of any point on the various surfaces after compaction shall comply with the following :

Surface	Tolerance from the specified Level
Sub-grade	± 25 mm
Sub- base	± 20 mm
Base-course	± 15 mm
Wearing course	± 10 mm

The negative tolerance for wearing course, shall not be permitted in conjunction with the positive tolerance for the base course, if the thickness of the wearing course is thereby reduced by more than 6 mm.

The longitudinal profile shall be checked with a 3.0 m long straight edge, along the centreline of the road. The transverse profile shall be checked with a camber board at intervals of 30m. Permitted tolerances are specified in the table below:

**Permitted tolerances of surface regularity for pavement courses**

No.	Type of construction	Longitudinal profile (Maximum permissible undulation when measured with a 3 m straight edge) (mm)
1.	Sub-grade	18
2.	Sub- base	18
3.	Base-course	12
4.	Asphalt macadam	10

#### **12.8.4 Rectification**

Where the surface irregularity of the sub-grade and the various pavement courses falls outside the specified tolerances, the Contractor shall rectify these in the manner described below and to the satisfaction of the Employer's Representative.

##### **(i) Sub-grade**

Where the surface is high, it shall be trimmed and suitably compacted. Where it is low, the deficiency shall be corrected by adding fresh material.

##### **(ii) Stabilised Sub-base**

Where the surface is high, the same shall be suitably trimmed while taking care that the material below is not disturbed due to this operation. Where the surface is low, the same shall be corrected as described below.

When the time elapsed between detection of irregularity and the time of mixing is less than two hours, the surface shall be scarified to a depth of 50 mm, supplemented with freshly mixed material as necessary and re-compacted to the relevant specification. When this time is more than two hours, the full depth of the layer shall be removed from the pavement and replaced with fresh material to the specification. In either case the area treated shall not be less than 5m long and 2m wide.

Where the surface is high or low, the top 75 mm shall be scarified, reshaped with added material as necessary and re-compacted. The area treated shall not be less than 5m long and 2m wide.

##### **(iii) Bituminous Construction**

For bituminous construction other than for a wearing course where the surface is low, the deficiency shall be corrected by adding fresh material and compacting in accordance with the specification. Where the surface is high, the full depth of the layer shall be removed and replaced with fresh material and compacted to the specification.

For wearing course where surface is high or low, the full depth of the layer shall be removed and replaced with fresh material and compacted to specifications. In all cases where removal and replacement of bituminous layer is involved, the area treated shall not be less than 5m long and 2 m wide.

### 12.8.5 Quality Control Test During Construction

For ensuring the requisite quality of construction, the materials and works shall be subjected to quality control test, as described hereinafter, by the Employer's Representative. The testing frequencies set-forth are the minimum required and the Employer's Representative shall have the authority to carry out tests as frequently as he may deem necessary to satisfy himself that the materials and works comply with the appropriate specifications. The tests and their frequency to be used for different materials and works shall be as detailed in the following Table:

Sr. No.	Type of construction	Test		Frequency
1.	Sub-base	i)	Gradation	1 test per 2000 m <sup>2</sup>
		ii)	Plasticity	As required
		iii)	Deleterious Constituents	As required
		iv)	CBR test	As required
		v)	Moisture content prior to compaction	1 test per 250m <sup>2</sup>
		vi)	Dry density	1 test per 500 m <sup>2</sup>
2.	Water Bound Macadam	i)	Gradation	1 test per 1000 m <sup>2</sup>
		ii)	Flakiness index	1 test per 2000 m <sup>2</sup>
		iii)	Plasticity of binding material	1 test per 1000 m <sup>2</sup>
3.	Bitumen Macadam	i)	Quality of binder	As required
		ii)	Aggregate impact value	1 test per 50 – 100 m <sup>2</sup> of aggregate
		iii)	Flakiness index	1 test per 50 - 100 m <sup>2</sup> of aggregate
		iv)	Grading of Aggregates	2 tests per day plant, both on the individual constituents and mixed aggregates from the dryer (one at plant and one at Municipal Lab)
		v)	Binder content	Periodic subject to 2 tests per day per plant
		vi)	Control of temp. of binder and aggregate for mixing and of the mix at the time of laying and rolling	All regular close intervals
		vii)	Rate of spread of mixed material	Regular control through checks on layer thickness
4.	Seal Coat	i)	Quality of binder	As required

Sr. No.	Type of construction	Test		Frequency
		ii)	Aggregate Impact Value	1 test per 2000 m <sup>2</sup>
		iii)	Flakiness Index	1 test per 2000 m <sup>2</sup>
		iv)	Aggregate grading	2 tests per day
		v)	Temp. of application	At regular close intervals
		vi)	Rate of spread 2 materials	2 tests per day

Where a specific procedure is not indicated for quality control tests in these specifications, the same shall be carried out as per prevalent accepted engineering practice and to the approval of the Employer's Representative.

Control shall be exercised by taking at least one measurement of density for each 1000 m<sup>2</sup> of compacted area or as required to yield the minimum number of test results for evaluating a day's work on a statistical basis. The determination of density shall be in accordance with IS: 2720 (Part 28). Test locations shall be chosen only through random sampling techniques. Control shall not be based on the result of any one test but on the mean value of a set of 5 – 10 density determinations. The number of tests in one set of measurements shall be five, as long as it is felt that sufficient control over material and the method of compaction is being exercised. If considerable variations are observed in individual density results, the minimum number of tests in one set of measurement shall be increased to ten. The acceptance of work shall be subject to the condition that the mean standard deviation for any set of results is below 0.08 g/cc.

For earth work in shoulders and in the top 500 mm portion of an embankment below the sub-grade, at least one density measurement shall be taken for every 500 square metres of each set of measurements. In other respects the control shall be similar as described earlier.

## **12.9 Slab Culvert**

### **12.9.1 General**

Where slab culverts are provided for cross drainage purposes, these shall conform to the following specifications. The concrete works specifications for construction of RCC slab and the rubble masonry specification for the supporting rubble walls are given in this specification.

### **12.9.2 Bitumen at Location of Contact**

Two coats of grade S 35 bitumen shall be applied to the top of the bed concrete at the point of contact with the RCC slab above.



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### **12.9.3 Free Draining Graded Gravel Backfill**

On each side of un-coursed rubble walls supporting the slab culvert, a free draining backfill of thickness 200 mm shall be provided. The material shall be granular, consisting of sound, tough, durable particles of crushed or uncrushed gravel, crushed stone or brickbats which will not become powdery under loads or in contact with water. The material shall be free from soft, thin, elongated or laminated pieces and vegetation or other deleterious substances. The material shall be graded and shall meet the grading requirements given above.

### **12.9.4 Weep Holes**

Weep holes as required or as directed by the Employer's Representative shall be provided in the masonry to drain water from the backfilling. Weep holes shall be of PVC pipe in rubble walls with M-15 concrete cushioning 75 mm thick. The weep holes shall extend through the full width of the masonry at a spacing of 1.5 m c/c and with a slope of 1 vertical to 20 horizontal towards the draining face.

## **12.10 Rough / Natural Faced Shahabad Stone Pavement**

### **12.10.1 Materials**

Hand cut rough/natural faced Shahabad stone shall be of the best quality and of suitable thickness, size etc and shall be subject to the approval of the Employer's Representative. The stone shall be hard, sound, durable, tough, free from flaws, cracks, decay and weathering. The edges shall be hand cut and dressed true and squares. The evenness of surfaces and edges of the slabs shall not be marred by careless dressing or handling and no patching up shall be allowed.

The under face may be left as required or rough dressed. Before taking up the work, samples of stone slabs to be used and their dressing shall be subject to the approval of the Employer's Representative. The work shall be carried out strictly in accordance with the approved samples.

### **12.10.2 Bedding/Backing Coat**

In case of plinth protection or other pavements over a concrete sub base, the bedding shall be of 12 mm thick 1:2 cement mortar

In case of pavement work for footpaths, approaches and other similar works, to be laid directly over levelled and consolidated ground, the bedding shall be of 150 mm thick quarry spoil and 60 mm thick stone grit or as otherwise approved by the Employer's Representative.

### **12.10.3 Laying and Fixing Stone Slabs and Tiles**

The specifications for Kotah stone flooring/skirting/facia described in this tender shall apply except that the joints shall be pointed with 1:3 cement mortar and finished flush or with grooves as approved. The joints shall be raked out uniformly to a depth of not less than 12 mm before grouting and pointing the same.

### **12.10.4 Curing**

The pavement work shall be kept well wetted for at least seven days.

### **12.10.5 Cleaning**

When the bedding and joints have been completed, set and attained the required strength, the surface shall be thoroughly cleaned and handed over free from any mortar stains, dust, dirt etc.

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## **12.11 Surface Water Drainage Systems**

### **12.11.1 General**

All surface storm water drains shall be constructed to the correct sizes and shapes as required for a sustained storm of 100 mm per hour. The finished product shall be sound and shall have smooth inside surfaces for optimum flow and be to the approval of the Employer's Representative.

### **12.11.2 Materials**

#### **(i) Common Bricks**

All common bricks shall be sound, hard, thoroughly baked, clean, of proper rectangular size and give a clear ring when tapped. They shall comply with IS 2212. All bricks shall be obtained from a manufacturer subject to the approval of the Employer's Representative.

Testing of bricks shall be in accordance with IS 2212. Mortar shall be composed of one part cement to three parts sand, mixed thoroughly on a clean watertight platform before the appropriate amount of water is added. Mortar shall be used within one hour of adding water to the mix and no softening or revival of mortar shall be permitted after one hour of mixing.

#### **(ii) Plaster**

Where specified, plaster shall be rendered 20 mm thick in cement mortar consisting of one part cement to three parts sand. Plasticizer may be used with cement with the approval of the Employer's Representative.

### **12.11.3 Setting Out**

As soon as the embankments or fill areas are completed in accordance with the requirements of related Sections of this document, the Contractor shall set out the lines for road-side and surface storm-water drains. The centre lines shall be marked with pegs at not more than 30 metre intervals and at turning points and positions of manholes, with the lines and levels of cut for drain laying clearly set out.

### **12.11.4 Execution**

Surface drains shall be laid in trenches dug to the correct levels and alignment and constructed to produce an even alignment and gradient. Over-excavation shall be made good by selected fill well compacted and to the satisfaction of the Employer's Representative.

## **13 Concrete**

### **13.1 Definitions**

Liquid Retaining structures shall be construed to mean any structure of which any part contains water or other process liquids, or which are designed or intended to protect spaces from ground water.

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## **13.2 Materials**

### **13.2.1 General**

The quality of material and method and control of manufacture and transportation of all concrete work irrespective of mix; whether reinforced or otherwise shall conform to the applicable portions of this specification.

The Employer's Representative shall have the right to inspect the sources of materials, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and the approval of the Employer's Representative obtained, prior to starting any concrete work.

The ingredients to be used in the manufacture of standard concrete shall consist solely of a standard type Portland/Portland pozzolana cement, clean sand, natural coarse aggregate, clean water, ice and admixtures if specially called for.

### **13.2.2 Storage**

All materials shall be stored in the required manner immediately upon delivery to the site. It will be the responsibility of the Contractor to provide and maintain requisite stocks, handle the materials with care and store them in such a manner that the materials will remain fresh for use at the appropriate time.

Cement shall be stored in silos or in dry weather proof and well ventilated structures the floors of which shall be at least 450 mm above ground level with adequate precautions to prevent moisture absorption. The storage arrangements shall be subject to the approval of the Employer's Representative and shall provide easy access for inspection. The different consignments shall be identifiable and shall be utilized in the order in which they are received at site or as instructed by the Employer's Representative.

Aggregates shall be so stored that different specified sizes are kept separate and protected against contamination by soil or other impurities. Adequate storage facilities shall be provided to prevent the possibility of intermixing of the different sizes of aggregates.

The use of wet fine aggregates shall be permitted if the moisture content is uniform and after such content is accurately determined to adjust the batching and the water content of the proposed mix. Wherever possible, the fine aggregate shall be kept dry.

All coarse and fine aggregates shall be stacked separately in stock piles in the material yard near the work site in bins properly constructed to avoid inter mixing of different aggregates. Contamination with foreign materials and earth during storage and while heaping the materials shall be avoided. The aggregate shall be of specified quality, not only at the time of receiving at site but also at the time of loading into mixer. Rakers shall be used for lifting the coarse aggregate from bins or stock piles. Coarse aggregate shall be piled in layers not exceeding 1.00 metre in height to prevent coning or segregation. Each layer shall cover the entire area of the stock pile before succeeding layers are started. Aggregates that have become segregated shall be rejected. Rejected material after remixing may be accepted, if subsequent tests demonstrate conformity with the required gradation.

### **13.2.3 Cement**

Cement shall be as per the latest version of IS 269. Cement for use in concrete for sewage treatment works and pumping stations shall be sulphate resistant. Tests shall be carried out as and when approved by the Employer's Representative. The cement shall be tagged for identification at location for sampling.

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Unless otherwise specified or called for in the contract, the cement to be used shall be selected from the following and the type selected shall be appropriate for the intended use and as per the Contract.

- 1 Sulphate resisting Portland cement conforming to IS 12330.
- 2 53 Grade ordinary Portland Cement conforming to IS 12269
- 3 Portland slag cement conforming to IS 455.
- 4 Portland pozzolana cement (fly ash based) conforming to IS 1489 (Part I)
- 5 Portland pozzolana cement (calcined clay based conforming to IS 1489 (Part 2)

Should the project require specific use of any of the following cements the same shall be used with the prior consent of the Employer's Representative and necessary precautions with regard to their setting and hardening time, time required for removal of shuttering and curing etc shall be taken after carefully complying with specific literature with regard to those types.

- 1 High alumina cement - conforming to IS 6452
- 2 Low heat cement - conforming to IS 12600
- 3 Super sulphate cement - conforming to IS 6909
- 4 Rapid hardening cement - conforming to IS 8041
- 5 Blended cement for finishing work as below

Other combinations of Portland cement with mineral admixtures of quality conforming to relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them and only in such case where it is specifically called for in the contract.

No pre-hardened cement shall be used on any permanent works.

#### **(i) Mineral Admixtures for Cement**

Pozzolana: Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of Employer's Representative, provided uniform blending with cement is ensured.

Fly ash (pulverized fuel ash): Fly ash conforming to IS 3812 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured.

Silica fume: Silica fume can be used as part replacement of cement provided it is of sufficient quality approved by the Employer's Representative and uniform blending with the cement is ensured.

Rice husk ash: Rice husk ash giving required performance and uniformity characteristics may be used with the approval of the Employer's Representative.

Metakaoline: Metakaoline having fineness between 700 to 900 m<sup>2</sup>/kg may be used as a pozzolanic material in concrete.

Ground Granulated Blast Furnace Slag: Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to IS 12089 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is assured.

Quality Assurance of Cement: A certified report attesting to the conformity of the cement to IS specifications by the cement manufacturer's chemist shall be furnished to the Employer's Representative, if demanded. The Contractor, shall make his own arrangements for the storage of adequate quantities of cement at the site of work.

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Storage of Cement: Cement in bags shall be stored and stacked in a shed, which is dry, leak-proof and moisture proof as far as possible. Storage under tarpaulins will not be permitted. Flooring of the shed shall consist of the two layers of dry bricks laid on well consolidated earth to avoid contact of cement bags with the floor. Stacking shall be about 150 to 200 mm clear above the floor using wooden planks. Cement bags shall be stacked at least 450 mm clear of the walls and in rows of two bags leaving a space of at least 600 mm between two consecutive rows. In each row the cement bags shall be kept closed together to reduce air circulation. Stacking shall not be more than ten bags high to avoid lumping under pressure. In stacks more than eight bags high, the cement bags shall be arranged in header and stretcher fashion i.e. alternately lengthwise and crosswise to tie the stacks together and minimize the danger of toppling over.

Damaged or reclaimed or partly set cement will not be used and shall be removed from the site. The storage arrangements shall be such that there is no dead storage consignments so cement shall be stored as received and shall be consumed in the order of their delivery.

Cement held in store for a period of ninety days or longer shall be retested before used in work. Should the Employer's Representative have reasons to consider that any cement is defective, then irrespective of its origin and/or manufacturers test certificate, such cement shall be tested immediately at a National Test Laboratory or other approved laboratory and until the results of such tests are found satisfactory, it shall not be used in any work.

#### 13.2.4 Aggregates

Aggregate in general designates both fine and coarse inert materials used in the manufacture of concrete.

Fine aggregate is aggregate most of which passes through 4.75 mm IS sieve.

Coarse aggregate is aggregate most of which is retained on 4.75 mm IS sieve. Aggregate shall comply with requirement of IS 383. As far as possible preference shall be given to machine broken and graded aggregate.

All fine and coarse aggregates proposed for use in the work shall be subject to the Employer's Representative's approval and after specific materials have been accepted, the source of supply of such materials shall not be changed without prior approval of the Employer's Representative.

Aggregate shall, except as noted above, consist of natural sand, crushed stone and gravel from a source known to produce satisfactory aggregate for concrete and shall be chemically inert, strong, hard, durable against weathering, of limited porosity and free from deleterious materials that may cause corrosion to the reinforcement or may impair the strength and/or durability of the concrete. The grading of aggregates shall be such as to produce a dense concrete of specified strength and consistency that will work readily into position without segregation and shall be based on the mix design and preliminary test on concrete specified.

The maximum percentages of permissible deleterious materials shall be as follows, subject to total combined impurities, limit of 5 percent by weight.

Impurity	Coarse Aggregate		Fine Aggregate	
	Crushed	Uncrushed	Crushed	Uncrushed
<b>Clay lumps</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
<b>Soft fragments</b>	<b>3</b>	<b>-</b>	<b>-</b>	<b>-</b>
<b>Fine material passing through 75 micron sieve</b>	<b>3</b>	<b>1</b>	<b>3</b>	<b>3</b>
<b>Shale</b>	<b>-</b>	<b>-</b>	<b>1</b>	<b>-</b>

<b>Coal, lignite</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
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**(i) Specific Gravity**

Aggregates having a specific gravity below 2.6 (saturated surface dry basis) shall not be used without special permission of the Employer's Representative.

**(ii) Fine Aggregate**

Fine aggregate except as noted above and for other than light weight concrete shall consist of natural or crushed sand conforming to IS 383. The sand shall be clean, sharp, hard, strong and durable and shall be free from dust, vegetable substances, adherent coating, clay, loam, alkali, organic matter, mica, salt or other deleterious substances which can be injurious to the setting qualities, strength or durability of the concrete.

Machine Made Sand: Machine made sand will be acceptable, provided the constituent rock composition is sound, hard, dense, non-organic, uncoated and durable against weathering. Machine made sand shall be accepted provided grading and fine particle limits conform to IS 383.

Screening and Washing: Sand shall be prepared for use by such screening or washing or both, as necessary, to remove all objectionable foreign matter while separating the sand grains to the required size fractions. Sand with a silt content of more than 3 percent will not be used unless the same is washed and silt content is brought within 3% by weight.

Foreign Material Limitations: The percentages of deleterious substances in sand, delivered to the mixer shall not exceed the following:

	<b>Foreign Material</b>	<b>Percent by weight</b>	
		<b>Uncrushed</b>	<b>Crushed</b>
i)	Material finer than 75 micron IS sieve	3	15
ii)	Shale	1	---
iii)	Coal and lignite	1	1
iv)	Clay lumps	1	1
v)	Total of all above substances including items (i) to (iv) for uncrushed sand and items (iii) and (iv) for crushed sand	5	2

Gradation: Unless otherwise approved, the grading of sand shall be within the limits indicated. Where the grading falls outside the limits of any particular grading zone of sieves, other than the 600 micron (IS) sieve by not more than 5%, the grading shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 micron (IS) sieve or to percentage passing any other sieve size on the coarser limit of grading zone I or the finer limit of grading zone IV. Fine aggregates conforming to Grading Zone IV shall not be used unless mix designs and preliminary tests have shown its suitability for producing concrete of specified strength and workability.

<b>IS Sieve Designation</b>	<b>Percentage passing for</b>			
	<b>Grading Zone I</b>	<b>Grading Zone II</b>	<b>Grading Zone III</b>	<b>Grading Zone IV</b>
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15 – 34	35 - 59	60 – 79	80 – 100
300 micron	5 – 20	8 - 30	12 - 40	15 - 50

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150 micron	0 - 10	0 - 10	0 - 10	0 - 15
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Fineness Modulus: The sand shall have a fineness modulus of not less than 2.2 or more than 3.2. The fineness modulus is determined by adding the cumulative percentages retained on the following IS sieve sizes (4.75 mm, 2.36 mm, 1.18 mm, 600 micron, 300 micron and 150 micron) and dividing the sum by 100.

**(iii) Coarse Aggregate**

Coarse aggregate for concrete, except as noted above and for other than light weight concrete, shall conform to IS 383. This shall consist of natural or crushed stone and gravel and shall be clean and free from elongated, flaky or laminated pieces, adhering coatings, clay lumps, coal residue, clinkers, sag, alkali, mica, organic matter or other deleterious matter.

Screening and Washing: Crushed rock shall be screened and/or washed for the removal of dirt or dust coating, if so required by the Employer's Representative.

Grading: Coarse aggregates shall be either single size or graded. The grading shall be within the limits on the table below. The aggregate pieces shall be angular in shape and shall have granular or crystalline surfaces.

Friable, flaky and laminated pieces, mica and shale, if present, shall be only in such quantities that will not, in the opinion of Employer's Representative, affect adversely the strength and/or durability of concrete.

The maximum size of coarse aggregate shall be the maximum size specified, but in no case greater than 1/4 of the minimum thickness of the member, provided that the concrete can be placed without difficulty to surround all reinforcement thoroughly and fill the corners of form.

Cobbles above 160 mm and up to any reasonable size can be used in plain mass concrete work of large dimensions up to a maximum limit of 20% by volume of concrete when specifically approved by the Employer's Representative.

For heavily reinforced concrete members, the nominal maximum size of the aggregate shall be 5 mm less than the minimum clear distance between the reinforcing main bars or 5mm less than the minimum cover to the reinforcement whichever is smaller. The amount of fine particles occurring shall not exceed 1% when determined by laboratory sedimentation tests as per IS 2386. After 24 hours immersion in water, a previously dried sample shall not have gained more than 10% of its oven dry weight in air, as determined by IS2386.

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IS Sieve Design	Percentage passing for single sized aggregate of nominal size					Percentage passing for Graded aggregate of nominal size			
	40mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16 mm	12.5mm
63 mm	100	--	--	--	--	100	--	--	--
40 mm	85 - 100	100	--	--	--	95 - 100	100	--	--
20 mm	0 - 20	85-100	100	--	--	30 -70	95-100	100	--
16 mm	--	--	85-100	100	--	--	--	90-100	--
12.5 mm	--	--	--	85-100	100	--	--	--	90-100
10 mm	0 - 5	0 - 20	0 - 30	0 - 45	85-100	10 - 35	25 - 55	30 -70	40 - 85
4.75 mm	--	0 - 5	0 - 5	0 - 10	0 - 20	0 - 5	0 - 10	0 - 10	0 - 10
2.36 mm	--	--	--	--	0 - 5	--	--	--	--

Foreign Material Limitations: **The percentages of deleterious substances in the coarse aggregate delivered to the mixer shall not exceed the following:**

	Foreign Material	Percent by weight	
		Uncrushed	Crushed
i)	Material finer than 75 micron IS sieve	3	3
ii)	Coal and lignite	1	1
iii)	Clay lumps	1	1
iv)	Soft fragments	3	--
v)	Total of all the above substances	5	5

### 13.2.5 Water

Water for mixing concrete shall be clean and free from harmful impurities, such as silt, organic materials, acids, alkalis, salts and oils. In general the water used shall be of potable quality. In case of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in IS 456 - 2000. The sample of water taken for testing shall be typical of the water proposed to be used for concreting with due account being paid to seasonal variations. The samples shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90% of the average strength of three similar concrete cubes prepared with distilled water as per IS - 516.

The initial setting time of test blocks made with the cement and the water proposed to be used shall not be less than 30 minutes and shall not differ by more than (+/-) 30 minutes from the initial setting time of control test blocks prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of IS 4031(Part 5).



Where water contains an excess of acid, alkali, sugar or salt, the Employer's Representative may refuse to permit its use. The following concentrations represent the maximum permissible values:

- 1 Limits of acidity: To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml. of 0.02 normal NaOH. The details of test shall be as per IS 3025 (Part 22)
- 2 Limits of alkalinity: To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml. of 0.02 normal H<sub>2</sub>SO<sub>4</sub>. The details of test shall be as per IS 3025 (Part 23).
- 3 Limits for Solids: Permissible limits for solids in the water shall be as below:

Solids	Percent	Method of Test (ref IS : 3025)
Organics	0.02	10 and 11 (organic solids = total solids minus ignited residue)
Inorganics	0.30	11 (ignited residue)
Sulphates (as SO <sub>4</sub> )	0.05	20
Alkali chloride (as Cl)	0.20	24
Suspended matter	0.20	12

- 4 d) pH: The pH value of water shall be not less than 6.

### 13.2.6 Admixtures

Admixtures may be used in concrete only with the approval of Employer's Representative based upon evidence that, with the passage of time, neither the compressive strength nor the durability will be reduced. When admixtures are used, the concrete mix design shall be amended accordingly. Admixtures shall be used as per manufacturers' instructions and in the manner and with the control as necessary or as specified by Employer's Representative.

The addition of admixtures during mixing to alter the properties of the concrete mix shall only be with the approval of the Employer's Representative in regard to quality, quantity and redesign of the mix and accompanied by separate preliminary tests.

Admixtures, if used, shall comply with IS 9103. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified. Admixtures should not impair durability of the concrete or combine with the constituent to form harmful compounds or increase the risk of corrosion of reinforcement.

The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures.

The relative density of liquid admixtures shall be checked for each drum containing admixtures and compared with the specified value before acceptance.

The chloride content of the admixtures shall be independently tested for each batch before acceptance. If two or more admixtures are used simultaneously in the same concrete, mix data should be obtained to assess their interaction and to ensure their compatibility.

#### (i) Calcium Chloride

Calcium chloride shall not be used for accelerating the setting of the cement for any concrete containing reinforcement or embedded steel parts.

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**(ii) Air Entraining Agents**

Neutralized vinsol resin or any other approved air entraining agent may be used to produce the specified amount of air in the concrete mix and these agents shall conform to the requirements of ASTM standard 6.260, Air Entraining Admixtures for Concrete if approved by the Employer's Representative. The recommended total air content of air entrained concrete is 4% (+/-) 1%. The method of measuring air content shall be as per IS1199.

**(iii) Retarding Admixtures**

Where prior approval has been given by the Employer's Representative, retarding agents may be added to the concrete mix in quantities in accordance with the manufacturer's recommendations.

**(iv) Water Reducing Admixtures**

Where prior approval has been given by the Employer's Representative, water reducing lignosulfonate mixture shall be added in quantities in accordance with the manufacturer's recommendations. The admixtures shall be added in the form of a solution.

**(v) Waterproofing Agents**

Where prior approval has been given by the Employer's Representative, chloride and sulphate free waterproofing agents shall be added in quantities in accordance with the manufacturer's recommendations.

**(vi) Other Admixtures**

The Employer's Representative may, at his discretion, approve the Contractor to use any other admixture in the concrete.

**13.2.7 Fly Ash**

The fly ash should have consistent quality satisfying the requirements of IS 3812 Parts I and II.

The source of fly ash should be so selected that test results of fly ash samples collected from these sources during last one year at a frequency of maximum one month intervals should satisfy the requirements of above codes.

The characteristics of fly ash to be used shall be as per the above two codes for each batch of fly ash.

If more than 15% fly ash is used, IS 3812 shall apply and specific care shall be taken in terms of curing, protecting, repairing, finishing, de-shuttering etc as detailed in Section 13.6.2

**13.3 Materials Testing**

The Employer's Representative shall have the right to inspect the sources of materials, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. The Contractor shall arrange such an inspection and the Employer's Representative approval shall be obtained prior to starting any concrete work.

The Employer's Representative, if he so requires, may order tests to be carried out, at the Contractor's expense, on cement, sand, coarse aggregate, water etc in accordance with the relevant Indian Standards.

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### 13.3.1 Tests on Cement

Tests on cement shall include (i) fineness tests, (ii) tests for normal consistency, (iii) tests for setting time, (iv) tests for soundness, (v) tests for compressive strength, (vi) tests for heat of hydration (by experiment and by calculations) in accordance with IS269.

### 13.3.2 Tests on Sand

Tests on sand shall include (i) sieve tests, (ii) tests for organic impurities, (iii) decantation tests for determining clay and silt content, (iv) specific gravity tests, (v) tests for unit weight and bulkage factor, (vi) tests for sieve analysis and fineness modulus.

### 13.3.3 Tests on Aggregate

Aggregates shall be tested before and after the concrete mix is established and when ever there is a change of the source or character of the materials.

Sampling of the aggregates for mix design and determination of suitability shall be taken under the supervision of the Employer's Representative and delivered to the laboratory, well in advance of the schedule for placing of concrete. Records of tests which have been made on proposed aggregates and on concrete made from this source of aggregates shall be furnished to the Employer's Representative in advance of the work for which it is to be used, in determining suitability of the proposed aggregate.

Tests on coarse aggregate shall include (i) sieve analyses, (ii) specific gravity and unit weight of dry, loose and rodded aggregate, (iii) soundness and alkali aggregate reactivity, (iv) petrographic examination, (v) deleterious materials and organic impurities, (vi) tests for aggregate crushing value.

Additional tests on aggregates would normally only be carried out if the Employer's Representative feels the materials are not in accordance with the specifications or if the specified concrete strengths are not obtained and shall be performed by the Contractor, at the Contractor's expense, at an approved test laboratory.

### 13.3.4 Tests on Water Stops

The water stops shall be tested in accordance with the Central Water Commission (India) standards and shall have the following properties:

Characteristics	Properties
Tensile strength	116 kg/cm <sup>2</sup> minimum (162 kg/cm <sup>2</sup> min. for rubber)
Ultimate elongation	300% minimum (500% minimum for rubber)
Tear resistance	49 kg/cm <sup>2</sup> minimum
Stiffness in flexure	25 kg/cm <sup>2</sup> minimum
Accelerated extractions	105 kg/cm <sup>2</sup> minimum (150 kg/cm <sup>2</sup> Minimum for rubber)
Ultimate elongation	250% minimum (350% minimum for rubber)
<u>Effect of alkali (7 days):</u>	
Weight increase	0.25% maximum
Weight decrease	0.10% maximum
Hardness change	+ 5 point
<u>Effect of alkali (28 days):</u>	

Weight increase	0.40% maximum
Weight decrease	0.30% maximum
Dimension change	+ 1%

### 13.4 Concrete Grades

The concrete used on the works of this project shall be of one of the following grades:

Grade	Minimum Crushing Strength of 150 mm cube at 28 days. In kg/cm <sup>2</sup>	
	Preliminary and Trial Mix Tests	Work Tests
M-100	135	100
M-150	200	150
M-200	260	200
M-250	320	250
M-300	380	300
M-350	440	350

- 1 The characteristic strength is defined as the strength of material below which not more than 5% of the test results are expected to fall.
- 2 In the designation of a concrete mix, the letter M refers to the mix and the number to the specified characteristic compressive strength of 150 mm size cubes at 28 days expressed in N/ mm<sup>2</sup>.

All concrete used on the work shall be dense, sound, homogeneous and durable and free from air voids, bleeding, honeycombing and other allied defects. For grade M-100 the Contractor may be allowed to use an approved nominal mix but for all other grades of concrete, mix designs are obligatory and preliminary test results shall be submitted to the Employer's Representative for approval before the commencement of concreting.

Mixes designed with ordinary Portland cement shall be redesigned if Pozzolona or other cement is to be used. In any event, whether Pozzolona or other cement is used or not, new mix designs shall be submitted for the Employer's Representative's approval for each new batch of cement that is received. To enable this, the cement stocks shall be so stored as to enable easy identification of different batches. Similarly, new mix designs will be required if the source of supply of aggregate is changed or a variation exceeding 10 percent in the sieve analysis is observed from the analysis of the aggregate used in the mix design.

#### 13.4.1 Standard Deviation

The standard Deviation for each grade of concrete shall be calculated separately.

##### Standard Deviation Based on Test Results

Number of test results - The total number of test results required to constitute an acceptable record for calculation of standard deviation shall be not less than 30. Attempts should be made to obtain the 30 test results, as early as possible, when a mix is used for the first time.

Standard deviation to be brought up to date - The calculation of the standard deviation shall be brought up to date after every change of mix design and at least once a month.

Determination of standard deviation:

- 1 Concrete of each grade shall be analysed separately to determine its standard deviation.

- 2 The standard deviation of concrete of a given grade shall be calculated using the following formula from the results of individual tests of concrete of that grade obtained as specified for test strength of sample:
- 3 Estimated standard deviation  $\Sigma = \sqrt{\{\Sigma \Delta^2 / (n-1)\}}$
- 4 Where  $\Delta$  = Deviation of the individual test strength from the average strength of a sample and n = Number of sample test results.
- 5 When significant changes are made in the production of concrete (for example changes in the materials used, mix design, equipments or technical control), the standard deviation value shall be separately calculated for such batches of concrete.

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in the table below may be assumed for a design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly. However, when adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from that shown in table below, it shall be permissible to use that value.

Grade of Concrete	Assumed Standard Deviation N/ mm <sup>2</sup>
M 10	3.5
M 15	
M 20	4.0
M25	
M30	5.0
M35	
M40	
M45	
M50	

- 1 Note: The above values correspond to the site control having proper storage of cement: weigh batching of all materials: controlled addition of water: regular checking of all materials: aggregate grading and moisture content: and periodical checking of workability: and strength. Where there is a deviation from the above, the values given in the above table shall be increased by 1 N / mm<sup>2</sup>.

### 13.5 Mix Designs

The quality of materials and method and control of manufacture and transportation of all concrete work in respect of a mix, whether reinforced or otherwise, shall be Design Mix Concrete as defined in IS 456-2000 and conform to the applicable portions of these specifications.

The different concrete mixes shall be designed by the Contractor for strength, workability and durability of the concrete and shall be strictly in compliance with the relevant standards. If it is found that an increase in the proportion of cement is necessary, the requisite adjustment shall be made. Batching shall be by weight and the combined aggregate shall have a continuous grading. The mixes should produce an average 28 day cube strength not less than that specified in this document for trial mix tests for the relevant grade. In the case of concrete for water retaining structures, the cement content shall be a minimum of 350 kg/m<sup>3</sup> of concrete. When admixtures are used, the mixes shall be redesigned with the test strengths conforming to those specified in this document. The workability of the mix shall permit satisfactory compaction with vibration, with no tendency to aggregate during handling, transporting and compaction.

In exceptional cases, where the reinforcement is so crowded that the compaction is difficult, the value of slump may be increased with the explicit approval of the Employer's Representative, but in no case shall it exceed 15 cm. Any increase in the slump beyond the values given shall be obtained by the use of additional cement in such quantities as to restrict the water-cement ratio to the maximum specified values. Special care shall be taken in the case of M-25 concrete where the water-cement ratio should not exceed 0.45 under any circumstances.

The minimum cement content for Design Mix Concrete shall be as per Appendix-A of IS:456 or as given below( as per government of gujarat circular), whichever is higher in kg/m<sup>3</sup> :

Grade	Minimum Cement Content (kg/m <sup>3</sup> ) of concrete
M-15	290
M-20	360
M-25	380
M-30	410
M-35	425

- 1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions stated in mineral admixtures. The additions of such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.
- 2 Minimum grade for plain concrete under mild exposure condition is not specified.

### 13.5.1 Adjustment of Minimum Cement Content

The adjustments to minimum cement contents should be made for aggregates other than 20 mm nominal maximum size as shown in the table below:

No	Nominal maximum aggregate size mm	Adjustments to minimum cement content kg/ m <sup>3</sup>
i)	10	+40
ii)	20	0
iii)	40	-30

- 1 For concrete of compressive strength greater than M-55 given design parameters may not be applicable and the values may be obtained from specialized literature and experimental results.
- 2 The mix shall be designed to produce the grade of concrete having the required workability and characteristic strength not less than the appropriate values given in the table above.

### **13.5.2 Degree of Control**

Selection of Water Cement Ratio: Since different cements and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water cement ratio, the relationship between strength and free water-cement ratio should be established for the materials actually to be used. In the absence of such data, the preliminary free water-cement ratio (by mass) corresponding to the target strength at 28 days may be selected from the relationship shown in Fig.1 of IS 10262 .

Alternatively, the preliminary free water cement ratio (by mass) corresponding to the target average strength may be selected from the relationship in Fig.2- IS 10262, using the curve corresponding to the 28 day cement strength to be used for the purpose.

Other relevant items to be used with design of mix should strictly conform to the relevant clauses and appendices of IS 10262.

The calculated mix proportions shall be checked by means of trial batches as per IS 10262.

The free water cement ratio, selected as above, should be checked against the limiting water cement ratio for the requirement of durability and the lower of the two values should be adopted.

Whenever there is a change either in required strength of concrete or water cement ratio or workability or the source of aggregates and/or cement, fresh tests shall be carried out to determine the revised proportion of the mix to suit the altered conditions. While designing mix proportions, over-wet mixes shall always be avoided.

While fixing the value for water cement ratio for the design mix, assistance may be derived from the standard graph showing the relationship between the 28 day compressive strength of concrete mixes with different water-cement ratios and the 7 day compressive strength of cement tested in accordance with IS269.

It will be the Contractor's sole responsibility to establish the concrete mix designs for different grades of concrete required in the work consistent with the workability required for the nature of work and also taking into consideration the assumed standard deviation to be expected at the site or by establishing the standard deviation based on 30 test results for each grade of concrete to produce concrete of the required strength, durability and surface finish. The materials and proportions used in making the tests to be carried out either at site or under laboratory conditions shall be similar in all respects to those to be actually employed in the works, as the object of these tests is to determine the proportions of cement, aggregates and water necessary to produce the concrete of the required consistency to give such specified strength.

### **13.5.3 Proportioning**

#### **(i) Aggregate**

The proportions to be determined by conducting preliminary tests, shall be by weight. These proportions of cement, fine and coarse aggregates shall be maintained during subsequent concrete batching by means of weigh batchers conforming to IS 2722, capable of controlling the weights within one percent of the desired value. Except where it can be shown to the satisfaction of the Employer's Representative, that supply of properly graded aggregate of uniform quality can be maintained over the period of work, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions. The different sizes shall be stacked in separate stockpiles. The gradings of coarse and fine aggregates shall be checked as frequently as practicable, as determined by the Employer's Representative, to ensure maintaining of grading in accordance with samples used in the preliminary mix design. The materials shall be stockpiled well in advance of use.

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**(ii) Cement**

The cement shall be measured by weight. Every facility should be provided to the Employer's Representative for sampling and inspection of stored cement at the site.

**(iii) Water**

Only such quantity of water shall be added to the cement and aggregate in the concrete mix as to ensure dense concrete, specified surface finish, and satisfactory workability consistent with the strength stipulated for each class of concrete. The water added to the mix shall be such as not to cause segregation of materials or the collection of excessive free water on the surface of the concrete.

Definition of water cement ratio

The water cement (W/C) ratio is defined as the weight of water in a mix (including the surface moisture of the aggregates) divided by the weight of the cement in the mix.

Water cement ratio

The actual water cement ratio to be adopted shall be determined in each instance by the Contractor and approved by the Employer's Representative.

Proportioning By Water-Cement Ratio

The W/C ratios as approved by the Employer's Representative shall be maintained. Contractor shall determine the water content of the aggregate as frequently as approved by the Employer's Representative as the work progresses and as specified in IS 2386 part III and the amount of mixing water added at the mixer shall be adjusted as approved by the Employer's Representative to maintain the specified W/C ratio. To allow for the variation in their moisture content, suitable adjustments in the weights of aggregates shall also be made.

**(iv) Concrete in Alkali Soils, Water & Aggregates**

Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis ( $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$ ) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occur when all the following are present together.

- 1 A high moisture level, within the concrete;
- 2 A cement with high alkali content, or another source of alkali;
- 3 Aggregate containing an alkali reactive constituent.

Where the service records of particular cement / aggregate combination are well established and do not include any instances of cracking due to alkali-aggregate reaction, no further precautions should be necessary. When the materials are unfamiliar, precautions should take one or more of the following forms:

- 1 Use of non-reactive aggregate from alternate sources
- 2 Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 per cent (as  $\text{Na}_2\text{O}$  equivalent).

Further advantages can be obtained by the use of fly ash (Grade I) conforming to IS 3812 or granulated blast furnace slag conforming to IS 12089 as part replacement of ordinary Portland cement (having total alkali content as  $\text{Na}_2\text{O}$  equivalent not more than 0.6 percent), provided that the fly ash content is at least 20 % or slag content is at least 50 %.

- 1 Measures to reduce the degree of saturation of the concrete during service such as the use of impermeable membranes
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- 2 Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix as approved by the Employer's Representative.

**(v) Chlorides in the Concrete**

Whenever there are chlorides in concrete, there is an increased risk of corrosion to the embedded metal. The higher the chloride content, and if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimise the chance of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete materials, as well as by diffusion from the environment should be limited. The total amount of chloride content (as Cl) in the concrete at the time of placing shall be as given below in the table.

**Limits of Chloride Content of Concrete**

Sl.No	Type or Use of Concrete	Maximum Total Acid soluble Chloride Content Expressed as kg/m <sup>3</sup> of Concrete.
i)	Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete	0.4
ii)	Reinforced concrete or plain concrete containing embedded metal	0.6
iii)	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

The total acid soluble chloride content should be calculated from the mix proportions and the major chloride contents of each of the constituents. The total chloride content of the concrete should be determined to the approval of the Employer's Representative.

**(vi) Sulphates in concrete**

Sulphates are present in most cements and in some aggregates. Excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO<sub>3</sub>, should not exceed 4 % by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix to the approval of the Employer's Representative.

The 4 % limit does not apply to concrete made with super sulphated cement complying with IS 6909 or as otherwise approved by the Employer's Representative.

**13.5.4 Consistency and slump**

Concrete shall be of a consistency and workability suitable for the conditions of the job. After the amount of water required is determined, the consistency of mix shall be maintained throughout the progress of the corresponding parts of the work and approved tests e.g. slump tests, compacting factor tests etc in accordance with IS 1199, which shall be conducted from time to time to ensure the maintenance of such consistency.

The following tabulation gives a range of workability which shall generally be used for various types of construction unless otherwise instructed by the Employer's Representative.

Workability of concrete:

Placing condition	Degree of workability	Slump (mm)
Blinding concrete; Shallow sections; Pavement using pavers	Very low	See note 1
Mass concrete; lightly reinforced sections in slabs, beams, walls, columns; floors; hand placed pavements; canal linings; strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns, slip form work; pumped concrete	Medium	50-100 75-100
Trench fill, in-situ piling	High	100-150
Tremie concrete	Very high	See notes

- 1 For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used.
- 2 The 'very low' category of workability where strict control is necessary, for example pavement quality concrete, measurement of workability by determination of compacting factor will be more appropriate than slump (see IS 1199) and a value of compacting factor of 0.75 to 0.80 is suggested.
- 3 In the 'Very high' category of workability, measurement of workability by determination of flow will be appropriate (see IS 9103).

When tested in accordance with IS 1199, the consistency of the concrete should be such that the maximum slumps, unless otherwise specified or permitted by the Employer's Representative do not exceed the following values.

Part of Structure	Maximum Slump (mm)
Footings and un-reinforced mass concrete	76
Slab and Floors	76
Columns, walls over 200 mm thick	102
Walls up to 200 mm thick	102
Equipment bases	127

### 13.5.5 Batching

To avoid confusion and error in batching, consideration shall be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS4925).

For large and medium project sites, concrete shall be sourced from ready-mixed concrete plants or from on-site or off-site batching and mixing plants (see IS 4926).

Except where it can be shown to the satisfaction of the Employer's Representative that supply of properly graded aggregate of uniform quality can be maintained over a period of work, the grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending it in the right proportions when required, the different sizes being stocked in separate stockpiles.

The accuracy of the measuring equipment shall be within  $\pm 2\%$  of the quantity of cement being measured and within  $\pm 3\%$  percent of the quantity of aggregate, admixtures and water being measured.

Volume batching shall be allowed only where weigh-batching is not practical and provided accurate bulk densities of materials to be used in concrete have already been established. Allowance for bulking shall be made in accordance with IS 2386 (Part 3). The mass volume relationship shall be checked as frequently as necessary, the given frequency being subject to the approval of the Employer's Representative to ensure that the specified grading is maintained.

The water-cement ratio shall be maintained at its correct value. To this end, determination of the moisture content in both the fine and coarse aggregates shall be made as frequently as possible, the given frequency being subject to the approval of the Employer's Representative according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture content. For the determination of moisture content in the aggregates IS 2386 (Part 3) shall be followed. To allow for the variation in the mass of aggregate due to variation in its moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, and in the case of nominal mixes the amount of surface water may be estimated from the values given in table below.

Surface water carried by aggregate

Aggregate	Approximate quantity of surface water	
	Percent by mass	l/m <sup>3</sup>
Very wet sand	7.5	120
Moderately wet sand	5.0	80
Moist sand	2.5	40
Moist gravel or crushed rock	1.25-2.5	20-40
The coarser aggregate the less water it will carry		

No substitutions in materials used on the work or alterations in the established proportions except as permitted as above shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

### 13.5.6 Mixing

Concrete shall be mixed in a mechanical mixer. The mixers shall comply with IS 1791 and IS 12119. The mixers shall be fitted with water measuring devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete shall be remixed.

The mixing time shall be at least two minutes. For more efficient mixers, manufacturers recommendations shall be followed.

The dosage of retardants, plasticisers and super-plasticisers shall be restricted to 0.5, 1.0 and 2.0 % respectively by weight of cementitious materials unless a higher value is agreed between the manufacturer and the Contractor based on performance tests.

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Each time the work stops, the mixer shall be cleaned out and when next commencing the mixing, the first batch shall have 10% additional cement to allow for sticking in the drum.

### **13.6 Cast-in-Place (In-Situ) Concrete**

#### **13.6.1 Execution**

##### **(i) Preparation for Placing**

All excess water shall be removed from the forms before concrete is placed. No flow of water shall be admitted to the section being concreted. The interior faces of forms shall be cleaned and any hard concrete, debris or foreign material shall be removed. The inner faces of the mixing and conveying equipment shall be similarly cleaned.

Reinforcement shall be secured, inspected and approved in compliance with the relevant specifications and shall be inspected and approved. Embedded metal shall be clean and free of old mortar, oil, mill scale and other encrustations and coatings. Wheeled concrete handling equipment shall pass over reinforcement nor shall walkways be supported on reinforcement.

Any earth sub-grade on which concrete is to be deposited shall be wetted lightly 24 hours in advance of concreting but not muddled. Re-rolling shall be carried out, where necessary, to create a smooth surface and all loose materials removed.

Where placement of concrete is directly onto a rock base, the rock surface shall be cleaned and washed and loose material removed with air blower or hosed before concreting. All stagnant water collected on the rock surface shall be removed before concreting.

Where a bond between old and new concrete surfaces is required, the steps and precautions stipulated for construction joints shall be adopted. Where no bond is necessary, the existing surface shall be cleaned, removing any dirt or deleterious material which might interfere with the concreting.

Before concrete is poured, the inside of the formwork shall be inspected to ensure that it has been cleaned and oiled. Temporary openings shall be provided where necessary to facilitate inspection, especially at the bottom of columns and wall forms, to permit removal of sawdust, wood shavings, binding wire, rubbish, dirt etc. Openings shall be placed or holes drilled so that these materials and water can be removed easily. Such openings / holes shall be later suitably plugged.

The Contractor shall install drainage and plumbing lines, floor and trench drains, conduits, hangers, anchors, inserts, sleeves, bolts, frames and other miscellaneous embedments to be cast in the concrete as necessary for the proper execution of the work. All such embedments shall be correctly positioned and securely held in the forms to prevent displacement during the depositing and vibrating of concrete.

Slots, openings, holes, pockets etc shall be provided in the concrete work in the positions as necessary.

Prior to concrete placement, all works shall be inspected and approved by Employer's Representative and if found unsatisfactory, concrete shall not be poured until all defects have been corrected.

Approval by the Employer's Representative of any and all materials and work as required herein shall not relieve contractor from his obligations to produce finished concrete in accordance with the Contract.

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**(ii) Foundation Bedding and Jointing**

All surfaces upon or against which concrete will be placed shall be suitably prepared by thoroughly cleaning, washing and dewatering to meet the various situations encountered in the work.

Soft or spongy areas shall be dug out and back-filled with either a soil cement mixture, lean concrete or clean sand fill compacted to a minimum density of 90% modified Proctor.

**(iii) Preparation of Rock Strata of Foundations**

To provide a tight bond with rock foundations, the rock surface shall be prepared and the following general requirements shall be observed:

Concrete shall not be deposited on large sloping rock surfaces. Where required, the rock shall be cut to form rough steps or benches to provide roughness or a more suitable bearing surface.

Rock foundation stratum shall be prepared by picking, barring, wedging or similar methods which will leave the rock in an entirely sound and un-shattered condition.

Shortly before concrete is placed, the rock surface shall be cleaned with high pressure water and air jet even though it may have been previously cleaned in that manner.

Prior to placing concrete, the rock surface shall be kept wet for a period of at least two hours unless otherwise approved by the Employer's Representative.

Before placing concrete on rock surfaces, all water shall be removed from depressions to permit thorough inspection and proper bonding of the concrete to the rock.

**(iv) Preparation of Earth Strata of Foundations**

All earth surfaces upon which or against which concrete is to be placed, shall be well compacted and free from standing water, mud or debris. Soft, yielding soils shall be removed and replaced with suitable earth and well compacted and as approved by the Employer's Representative. Where specified, lean concrete shall be placed on the earth stratum for receiving concrete. The surface of absorptive soil against which concrete is to be placed shall be moistened thoroughly.

**(v) Preparation of Concrete Surfaces**

Preparation of concrete surfaces upon which additional concrete is to be placed, shall be scarified and cleaned while the concrete is between its initial and final set. This method shall be used wherever practicable and shall consist of cutting the surface with picks and stiff brooms and by use of an approved combination of air and water jet and as approved by Employer's Representative. Great care shall be taken in performing this work to avoid removal of too much mortar and the weakening of the surface by loosening of aggregate. When it is not practicable to follow the above method, air tools shall be employed to remove laitance and roughen the surface.

The required final result shall be a pitted surface from which all dirt, unsound concrete, laitance and glazed mortar have been removed.

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**(vi) Cleaning and Bonding of Formed Construction Joints**

Vertical construction joints shall be cleaned as specified above or by other methods and as approved by Employer's Representative. In placing concrete against formed construction joints, the surfaces of the joints, where accessible, shall be coated thoroughly with the specified bed-joint bonding mortar immediately before being covered with concrete or by scrubbing with wire brushes, dipped into the fresh concrete. Where it is impracticable to apply such a mortar coating, special precautions shall be taken to ensure that the new concrete is brought into intimate contact with the surface of the joint with the aid of vibrators and other suitable tools.

**(vii) Positioning of Water Stops**

Water stops shall be provided in the available maximum lengths and as far as possible, jointing shall be avoided. All joints, when unavoidable, shall be field jointed for water tightness as per manufacturer's specifications.

The water stops shall be positioned with suitable temporary supports to render adequate rigidity to the water stops while concreting. The exposed surfaces of water stops revealed after first concreting shall be cleaned thoroughly of all the droppings, mortar splashings etc before the next pour of concrete.

**(viii) Bonding Treatment (Mortar)**

All rock or concrete surfaces upon which new concrete is to be placed shall be scarified, cleaned and wetted as specified herein.

Immediately prior to placing new concrete, the scarified surface of the existing concrete shall be thoroughly wetted.

**(ix) Cleaning of Equipment**

All equipments used for mixing, transporting and placing of concrete shall be maintained in clean condition. All pans, buckets, hoppers, chutes, pipe lines and other equipments shall be thoroughly cleaned after each period of placement.

**(x) Conveying and Placing Concrete**

Concrete shall be poured or placed only after the forms and reinforcement have been inspected and approved, for which purpose the Contractor shall give the Employer's Representative at least two day's notice. Generally, the use of aluminium equipment shall not be permitted in any operation where the equipment and concrete are likely to come in contact with each other, unless the aluminium surfaces have to be adequately treated to prevent reaction with and having a harmful effect on the concrete.

All buckets, containers or conveyers used for transporting concrete shall be mortar-tight. All means of conveyance shall be adopted to deliver concrete of the required consistency and plasticity without segregation or loss of slump whatever method of transportation is employed. Chutes shall not be used to transport the concrete without the approval of the Employer's Representative and concrete shall not be re-handled before placing.

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Conveying - Concrete shall not be released from a mixer, hopper, frame or other conveyance or device through a height exceeding two metres or through reinforcement, in a manner likely to cause segregation. Tremmies discharging close to the point of concreting shall be provided as required. The use of chutes will be restricted to specific locations approved by the Employer's Representative. Concrete shall be deposited directly into the conveyance and from the conveyance directly into the locations in the structure. Deposition of concrete shall be so done to maintain, as far as possible, a level surface throughout. Manual labour may be used for conveying and placing mixed concrete provided the above requirements are not contravened.

Placing Concrete - Concrete shall be placed in position and compacted within 30 minutes after the first addition of water to the mix and no concrete showing signs of initial set shall be used. Re-tampering of set concrete is prohibited.

- 1 Lifts: Concrete shall be poured into forms after mixing in a manner that will prevent segregation of the ingredients and in horizontal layers not exceeding 2,000 mm thick.
  - a Walls: Concrete for walls of water retaining structures, including tank exterior walls, shall be poured, where practicable, as one continuous operation from footing to top of the wall. Each section shall be left in place at least seven days before the adjoining section is similarly concreted.
  - b Slabs: Concrete between approved joints shall be poured in one continuous operation in checker-board fashion and shall be allowed to stand at least seven days before adjoining sections are concreted.
  - c Concreting of beams and slabs shall be continuous and monolithic with the floor.
- 2 Pumping Concrete: No increase in the water-cement ratios or specified slumps will be permitted to pumped concrete. The minimum conveyance tube shall be minimum diameter of 100 mm and capable of maintaining the specified pour rates.
- 3 Pour Rules:
  - a Vertical Elements: concrete shall be placed in lifts as specified at a rate that does not cause excessive stresses in the formwork or a hardening of the top layer before next lift is poured.
  - b Slabs :Concrete shall be poured at an appropriate time that ensures that all new concrete poured is adjoined to concrete that is still plastic and before the initial set of the previous placing.
  - c Construction Joints: Concreting adjoining a construction joint shall not be until the existing surface has been cured for at least seven days, unless otherwise approved by the Employer's Representative.

Before any concrete is placed, the entire placing programme, consisting of equipment, layout, proposed procedures and methods shall be submitted to Employer's Representative for approval and no concrete shall be of such size and design as to ensure a practically continuous flow of concrete during depositing without segregation of materials, considering the size of the job and placement location.

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**(xi) Time Interval between Mixing and Placing**

Concrete shall be placed in its final position before the cement reaches its initial set and concrete shall normally be compacted in its final position within thirty minutes of leaving the mixer and once compacted, it shall not be disturbed. On no account shall water be added after the initial mixing. Concrete which has become stiff or has been contaminated with foreign materials shall be rejected.

**(xii) Avoiding Segregation**

Concrete shall, in all the cases, be deposited as nearly as practicable directly in its final position and shall not be re-handled or caused to flow in a manner which will cause segregation, loss of material, displacement of reinforcement, shuttering or embedded inserts or impair its strength. For locations where direct placement is not possible and in narrow forms, the Contractor shall provide suitable props and discharge pipes to confine the movement of concrete. Special care shall be taken when concrete is dropped from a height, especially if reinforcement is in the way, particularly in columns and thin walls.

**(xiii) Placing by Manual Labour**

Except as otherwise approved by Employer's Representative, concrete shall be placed using approved implements and shall not be dropped from a height of more than 2.0 m or handled in a manner which will cause segregation.

**(xiv) Placing by Mechanical Equipment**

The following specifications shall apply when placing of concrete by use of mechanical equipment is specially called for or is warranted, considering the nature of work involved.

The control of placing shall begin at the mixer discharge. Concrete shall be discharged by a vertical drop into the middle of the bucket or hopper and this principle of a vertical discharge of concrete shall be adhered-to throughout all stages of delivery until the concrete comes to rest in its final position.

All concrete shall be conveyed from the mixer to the place of final deposit in suitable buckets, dumpers or containers which shall be leak-tight. All means of conveyance shall be adopted for delivering concrete to the required consistency/ workability and plasticity without segregation.

Central bottom-opening buckets of a type that provides for positive regulation of the amount and rate deposition of concrete shall be employed.

In placing concrete in large open areas, the buckets shall be located directly over the position designated and then lowered for dumping. The open bucket shall remain clear of any concrete already in place and the height of drop shall not exceed 2.0 m. The bucket shall be opened slowly to avoid high vertical bounce. The placing of concrete in any manner which results in separation of ingredients or disturbance of previously placed concrete will not be permitted.

**(xv) Placement in Restricted Forms**

Concrete placed in restricted forms shall be subject to the requirements for vertical delivery of limited height to avoid segregation and shall be deposited as nearly as practicable in its final position.

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**(xvi) Chuting**

Where it is necessary to use transfer chutes, specific approval of the Employer's Representative must be obtained with regards to the type, length, slopes, baffles, vertical terminal and timing of operations. These shall be arranged so that almost continuous flow of concrete is obtained at the discharge and without segregation. To allow for the loss of mortar against the sides of the chutes, the first mixes shall have less coarse aggregate. During cleaning of chutes, the waste water shall be kept clear of the forms. The concrete shall not be permitted to fall from the end of the chutes by more than 1.0 m. Chutes, when approved for use, shall have slopes not flatter than 1 vertical to 3 horizontal and not steeper than 1 vertical to 2 horizontal. Chutes shall be metal and of rounded cross section. The slopes of all chute sections shall be approximately the same. The discharge end of the chutes shall be maintained above the surfaces of the concrete in the forms.

**(xvii) Placing by Pumping/ Pneumatic Placers**

Concrete may be conveyed and placed by mechanically operated equipment e.g. pumps or pneumatic placers, with the approval of Employer's Representative. The slump shall be held to the minimum, necessary for conveying concrete by this method.

When pumping is adopted, before pumping of concrete is started, the pipelines shall be lubricated with one or two batches of mortar composed of one part cement and two parts sand. The concrete mix shall be specially designed to suit pumping. Care shall be taken to avoid stoppages in work once pumping has started.

When pneumatic placing is used, the manufacturer's advice on the layout of pipelines shall be followed to avoid blockages and excessive wear. Restraint shall be provided at the discharge box to cater for the reaction at the end.

The manufacturer's advice shall be followed regarding concrete quality and all other related matters when pumping or pneumatic placing equipment is used.

**(xviii) Concrete in Layers**

Concreting, once started, shall be continuous until the pour is completed. Concrete shall be placed in successive horizontal layers of uniform thickness ranging between 150 and 900 mm as approved by Employer's Representative. These shall be placed as rapidly as practicable to prevent the formation of cold joints or planes of weakness between each succeeding layer within the pour. The thickness of each layer shall be such that it can be deposited before the previous layer has stiffened. The bucket loads or other units of deposit, shall be located progressively along the face of the layer with such overlap to facilitate spreading the layer of uniform depth and texture with a minimum of shovelling.

The top surface of each pour and bedding planes shall be approximately horizontal unless otherwise instructed.

**(xix) Compaction**

Effective compaction of newly placed concrete shall be obtained by vibration, agitation, spading and rodding the concrete within the forms. At least two vibrators in dependable working condition shall be available before commencement of concreting and kept in working condition during the scheduled concreting period, each under the charge of an experience workman.

All concrete, excepting slabs of thickness 10 cm or less, shall be compacted with high frequency, mechanical vibrating equipment supplemented by hand spading and tamping. Concrete slabs 10 cm or less in thickness shall be compacted by wood or metal tampers, spading and settling with a heavy levelling straight edged beam.

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Vibrators shall be designed to operate with the vibrating element having a frequency of not less than 7000 impulses per minute. The equipment shall, at all times, be adequate, in terms of units and power, to consolidate the poured concrete. The depth of immersion shall be appropriate for the structure being concreted and the location of concreting.

The vibrators shall not touch the reinforcement. When vibrating a freshly placed layer, the vibrator shall be pushed down vertically into the preceding plastic layers and withdrawn gradually, producing a dense concrete free of set concrete. The intervals at which the vibrator should be immersed shall not exceed 2/3 of the apparent effective area of vibration of the unit used. Excessive vibration and segregation of aggregates shall be avoided.

For concrete containing an approved retarding admixture for structural walls, each layer of concrete shall be in place and compacted for at least 30 minutes before the next layer is placed. Bleed water on the surface of the concrete shall be removed before additional concrete is placed and the concrete in place shall be re-vibrated before the next lift is placed. At the top of walls and columns, concrete containing excess water or fine aggregates cause by vibration shall be removed while still plastic and the space filled with compacted concrete of the correct proportion and vibrated in place.

#### **(xx) Slabs**

For slabs, screeds shall be set at maximum of 2.5 metres. Centres and the correctness of elevations shall be checked with an instrument level. The concrete shall be compacted and tamped to bring ten mm of mortar to the surface and wood floated to straight edges and screeds. The finished surfaces shall be level or sloped as required and the maximum deviation permissible being 6 mm from 3m straight edge for the exposed finishes. No steel or plastic floats shall be used for initial floating. Unless otherwise specified, special finishes shall be applied only after the surface has sufficiently hardened. All laitance and bleed water shall be removed as it appears.

Concrete shall be compacted during placing with approved vibrating equipment until the concrete has been consolidated to the maximum practicable density, is free of pockets of coarse aggregate and fits tightly against all form surfaces, reinforcement and embedded fixtures. Particular care shall be taken to ensure that all concrete placed against the form faces and into corners of forms or against hardened concrete at joints is free from voids or cavities. The use of vibrators shall be consistent with the concrete mix and caution is to be exercised to not over vibrate the concrete to the point of segregation.

#### **(xxi) Vibrators**

Vibrators shall conform to IS specifications. The type of vibrators to be used shall depend upon the structure where concrete is to be placed. Shutter vibrators, to be effective, shall be firmly secured to the formwork which must be sufficiently rigid to transmit the vibrations and strong enough not to be damaged by it. Immersion vibrators shall have load frequency amplitude and acceleration as per IS 2505 depending on the size of the vibrator. Immersion vibrators, in sufficient numbers and each of adequate size shall be used to properly consolidate all concrete. Tapping or external vibrating of forms by hand tools or immersion vibrators will not be permitted.

The exact manner of application and the most suitable machines for the purpose shall be selected and be operated by experienced operatives. Immersion vibrators shall be inserted vertically at points not more than 450 mm apart and withdrawn when air bubbles cease to come to the surface. Immersion vibrators shall be withdrawn very slowly. In no case shall immersion vibrators be used to transport concrete inside the forms. Particular attention shall be paid to vibration at the top of lift in a column or wall.

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When placing concrete in layers which are advancing horizontally as the work progress, great care shall be exercised to ensure adequate vibration, blending and melding of the concrete between the successive layers.

Immersion vibrators shall penetrate the layer being placed and also penetrate the layer below while the under layer is still plastic to ensure good bond and homogeneity between the two layers and prevent the formation of cold joints.

Care shall be taken to prevent contact of immersion vibrators against reinforcement steel. Immersion vibrators shall not come in contact with reinforcement steel after start of initial set. They shall also not be allowed to come in contact with forms or finished surfaces.

Form attached vibrators shall be used only with specific authorisation of Employer's Representative.

The use of surface vibrators will not be permitted under normal conditions. However, for thin slabs, surface vibration by specifically designed vibrators may be permitted, upon approval of Employer's Representative.

Formation of stone pockets or mortar ponding in corners and against faces of forms shall not be permitted. Should these occur, they shall be dug out, reformed and refilled to a sufficient depth and shape for thorough bonding as approved by Employer's Representative.

#### **(xxii) Placement Intervals**

Each placement of concrete shall be allowed to set for a period of 48 hours or longer when required, before the start of subsequent placement. A time gap between the two adjoining pours in the horizontal plane and the two adjacent pours in the vertical plane shall be seven days and three days respectively.

Except when placing with slip forms, each placement of concrete in multiple lift work shall be allowed to set for at least 24 hours after the final set of concrete and before the start of a subsequent placement.

#### **(xxiii) Special Provision in Placing**

When placing concrete in walls with openings, in floors of integral slab and beam construction and other similar conditions, the placing shall stop when the concrete reaches the top of the opening in walls or bottom horizontal surface of the slabs as the case may be. Placing shall be resumed before the concrete in place takes initial set, but not until it has had time to settle as determined by Employer's Representative.

#### **(xxiv) Placing Concrete through Reinforcing Steel**

When placing concrete through reinforcing steel, care shall be taken to prevent segregation of the coarse aggregate. Where the congregation of steel makes placing difficult, it may be necessary to temporarily move the top steel aside to get proper placement and then restore the reinforcing steel to design position.

#### **(xxv) Bleeding**

Bleeding or free water on top of concrete being deposited into the forms shall require stopping the concrete pour and the conditions causing this shall be corrected before any further concreting is resumed.

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**(xxvi) Rain or Wash Water**

No concrete shall be placed in wet weather or on a water covered surface. Any concrete that has been washed by heavy rain shall be entirely removed, if there is any sign of cement and sand having been washed away from the concrete mixture. To guard against damage which may be caused by rain, the works shall be covered with tarpaulins immediately after the concrete has been placed and compacted before leaving the work unattended. Any water accumulating on the surface of the newly placed concrete shall be removed by approved means and no further concrete shall be placed thereon until such water is removed. To avoid water flowing over or around freshly placed concrete, suitable drains and sumps shall be provided.

**(xxvii) Concreting in Hot Weather**

The Contractor's methods shall comply with the recommendations ACI 305, Hot Weather Concreting, as modified and supplemented below.

The Contractor shall take great care during hot weather to prevent the cracking or crazing of concrete. The Contractor shall arrange for concrete to be placed in the early morning or late evening as directed by the Employer's Representative.

The Contractor shall have particular regard to the requirements specified herein for curing.

Formwork shall be shaded from direct exposure to the sun both prior to placing of the concrete and during its setting. The Contractor shall take appropriate measures to ensure that reinforcement in and projecting from the section to be concreted is maintained at the lowest temperature practicable.

Concrete at placing shall have a temperature of not more than 32 °C. If necessary, the Contractor shall cool the aggregates and mixing water by methods approved by the Employer's Representative.

Where necessary, the Contractor shall design, install and operate a cooling system by which cooling water is pumped through a piping system in order to decrease the heat of hydration during concreting. The proposal for such a cooling system shall be submitted to the Employer's Representative for his approval two weeks prior to the concreting operations.

The temperatures of ambient air, concrete at various levels and at intervals not exceeding 5 metres and cooling water where applicable shall be measured by means of thermocouples and recorded with a Philips type PR 3210 A/00 recorder or similar approved.

**(xxviii) Placing of Concrete Under Water**

Under all ordinary conditions all foundations shall be completely dewatered and concrete placed in the dry. However, when concrete placement under water is necessary, all work shall conform to IS 456 and procedure shall be as follows:

Concrete shall be deposited under water by means of tremies or bottom-drop buckets of approved type.

All work requiring placement of concrete underwater shall be designed, approved and inspected with regard to the local circumstances and purposes. All under water concrete shall be placed according to the specifications and as approved by the Employer's Representative.

**(xxix) Protection**

All concrete shall be protected against damage.

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**(xxx) Corrosion Resistant Lining**

Where required, corrosion resistant linings shall be applied strictly according to the manufacturer's instructions. The work shall be performed by experienced personnel under the supervision of a qualified representative of the manufacturer. The completed lining shall be securely bonded to the substrate and provide the required corrosion resistant protection.

**(xxxi) Installation of Pipes, Electrical Conduits etc Through Concrete Structures**

Wherever required, the Contractor shall install in place, before concreting, any pipe, electrical conduit or other special item that passes through or terminates at any concrete wall. Alternatively the Contractor shall obtain the prior approval of the Employer's Representative of shop drawings of the methods he proposes to adopt, particularly if he intends to leave an opening and install the special item later

After approval that a special item may be concreted in later, the opening shall be accurately fashioned to receive it. Pipes passing through walls or floors of water retaining or earth supporting structures shall be provided with welded puddle flanges and the opening provided shall take this into account.

- 1 The opening provided shall be of sufficient size to permit accurate final alignment of the embedded fitting without deflecting any part and allowing adequate space for satisfactory spacing where the pipe passes through openings so formed.
- 2 The box-outs shall be provided with continuous keyways to hold the concrete filling in place and ensure water-tightness.
- 3 The space left within the box-outs and around the special item positioned in place, shall be filled with non-shrink grout or non-shrink concrete as approved by the Employer's Representative.

**(xxxii) Mass Foundations**

Mass foundations shall be poured in lifts not exceeding 1.5 m. in height unless otherwise approved by Employer's Representative.

**(xxxiii) Treatment of Construction Joints on Resuming Concreting**

All laitance and loose stones shall be thoroughly and carefully removed by wire brushing/ hacking and surface washed.

Just before concreting is resumed, the roughened joint surface shall be thoroughly cleaned and loose matter removed and then thoroughly wetted. The new concrete shall be well worked specially against the prepared face. Special care shall be taken to obtain thorough compaction and to avoid segregation of the concrete along the joint plane.

**(xxxiv) Water**

Clean water in pipes under pressure shall be provided by the contractor with all necessary equipment for giving a nozzle pressure of not less than 2.0 kg/cm<sup>2</sup> for the convenient and effective jetting of rock foundations and concrete surfaces, for cooling aggregate required for concrete, for curing concrete and other requirements.

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### **(xxxv) Protecting Fresh Concrete**

Fresh concrete shall be protected from the elements, from defacement and damage due to construction operations by leaving forms in place for ample periods. Newly placed concrete shall be protected by approved means, such as tarpaulins, from rain, sun and winds. Steps, as approved by the Employer's Representative, shall also be taken to protect immature concrete from damage by debris, excessive loading, vibration, abrasion or contact with other materials or otherwise disturbed. If it is necessary that workmen enter the area of freshly placed concrete, bridges shall be placed over the area.

#### **13.6.2 Concrete for Large Pours**

This clause applies to large concrete pours where measures need to be taken to deal with the generation of heat and attendant volume change to minimise cracking.

If available, coarse aggregate shall be of limestone or other aggregate with a low coefficient of thermal expansion and of angular shape.

Measures shall be taken to limit the effects of thermal movement in the concrete.

The maximum temperature during hydration shall not exceed 65 °C.

The concrete mix may include an approved type of water reducing /workability admixture.

Form-work for the sides shall be of minimum 19 mm thick plywood or equivalent thermal resistant to ensure that the maximum specified thermal gradient is not exceeded during curing.

All formwork for pits, ducts, rebates and holding down bolts shall be constructed so that it can be easily collapsed to facilitate removal after the initial set of the concrete. The top of formwork for holes shall be covered to prevent entry of excess grout or other substances.

Standby plant shall be available for all plant used for the construction of the foundations. For compressors, vibrators, cranes, concrete pumps, lighting equipment and the like, standby plant shall be on site before concreting commences.

Concrete shall be placed in single pours lasting no more than 16 hours. The sequence of placing shall be such, that exposed concrete shall be covered with fresh concrete within one hour of first mixing of the exposed concrete. Re-compaction of the original with the fresh concrete shall be undertaken to ensure a homogenous mass without a cold joint.

The concrete shall be placed and compacted in such a manner as to ensure that cracking due to plastic settlement does not occur.

On completion of a pour, the top surface shall be steel trowel finished and the exposed concrete shall be sprayed with an approved curing compound. Space shall be arranged around the pour to allow the free flow of air during curing.

The poured concrete shall be protected if necessary with insulation to limit the thermal gradient between the core and the surface to below 20 °C. The pour shall contain thermocouples distributed within the concrete in accordance with the Contractors design. The Contractor shall measure and record the internal and surface concrete temperatures daily until the formwork is stripped.

The formwork and insulation shall be left in place until the surface temperature is at the average ambient daily temperature.

The method statement for the construction of each large pour shall include the following information:

1. Details of the mix design and source of supply.
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2. Full details of the formwork with particular reference to the installation of holding down bolt formers.
3. Details of the placing procedure including method of placing, standby arrangements, number of vibrators and number of supervisors and operatives.
4. Details of insulation for the pours and how the pours are to be cured.
5. Details of how the concrete is to be placed and compacted without cold joints and without cracking resulting from plastic settlement.

Within six weeks after construction of large pours, the Contractor shall issue a construction report containing full details of the construction, materials testing results and as-built drawings.

### **13.6.3 Concrete for Machine Foundations**

Design and construction of machine foundations shall be carried out in accordance with IS 2974.

After commissioning rotating machines, the Contractor shall carry out a full vibration survey to record the vibrations of the foundations. The results of the survey shall be submitted to the Employer's Representative.

### **13.6.4 Joints in Concrete**

#### **(i) General**

Provision shall be made for expansion and contraction in concrete by the use of special joints located as necessary. Construction joint surfaces shall be as specified or as approved by Employer's Representative.

Concrete shall be placed without interruption until completion of the part of the work between predetermined construction joints. The time lapse between the pouring of adjoining units shall be as specified or as approved by Employer's Representative.

Construction joints shall be avoided if possible or their number minimised. Concreting shall be carried out continuously up to construction joints the position and arrangement of which shall be indicated by the Contractor's designer. Construction joints shall comply with IS 11817.

Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete in order to create rough/uneven surface. Laitance and cement slurry shall be cleaned out by using wire brushes on the surface of the joint immediately after initial setting of the concrete. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed against it. In the case of construction joints at locations where the previous pour has been cast against shuttering, the aggregate of the previously poured concrete shall be exposed using a high pressure water jet or by another appropriate means.

At least 3 weeks prior to commencement of concreting, the Contractor shall supply drawings to the Employer's Representative indicating all expansion or other movement joints both vertical and horizontal including details of the type of joint to be provided, the method of concreting, the concreting lifts to be achieved in a single continuous operation and any other relevant details. One copy of the drawing, approved or modified, shall be returned to the Contractor.

Expansion joints shall be indicated on the Contractor's drawings. The width of the joint shall generally be 13 mm. Except where synthetic rubber (sealant) sealed joints are specified, joint filler and joint sealer shall be provided, with the filler to between 13 mm and 19 mm from the concrete face and then the sealer finished flush with surface. At synthetic rubber sealed joints, the filler shall be to 13 mm from the concrete face to receive sealant, unless otherwise specified.

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All Construction joints shall be provided with suitable keyways or other keying methods. The old surface shall be roughened until the clean aggregate embedded in the mortar matrix is exposed, by chipping, sand-blasting or application of a surface mortar retardant followed by washing and scrubbing with a stiff brush. Reinforcement and water-stops shall be effectively protected. The prepared surface shall be kept wet for at least 24 hours before placing new concrete. Immediately prior to commencement of the new concreting, water shall be deposited on the prepared horizontal surface of the old concrete. If water-stops are not used, the coarseness amplitude of the prepared surface shall be at least 6 mm.

Roof and floor slabs shall be poured in alternating checker-board fashion between approved construction joints. Concreted sections shall be fully cured before adjoining sections are concreted. All construction joints in floor slabs and rafts shall be painted with a 230 mm wide strip of bitumen paint to be applied in two thick layers.

Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develops a proper bond with old concrete.

Where high shear resistance is required at the construction joints, shear keys shall be provided.

Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

If the stopping of concreting becomes unavoidable, a properly formed construction joint shall be made where the work is stopped. Joints shall be either vertical or horizontal. In the case of an inclined or curved member, the joints shall be at right angles to the axis of the member. Vertical joints in walls shall be kept to a minimum. Vertical joints shall be formed against a stop board, horizontal joints shall be level and wherever possible, arranged so that the joint lines coincide with the architectural features of the finished work. Battens shall be nailed to the formwork to ensure a horizontal line and if approved, shall also be used to form a grooved joint. For tank walls, similar work joints shall be formed as per IS 3370. Concrete that is in the process of setting shall not be disturbed or shaken by traffic either on the concrete itself or upon the shuttering. Horizontal and vertical construction joints and shear keys shall be located and shall conform in detail to the Contractor's approved drawings unless otherwise approved by Employer's Representative. The joints shall generally be in accordance with the following:

**(ii) Column Joints**

In a column, the joint shall be formed 75 mm below the lowest soffit of the beams, including haunches if any. In flat slab construction, the joint shall be 75 mm below the soffit of column capital. At least two hours shall elapse after depositing concrete in column, piers or walls, before depositing in beams, girders or slabs supported thereon.

**(iii) Beam and Slab Joints**

Concrete in a beam shall be placed throughout without a joint but if the provision of a joint is unavoidable, the joint shall be vertical and at the centre or within the middle third of the span unless otherwise approved. Where a beam intersects a girder, the joints in the girder shall be offset a distance equal to twice the width of the beam and additional reinforcement provided for shear. The joints shall be vertical throughout the full thickness of the concrete member. A joint in a slab shall be vertical and parallel to the principal reinforcement. Where it is unavoidable at right angles to the principle reinforcement, the joint shall be vertical and at the middle of span.

**(iv) Joints in Liquid Retaining Structures**

Vertical construction joints in watertight construction will not be permitted. Where a horizontal construction joint is required to resist water pressure, special care shall be taken in all phases of its construction to ensure maximum water-tightness.

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**(v) Expansion and Movement Joints**

Joint filler shall consist of a proven bituminous compound approved by the Employer's Representative. Application of the filler shall be strictly in accordance with the manufacturer's instructions.

The Contractor shall supply, for the Employer's Representative's approval, details of the proposed materials including the mechanical properties. The manufacturer shall design the width and thickness of the elastomeric compound to accommodate the maximum designed thermal shrinkage movement at the joint.

Joint Sealers shall be of impermeable ductile material providing a water-tight seal through the full joint movement range. Details of joint sealing are given in Section of this tender document.

**(vi) Water-Stops**

Water bars or water stops shall be extruded from a polyvinyl chloride compound containing the plasticizers, resins, stabilizers and other ingredients needed to impart the required characteristics or from synthetic rubber.

The Contractor shall supply to the Employer's Representative, details of the thickness of the water-stop offered by him to indicate its adequacy to withstand the design pressures.

All water-stop intersections such as ells, tees, crosses etc shall be fabricated by the manufacturer and shall have sufficiently long legs to permit field butt splicing.

Water-stops shall be provided in all expansion and movement joints. Water-stops shall be continuous in joints, following offsets and angles in joints until spliced to water-stops at intersections and thereby completely sealing the structure. The flanges of water-stops shall be secured to the reinforcement with 18 gauge wire ties at a maximum spacing of 45 centimetres or with a PVC binding where that is specifically recommended by the water-stop manufacturer.

PVC water-stops shall be neatly fused and synthetic rubber water-stops vulcanized at joints and connections unless explicitly otherwise specified by the manufacturer.

Water stops shall be provided at all vertical construction joints in walls of water retaining structures and all expansion joints in water retaining structures and wherever specified or directed by the Employer's Representative,.

Water stops shall not be exposed to direct sunlight for long periods. Before being concreted, water stops shall be cleaned of all foreign materials. Wherever provided, water stops shall be placed in such a manner that they are embedded in the adjacent sections of the panels for equal width.

The storage, fixing in position, splicing of water stops shall be as per manufacturer's instructions.

Water stops shall be fully supported in the formwork, be free of nails and clear of reinforcement and other fixtures. Damaged water stops shall be replaced and during concreting care shall be taken to place concrete so that water stops do not bend or distort.

The different type of water stops to be used in liquid retaining structures shall be as follows:

	Type of Joint	Type of Water Stops
1.	Partial/ complete construction joint in walls and slabs	150 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness

2.	Expansion joints in walls and slabs	225 mm wide, ribbed with hollow centre bulb and 9 mm minimum thickness
3.	Construction joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
4.	Construction joint in wall	150 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
5.	Partial/ complete construction joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness
6.	Expansion joint in raft	225 mm wide, ribbed with hollow centre bulb and 5 mm minimum thickness

(vii) Dowels

Dowels for concrete work, not likely to be taken up in the near future, shall be wrapped in tar paper and burlap.

### 13.6.5 Curing

#### (i) Curing Formed Concrete

All concrete shall be cured by keeping it continuously damp for the period of time required for complete hydration and hardening to take place. Curing shall be by use of the water curing method, specified liquid membrane forming compound or concrete curing paper, the specified use of any method being subject to the approval of the Employer's Representative.

Preference shall be given to the use of continuous sprays or ponded water, continuously saturated covering of sacking, canvas, hessian or other absorbent materials, or approved effective curing compounds applied with spraying equipment capable of producing a smooth, even textured coat. Extra precautions shall be exercised in curing concrete during hot weather. The quality of curing water shall be the same as that used for mixing the concrete.

Certain types of finish or preparation for overlaying concrete must be made at certain stages of the curing process and special treatment may be required for specific concrete surface finishes.

Curing of concrete made of high alumina cement and super-sulphated cement shall be carried out as approved by the Employer's Representative.

The structural elements with concrete having water binder ratio less than or equal to 0.4 or partial replacement of cement by pozzolanic materials (5% or above replacement by silica fume or high reactivity metakaoline, or 15% or above by fly ash) shall be cured in two stages, initial curing and final curing.

The initial curing should be started not later than three hours or after the initial setting time, whichever is lower, after placement of concrete. The concrete surfaces exposed to the environment shall be covered by plastic sheet or other type of impermeable covers. The initial curing should be continued up to a minimum period of 12 hours or 2 hours plus final setting time of concrete, whichever is higher.

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Final curing shall be with water and commence immediately after initial curing and continue for a minimum period of 14 days.

**(ii) Continuous Spraying**

Curing shall be assured by the use of an ample water supply under pressure in pipes, with all necessary appliances of hose sprinklers and spraying devices. Continuous fine mist spraying or sprinkling shall be used, unless otherwise specified or approved by Employer's Representative.

**(iii) Alternative Curing Methods**

Whenever, in the judgment of the Contractor's designer and with the approval of the Employer's Representative, it may be necessary to omit the continuous spray method, covering of clean sand or other approved means such as wet gunny bags, which will prevent loss of moisture from the concrete, may be used. Any type of covering which would stain or damage the concrete during or after the curing period shall not be used. The covering shall be kept continuously wet during the curing period.

For curing of concrete in pavements, side-walks, floors, flat roofs or other level surfaces, the ponding method of curing is preferred. The method of containing the ponded water shall be approved by Employer's Representative. Special attention shall be given to edges and corners of slabs to ensure proper protection to these areas. The ponded areas shall be kept continuously filled with water during the curing period.

**(iv) Curing Equipment**

All equipments and materials required for curing shall be on hand and ready for use before the concrete is placed.

**(v) Membrane Curing**

Approved curing compounds may be used in lieu of moist curing with the permission of Employer's Representative. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering, the concrete surface closely may also be used to provide an effective barrier against evaporation.

For concrete containing Portland pozzolona cement, Portland slag cement or mineral admixtures, an increased period of curing may be required.

**13.6.6 Repair and Replacement of Unsatisfactory Concrete**

Immediately after shuttering is removed, the surfaces of concrete shall be very carefully inspected and all defective areas called to the attention of Employer's Representative who may permit patching of the defective areas or else reject the concrete either partially or entirely. Rejected concrete shall be removed and replaced by the Contractor. Holes left by form bolts etc shall be filled and made good with mortar composed of one part of cement to one and half parts of sand, that passes through a 2.36 mm IS sieve, after removing any loose stones adhering to the concrete. Mortar filling shall be struck off flush at the face of the concrete. The concrete surface shall be finished as described under the particular item of work.

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Superficial honey combed surfaces and rough patches shall be similarly made good immediately after removal of shuttering, in the presence of Employer's Representative and superficial water and air holes shall be filled in. The mortar shall be well worked into the surface with a wooden float. Excess water shall be avoided. Unless instructed otherwise by Employer's Representative, the surface of exposed concrete placed against shuttering shall be rubbed down immediately on removal of shuttering to remove fine or other irregularities. Care shall be taken to avoid damaging the surfaces. Surface irregularities shall be removed by grinding.

If reinforcement is exposed or the honey combing occurs at vulnerable positions. such as at the ends of beams or columns, it may be necessary to cut out the member completely or in part and reconstruct. The decision of Employer's Representative shall be final. If in the opinion of the Employer's Representative only patching is necessary, the defective concrete shall be cut out until solid concrete is reached (or to a minimum depth of 25 mm), the edges being cut perpendicular to the affected surface or with a small under cut if possible, anchors, tees or dowels shall be provided in slots whenever necessary to attach the new concrete securely in place. An area extending several centimetres beyond the edges and the surfaces of the prepared voids shall be saturated with water for 24 hours immediately before the patching material is placed.

**(i) Use of Epoxy Mortar**

The use of epoxy mortar for bonding fresh concrete used for repairs will be permitted upon written approval of Employer's Representative. Epoxy mortar shall be applied in strict accordance with the instruction of the manufacturer.

**(ii) Method of Repair**

Small size holes having surface dimensions about equal to the depth of the hole, holes left after removal of form bolts, grout insert holes and slots cut for repair of cracks shall be repaired as follows:

The hole to be patched shall be roughened and thoroughly soaked with clean water until absorption stops.

A 5 mm thick layer of grout of equal parts of cement and sand shall be well brushed into the surface to be patched followed immediately by the patching concrete which shall be well consolidated with a wooden float and left slightly proud of the surrounding surface. The concrete patch shall be built up in 10 mm thick layers. After an hour or more, depending upon weather conditions, it shall be worked off flush with a wooden float and a smooth finish obtained by wiping with hessian. Steel trowels shall not be used for this purpose. The mix for patching shall be of the same materials and in the same proportions as that used in the concrete being repaired, although some reduction in the maximum size of the coarse aggregates may be necessary and the mix shall be kept as dry as possible.

Mortar filling by air pressure (guniting) shall be used for repair of areas too large and/ or too shallow for patching with mortar. Patched surfaces shall be given a final treatment to match the colour and texture of the surrounding concrete. White cement shall be substituted for ordinary cement, if so approved by Employer's Representative, to match the shade of the patch with the original concrete.

**(iii) Curing of Patched Work**

The patched area shall be covered immediately with an approved non-staining water-saturated material such as gunny bags, which shall be kept continuously wet and protected against the sun and wind for a period of 24 hours. Thereafter, the patched area shall be kept wet continuously by a fine spray of water for not less than 10 days.

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**(iv) Approval by Employer's Representative**

All materials, procedures and operations used in the repair of concrete and also the finished repair work shall be subject to the approval of Employer's Representative. All fillings shall be tightly bonded to the concrete and shall be sound and free from shrinkage cracks after the fillings have been cured and dried.

**13.6.7 Finishing**

This specification is intended to cover the treatment of concrete surfaces of all structures.

**(i) Finishes for Formed Surfaces**

The type of finish for formed concrete surfaces shall be as follows, unless otherwise approved by the Employer's Representative:

For surfaces against which backfill or concrete is to be placed, no treatment is required except repair of defective areas.

For surfaces below grade, which will receive waterproofing treatment, the concrete shall be free of surface irregularities which would interfere with proper application of the waterproofing materials which is specified for use.

Surfaces which will be exposed to the weather and which would normally be level, shall be sloped for drainage. Unless a horizontal surface is specially specified or a particular slope required, the tops of narrow surfaces such as staircase treads, walls, curbs and parapets shall be sloped across the width at 1 in 30. Broader surfaces such as walkways, roads, parking areas and platforms shall be sloped at 1 in 50. Surfaces that will be covered by backfill or concrete, sub floors to be covered with concrete topping, terrazzo or quarry tile and similar surfaces shall be smooth, screeded and levelled to produce even surfaces. Surface irregularities shall not exceed 6mm. Surfaces which will not be covered by backfill, concrete or tile topping such as external decks, floors of galleries and sumps, parapets, gutters, sidewalks, floors and slabs shall be consolidated, screeded and floated.

Excess water and laitance shall be removed before final finishing. Floating may be done by hand or power tools and started as soon as the screeded surface has attained a stiffness to permit finishing operations and these shall be the minimum required to produce a surface uniform in texture and free from screed marks or other imperfections. Joints and edges shall be tooled as required or as approved by the Employer's Representative.

**(ii) Standard Finish for Exposed Concrete**

Exposed concrete shall mean any concrete other than floors or slabs exposed to view upon completion of the job. Unless otherwise specified on the drawings, the standard finish for exposed concrete shall be of smooth finish.

A smooth finish shall be obtained with the use of lined or plywood forms having smooth and even surfaces and edges. Panels and form linings shall be of uniform size and be as large as practicable and installed with closed joints. Upon removal of forms, the joint marks shall be smoothed off and all blemishes, projections etc removed, leaving the surfaces smooth and unmarred.

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**(iii) Integral Cement Concrete Finish**

When required, an integral cement concrete finish of specified thickness for floors and slabs shall be applied either monolithically or bonded, as specified in IS2571. The surface shall be compacted and then floated with a wooden float or power floating machine. The surface shall be tested with a straight edge and any high and low spots eliminated. Floating or trowelling of the finish shall be permitted only after all surface water has evaporated. Dry cement or a mixture of dry cement and sand shall not be sprinkled directly on the surface of the cement finish to absorb moisture or to stiffen the mix.

**(iv) Rubbed Finish**

A rubbed finish shall be provided only on exposed concrete surfaces as required. Upon removal of forms, all fins and other projections on the surfaces shall be carefully removed, offsets levelled and voids and/ or damaged sections repaired. The surfaces shall then be thoroughly wetted and rubbed with carborundum or other abrasive. Cement mortar may be used in the rubbing, but the finished surfaces shall not be brush coated with either cement or grout after rubbing. The finished surfaces shall present a uniform and smooth appearance.

**13.6.8 Field Quality Control**

All concreting shall be supervised by the Employer's Representative and in order to enable the Employer's Representative to make the requisite arrangements, the Contractor shall give him adequate notice of the proposed concreting operations which, except under special circumstances, shall not be less than 24 hours after checking reinforcement and formwork. Any concreting done in the absence of, or without the express permission of the Employer's Representative is liable to rejection.

**13.6.9 Tests**

All tests specified in the Indian Standards shall be regularly carried out together with any additional tests the Employer's Representative may require to satisfy himself regarding the quality of the work done.

If the results of any tests indicate the concrete in question is unsatisfactory in any respect, the Contractor shall take any steps indicated by the Employer's Representative to rectify the same and if such rectification is not found to be satisfactory or adequate, the section in question shall be removed and re-concreted.

While all the tests stipulated in the Indian Standards are necessary, the carrying out of the field slump-tests and the making of the specified works test cubes from every batch of concrete, or as otherwise specified by the Employer's Representative, shall be carried out as an invariable general rule.

The following requirements in respect of concrete testing will be rigidly applied throughout the duration of the Contract to all permanent works.

**(i) Sampling Procedure**

Sampling and testing shall be in accordance with IS 1199 and IS 516. Evaluation of the results and acceptance or rejection of the concrete will be done as described below.

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Six cubes shall be obtained from each mix during each working period. Half the number in each sample shall be tested at 7 days and the balance at 28 days. Where the tests are carried out in the site laboratories, companion cubes shall be tested on the dates on which the representative samples are tested at site at an independent laboratory approved by the Employer's Representative. If a significant difference is noticed between the two sets of results all further testing shall be done at the approved laboratory until the site equipment is rectified satisfactorily. No reduction in the frequency or number of samples taken shall be made without the explicit approval of the Employer's Representative who, if agreeing to any reduction, shall have such a decision mainly on the consistency of good results achieved over an acceptable period. Any deterioration in quality will result in the more rigorous schedule being re-implemented.

The values given in table below may be taken for general guidance in the case of concrete made with ordinary cement. In all cases, the 28 day compressive strength specified shall alone be the criterion for acceptance or rejection of the concrete. If however, from tests carried out for a particular job over a reasonably long period, it has been established to the satisfaction of the Employer's Representative that a suitable ratio between 28 days compressive strength and the modulus of rupture at 72 (+/-) 2 hours or 7 days or compressive strength at 7 days may be accepted, the Employer's Representative may suitably relax the frequency of 28 day compressive strength tests, provided the expected strength values at the specified early age are consistently met.

**Optional Tests Requirements of Concrete:**

Grade of Concrete	Compressive strength on 15 cm cubes min. at 7 days N / mm <sup>2</sup>	Modulus of rupture by beam test min.	
		At 72 (+/-) 2 hours N / mm <sup>2</sup>	At 7 days N / mm <sup>2</sup>
M 10	7.0	1.2	1.7
M 15	10.0	1.5	2.1
M 20	13.5	1.7	2.4
M 25	17.0	1.9	2.7
M 30	20.0	2.1	3.0
M 35	23.5	2.3	3.2
M 40	27	2.5	3.4

**(ii) Test Specimen**

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the form work or to determine the duration of curing or to check the testing error. Additional cubes may also be required for testing cubes cured by accelerated methods as described in IS 9013 - 1978. The specimen shall be tested as described in IS 516 - 1959.

### (iii) Frequency

The minimum frequency of sampling of concrete of each grade shall be in accordance with following table:

Quantity of Concrete m <sup>3</sup>	Number of Samples
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 & above	4 + one per additional 50m <sup>3</sup>

At least one sample shall be taken from each shift. Where concrete is in continuous production, such as at a ready-mixed concrete plant, the frequency of sampling may be agreed upon mutually by suppliers and purchasers.

### (iv) Test Strength of Samples

The test strength of the samples shall be the average of the strength of three specimens. The individual variation should not be more than (+/-) 15 percent of the average.

### (v) Standard Deviation

This section should be read in conjunction with Section 13.3 13.4.1 of this specification.

The standard deviation and coefficient of variation shall be computed for a set of any 10 consecutive tests. The probable minimum strength of the batch, as calculated from the results of the 10 tests, based on failure probability of 1 in 10, shall then be compared with the specified minimum strength for the relevant grade of concrete.

- 1 If the calculated minimum strength exceeds the specified minimum strength by 10 percent or more, the Contractor will be permitted to redesign the mix with a lower cement content, if feasible.
- 2 If the calculated strength exceeds the specified minimum strength by not more than 10 percent, the mix design shall be used for subsequent batches of concrete.
- 3 If the calculated strength falls short of the minimum specified strength but by not more than 10 percent, the decision to accept or reject the representative batch of concrete will be at the sole discretion of the Employer's Representative. The location of the batch in the structure, the maximum stresses likely to occur therein, the calculated strength of the cubes and other relevant factors will be taken into consideration, but his decision, once given shall not be subject to question or dispute nor shall it be subsequently quoted as a precedent.
- 4 If the calculated minimum strength falls short of the specified minimum strength by more than 10 percent, the representative batch of concrete shall be rejected.
- 5 All water retaining structures shall be tested for water-tightness in conformance with the requirements of IS 3370 (Part I) – 1965, section 10 to the satisfaction of the Employer's Representative.

### 13.6.10 Acceptance Criteria

The concrete shall be deemed to comply with the strength requirements when both the following conditions are met:



- (a) The mean strength determined from any group of four consecutive test results complies with the appropriate limits in column 2 of the table below
- (b) Any individual test result complies with the appropriate limits in column of Table below.

Characteristic Compressive Strength Compliance Requirement:

Specified grade	Mean of the group of 4 non-overlapping consecutive test results in N / mm <sup>2</sup>	Individual test results in N / mm <sup>2</sup>
M 15	$= / > f_{ck} + 0.825 \times \text{established standard deviation (rounded off to nearest 0.5 N/mm}^2)$	$= / > f_{ck} - 3 \text{ N/mm}^2$
	Or $= / > f_{ck} + 3 \text{ N / mm}^2$ whichever is greater	
M 20 or above	$= / > f_{ck} + 0.825 \times \text{established standard deviation (rounded off to nearest 0.5 N / mm}^2)$	$= / > f_{ck} - 4 \text{ N / mm}^2$
	or $= / > f_{ck} + 4 \text{ N / mm}^2$ whichever is greater	

Note – In the absence of an established value of standard deviation, the values given in (assumed standard deviation) may be assumed and an attempt should be made to obtain the results of 30 samples as early as possible to establish the value of standard deviation.

#### (i) Flexural Strength

When both the following conditions are met, the concrete complies with the specified flexural strength.

- 1 The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm<sup>2</sup>
- 2 The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm<sup>2</sup>

#### (ii) Quantity of Concrete Represented by Strength Test Results.

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches.

For the individual test result requirements given in column 2 of above table or in item (b) of flexural strength , only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60m<sup>3</sup>.

If the concrete is deemed not to comply pursuant to the above, the structural adequacy of the parts affected shall be investigated and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

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### **(iii) Alterations and Concreting against Surfaces**

Existing concrete surfaces which are to receive new concrete shall be heavily sand-blasted to expose the coarse aggregate and produce a clean, coarse textured surface. Such prepared surfaces shall be coated with an epoxy bonding or other approved coating immediately prior to concreting. The compound shall be equal or superior to "Sikastix Adhesive" manufactured by the Sika chemical company and shall be mixed and applied strictly in accordance with the manufacturer's recommendations under different conditions.

## **13.7 Ready Mixed Concrete**

### **13.7.1 General**

Ready mixed concrete (RMC) shall comply with the requirements of IS 4926 or the latest Indian Standard.

Concrete delivered at site shall be in a plastic condition and requiring no further treatment before being placed in the position in which it is to set and harden.

The continuing mixing of concrete during transport shall be at a reduced speed to prevent segregation.

Concrete shall be produced by completely mixing cement, aggregates, admixtures (if any) and water at a stationary central mixing plant and delivered in transit mixers.

Concrete may be produced in a transit mixer at the batching plant, with the mixing being carried out entirely in the transit mixer either during the journey or on arrival at the site of delivery. No water shall be added to the aggregate and cement until the mixing of concrete commences.

### **13.7.2 Manufacturing**

The ready-mixed concrete shall be manufactured and supplied on either of the following bases:

- 1 Specified strength based on 28-day compressive strength of 15 cm cubes tested in accordance with IS: 456-2000.
- 2 Specified mix proportion.

Where the contract requires using ready mix concrete of designated strength, the Contractor shall procure the same from approved suppliers only and Section of this tender document shall also apply to concreting done with ready mix concrete.

When the concrete is manufactured and supplied on the basis of specified strength, the responsibility for the design of mix shall be that of the manufacturer and the concrete shall conform to the requirements specified.

When the concrete is manufactured and supplied on the basis of specified mix proportions, the responsibility for the design of the mix shall be that of the mix designer and the concrete shall conform to the requirements specified.

### **13.7.3 Supply**

Ready mix concrete prepared and transported will be as per IS 4926 of 1976 or the latest IS Code.

Water is not to be added to ready mixed concrete on site.

Ready mix concrete will be brought to the site from the RMC plant only by transit mixers (agitators).

Every transit mixer will carry a delivery ticket, stating the minimum following details:

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- a. Name of manufacturer and depot
- b. Serial number of the ticket.
- c. Date
- d. Truck number
- e. Name of Contractor to whom the RMC is being supplied
- f. Location of contract
- g. Grade of concrete.
- h. Specified workability
- i. Cement content and grade of cement
- j. Time of loading
- k. Quality of concrete.

When the truck arrives on site, the drum, should always be rotating at about 10 to 15 rev/min, for at least three minutes, to ensure that the concrete is thoroughly mixed and uniform before discharge.

When a truck mixer or agitator is used for the mixing or transportation concrete, no water from the truck-water system or from elsewhere shall be added after the initial introduction of the mixing water for the batch,

Unless otherwise specified, when a truck or agitator is used for transporting concrete, the concrete shall be delivered to the site of the work and the discharge shall be complete within 1 ½ hour when the prevailing atmospheric temperature is above 20°C and within 2 hours when the prevailing atmosphere temperature is at or below 20°C of adding the mixing water to the mix of cement and aggregate or adding the cement to the aggregate which ever is earlier.

### 13.8 Plain Cement Concrete

For plain cement concrete work, the specification for cement, sand, fine and coarse aggregates and water shall be the same as that specified in reinforced concrete but the proportion of mix will be nominal and the ratio of fine and coarse aggregate may be slightly adjusted within limits, keeping the total value of aggregates to a given volumes of cement constant to suit the sieve analysis of both the aggregates. Cement shall not be measured by volume and shall always be used directly from the bags (i.e. 50 kg/bag).

The nominal maximum size of coarse aggregate for 1:2:4 mix shall be as specified for reinforced concrete and for 1:3:6 and 1:4:8 mix shall be 40 mm for concrete 300 mm and more thick and 25mm for concrete less than 300 mm thick.

The quantity of water used shall be such as to produce concrete of the consistency required by the particular class of work and shall be decided by the use of a slump cone. Sufficient care should be taken to ensure that no excess quantity of water is used.

Mix proportion	Cement in bags	Sand m <sup>3</sup>	Coarse Aggregate m <sup>3</sup>			Water
			40 mm	20 mm	12mm	
Ordinary mix in volume						
1:5:10	2.60	0.475	0.6623	0.2583	-	156
1:4:8	3.40	0.500	0.6883	0.6883	-	153
1:3:6 (with 40mm aggr.)	4.4	0.485	0.672	0.672	0.262	176
1:3:6 (with 20 mm aggr.)	4.4	0.485	-	0.727	0.242	162.5
1:2:4 (with 20 mm aggr.)	6.4	0.47	-	0.705	0.235	205

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1:2:4 (with 40 mm aggr.)	6.4	0.47	0.544	0.241	0.126	235
1:1.5:3	8.0	0.441	-	0.6615	0.2205	240
1:1:2	12.20	0.45	-	0.675	0.225	330

The slump shall be specified for each class of work and shall in general be as follows:

Type of concrete	Max. slump (in mm)
Mass concrete	50
Concrete below water proofing treatment	50
Coping	25
Floor paving	50

All plain concrete shall be mixed in a drum type powder driven machine with a loading hopper which will permit the accurate measure of various ingredients. If hand mixing is authorised, it should be done on a watertight platform.

The mixing of each batch in the concrete mixer shall continue for not less than 1.5 minutes after the materials and water are in the mixer. The volume of mixed materials per batch shall not exceed the manufacturers rated capacity of the mixer. The mixer shall rotate at a peripheral speed of about 60 metres per minute.

### **13.9 Pre-Cast Concrete**

#### **13.9.1 General**

Pre-cast concrete and pre-cast reinforced concrete shall comply with IS 456 and with the following requirements.

Pre-cast concrete units shall incorporate sufficient lifting points and reinforcement to ensure the safe handling, transport and erection.

Where necessary, the Contractor's shop drawings shall include details of the lifting inserts, methods to be adopted to join the pre-cast units to other structures or parts thereof and the allowances made to receive work of other engineering specialties employed on the works.

Pre-cast concrete cladding panels shall be cast in formwork capable of producing a uniform fair faced finish.

Where appropriate, indelible identification and orientation marks shall be put on pre-cast concrete components in such a position that the marks shall not show or be exposed in the finished work.

#### **13.9.2 Execution**

##### **(i) Casting**

The pre-cast units shall be cast to the size and configuration required or otherwise specified.

The units shall be reinforced as necessary for the stresses likely to be caused by the methods of handling, transport and installation envisaged by the Contractor.

The longitudinal reinforcement shall have a minimum cover of 12 mm or twice the diameter of the main bar, whichever is more, unless otherwise approved, except for fencing or electric posts where the minimum cover shall be 25 mm.

The units shall be equipped with approved lifting devices for safe handling and easy installation.

Concrete used for pre-casting the units shall be thoroughly compacted by vibration or tamping to give a dense concrete free from voids and honeycombing.

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The exposed surfaces shall be finished as specified or with dense, smooth trowel led finish free from flaws and irregularities and true to the required configuration.

All angles of the pre-cast units, with the exception of any angles resulting from the splayed or chamfered faces, shall be true right angles. The arises shall be clean and sharp except those specified or shown to be rounded. The wearing surface shall be true to the required lines. On being fractured, the interior of the units should present a clean homogenous appearance.

Pre-cast units shall be cured to the maximum compressive strength for the specified class of concrete before the units are handled or lifted for transport or installation.

## **(ii) Curing**

After having been cast in the mould or form, the concrete shall be adequately protected during setting in the first stages of hardening from shocks and from harmful effects of sunshine and wind. The concrete shall be cured at least for 10 days from the date of casting.

All pre-cast work shall be protected from the direct rays of the sun for at least 7 days after casting and during that period each units shall be kept constantly watered or completely immersed in water if the size of unit so permits. Otherwise curing practices as given in clauses stated earlier shall be followed.

The pre-cast articles shall be matured for 28 days before being incorporated into the Works so that the concrete shall have sufficient strength to prevent damage when handled. Side shutters shall not be struck in less than 24 hours after depositing the concrete and no pre-cast unit shall be lifted until the concrete reaches a strength of at least twice the stress to which the concrete may be subjected at the time of lifting.

Pre-cast units shall be clearly marked to indicate the top of member and its location and orientation in the structure. The reinforced side of the units shall be distinctly marked.

Pre-cast units shall be stored, transported and placed in position in such a manner that they will not be overstressed or damaged. The lifting and removal of pre-cast units shall be undertaken without causing shocks, vibration or being put under bending stresses. Before lifting and removal takes place, the Contractor shall satisfy Employer's Representative that the methods he proposes to adopt for these operations will not overstress or otherwise affect the strength of the pre-cast units.

## **(iii) Installation**

The installation shall be fully coordinated with the works of the other engineering specialities comprising the Works and the units shall be installed and secured at such times as to prevent any delay in the progress of the works.

Pre-cast units shall be aligned and secured in accordance with the approved shop and working drawings.

The installation shall be in a neat, workmanlike manner. On completion, all surplus materials or debris arising out of the work shall be removed from the site.

## **13.10 Reinforcement**

### **13.10.1 General**

No re-rolled material shall be accepted. If instructed by the Employer's Representative, the Contractor shall submit the manufacturer's test certificates for the steel. Random tests on steel supplied by the Contractor may be performed by the Employer as per relevant Indian Standards. Each steel bar shall be identified by the number duly moulded on the bar itself.

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### **13.10.2 Submittals**

Bar bending schedules for reinforced concrete works shall be provided by the Contractor. The submittals for extra or modified work shall also be made by the Contractor at least two weeks prior to commencement of bending. Dimensions shown on the submittals furnished by the Contractor shall be his responsibility and approval of the submittals shall not constitute approval of the dimensions thereon.

### **13.10.3 Tie Wire**

Tie wire shall be of annealed steel, 16 gauge minimum.

### **13.10.4 Supports and Accessories**

Support blocks shall be of concrete with embedded wire ties or dowels for placement on grade or on membranes. Reinforcement for footings, grade beams and slabs on sub-grade shall be supported on pre-cast concrete blocks as approved by the Employer's Representative. The use of pebbles or stones shall not be permitted. The blocks are to be embedded.

Plastic coated spacers or accurately dimensioned concrete blocks shall be used in all water retaining surfaces, roofs of water retaining structures and in all interior or exterior surfaces exposed to weather after completion of the structure. Plastic cover blocks of approved manufacture will be permitted at the discretion of the Employer's Representative.

### **13.10.5 Dowels**

Where so required, reinforcing bar dowels shall be provided in new work and for anchorage to existing concrete. Where anchorage to existing concrete is required, a non-shrinking epoxy type grout or approved equal or deferred bolting devices shall be provided in each case, conforming to the relevant requirement specified in the section for cast-in-situ concrete.

### **13.10.6 Testing**

Testing of materials shall be at the Contractor's expense and as instructed by the Employer's Representative and when so tested, shall conform to the relevant standards. Tests may be ordered on bars as selected by the Employer's Representative from material at the site or from any place of distribution. Each sampling selection shall include at least two pieces, each 500 mm long.

The Contractor shall submit the manufacturer's test certificates. Regular tests on the steel supplied shall be performed by the Contractor at an approved laboratory in the presence of the Employer's Representatives as per relevant Indian Standards. The Employer's Representative may require the Contractor to perform tests of samples at random as per relevant Indian Standard. The quality, grade, colour coding embossing marks etc shall all be to the entire satisfaction of the Employer's Representative. Steel not conforming to the above test criteria shall be rejected.

The chemical, physical and mechanical properties of the steel reinforcement bars shall be as per IS 1786. Unless otherwise specified, the selection and preparation of test samples shall be as per the requirements of IS 2062.

All test pieces shall be selected either from the cuttings of bars or from any bar after it has been cut to the required or specified size and the test piece taken from any part of it. In either case, the test piece shall be detached from the bar in the presence of the Employer's Representative.

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The test pieces shall be full sections of the bars and shall be subjected to physical tests without any further modifications. No reduction in size by machining or otherwise shall be permissible, except in case of bars of size 28 mm and above. No test piece shall be annealed or otherwise subjected to heat treatment. Any straightening which a test piece may require shall be done cold.

For the purpose of carrying out tests for tensile strength, proof stress, percentage elongation and percentage elongation at maximum force for bars of 28 mm in diameter and above, deformations of the bars only may be machined. For such bars, the physical properties shall be calculated using the actual area obtained after machining.

Title	IS No.	ISO No.
Mechanical testing of metals - Tensile testing	1608	6892
Methods for bend test	1599, 7438 & 1786	15630-1
Method for re-bend test for metallic wires & bars	1786	15630-1

Chemical Composition of the bars shall conform to the following requirement

Constituents	Maximum permissible percent							Permissible max. Variation
	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600	
Carbon	0.300	0.250	0.300	0.250	0.300	0.250	0.300	0.020%
Sulphur	0.060	0.045	0.055	0.040	0.055	0.040	0.040	0.005%
Phosphorus	0.060	0.045	0.055	0.040	0.050	0.040	0.040	0.005%
Sulphur & Phosphorus	0.110	0.085	0.105	0.075	0.100	0.075	0.075	0.010%

Notes:

- 1 For welding of deformed bars, the recommendations of IS 9417 shall be followed.
- 2 In case of deviations from the specified maximum, two additional test samples shall be taken from the same batch and subjected to the test or tests in which the original sample failed. Should both additional test samples pass the test, the batch from which they were taken shall be deemed to comply with this standard. Should either of them fail, the batch shall be deemed not to comply with this standard.

Mechanical Properties of High Strength Deformed Bars

Nominal Size in mm	Tolerance on the nominal mass in percent		
	Batch	Individual sample	Individual sample for coils only
Up to and including 10	± 7	-8	± 8
Over 10 up to and including 16	± 5	-6	± 6
Over 16	± 3	-4	± 4

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Note: To satisfy Clause 26 of IS 456 -2000, no mixing of different types of grades of bars shall be allowed in the same structural members as main reinforcement, without prior written approval of the Employer's Representative.

#### **13.10.7 Fabrication and Delivery**

Tagged reinforcement bundles which can be easily identified shall be stored at the site in sufficient quantities to enable uninterrupted progress of the work. These shall be so stored as to prevent damage or undue exposure to harmful weather conditions.

#### **13.10.8 Stacking and Storage**

Steel for reinforcement shall be stored in such a way as to prevent distorting and corrosion. The steel for reinforcement shall not be kept in direct contact with ground. Fresh / fabricated reinforcement shall be carefully stored to prevent damage, distortion, corrosion and deteriorations. Care shall be taken to protect steel from exposure to saline atmospheres during storage, fabrication and use. This may be achieved by treating the surface of the reinforcement with a cement wash or by other suitable methods. Bars of different classification, size and length shall be stored separately to facilitate their issue in such sizes and lengths to cause minimum wastage in cutting from standard lengths.

#### **13.10.9 Bending and Forming**

Bars shall be fabricated accurately to dimensions, forms and shapes indicated by methods that will not damage the bars. Heating for purposes of bending will not be permitted. Field-bending of bars that are partially embedded in concrete shall not be done unless such procedure is specifically approved by the Employer's Representative.

All bars shall be accurately bent according to the sizes and shapes shown on the approved detailed working drawings and bar bending schedules. Bars shall be bent gradually by machine or other approved means. Reinforcing bars shall not be straightened and re-bent. Bars containing cracks or splits shall be rejected. Bars shall be bent cold unless specifically approved by the Employer's Representative.

Where approved, bars bent hot shall not be heated beyond a cherry red colour (not exceeding 645 °C) and after bending shall be allowed to cool slowly with out quenching. Bars incorrectly bent shall be used only after straightening and re-bending, such as shall not, in the opinion of the Employer's Representative, injure the material. No reinforcement bar shall be bent when in position in the work without approval, whether or not it is partially embedded in hardened concrete. Bars having kinks or bends other than those required by design shall not be used.

Where reinforcement bars are necessarily bent aside at construction joints and afterwards bent back into their original position, care shall be taken to ensure that, at no time, the radius of the bend is less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars to ensure that the concrete around the bar is not damaged.

#### **13.10.10 Laps**

Laps and splices for reinforcement shall be as shown on the approved Contractor's drawings. Splices in adjacent bars shall be staggered and the locations of all splices shall be subject to the approval of the Employer's Representative. Bars shall not be lapped unless the length required exceeds the maximum available lengths of bars at site.

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### **13.10.11 Reinforcing Bars for Masonry**

Reinforcing bars for masonry shall be shop fabricated.

### **13.10.12 Exposure conditions**

Exposure conditions are defined in the table below:

Environment	Exposure Conditions
Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal areas.
Moderate	Concrete surfaces sheltered from severe rain Concrete exposed to condensation and rain Concrete continuously under water Concrete in contact or buried under non-aggressive soil/ground water Concrete surfaces sheltered from saturated salt air in coastal areas
Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or severe condensation. Concrete completely immersed in sea water Concrete exposed to coastal environments
Very severe	Concrete surfaces exposed to seawater spray or corrosive fumes Concrete in contact with or buried under aggressive sub-soil/ground water.
Extreme	Concrete surfaces in tidal zones Members in direct contact with aggressive liquid or solid chemicals Concrete exposed to sewage, sewage effluent, sewage sludge and digester gases.

### **13.10.13 Fusion Bonded Epoxy Coating**

Where fusion bonded epoxy coating (FBEC) is to be applied to reinforcement bars, it shall conform to IS 13620.

The coating material shall conform to Annex A1 of IS 13620.

The surface of the steel reinforcing bars to be coated shall be cleaned by abrasive blast cleaning to near white metal.

The protective coatings shall be applied by the electrostatic spray method.

The film thickness of the coating shall be evaluated by bending production-coated bars around a mandrel as prescribed in IS 13620.

Tests, retests and permissible coating damage shall be in accordance with IS 13620. Coating damage shall be repaired with the repair compound supplied by the coating manufacturer.

#### 13.10.14 Nominal cover to reinforcement

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. The dimension shall be used in the design and indicated on the Contractor's detailing drawings. Cover shall be not less than the diameter of the bar. Unless otherwise specified, cover to reinforcement shall be provided generally as per guidelines of IS 456.

Minimum values for the nominal cover of normal weight aggregate concrete which should be provided to all reinforcement, including links depends on the condition of exposure. The nominal cover to meet durability requirements is shown in the table below:

Environment	Nominal concrete cover in mm not less than
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75

- 1 For main reinforcement of up to 12 mm diameter subject to mild exposure, the nominal cover may be reduced by 5 mm
- 2 Unless specified otherwise, the actual concrete cover should not deviate from the required nominal cover by +10 mm
- 3 For exposure conditions severe and very severe, a reduction of 5 mm may be made, where concrete grade is M 35 and above.

Unless otherwise approved by the Employer's Representative, clear concrete cover for reinforcement (exclusive of plaster or other decorative finish shall be as follows:

- 1 At each end of a reinforcing bar not less than 25mm or less than twice the diameter of the bar.
- 2 For a longitudinal reinforcing bar in a column, nominal cover shall in any case not be less than 40 mm or less than the diameter of such bar. In the case of column of maximum dimensions of 200 mm or less, whose reinforcing bars do not exceed 12 mm, a cover of 25 mm may be used.
- 3 For longitudinal reinforcing bars in a beam cover shall be not less than 25mm, or less than diameter of the bar.
- 4 For tensile, compressive, shear, or other reinforcement in a slab, cover shall be not less than 25 mm, or less than the diameter of the bar.
- 5 For any other reinforcement not less than 15 mm, or less than the diameter of the bar.
- 6 For footings and other principal structural members in which the concrete is deposited directly against the ground, the cover to the bottom reinforcement shall be 75 mm. If concrete is poured on a layer of lean concrete the bottom cover may be reduced to 50 mm.

- 7 For concrete surfaces exposed to the weather or the ground after removal of forms, such as retaining walls, grade beams, footing sides and tops etc, not less than 50 mm for bars larger than 16 mm diameter and not less than 40 mm for bars 16 mm diameter or smaller.
- 8 Increased cover thickness may be provided when surfaces of concrete members are exposed to the action of harmful chemicals (as in the case of concrete in contact with earth faces contaminated with such chemicals), acid, vapour, saline atmosphere, sulphurous smoke (as in the case of steam-operated railways) digester gases etc and such increase of cover may be between 15 mm and 50 mm beyond the figures given above (1 to 6) as may be specified by the Employer's Representative. The interior of sludge digestion tanks will fall into this category.
- 9 For reinforced concrete members, totally immersed in sea water, the cover shall be 40 mm more than specified (1 to 6) above.
- 10 For reinforced concrete members, periodically immersed in sea water or subject to sea spray, the cover of concrete shall be 50 mm more than that specified (1 to 6) above.
- 11 For concrete of grade M 25 and above, the additional thickness of cover specified in (8), (9) and (10) above may be reduced to half. In all such cases the cover should not exceed 75 mm
- 12 Protection to reinforcement in cases where concrete is exposed to harmful surroundings may also be given by providing dense impermeable concrete with an approved protective coating. In such cases, the extra cover, as stated in (7) and (8) above, may be reduced with the approval of the Employer's Representative.
- 13 The minimum clear distance between reinforcing bars shall be in accordance with IS 456.

The minimum values of nominal cover for normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance is shown in the table below:

Fire resistanc e	Nominal cover						Column s
	Beams		Slabs		Ribs		
	Simply Supporte d	Continuou s	Simply Supporte d	Continuou s	Simply Supporte d	Continuou s	
Hr	mm	mm	mm	mm	mm	mm	mm
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	35	20	40
2	40	30	35	25	45	35	40
3	60	40	45	35	55	45	40
4	70	50	55	45	65	55	40

- 1 The nominal covers given relate specifically to the minimum member .

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### **13.10.15 Placing of Reinforcement**

Reinforcement shall be accurately fixed by any approved means and maintained in the correct position by the use of blocks, spacers and chairs as per IS 2502 to prevent displacement during placing and compaction of concrete.

Any steel not conforming to the specifications shall be rejected. All reinforcement shall be clean, free from grease, oil, paint, dirt, loose mill scale, loose rust, dust, bituminous material or any other substances that will destroy or reduce the bond. All rods shall be thoroughly cleaned before being fabricated. Pitted and defective rods shall not be used.

Unless otherwise specified, reinforcement shall be placed within the following tolerances :

- 1 For effective depth, 200 mm or less + /- 10 mm
- 2 For effective depth, more than 200 mm + /- 15 mm

The correct cover shall be maintained by cement mortar blocks or other means approved by the Employer's Representative, as described in Section of this tender.

### **Cleaning**

Before placing reinforcement and again prior to concrete placement, the reinforcement shall be cleaned of loose mill scale, rust, oil or other coating that would reduce strength or bond. Steps shall be taken to ensure that the reinforcement shall not contact form coatings, release agents, bond breaker or curing compounds.

### **(i) Positioning of Reinforcement**

Reinforcement shall be kept in the correct position using the following methods:

For beam and slab construction, pre-cast cover blocks in cement mortar 1:2 (1 cement : 2 coarse sand) about 4 x 4 cm section and of thickness equal to the specified cover shall be placed between the bars and shuttering, to secure and maintain the requisite cover of concrete over reinforcement.

For cantilevered and doubly reinforced beams or slabs, the vertical distance between the horizontal bars shall be maintained by introducing chairs, spacers or support bars of steel at 1.0 metre or shorter spacing to avoid sagging.

For columns and walls, the vertical bars shall be kept in position by means of timber templates with slots accurately cut in them; or with 1:2 cement mortar blocks (1 cement : 2 coarse sand) of the required size suitably tied to the reinforcement to ensure that they are in correct position during concreting.

For other RCC structures such as arches, domes, shells, storage tanks etc a combination of cover blocks, spacers and templates shall be used as approved by Employer's Representative.

### **(ii) Tying in Place**

The reinforcement shall be accurately placed and tied securely with tying wire at all points where bars cross. Stirrups shall be tied to bars at both the top and bottom. The loose ends of the tying wire shall be bent inwards to prevent them projecting out of the concrete cover provided, taking special care at surfaces where a form finish has been specified. Bars and fabric shall be supported as described in Section of this tender.

Bars intended to be in contact at crossing points shall be securely bound together at all such points with 16 gauge annealed soft iron wire. When epoxy coated reinforcement is used, the wire shall be plastic coated. The vertical distances required between successive layers of bars in beams or similar members shall be maintained by the provision of spacer bars at such intervals that the main bars do not perceptibly sag between adjacent spacer bars.

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**(iii) Splices**

Unless otherwise approved, splices shall be wired contact lap splices and conform to the relevant local standard or to IS 2502.

No splicing of vertical bars will be allowed except at approved horizontal construction joints.

Splices in horizontal bars shall be lapped with at least one continuous bar between adjacent splices. The minimum spacing of splices in any one run of bar shall be 6 m and in slabs which contain two layers of reinforcement, splices in opposite layers shall be offset by at least 1.5 m.

**(iv) Welding**

Welding of reinforcement shall not be permitted unless specifically approved. If welding is approved, the work shall be carried as per IS 2751, according to best modern practices and as approved by the Employer's Representative. Where permitted, the bars shall be shop or field welded by experienced welders by the direct electric arc process, using low hydrogen electrodes. In all cases of important connections, tests shall be made to prove that the joints are of the full strength of bars welded. The completed weld shall develop a minimum strength of 125 percent of the bar yield strength.

All surfaces close to the weld shall be cleaned free of loose mill scale or other foreign material. The same precautions shall be taken each time an electrode is charged. Chip burned edges shall be cleaned before welds are deposited.

When wire-brushed, completed welds shall exhibit uniform section, smoothness of welded metal, feather edges without undercuts or overlays, freedom from porosity and clinker and good fusion, with penetration into the base metal. Defective welds or parts of welds shall be cut out and re-done satisfactorily. Defective welds or parts thereof shall not be removed by using a cutting torch.

**(v) Welded Wire Mesh**

Welded fabric shall be placed on approved supports to hold it in place during concreting. The fabric shall be laid flat in one plane and bent as required to fit the work. Laps shall be a minimum of one mesh. At laps, alternate wires shall be tied with tying wire.

**(vi) Additional Reinforcement**

Additional reinforcement shall be provided at sleeves and openings as required.

**(vii) Inspection**

Erected and secured reinforcement shall be inspected and approved by the Employer's Representative prior to placement of concrete.

**13.10.16 Field Quality Control**

The Contractor shall appoint an experienced officer to make continuous inspections of the reinforcement during cutting, bending, placing in position, tying and cleaning before the pouring of concrete. He shall effect any corrections or irregularities noted or requested by the Employer's Representative.

Welding for all shop and field welded reinforcing steel bars shall be inspected by the assigned Contractor's officer and regular inspections may be required by the Employer's Representative who shall be given the fullest opportunity to witness the welding operations.

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## **13.11 Formwork**

### **13.11.1 General**

The Contractor shall submit to the Employer's Representative sufficient details of the proposed shoring and formwork to enable the Employer's Representative to satisfy himself about their general adequacy and effectiveness. Forms, shoring and false work shall be adequate for imposed live and dead loads, including equipment, the height of concrete drop, concrete and foundation pressures, stresses, lateral stability and other safety factors during construction.

The formwork used in the works shall, unless otherwise specified herein, or approved or permitted by the Employer's Representative, comply with IS 14687.

### **13.11.2 Materials**

All formwork shall be constructed of timber, sheet metal or other approved materials, capable of providing the required finish. Where a special finish is required, the Contractor shall provide, before commencement of fabrication, all details of the materials and means he proposes to adopt to obtain the finish. All materials used shall be dimensionally stable on exposure to extremes of weather. Sliding forms and slip forms may be used with the approval of Employer's Representative.

### **13.11.3 Formwork Requirements**

The design of formwork shall take into account all the vertical and lateral loads that the forms will be carrying including live and vibration loadings.

Forms shall conform to the shapes, lines, grades and dimensions including camber of the concrete as necessary. Ample studs, waler braces, straps, shores etc shall be used to hold the forms in proper position without any distortion whatsoever until the concrete has set sufficiently to permit removal of the forms. Forms shall be strong enough to permit the use of immersion vibrators. In special cases, form vibrators may also be used. The shuttering shall be close boarded. Timber shall be well seasoned, free from sap, loose knots, worm holes, warps or other surface defects in contact with the concrete. Faces coming in contact with concrete shall be free from adhering grout, plaster, paint, projecting nails, splits or other defects. Joints shall be sufficiently tight to prevent loss of water and fine material from the concrete.

Plywood shall be used for exposed concrete surfaces, where called for. Sawn and wrought timber may be used for unexposed surfaces. Inside faces of forms for concrete surfaces which are to be rubbed finished shall be planed to remove irregularities or unevenness in the face. Form work with lining will be permitted.

All new and used form lumber shall be maintained in a good condition with respect to shape, strength, rigidity, water tightness, smoothness and cleanness of surfaces. Form lumber unsatisfactory in any respect shall not be used and if rejected by Employer's Representative shall be removed from the site.

Shores supporting successive stories shall be placed directly over those below or be so designed and placed that the load will be transmitted directly to them. Trussed supports shall be provided for shores that cannot be secured on adequate foundations.

Formwork, during any stage of construction, showing signs of distortion or distorted to such a degree that the intended concrete work will not conform to the exact contours required, shall be repositioned and strengthened. Poured concrete affected by faulty formwork shall be entirely removed and the formwork corrected prior to placing new concrete.

Excessive construction cambers to compensate for shrinkage settlement etc that may impair the structural strength of members will not be permitted.

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Forms for substructure concrete may be omitted when, in the opinion of Employer's Representative, the open excavation is firm enough to act as the form. Such excavations shall be slightly larger than required by the drawings to compensate for irregularities in excavation and to ensure the design requirements are met.

Forms shall be so designed and constructed that they can be stripped in the order required and their removal does not damage the concrete. Face formwork shall provide true vertical and horizontal joints conforming to the architectural features of the structure as to location of joints and be as approved by Employer's Representative.

The formwork shall be so constructed that up and down vertical adjustment can be made smoothly. Wedges may be used at the top or bottom of timber shores, but not at both ends, to facilitate vertical adjustment or dismantling of formwork.

Where exposed smooth or rubbed concrete finishes are required, the forms shall be constructed with special care so that the desired concrete surfaces can be obtained which require a minimum finish.

#### **13.11.4 Form Coating**

Form coating shall be non-grain raising and non-staining resin type coating or other suitable non-staining mould oil which will not leave residual matter on the surface of the concrete or adversely affect bonding to concrete of paint, plaster, mortar, protective coatings, waterproofings or other applied materials. The coatings shall not contain any mineral oils, paraffin, waxes or other non-drying ingredients, nor, in the case of surfaces in contact with potable water, any toxic ingredients of any type whatsoever.

#### **13.11.5 Metal Forms**

Metal forms shall be true to detail in condition, clean, free from dents, bends, rust and oil or other defects likely to impair the specified finish.

#### **13.11.6 Round Column Forms**

Forms for round columns shall be of metal tubes of materials described for metal forms, fibre glass reinforced plastic or other approved material.

#### **13.11.7 Tie Bolts**

Only tie bolts which avoid embedding any metal parts permanently within 50 mm of the concrete surface, shall be permitted. Voids remaining after the removal of all or part of each tie bolt shall be filled flush with the surrounding concrete using a freshly prepared non-shrink cement and fine aggregate paste.

In the case of structures designed to retain an aqueous liquid, the Contractor shall ensure that the measures adopted shall not impair the water tightness of the structure. Tie bolts which form a continuous hole through a structure designed to retain an aqueous liquid shall not be used.

#### **13.11.8 Form Joint Sealers**

Effective precautions shall be taken to ensure that joints between form panels are sufficiently water tight to prevent honey combing resulting from the escape of mortar during the placing and vibration of concrete. The joints shall be sealed with resilient foam rubber strips, non hardening plastic type caulking compound free from oil or other such material or compound as may be approved by the Employer's Representative. Form tie holes shall be plugged with plastic caulking compound, tight fitting rubber plugs or equal.

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#### **13.11.9 Moulds**

Moulds for grooves, drips, rebates, profiles, chamfers and other similar items shall be of a smooth-milled approved timber or standard extruded polymer plaster units of the required shapes.

#### **13.11.10 Bracing Shuttering and Props**

Shuttering shall be braced, struted, propped and so supported that it shall not deform under weight and pressure of the concrete and also due to the movement of men and other materials. Bamboos shall not be used for props or cross bracings.

The shuttering for beams and slabs shall be so erected that the shuttering on the sides of beams and under the soffits of slabs can be removed without disturbing the beam bottoms.

Re-propping of beams shall not be done except when props have to be reinstated to support construction loads anticipated to be in excess of the design load. Vertical props shall be supported on wedges or other measures shall be taken whereby the props can be gently lowered vertically while striking the shuttering.

If the shuttering for a column is erected for the full height of the column, one side shall be left open and built upon sections as placing of concrete proceeds, or windows may be left for pouring concrete from the sides to limit the drop of concrete to 1.0 m. or as otherwise approved by Employer's Representative.

#### **13.11.11 Chamfers & Fillers**

All corners and angles exposed in the finished structure shall be formed with mouldings to form chamfers or fillers on the finished concrete. The standard dimensions of chamfers and fillets, unless otherwise specified, shall be 20 x 20 mm. Care shall be exercised to ensure accurate mouldings. The diagonal face of the moulding shall be planed or surfaced to the same texture as the forms to which it is attached.

#### **13.11.12 Vertical Construction Chamfers**

Vertical construction joints on faces which will be exposed at the completion of the work shall be chamfered as above except where not permitted by Employer's Representative.

#### **13.11.13 Form Types for Surface Finishes**

Concrete surface finishes shall generally be of the following types

- 1 All interior faces of walls and exposed roofs of structures of above and below grade and exterior surfaces above finished grade shall have a smooth form finish.
  - 2 All exterior walls below finished grade and other surfaces not included in category (1) above, shall have a rough finish, unless otherwise specified.
  - 3 Metal, plywood or forms of other approved material shall be used to provide a smooth finish.
  - 4 Plywood or board forms of lesser quality may be used to provide rough finishes.
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#### **13.11.14 Shoring and Falsework**

Shoring and false work shall be designed to distribute loads safely over the base area on which the shoring is erected. Adequate precautions shall be taken against undermining or settlement particularly against wetting of soils, when cleaning forms or curing concrete or by any other cause.

##### **(i) Alignment and Camber**

All forms shall be constructed to produce the required lines, grades and camber as required, in the finished structure. The tolerance on line and level shall not exceed 3 mm. In the absence of any specific camber, the forms for soffits of beams, other than pre-stressed beams, shall under normal circumstances be constructed to provide an upward camber of 6 mm for every 3 metres of clear span.

##### **(ii) Means Adopted**

S-Jacks, wedges or similar approved means shall be used to induce the required camber in the forms and to correct any settlement which may occur either before or during the placing of concrete.

#### **13.11.15 Construction**

Form windows shall be provided as necessary to provide access for placement and vibration of concrete. The windows shall be adequately sized to admit chutes and vibrators and should generally be spaced at 2 metre intervals. The windows shall be firmly closed and braced before placing concrete at higher levels.

Temporary openings shall be provided in wall and column forms for inspection and cleaning. All inner surfaces of forms shall be cleaned before any concrete is poured.

Reglets and rebates to receive flashing, frames and other equipment shall be properly formed. Dimensions, details and precise positions of all such reglets and rebates shall be ascertained from the suppliers of the flashings, frames or equipment, if supplied under a separate contract.

If form materials are found to be fit for reuse, they shall be cleaned and re-conditioned before re-erection.

#### **13.11.16 Embedded Piping and Other Hardware**

Before the commencement of fabrication of the formwork, all trades requiring openings for the passage of pipes, electrical conduits and other inserts shall be consulted and the necessary pipe sleeves, anchors or other inserts shall be properly and accurately installed by the representative trades or adequate details obtained which would enable the requisite openings to be correctly positioned. Pipes and conduits, when embedded shall not weaken the construction and no pipes, other than electric conduits, shall be permitted to be embedded within a slab not exceeding 12 cm thick. Conduits placed in a concrete slab shall not have an outside diameter exceeding 1/3 the thickness of the slab and shall be placed between the upper and lower layers of reinforcement. Conduits may be embedded in walls if the outside diameter is less than 1/3 the wall thickness and they are not spaced closer than at three diameters centre to centre and do not otherwise weaken the wall.

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### **13.11.17 Field Quality Control**

Tell-tale devices or other methods shall be adopted, where approved, to detect movements and deflection of forms during concrete placement. The required slab and beam cambers and verticality and the specified batter of column sides shall be regularly checked, corrected and maintained as concrete loads are applied on the forms. Workmen shall be assigned to check forms and seal all mortar leaks discovered during concreting.

### **13.11.18 Inspection of Formwork**

Any member which is to remain in position after the general dismantling is completed should be clearly marked.

Material used should be checked to ensure that, wrong items / rejects are not used.

If there are any excavations nearby which may influence the safety of the formwork, corrective and strengthening action shall be taken.

The bearing soil must be sound and well prepared and sole plates shall bear well on the ground and;

- 1 Sole plates shall be properly seated on their bearing pads or sleepers.
- 2 The bearing plates of steel props shall not be distorted.
- 3 The steel parts on the bearing members shall have adequate bearing areas.

Safety measures to prevent the impact of traffic, scour due to water etc should be taken. Adequate precautionary measures shall be taken to prevent accidental impacts etc.

Bracing, struts and ties shall be installed along with the progress of formwork to ensure the strength and stability of the formwork at intermediate stages. Steel sections (especially deep sections) shall be adequately restrained against tilting, over turning.

When adjustable steel props are used, they shall:

- 1 Be undamaged and not visibly bent;
- 2 Be complete with the steel pins provided by the manufacturers;
- 3 Be restrained laterally near each end; and
- 4 Have means for centralising beams placed in the fork-heads.

Screw adjustment of adjustable props shall not be over extended.

Double wedges shall be provided for adjustment of the form to the required position wherever any settlement / elastic shortening of the props may occur. Wedges should be used only at the bottom end of single props. Wedges should not be too steep and one of the pair should be tightened / clamped down after adjustment to prevent shifting.

The number of nuts and bolts shall be adequate.

All provisions of the design shall be complied with.

Cantilever supports shall be adequate.

Props shall be directly under one another in multistage constructions as far as possible.

Guy ropes or stays shall be properly tensioned.

There shall be adequate provision for the movement and operation of vibrators and other construction plant and equipment.

The required camber shall be provided over long spans.

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Supports shall be adequate and in plumb within the specified tolerances.

### **13.11.19 Removal of Forms and Shoring and Striking**

Contractors shall record on the drawings or a special register, the date upon which the concrete is placed in each part of the work and the date on which the shuttering is removed there from.

In no circumstances shall forms be struck until the concrete reaches a strength of at least twice the stress due to self weight and any construction erection loading to which the concrete may be subjected at the time of striking the formwork.

The striking of formwork shall be as approved by the Employer's Representative. Generally, however, the following table gives the minimum periods that must elapse before the formwork is removed, reckoned from the time the pouring of concrete was completed.

Position of Formwork and Props	Minimum days for Removal
Walls	1
Sides of beams and columns	1
Slabs (props left under)	3
Props to slabs (spans not exceeding 4 1/2 metres)	7
Props to slabs (spans exceeding 4 1/2 metres)	14
Beam soffits (props left under)	7
Props to beams (spans not exceeding 6 metres)	14
Props to beams (spans exceeding 6 metres)	21

The stripping time recommended above may be modified subject to the approval of the Employer's Representative.

The number of props left under beams and slabs and their sizes and the position shall be such as to safely carry the full dead load of the slab, beam or arch together with any live load likely to occur during curing or further construction.

Where the shape of an element is such that the formwork has re-entrant angles, the form work shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

Striking shall be done slowly with utmost care to avoid damage to arises and projections and without shock or vibration, by gently easing with wedges. If, after removing the formwork, it is found that timber has been embedded in the concrete, it shall be removed and made good.

Reinforced temporary openings shall be provided, as approved by Employer's Representative, to facilitate removal of formwork which otherwise may be in-accessible.

Tie rods, clamps, form bolts etc which shall be entirely removed from walls or similar structures shall be loosened not sooner than 24 hours nor later than 40 hours after concrete has been deposited. Ties, except those required to hold forms in place, may be removed at the same time. Ties withdrawn from walls and grade beams shall be pulled towards the inside face. Cutting ties back from the faces of walls and grade beams will not be permitted.

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### **13.11.20 Restrictions**

No permanent load or loads from construction equipment shall be imposed on columns, supported beams or supported slabs until the concrete has attained at least twice the compressive strength necessary to sustain the imposed loads.

### **13.12 Construction Tolerances**

#### **13.12.1 General**

Tolerances are a specified permissible variation from the designed lines, grade or dimensions as approved by the Employer's Representative. No tolerances specified for horizontal or vertical building lines or footings shall be constructed beyond the legal boundaries. Unless otherwise approved by the Employer's Representative, the following tolerances shall be permitted:

#### **13.12.2 Tolerances for Reinforced Concrete Buildings**

##### **(i) Variation from plumb**

In the line and surfaces of columns, piers, walls and in buttresses: 5 mm per 2.5 m, but not more than 25 mm.

For exposed corner columns and other conspicuous lines.

In any bay or 5 m maximum:	(+/-) 5 mm
In 10 m or more:	(+/-) 10 mm

##### **(ii) Variation from the design levels or grades**

In slab soffits, ceilings, beam soffits and in arises.

1 In 2.5 m.:	(+/-) 5 mm
2 In any bay or 5 m. maximum:	(+/-) 8 mm
3 In 10 m. or more:	(+/-) 15 mm

For exposed lintels, sills, parapets, horizontal grooves and other conspicuous lines.

4 In any bay or 5 m. maximum:	(+/-) 15 mm
5 In 10 m or more	(+/-) 10 mm

##### **(iii) Variation in linear building lines**

In any bay or 5 m. maximum:	(+/-) 10 mm
In 10 m. or more:	(+/-) 20 mm

##### **(iv) Sizes and locations of sleeves, openings in walls and floors**

Allowable tolerance	(+/-) 5 mm (excludes anchor bolts)
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##### **(v) Variation in cross-sectional dimensions of columns, beams slabs and walls**

Allowable tolerance	+10 mm/- 5 mm
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**(vi) Footings**

Variation in dimensions in plan: +50 mm/-5 mm

Misplacement or eccentricity: 2% of footing within the direction of misplacement but not more than 50 mm

Reduction in thickness: (-) 5% of specified thickness subject to maximum of 50 mm

**(vii) Variation in steps**

Rise in a flight of stairs (+/-) 3.0 mm

Tread in a flight of stairs (+/-) 5.0 mm

Rise in consecutive steps (+/-) 1.5 mm

Tread in consecutive steps (+/-) 3 mm

**13.12.3 Tolerances in other Concrete Structures**

**(i) All structures:**

Variation of the constructed linear outline from established position in plan.

In 5 m.: (+/-) 10 mm

In 10 m. or more: (+/-) 15 mm

Variation of dimensions to individual structure features from established positions in plan.

In 20 m. or more: (+/-) 25 mm

In buried constructions: (+/-) 150 mm

Variation from plumb, from specified batter or from curved surfaces of all structures.

In 2.5 m.: (+/-) 10 mm

In 5.0 m.: (+/-) 15 mm

In 10.0 m. or more: (+/-) 25 mm

In buried constructions: (+/-) Twice the above limits.

**Variation from level or grade indicated on drawings in slabs, beams, soffits, horizontal grooves and visible arises.**

In 2.5 m.: (+/-) 5 mm

In 7.5 m. or more: (+/-) 10 mm

In buried constructions: (+/-) Twice the above limits.

Variation in cross-sectional dimensions of columns, beams, buttresses, piers and similar members.

Allowable tolerance (+)12 mm/(-) 6 mm

Variation in the thickness of slabs, walls, arch sections and similar members.

Allowable tolerance (+)12 mm/(-) 6 mm

**(ii) Footings for columns, piers, walls, buttresses and similar members:**

Variation of dimensions in plan: (+)50 mm/(-)12 mm

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Misplacement or eccentricity: 2% of footing within the direction of misplacement but not more than 50 mm

Reduction in thickness: 5% of specified thickness subject to a maximum of 50 mm

**(iii) Other Tolerances**

Tolerances in other types of structures shall generally conform to those given in Clause 2.4 of Recommended Practice for concrete form work IS 14687.

**13.13 Cement Grouting**

**13.13.1 General**

These specification clauses refer to grouting where required in excavated rocky strata.

**13.13.2 Requirements**

The Contractor shall furnish all tools, equipment, materials and labour for furnishing and placing grout to stop leaks and permanently control the inflow of water through rock faces when necessary for the proper construction of the Works or if instructed to do so by the Employer's Representative.

The Contractor shall carry out the works in accordance with the requirements of IS 6066 – 1971,

**13.13.3 Construction Plant and Products**

**(i) Equipment**

The equipment used shall be of type, capacity and mechanical condition suitable for satisfactorily completing the work. The power and equipment and their layouts shall conform to all relevant regulations and safety codes applicable to the particular area. All motors shall be equipped with suitable mufflers and scrubbers.

Standard drilling equipment of the rotary type shall be used to perform the drilling. Rotary percussion drills of any type will not be permitted to be used. The drilling equipment utilized within subsurface structures shall be capable of drilling at any orientation to a maximum depth of 7.5 metres.

Holes shall be grouted using the shortest practicable length of line. Fouling of the equipment shall be prevented by maintaining a continuous flow of grout and by periodically flushing with water. A water supply shall be directly connected into the grout supply line. Pressure gauges and adequate valves required for by-pass and shut-off shall be attended constantly by qualified operators at the collar of the hole being grouted.

Additional grout headers, to a maximum of six, shall be available to interconnect holes. Such interconnected holes shall be grouted simultaneously as long as the capacity of the mixing and pumping system permits the design grouting pressure to be maintained.

The Contractor shall be equipped to continuously flush with fresh water, as approved by the Employer's Representative, those interconnected holes he is not able to grout, if the grout take in a series of interconnected holes exceeds the pump capacity.

The general requirements for the cement grout plant shall include two independent, operational grout pumps connected to allow switching from one to the other in the event of mechanical failure without interrupting the grout flow, operational stand-by equipment for each element of the operation shall be available at the job site.

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## (ii) Materials

Mixes consist of cement, water, sand and an approved fluidifier in the proportions as designated by the Contractor's designer and approved by Employer's Representative. The mix may, from time to time, be amended to suit the conditions encountered in particular locations. The water cement ratio by volume shall be varied to meet the characteristics of each holes as revealed by the grouting operation and may range between 10.0 and 0.6. If after mixing, the grout cannot be placed for any reason whatsoever, it shall be wasted.

The proportions of grout shall produce a flowable mixture consistent with a minimum water content and shrinkage. The grout proportions shall be limited as follows:

Use	Grout thickness	Mix. proportions	W/C. Ratio in (Max.)
a) Fluid mix	Under 25 mm	One part Portland cement to one part sand.	0.44
b) General	more than 25 mm but less than 50 mm	One part Portland cement to 2 parts of sand.	0.53
c) Stiff mix.	50 mm and over	One part Portland cement to 3 parts of sand.	0.53

Variations in grout mixes and procedures shall be permitted if approved by the Employer's Representative.

Special grout shall be provided in strict accordance with the manufacturer's instructions.

### 1. Cement Water and Sand

All cement, water and sand shall be as that used in concrete.

### 2. Fluidifier

Fluidifiers shall be compounds possessing characteristics which will improve the fluidity of the mixture and assist in dispersing shrinkage of the grout. Bentonite or other clay like materials are not acceptable as fluidifiers. Fluidifiers shall be furnished in moisture resistant sacks, shipped in dated sealed containers and shall be handled and stored to avoid absorption of moisture, damage or waste. Material which has become caked due to moisture absorption shall not be used in the work. No fluidifier shall be used that has exceeded the manufacturer's recommended shelf life.

### 3. Pipes

All metal pipes and fittings required for grouting operations shall be furnished, cut, threaded, fabricated and embedded by the Contractor. The pipes shall conform to IS 6631 – 1972.

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### **13.13.4 Execution**

#### **(i) General**

All holes for cement grouting shall be drilled at the locations, in the directions and to the depths approved by the Employer's Representative, as the grouting operations proceed. Grouting shall be performed in the presence of the Employer's Representative. The actual number, depth sequence and spacing of holes and the pressures, pumping rates and grout mixes to be used for grout injections will depend upon the nature of the rock, the results of the water pressure tests or observations and the results of previous grouting operations. They will be determined by the Contractor and subject to the approval of the Employer's Representative.

#### **(ii) Supervision**

The Contractor shall have an experienced supervisor directing his grouting operations. The supervisor shall be experienced in cement grouting in rock.

#### **(iii) Grout Hole Drilling and Preparation**

The holes at the maximum required spacing are referred to as primary holes, hereafter. The number of grout holes shall be increased progressively by split spacing between the primary holes as approved by the Employer's Representative. The type of bit used for drilling shall be at the discretion of the Contractor. The minimum diameter of the hole shall be 38 mm at the point of maximum penetration. Only clean water may be used as a circulating medium when drilling grout holes. Recirculated water shall not be used. Grout hole drilling ahead of the grouting operation shall be limited to the extent that can be grouted within two calendar weeks.

Grout pipes shall be installed in a workman like manner and shall be thoroughly cleaned of all dirt, grease, oil grout and mortar immediately before embedment. All grout pipes shall be sealed to the rock. On completion of grouting, grout pipes shall be cut off flush with the rock line and the holes shall be thoroughly washed before grouting, to the approval of the Employer's Representative. Drill cuttings, fragments and slurry shall be removed from the hole by an air/water jet applied at the bottom of the hole and returned through the hole to the surface. Washing shall continue until all debris is removed from the hole and the return water is clear.

Surfaces to be grouted shall be thoroughly roughened and cleaned of all foreign matter and laitance. Prior to grouting, hardened concrete surfaces to be grouted shall be saturated with water.

The cleaning of bedding planes, joints and fractures shall be accomplished by pumping water through the grout connection at the anticipated grouting pressure. Such pressure washing shall continue at the desired pressure as long as there is an increase in the rate of water intake.

Holes in which the optimum pressure cannot be reached shall be washed for as long as the fracture filling is being removed, as will be revealed by the escape of muddy water through nearby openings and for not less than five minutes unless otherwise approved. Open holes in which no pressure can be built up shall be washed for a minimum of five minutes or for such a period as fractures or joint filling, as determined by the Employer's Representative.

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Each grout hole shall be water pressure tested immediately prior to grouting. Water shall be injected through the test apparatus and through the grout connection. All holes shall be tested at pressures to be determined by the Employer's Representative, but not to exceed 7 kgf/cm<sup>2</sup>. Water tests shall consist of water absorption under designated grouting pressures for a maximum of 10 minutes. This procedure is designated as the water pressure check. Expandable rubber packers shall be provided to seal off the portion of the hole to be tested as instructed. Atmospheric or open hole testing may be required in addition to the pressure testing. A selected number of holes will be utilized for water pressure check holes to determine the grouting effectiveness after the primary holes are grouted.

(iv) **Grouting under equipment and base plates**

Anchor bolts, anchor bolt holes and the bottom of equipment and column base plates shall be cleaned of all oil, grease, dirt and loose material. The use of hot, strong, caustic solution for this purpose shall be permitted.

Water in anchor bolt holes shall be removed before grouting is started.

Forms around base plates shall be tight to prevent leakage of the grout.

Adequate clearance shall be provided between forms and base plates to permit grout to be worked properly into place.

(v) **Grouting**

Unless specifically approved by the Employer's Representative, each grout hole shall be grouted individually. Approval may be given to grout adjacent holes penetrating the same geologic stratum up to a maximum of six, if communication is established between the holes during grouting and if the water pressure test results in each hole have revealed similar requirements for grout mix and pressure.

Grouting, once started, shall be done quickly and continuously to prevent segregation, bleeding and breakdown of initial set. Grout shall be worked from one side of one end to the other to prevent entrapment of air. To distribute the grout and to ensure more release from entrapped air, link chains shall be used to work the grout into place.

Grouting through holes in base plates shall be by pressure grouting.

Grouting pressure to be used in the work will vary with conditions encountered in different holes and the pressures used for each holes will be as approved by the Employer's Representative. It is anticipated that pressures will range from 0.7 to 7 kgf/cm<sup>2</sup>, but in no event will pressures exceeding 10.5 kgf/ cm<sup>2</sup> be required.

(vi) **Grout Inspection**

Once started, the grouting of a hole shall not be interrupted without approval of the Employer's Representative. If necessary to prevent premature stoppage, periodic applications of water under pressure shall be made. Under no conditions shall the pressure or rate of pumping be increased or decreased suddenly. The grouting of any hole shall not be considered complete until refusal. Refusal is defined as a grout injection rate of zero litres per minute measured over a five-minute interval at 100 percent grouting pressure, although in no case will the Contractor be required to pump into a hole in which the grout takes below 30 litres per hour for more than four hours.

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The Contractor shall caulk all grout leaks as they develop, as approved by the Employer's Representative. Caulking shall begin on the leaks with the highest volume and progress to those of lesser volume until all leaks are caulked. Prior to grouting, the Employer's Representative may require caulking of leaks which have shown high volume during water pressure testing. If due to the size and continuity of fractures, it is found impossible to reach the required pressure after pumping a reasonable volume of grout at the minimum workable water-cement ratio, or a mortar grout with the maximum volume of sand at the minimum workable water-cement ratio, the speed of pumping shall be reduced or pumping shall be stopped temporarily and intermittent grouting shall be performed, allowing sufficient time between grout injections for the grout to stiffen. If the desired result is still not obtained, grouting the hole shall be discontinued when approved. In such an event, the hole shall be cleaned, the grout allowed to set and additional drilling and grouting shall then be continued to the this hole or in the adjacent area as approved until the desired resistance is developed.

After grouting refusal is reached, the pressure on the hole shall be maintained by means of a stop-cock or other suitable device until the grout has set.

Grout check holes shall be drilled after the primary hole has been grouted to assess the grouting effectiveness. Additional grouting and drill holes shall be placed between the primary holes as approved by the Employer's Representative.

**(vii) Clean-up**

During grouting operation, the Contractor shall take such precautions as may be necessary to prevent drill cuttings, equipment oil, wash water and grout from defacing or damaging the permanent structure. The Contractor shall furnish such pumps as necessary to care for waste water and materials from his operations and clean up waste water and materials from his operations. The clean-up procedure shall be to the satisfaction of the Employer's Representative.

**(viii) Records**

The Contractor shall keep records of all grouting operations including:

- 1 logs of grout holes;
- 2 hole locations and depths;
- 3 results of washing and pressure testing operations;
- 4 time of each change of grouting operation;
- 5 pressure;
- 6 rate of pumping;
- 7 amount of cement for each change of water cement ratio; and
- 8 any other data which he considers pertinent and important.

All records shall be in a form approved by the Employer's Representative and shall contain all data as required by the Employer's Representative.

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### **13.14 Damp Proof Courses**

The surface to receive a damp proof course shall be cleaned and carefully swept to remove all dust, laitance etc and shall be approved by the Employer's Representative. Damp proof courses shall be cement concrete. An approved waterproofing compound at 3% by weight of cement or as otherwise approved by the manufacturer shall be mixed into the cement mortar for this concrete. The damp proof course shall be laid to the full width of the wall and the edges shall be straight, even and truly vertical. Wooden forms shall be used to obtain good edges. No masonry work shall be commenced onto a freshly laid damp proof course until it has cured for 48 hours but the curing of cement concrete shall be continued along with the masonry work. Specifications for cement, sand, aggregate and water shall be as described for concrete works.

The concrete of ground floors shall be laid in two layers. The top of the lower layer of concrete shall be painted with two coats of A-90 grade bitumen (conforming to IS: 1580) applied at the rate of 1.5 kg/m<sup>2</sup>. The top surface of the lower layer shall be finished smooth while laying the concrete so that the bitumen can be applied uniformly. The bitumen shall be applied after the concrete has set and is sufficiently hard. Bitumen felt conforming to IS: 1322 shall be sandwiched in the sub-floor laid in two layers.

### **13.15 Bunds**

Bunds shall be provided around every storage vessel may contains materials potentially harmful to the environment.

The capacity of every bund shall be at least 120% of the volume of the largest vessel contained in the bund.

Each bund floor shall drain to a sump into which a portable submersible pump could be lowered.

The bund lining shall be resistant to the chemical being stored. The walls of the bund shall be a maximum of 1200 mm high and designed to support any load induced by the bund being full.

No pipe, cable or duct shall pass through the floor or walls of a bund.

### **13.16 Testing of Structures**

#### **13.16.1 Inspection of Structures**

Immediately after stripping formwork, all concrete shall be carefully inspected and any defective work or small defects, either removed or made good before concrete has thoroughly hardened, as instructed by Employer's Representative.

In case of doubt regarding the grade of concrete used or results of cube strength are observed to be lower than the designed strength as per specifications at 28 days, compressive strength test of concrete based on core test, ultrasonic test and/or load test shall be carried out by the digital ultrasonic concrete tester as approved by the Employer's Representative.

The Contractor shall also conduct conclusive tests such as ultrasonic pulse test, core test etc to prove the suitability of concrete, in case cube tests give unsatisfactory results.

#### **13.16.2 Core Test**

The points from which cores are to be taken and the number of cores required, shall be at the discretion of the Employer's Representative and shall be representative of the whole of the concrete concerned. In no case shall fewer than three cores be tested. Cores shall be prepared and tested as described in IS 516

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Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength of less than 75%.

In case the core test results do not satisfy the requirements as above, or where such tests have not been done, load testing may be resorted to.

#### **13.16.3 Load Tests on Parts of Structures**

Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete. The structure should be subjected to a load equal to the full dead load of the structure plus 1.25 times the imposed load for a period of 24 hours and then the imposed load shall be removed.

The deflection due to imposed loads only shall be recorded. If, within 24 hours of removal of the imposed load, the structure does not recover at least 75% of the deflection under the imposed load, the test may be repeated after a lapse of 72 hours. If the recovery is less than 80%, the structure shall be deemed to be unacceptable.

If the maximum deflection in mm during 24 hours under load is less than  $40L^2/D$ , where L is the effective span in metres and D the overall depth of the section in mm, it is not necessary for recovery to be measured and the recovery provision as above will not apply.

#### **13.16.4 Other Non-destructive Test Methods**

Other non-destructive test methods may be adopted, in which case the acceptance criteria shall be agreed upon between the Employer's Representative and the Contractor and the test shall be done under expert guidance.

Non-destructive tests are used to obtain an estimation of the properties of the concrete in the structure. The methods adopted include ultrasonic pulse velocity [see IS 13311 (Part 1)] and rebound hammer [IS 13311 (Part 2)], probe penetration, pull out and maturity. Non destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

Members other than flexural members should be investigated by analysis.

#### **13.16.5 Hydraulic Testing of Water Retaining Structures**

For a test of liquid retention, concrete structures should be cleaned and initially filled to the normal maximum level with the specified liquid (usually water) at a uniform rate of not greater than 2 m in 24 hours.

When first filled, the liquid level should be maintained by the addition of further liquid for a stabilizing period while absorption and autogenous healing take place. The stabilizing period may be 7 days for a maximum design crack width of 0.1 mm or 21 days for 0.2 mm or greater. After the stabilizing period, the level of the liquid surface should be recorded at 24 hour intervals for a test period of 7 days. During this 7-day test period the total permissible drop in level, after allowing for evaporation and rainfall, should not exceed 1/500 of the average water depth of the full tank, 10 mm or another specified amount.

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Notwithstanding the satisfactory completion of the test, any evidence of seepage of the liquid to the outside faces of liquid-retaining walls should be assessed against the requirements of the specification. In the case of tanks whose external faces are exposed or can be left exposed prior to testing, all leakages, wet patches and the like, shall be marked out on the outside of walls during test. The tank shall then be emptied and any necessary remedial treatment of the concrete, cracks or joints shall be carried out from the liquid face by grouting, waterproofing, plastering etc as necessary to the entire satisfaction of the Employer's Representative. The tank shall again be tested for leakage after rectification. The work shall not be accepted unless the water tightness is established.

**When a remedial lining is applied to inhibit leakage at a crack, it shall have adequate flexibility and have no reaction with the stored liquid.**

Should the structure not satisfy the 7-day test, then after the completion of the remedial work it should be refilled and if necessary left for a further stabilizing period; a further test of 7 days' duration should then be undertaken in accordance with this clause.

The external surfaces of the structure shall then be plastered and cured as per the specification. The water from the compartments shall then be drained and the inner surface of the tank in all compartments be checked and any defects rectified. After satisfactory completion of checks, internal coatings shall be applied as required.

Backfilling, in case of underground sumps, and waterproofing the roof where specified, shall be carried out after testing and rectification of defects.

#### **13.16.6 Unsatisfactory Tests**

Should the results of any test prove unsatisfactory, or the structure shows signs of weakness, undue deflection or faulty construction, the Contractor shall remove and rebuild the member or members involved or carry out such other remedial measures as may be required to the approval of the Employer's Representative.

The completion certificate shall not be given unless the test for water tightness as described above is carried out to the entire satisfaction of the Employer's Representative.

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## **14 Piling**

### **14.1 General**

Pile foundations may be necessary for supporting structures where the subsoil is considered to have insufficient bearing capacity. The Contractor shall carry out the detailed design of these structures in accordance with the Contract Conditions and Employer's Requirements and shall determine the type of foundation required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures.

Piles shall be designed, constructed and tested in accordance with the relevant sections of IS 2911.

Excavation, concrete, steel reinforcement and steel casing, where applicable, shall conform to the relevant Clauses of the Specification. At least 21 days before the Contractor intends to commence piling work on the Site, the Contractor shall submit for the Employer's Representative's approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full design and driving calculations. The details to be submitted shall include the Contractor's proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the Site until the Employer's Representative's approval to the Contractor's proposal has been received.

Notwithstanding the requirements outlined in this section, the design shall be entirely the Contractor's responsibility.

### **14.2 Types of Piles**

Bearing piles shall be driven reinforced pre-cast concrete or cast in-situ concrete piles.

All concrete for piles shall be in sulphate resisting cement, unless the Contractor can document that a lesser quality complies with the actual aggressiveness of soil and ground water. The use of a lower quality is subject to the approval of the Employer's Representative.

### **14.3 Design of Piles**

Piles shall be designed to sustain the required loads with settlements not exceeding those specified. Allowance shall be made in the design for the incidence of negative skin friction where appropriate and for resisting the necessary tensile forces due to the swelling and heave of any soil stratum.

Piles shall be designed to have a bearing capacity of at least 2.5 times the working load (working load = design load).

The permissible loading of piles shall be modified where necessary to allow for particular conditions: piles in close proximity or in groups, soil strength, groundwater level and other relevant factors.

The piles shall be of sufficient cross-section and length, and configured in a way to sustain the loads designed or specified without settlement (of single piles combined with additional settlements due to group action) exceeding the following:

- Working load                      allowable settlement 8 mm
- 1.5 × Working load              allowable settlement 10 mm
- 2 × Working load                allowable settlement 12 mm

These settlements shall include both permanent and elastic deflections. Measurement of the settlement shall be made on first achieving the specified load. Measurement of the settlement shall be made at the point of application of the load.

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Where piles in place are subjected to handling, stacking and pitching or bending moments and/or shear forces, these shall be combined with the vertical loads (either in compression or tension) to satisfy the design requirements of BS 8110 Parts 1, 2 and 3.

The average compressive stress in the concrete of bearing piles under working load shall not exceed 25% of the characteristic cube strength at 28 days, calculated on the total cross sectional area of the pile shaft.

#### **14.4 Preliminary Test Piles**

After the Employer's Representative has approved the Contractor's proposals and calculations for the piling system, preliminary test piles shall be constructed to the approval of the Employer's Representative.

These shall be loaded to two times the working load to prove the design and system and to demonstrate that the safe load requirements can be achieved by the piling method proposed.

The preliminary test piles shall be located in places proposed by the Contractor and approved by the Employer's Representative. The Employer's Representative shall be given at least 48 hours notice of commencement of construction of the preliminary pile which is to be test-loaded.

The preliminary test piles shall be constructed and installed in a manner similar to that to be used for the construction of the working piles by the use of similar equipment and materials. Any variation will only be permitted with the prior approval of the Employer's Representative.

For the preliminary piles that are to be test loaded, a detailed record of the progress during construction/installation shall be made and submitted to the Employer's Representative daily.

The pile shafts shall be terminated at the normal cut-off level or at some other level as required by the Employer's Representative.

The pile shafts shall be extended where necessary above the cut-off level of working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or falling debris and to permit exposure of the reinforcement.

Where the pile shaft is extended above the cut-off level of the working piles in soils that would influence the load bearing capacity of the pile, a sleeve shall be left in place during testing to eliminate friction that would not arise in working piles.

If the cut-off level is below ground level and the shaft is not extended and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile shaft or other means satisfactory to the Employer's Representative shall be employed. Adequate clearance shall be given between the top of the pile shaft and the bottom of the sleeve to permit unrestricted movement of the pile.

For a pile that is tested in compression, the pile head or cap shall be formed to give a plane surface, which is normal to the axis of the pile and sufficiently large to accommodate the loading and settlement measuring equipment. The pile head or cap shall be adequately reinforced or protected to prevent damage due to the concentrated application of load from the loading equipment.

The pile cap shall be concentric with the test pile and the joint between the cap and the pile shall have a structural strength equivalent to that of the pile.

A sufficient clear space shall be made under any part of the cap projecting beyond the section of the pile so that at the maximum anticipated settlement, load is not transmitted to the ground except through the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load that is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

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If the preliminary test pile fails to meet the requirements, the piling system proposed will be considered unsatisfactory. The Contractor shall then submit revised proposals and calculations for the approval of the Employer's Representative. Unless otherwise agreed by the Employer's Representative, any test pile that has failed the preliminary test will be rejected and the Employer's Representative and the Contractor shall provide one or more further test piles and tests to prove his modified system.

#### **14.5 Lengths and Tolerances**

The Contractor shall determine the approximate lengths of piles by examination of the available geotechnical information.

In case the available geotechnical information does not describe the ground conditions to a sufficient depth to ensure safety, additional soil investigations shall be carried out by the Contractor to the Employer's Representative's approval.

Piles shall be constructed within the following tolerances:

- in plan, at the working level of the piling rig  $0.15 \times B$  in any direction from the designed position; B = pile dimension (diameter or side);
- 1 in 75 from the vertical for a vertical pile;

The cross-sectional dimensions of the pile shall not be less than those proposed by the Contractor nor shall they exceed them by more than  $0.015 \times B$  (B = pile dimension, diameter or side).

No face of a pre-cast pile shall deviate by more than 6 mm from a straight edge 3 m long joining two points on that face, nor shall the centre of area of the pile at any cross section deviate more than  $1/500$  of the pile length from a line joining the centres of area of the ends of the pile.

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#### **14.6 Sequence for Constructions**

The sequence of construction of piles shall be to the approval of the Employer's Representative and shall be arranged to minimise the vertical and lateral displacement of piles already installed. Levels of the tops of adjacent piles or the structures founded upon them or any other structures shall be measured at intervals while a pile is being installed. Driven piles which have risen, shall be re-driven or forced down to the original resistance.

#### **14.7 Driving Piles**

The Contractor shall submit for the Employer's Representative's approval, details regarding the suitability, efficiency and energy of his driving equipment.

Pre-cast concrete piles shall not be driven until the concrete has achieved the specified characteristic strength.

Cast-in-situ piles driven with steel casing shall be bottom driven using a casing that shall not distort or buckle during driving. Concrete casing shall be driven on the pile shoe using a mandrel.

Each pile shall be driven continuously until the approved set and/or depth has been reached except that the Employer's Representative may permit the suspension of driving if he is satisfied that the rate of penetration prior to cessation of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving was beyond the control of the Contractor.

A follower (long dolly) shall not be used except with the approval of the Employer's Representative who will then require the set to be revised to take into account the reduction in the effectiveness of the hammer blow.

The final set of each pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25 mm.

When a final set is being measured the following requirements shall be met:

1. The exposed part of the pile shall be in good condition without damage or distortion;
2. The dolly and packing, if any, shall be in sound condition;
3. The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis;
4. The hammer shall be in good condition, delivering adequate energy per blow and operating correctly; and
5. The temporary compression of the pile shall be recorded, if required by the Employer's Representative.

The Contractor shall give adequate notice and provide all facilities to enable the Employer's Representative to check driving resistances. A set for purposes of the Contract shall only be taken in the presence of the Employer's Representative unless otherwise agreed.

At the start of the work and in new areas or sections, a detailed driving record shall be obtained over the full length of the first pile and during the last 3 m of driving of subsequent piles to establish the behaviour of the piles.

The Contractor shall inform the Employer's Representative without delay if an unexpected change in driving characteristics is noted. A detailed record of driving resistance over the full length of the nearest available pile shall be taken.

Re-drive checks, if required, shall be carried out by a procedure to be agreed by the Employer's Representative.

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Piles shall be driven in an approved sequence to minimise the detrimental effects of heave and lateral displacement of the ground.

Measurements shall be taken to determine the movement of ground or any pile resulting from the driving process when required by the Employer's Representative.

Where piles have risen as a result of driving adjacent piles, the Contractor shall submit to the Employer's Representative his proposals for correcting detrimentally affected piles and for avoidance or control of heave effects in subsequent work

Jetting may be carried out only when approved by the Employer's Representative and the Contractor shall submit detailed proposals and it shall not normally be undertaken over the last 3 m of penetration.

#### **14.8 Repair and Lengthening of Piles**

In preparation for repairing the head of a pile, the concrete shall be cut off square at sound concrete to expose the reinforcement and all loose particles shall be removed by wire brushing followed by washing with water.

If the pile is to be subjected to further driving the head shall be replaced with concrete of an approved class.

If the pile has been completely driven but the sound concrete is below cut-off level, the pile shall be made good to cut-off level with concrete of a class not inferior to that of the concrete of the pile.

In preparation for lengthening a normal reinforced pile, the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

For lap or splice joints, sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete.

Other methods of lengthening shall be subject to approval by the Employer's Representative.

Repaired or lengthened piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

#### **14.9 Reinforcement**

Unless otherwise required by the design, cast in situ piles shall be reinforced over the whole of their length.

The minimum longitudinal reinforcement shall be 1.0% of the gross concrete area in the top 3 m of the pile and 0.8% of the gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Unless otherwise required by the design, reinforcement in pre-cast concrete piles shall comply with the following minimum requirements:

Area of longitudinal reinforcement of 12 mm diameter minimum shall be at least 1% of the gross concrete area (cast in-situ and pre-cast concrete piles);

Lateral reinforcement shall be in the form of hoops or links not less than 6 mm diameter. Over a distance of 3 times the width of the pile measured from each end of the pile the volume of lateral reinforcement shall be not less than 0.6% of the gross volume. In the body of the pile, the lateral reinforcement shall not be less than 0.4% spaced at not more than half the width of the pile. The transition between the close spacing near the ends and the maximum spacing shall be made gradually over a length equal to 3 times the width.

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Piles of rectangular cross section shall have a minimum of 4 longitudinal reinforcement bars and piles of circular cross section shall have a minimum of 6 longitudinal reinforcement bars. Bars shall be 12 mm diameter minimum. The main longitudinal bars shall be level at the top of the pile and fit tightly into the shoe if one is used.

Hoops and links shall fit tightly against longitudinal bars and be bound to them by welding or soft iron wire with the free ends turned inwards. The longitudinal bars shall be held apart by spreader forks not more than 1.5 m apart.

The main longitudinal reinforcing bars in piles not exceeding 12 m in length shall be in one continuous length unless otherwise required. In piles exceeding 12 m in length, joints will be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be such that the full strength of the bar is effective across the joint.

The cover to the outermost reinforcement, including binding wire shall not be less than 60 mm measured to the inside of the casing. Lap or splice joints shall be provided with sufficient link bars or other elements to resist eccentric forces. Laps shall have a minimum length of 40 times the diameter of the main longitudinal reinforcement.

Main longitudinal reinforcement shall project a minimum of 40 times the bar diameter above the cut-off level of the pile. For pre-cast piles, compliance with this requirement will necessitate breaking down of the pile head after driving.

#### **14.10 Pile Shoes**

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

#### **14.11 Records**

The Contractor shall maintain a complete record of all piling works that shall include the following where relevant:

- pile type and number
  - nominal diameter or dimension, pile length
  - date of casting and date driven
  - depth from ground level to toe of pile
  - depth from ground level to bearing stratum
  - set of pile or pile tube in mm per 10 blows or blows per 25 mm of penetration for first piles in new areas or sections, sets taken at intervals during the last 3 m of driving for subsequent piles
  - final set, weight and drops of hammer
  - details of any obstructions observed.
  - ground level at pile position at commencement of pile installation
  - pile cut-off level
  - length of temporary or permanent casing
  - length and details of reinforcement
  - concrete mix
  - volume of concrete supplied to pile where this can be measured in practice
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All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Employer's Representative at the completion of each day's work.

#### **14.12 Pre-cast Reinforced Concrete Piles**

Pre-cast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners.

#### **14.13 Cast-In-Situ Piles**

##### **14.13.1 Driven or Bored Cast-in-situ Piles**

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of pre-cast concrete, augured or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes, where applicable, shall be watertight during driving and completion of driven cast-in-situ piles. Permanent casing shall be inspected, by using a light lowered from the top after installation to ensure that the casing is neither damaged nor deformed and that all loose soil has been removed from the bottom of bored piles.

Drilling mud shall not be used unless otherwise approved by the Employer's Representative.

##### **14.13.2 Casing for Cast-in-situ Piles**

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing may either be permanent or temporary.

Steel casing shall be delivered to Site in as a long length as can be conveniently handled. Ends shall be prepared for butt-welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt-welding so that the full strength of the original section is developed. Welded joints shall be watertight.

##### **14.13.3 Concreting Cast-in-situ Piles**

Concrete in cast-in-situ piles shall be in accordance with the requirements. The slump for the concrete shall be agreed with the Employer's Representative prior to concreting preliminary test piles. Concrete filling in cast-in-situ piles shall be placed continuously. Removal of temporary casings must be complete before the placed concrete loses its workability to ensure that the concrete is not lifted, but placing of concrete shall keep in advance of withdrawal of casing to prevent necking.

Pile heads shall be stripped down and bonded into the pile caps as specified for pre-cast concrete piles.

#### **14.14 Pile load tests**

##### **14.14.1 General**

Pile load tests shall be carried out in the following situations:

- when using a type of pile or installation method that is outside comparable experience and which has not been tested under comparable soil and loading conditions;
  - when using a piling system which is outside the experience of the operatives carrying out the work;
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- when the piles will be subject to loading for which theory and experience do not provide sufficient in the design. The pile testing procedure should then provide loading similar to the anticipated loading; and
  - when observations during the process of installation indicate pile behaviour that deviates strongly and unfavourable from the behaviour anticipated on the basis of the site investigation or experience when additional ground investigations do not clarify the reasons for this deviation.

Load test can be as a static test or a dynamic test.

If one pile load test is carried out, it shall normally be located where the most adverse ground conditions are believed to occur. If this is not possible, an allowance shall be made when deriving the characteristic value of the bearing resistance.

If load tests are carried out on two or more test piles, the test location shall be representative of the site of the pile foundations, and one of the test piles shall be located where the most adverse ground conditions are believed to occur.

Between the installation of the test pile and the beginning of the load test, adequate time shall be allowed to ensure that the required strength of the pile material is achieved and the pore pressures have regained their initial values.

#### **14.14.2 Static Load Tests**

##### **(i) Loading procedure**

The pile load test procedure, particularly with respect to the number of loading steps, the duration of the loading steps and the application of load cycles, shall be such that conclusions can be drawn about the deformation behaviour, creep and rebound of a pile foundation from the measurements on the pile. For trial piles, the ultimate loading shall be such that conclusions can also be drawn about the ultimate failure load.

Devices for the determination of forces, stresses or strains and displacements shall be calibrated prior to the test.

The direction of the applied force to compression or tension pile tests shall coincide with the longitudinal axis of the pile.

In general, pile load tests for the purpose of designing a tensile pile foundation should be carried out to failure. Extrapolation of the load-displacement graph for tension tests should normally not be used, especially in the case of transient loading.

##### **(ii) Trial piles**

The number of trial piles required to verify the design shall be selected on the following aspects:

- the ground conditions and their variability across the site;
  - type of structure;
  - documented evidence of the performance of the same type of pile in similar ground conditions; and
  - the total number and types of piles in the foundation design.
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The ground conditions at the test site shall be investigated thoroughly. The depth of borings or files tests shall be sufficient to ascertain the nature of the ground both around and beneath the pile tip. It shall include all strata likely to contribute significantly to pile deformation behaviour, at least five times the diameter beneath the pile tip, unless sound rock or very hard soil is found at a lesser depth.

The method used for installation of the trial piles shall be fully documented.

**(iii) Working piles**

The number of working pile load tests shall be selected on the basis of the recorded findings during construction.

The load applied to working test piles shall be at least equal to the design load governing the design of the foundation.

### **14.14.3 Dynamic Load Tests**

**(i) General**

The results of dynamic load tests may be used for design provided an adequate site investigation has been carried out and the method has been calibrated against static load tests on the same type of pile of similar length and cross-section, and under comparable soil conditions.

Dynamic test results shall always be considered in relation to each other.

Dynamic load tests may be used as an indicator of the consistency of the piles and to detect weak piles (integrity testing).

In a dynamic load test the pile is instrumented with accelerometers and strain gauges within two pile diameters of the top of the pile.

The gauges are connected to a recording and data processing device. During blows on the pile signals from the gauges are recorded and processed for assessment of pile bearing capacity. The data processing will be of two kinds: one simple (CASE or likewise method) and one more exact method based on signal matching (CAPWAP or likewise program).

In the CASE method or likewise the following data shall be registered and reported:

- bearing capacity;
  - toe resistance and skin friction;
  - maximum compression stress, acceleration, velocity and displacement;
  - maximum tension stress in pile;
  - pile structural integrity; extent and location of damage;
  - maximum energy transferred to the pile;
  - blows per minutes for hammer check;
  - blow number;
  - input and reflection of force, velocity, upward and downward force waves; and
  - load versus deflection of cushions and of pile toe bearing'
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CAPWAP or likewise program determines that set of soil resistance parameters which produces the best match between measured and computed pile top force and velocity. After CAPWAP analysis, additional information produced than from CASE is:

- deformation properties, ultimate capacities and soil damping parameters for each soil segment of normally 1 m length;
- unit skin friction for each segment and end bearing;
- maximum of tension and compression forces and stresses;
- pile structural damping;
- dynamic pile toe displacement; and
- graph on bearing capacity and pile stresses versus blow count.

An introductory program (WEAP) can be utilised before pile driving to assess preliminary combinations of sets and bearing capacities for specified pile driving equipment and soil conditions.

Well-experienced experts shall carry out the data processing.

#### **(ii) Dynamic Load Test Procedure**

The Contractor shall notify the Employer's Representative at least two weeks prior to dynamic testing

The Contractor shall submit a qualified testing consultant and his experience to the Employer's Representative for approval.

The Employer's Representative shall determine if the test is to be performed or if some pile waiting periods at the proposed site is required before a decision will be made.

The Employer's Representative will establish a date for the tests and will also determine the location of all piles to be dynamically load tested.

#### **(iii) Dynamic Load Test Procedure on Driven Piles**

The Contractor shall supply all personnel and equipment needed to strike the test pile with the hammer.

The Contractor shall provide the hammer (drop, diesel, etc) or the crane to lift a steel ram weight by a single non-twisting cable and be able to strike the pile top by means of full-gravity-fall.

The testing consultant personnel will drill holes into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurement, the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Employer's Representative.

The Employer's Representative may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed the Contractor shall prepare and submit a complete report to the Employer's Representative.

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**(iv) Dynamic Load Test Procedure on Bored Piles.**

The Contractor shall prepare the pile top and, if necessary, improve the structural integrity of the pile top to resist a sharp impact force. All loose concrete at the pile top shall be removed. The top portion of the bored pile shall be extended a length of at least two times the diameter of the bored pile with the same diameter as the bored pile. The extended portion of the bored pile shall be cast with concrete having a minimum compressive strength of 40 MPa.

Additional shear reinforcement such as spiral hoops at the pile top is recommended for the impact force. The Contractor shall provide the windows for the installation of instruments by means of burring  $0.35 \times 0.35 \text{ m}^2$  to the steel casing using a cutting torch.

On top of the bored pile, a timber cushion shall be placed under a steel plate to act as a hammer cushion. Adhesive material may be applied between the pile top and the timber.

The Contractor shall provide an additional steel casing inserted into the pile top. This casing shall act as a guide for the steel ram weight, having a length not less than the summation of the drop height and the length of the steel ram weight. A vibrating hammer shall be used to secure and stabilise the steel casing.

The Contractor shall supply all personnel and equipment needed to strike the test pile with the steel ram weight. The Contractor shall provide a crane which has the capability to lift the steel ram weight by a single non-twisting cable and be able to strike the pile top by mean of full-gravity-fall.

The testing consultant personnel will drill holes in the windows of the left-in-place steel casing into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurement, the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Employer's Representative.

The Employer's Representative may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed the Contractor shall prepare and submit a complete report to the Employer's Representative.

**(v) Load Test Report**

The Contractor shall, within 24 hours of the completion of the tests, submit to the Employer's Representative a complete record of each pile test. Where appropriate, this report shall include:

- a description of the site;
  - the ground conditions with reference to ground investigations;
  - the pile type;
  - a description of the loading and measuring apparatus and the reaction system;
  - calibration documents of the load cells, the jacks and the gauges;
  - the installation record of the test piles;
  - photographic records of the pile and the test site;
  - test results in numerical form;
  - time settlement plots for each applied load when a step loading procedure is used;
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- the measured load-settlement behaviour; and
- justification of the reasons for any departures from the recommendations.

#### 14.14.4 Piles in Compression

##### (i) Ultimate Bearing Resistance from Static Pile Load Tests

Trial piles to be tested shall be installed in the same manner as the piles that will form the foundation and shall be founded in similar stratum.

In the case of a very large diameter pile, it is often impractical to carry out a load test on a full size trial pile. Load tests on smaller diameter trial piles may be considered provided that:

- the ratio of the trial pile/working pile diameter is not less than 0.5;
- the smaller diameter trial piles are fabricated and installed in the same way as the piles used for the foundations; and
- the trial pile is instrumented in such a manner that the base and shaft resistance can be derived separately from the measurements.

In the case of a pile foundation subjected to down drag, the pile resistance at failure or at a displacement which equals the criterion for the verification of the ultimate limit state determined from the load test results shall be corrected by subtracting the measured or the most unfavourable design positive skin friction force in the compressible stratum from the forces measured at pile head.

When deriving the ultimate characteristic bearing resistance  $R_{cc}$  from values  $R_{cms}$  measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the table below shall be satisfied using the equation:

$$R_{cc} = \frac{R}{\gamma_{ns}}$$

**Factors  $\gamma_{ns}$  to derive  $R_{cc}$ :**

Number of load tests	1	2	>2
$\gamma_{ns}$ on average $R_{cms}$	1,5	1,35	1,3
$\gamma_{ns}$ on lowest $R_{cms}$	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value,  $R_{cc}$ , should be divided into components of base resistance,  $R_{cbc}$ , and shaft resistance,  $R_{csc}$ , such that:

$$R_{cc} = R_{cbc} + R_{csc}$$

The design bearing resistance,  $R_d$ , shall be derived from

$$R_{cd} = \frac{R_{cbc}}{\gamma_{bs}} + \frac{R_{csc}}{\gamma_{ss}}$$

where  $\gamma_{bs}$  and  $\gamma_{ss}$  are taken from the table below.

Values of  $\gamma_{bs}$ ,  $\gamma_{ss}$  and  $\gamma_{ts}$ :

Component factors	$\gamma_{bs}$	$\gamma_{ss}$	$\gamma_{ts}$
Driven piles	1,3	1,3	1,3
Bored piles	1,6	1,3	1,5
CFA piles	1,45	1,3	1,4

Normally the load test only provides the pile load test versus settlement and time versus settlement diagrams without distinction between point and shaft resistance. Therefore, it is often not possible to distinguish between partial factors for the assessment of the design value of base resistance and shaft resistance. Instead a partial factor on the ultimate characteristic pile resistance  $R_{cc}$  may be taken as the  $\gamma_{ts}$  values given in the table above.

## (ii) Ultimate Bearing Resistance from Pile Driving Formulae

If pile-driving formulae are used to assess the ultimate bearing resistance of individual compression piles in a foundation, the validity of the formulae shall have been demonstrated by previous experimental evidence of good performance or static load tests on the same type of pile of similar length and cross-section and in the similar ground conditions.

Pile driving formulae shall only be used if the stratification of the ground has been determined.

In the design, the number of piles to be re-driven shall be specified. If re-driving gives lower results, these shall be used as the basis for ultimate bearing resistance assessment. If re-driving gives higher results, these may be taken into consideration.

Re-driving should usually be carried out in silt soils, unless local comparable experience has shown it to be unnecessary.

## (iii) Ultimate Bearing Resistance from Dynamic Load Tests

Dynamic load tests and their evaluation can be used to assess pile-bearing resistance of individual compression piles. The validity of the evaluation shall have been demonstrated by previous evidence of acceptable performance or static load tests on the same pile type of similar length and cross-section and in similar soil conditions. The input energy level during the dynamic load testing shall be high enough to allow for an appropriate interpretation of the pile capacity at a correspondingly high enough strain level.

When deriving the ultimate characteristic bearing resistance  $R_{cc}$  from values  $R_{cmd}$  measured in two or several dynamic pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the table below shall be satisfied using the equation:

$$R_{cc} = \frac{R_{cmd}}{\gamma_{nd}}$$

Factors  $\gamma_{nd}$  to derive  $R_{cc}$ :

Number of load tests	2	4	>4
a) $\gamma_{nd}$ on average $R_{cmd}$	1,5	1,35	1,3
b) $\gamma_{nd}$ on lowest $R_{cmd}$	1,5	1,25	1,1

In order to derive the ultimate design bearing resistance, the characteristic value,  $R_{cc}$ , should be divided into components of base resistance,  $R_{cbc}$ , and shaft resistance,  $R_{csc}$ , such that

$$R_{cc} = R_{cbc} + R_{csc}$$

The design bearing resistance,  $R_{cd}$ , shall be derived from

$$R_{cd} = \frac{R_{cbc}}{\gamma_{bd}} + \frac{R_{csc}}{\gamma_{sd}}$$

where  $\gamma_{bd}$  and  $\gamma_{sd}$  are taken from the table below.

Values of  $\gamma_{bd}$ ,  $\gamma_{sd}$  and  $\gamma_{td}$

Component factors	$\gamma_{bd}$	$\gamma_{sd}$	$\gamma_{td}$
Driven piles	1,4	1,4	1,4
Bored piles	1,7	1,4	1,6

In case  $R_{cbc}$  and  $R_{csc}$  are not known the design bearing resistance  $R_{cd}$  is derived from

$$R_{cd} = \frac{R_{cc}}{\gamma_{td}}$$

#### 14.14.5 Piles in Tension

##### (i) Ultimate tensile resistance from static pile load tests

Pile load tests to determine the ultimate tensile resistance  $R_{tc}$  of an isolated pile shall be carried out in accordance with Clause of the tender.

When deriving the ultimate characteristic resistance  $R_{tc}$  from values  $R_{tms}$  measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions of the table below shall be satisfied using the equation:

$$R_{tc} = \frac{R_{tms}}{\gamma_{nt}}$$

Factors  $\gamma_{nt}$  to derive  $R_{tc}$ :

Number of load tests	1	2	>2
a) $\gamma_{nt}$ on average $R_{tms}$	1,5	1,35	1,3
b) $\gamma_{nt}$ gnt on lowest $R_{tms}$	1,5	1,25	1,1

Normally when piles are loaded in tension, more than one pile shall be tested. In the case of a larger number of tension piles, at least 2% shall be tested.

The design tensile resistance,  $R_{td}$ , shall be derived from

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$$R_{td} = \frac{R_{tc}}{\gamma_m}$$

where  $\gamma_m = 1.6$ .

#### **14.14.6 Supervision of construction**

A pile installation plan shall be the basis for the construction work.

The plan should give the following design information:

- the pile type with designation if standardised or technical approval otherwise;
- the location and inclination of each pile and tolerances on position;
- pile cross-section;
- pile length;
- number of piles;
- required pile load carrying capacity;
- pile toe level or the required penetration resistance;
- installation sequence;
- known obstructions; and
- any other constraints on piling activities.

The installation of all piles shall be monitored and records shall be made at site and as the piles are installed. A record signed by the supervisor of the work and the pile manufacturer shall be kept for each pile.

The record for each pile shall include the following, where appropriate:

- pile type and installation equipment;
  - pile number;
  - pile cross-section, length and reinforcement;
  - data and time of installation (including interruptions to the construction process);
  - concrete mix, volume of concrete used and method of placing for cast-in-situ piles;
  - pumping pressures of the grout or concrete, internal and external diameters, pitch of screw and penetration per revolution (for continuous flight auger piles or other injection piles);
  - for driven piles, the values of driving resistance measurements such as weight and drop or power rating of hammer, blow frequency and number of blows for at least the last 0.25 m penetration;
  - the power take-off of vibrators (where used);
  - the torque applied to the drilling motor (where used);
  - for bored piles, the strata encountered in the borings and the condition of the base, if the performance of the base is critical;
  - obstructions encountered during piling; and
  - deviations of positions and directions and as-built elevations.
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Records shall be kept for at least a period of five years after completion of the works. As-built record plans shall be compiled after completion of the piling and be kept with the construction documents.

If site observations or inspection of records reveal uncertainties with respect to the quality of installed piles, additional investigations shall be carried out to determine the as-built conditions of the piles and whether remedial measures are necessary. These investigations shall include either re-driving or pile integrity tests, in combination with soil mechanics field tests adjoining the suspected piles and static pile load tests.

Tests shall be used to determine the integrity of piles for which the quality is sensitive to the installation procedures if the procedures cannot be monitored in an alternative reliable way.

Dynamic low-strain integrity tests can be used for a global evaluation of piles that might have severe defects or that may have caused a serious loss of strength in the soil during construction. Since defects like insufficient quality of concrete and thickness of concrete cover, affecting the long-term performance of a pile, often cannot be found by dynamic tests, other tests such as sonic tests, vibration tests or coring may be needed in supervising the execution.

## **15 Structural Steel**

### **15.1 Materials**

All structural steel shall be of standard sections and shall be free of scale, blisters, laminations, cracked edges and defects of any sort. The Contractor shall furnish duplicate copies of all mill orders and/ or the test report received from the mills, to the satisfaction of the Employer's Representative.

All structural steel and electrodes shall comply in all respects with IS for structural steel.

Any other quality may be used only if approved by the Employer's Representative. Such permission shall be preceded by yield point stress, ultimate tensile stress, ductility, weldability tests or any other characteristics as required by the Employer's Representative.

Steel castings shall conform to Grade III of IS 1030- Specifications for steel casting for general engineering purposes.

#### **15.1.1 Dimensions and Tolerances**

##### **(i) General**

The dimensional and weight tolerance for rolled shapes shall be in accordance with IS: 1852 for indigenous steel and equivalent applicable codes for imported steel.

An acceptable deviation from flatness in girder webs in the length between the stiffeners or in a length equal to the girder depth shall be  $1/150$  th of the total web depth.

A reasonable limit for combined warping and tilt on the flange ends of a built up member is  $1/200$  th of the total width of flange or 3 mm whichever is smaller measured with respect to centreline of flange.

Lateral deviation between centreline of web plates and centreline of flange plates at the contact surface, in the case of built up sections, shall not exceed 3 mm

Columns bearing on each other or resting on base plates and compression joints designed for bearing shall be milled true and square to ensure proper bearing and alignment. Base plates shall also have their surfaces milled true and square.

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**(ii) Rolled Shapes**

The dimensions, form, weight and tolerances of all hot rolled shapes (and other members) shall comply with the relevant Indian Standards.

**(iii) Cold Formed Sections**

The dimensions and tolerances of all cold formed light gauge structural steel sections shall conform to clauses 4 and 5 of I.S 811- Specification for cold formed light gauge structural steel sections.

**(iv) Castings**

All steel castings shall conform to IS 4899 and grey iron castings shall comply with IS 210 and malleable castings with IS 2108 or latest version.

**15.2 Execution**

**15.2.1 General**

In general, fabrication shall conform to the requirements of IS 800.

The Contractor shall deliver the component parts of the steelwork in an undamaged state at the site of the works and the Employer's Representative shall be entitled to refuse acceptance of any portion which has been bent or other wise damaged before actual delivery.

**15.2.2 Workmanship**

All workmanship shall be of first class quality in every respect to the greatest accuracy being observed to ensure that all parts fit together properly on erection.

All ends shall be cut true to planes and shall fit the abutting surfaces closely.

All stiffeners shall fit tightly at both ends.

All butt ends of compression members shall be in close contact through the area of the joints.

All holes in plates and section between 12 mm and 20 mm thick shall be punched to such diameter that 3 mm of metal is left all around the hole to be cleaned out to correct size by reaming.

Base connections shall be provided as required and the greatest accuracy of workmanship shall be ensured to provide the best connections.

**15.2.3 Erection and Marking**

Erection and fabrication shall be according to IS 800-1984 section-11. During erection, the work shall be securely braced and fastened temporarily to provide safety for all erection stresses etc. No permanent welding shall be done until proper alignment has been obtained.

Any parts which do not fit accurately or which are not in accordance with the approved fabrication drawings and specifications shall be liable to rejection and if rejected.

**15.2.4 Straightening**

All materials shall be straight and free from twists. If rectification is necessary, this shall be affected by cold working and applying pressure, but not by hammering or any other method that will affect or damage the metal. Material with sharp kinks or bends shall be rejected.

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### **15.2.5 Cutting**

Cutting shall be effected by shearing, sawing, cropping or gas cutting and shall be reasonably square and free from distortion with all burrs removed. If approved by the Employer's Representative the edges shall be ground afterwards.

For gas cutting of high tensile steel, sufficient steel shall be left over beyond the required profile to enable all metal hardened by heat to be removed by machining.

Except where material is subsequently joined by welding, no load transmitting surface shall be gas cut.

Plates in built-up members shall be end edge planed, except where flats with square edges are used. Plates specified to be planed milled or chipped, shall be cut in the first instance to such a size as to allow 3 mm to be planed, milled or chipped from the sides or ends.

Edges or gussets not exceeding 8 mm thickness may be sheared in a machine which can take the full side in one cut. Edges of thicker gussets shall be prepared by planing milling or grinding.

Edge preparation for welding of surfaces shall be carried out by grinding, planing or milling but not by shearing or cropping.

### **15.2.6 Holing**

Holes for rivets or bolts shall not be formed by gas cutting. Drilled or reamed holes shall be cylindrical and perpendicular to the surface. Finished holes shall not be more than 1.5mm larger than the specified diameter of bolts and rivets up to 25 mm diameter. For larger sizes the finished holes shall not be more than 2 mm larger than the specified diameter of the bolts and rivets.

Holes for turned and fitted bolts shall be drilled to a slightly smaller diameter and reamed to a diameter equal to the nominal diameter of the shank or barrel subject to H8 tolerances specified in IS 919.

Holes through more than one thickness of material shall, where possible, be drilled after the members are assembled and tightly clamped or bolted together. Punching may be permitted before assembly provided the holes are punched 3 mm less than the required size and reamed after assembly to the full diameter. The thickness of material punched shall not be more than 16mm

When holes are drilled in one operation through two or more separable parts, these parts shall be separated after drilling and all burrs removed.

Matching holes for rivets or black bolts shall register with each other so that a gauge 1.5mm or 2mm, depending of bolt size, less in diameter than the diameter of the hole shall pass freely through the assembled members in a direction perpendicular to the member surface.

For parts connected with turned and fitted bolts or close tolerance barrel bolts, the matching holes shall be drilled through all the thickness in one operation after securing the parts firmly together and subsequently reamed to size. Where this is not practicable, the parts shall be drilled and reamed separately through hard bushes steel jigs. All holes not drilled through all thicknesses at one operation shall be drilled to a smaller size and reamed out after assembly.

All holes, whether for shop or field connections, shall be accurately centred and matched to render reaming or drifting unnecessary during erection. Members with poorly matching holes shall be rejected.

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### 15.2.7 Bolting

Installation of high strength friction grip bolts in joints shall comply with IS: 4000. The diameter of the bolt holes must not be more than 1.5mm larger than the nominal diameter of the bolt. All contact surfaces in a connection including those associated with the nut heads, nuts and washers shall be free of scale, burrs, dirt and other foreign matter tending to inhibit uniform sealing of the joint components.

### 15.2.8 Riveting

Rivets shall be heated uniformly throughout their lengths and shall, when driven, completely fill the holes.

Riveted members shall have all parts firmly drawn and held together before and during riveting, for multiple riveted connections, a service bolt shall be provided in every third or fourth hole.

All loose, burred or otherwise defective rivets shall be cut out and replaced before loading the structure.

### 15.3 Testing and Inspection

All structural steel and other materials supplied by the Contractor shall be supported by a manufacturer's test certificate conforming compliance with the relevant specifications. The Employer's Representative may order further sampling and testing on any item brought to site.

The Employer's Representative shall have free access at all reasonable times to the Contractor's manufacturer's fabrication shop or yard and shall be provided with all co-operation and facilities for inspection and no work shall be taken down, painted or despatched until it has been inspected and passed. All gangs, templates, tool etc required shall be supplied by the Contractor.

Inspection by the Employer's Representative and testing by approved authorities will not relieve the Contractor of his liability to fulfil his contractual obligations.

### 15.4 Tolerances for Steel Structures

Tolerances stated below shall be achieved after the entire structure, or part thereof, is in line, level and plumb.

Deviation of column axes at foundation top level with respect to true axes

a) In longitudinal direction  $\pm 5 \text{ mm}$

b) In lateral direction  $\pm 5 \text{ mm}$

Deviation in the level of bearing  
surface of columns at foundation top  
with respect to true level  $\pm 5 \text{ mm}$

Out of plumbness (verticality) of column from true vertical axis, as measured at column top

a) For columns up to and including 15 m in height  $\pm 1/1000$  of column height in mm or  $\pm 15 \text{ mm}$  whichever is less

b) For columns exceeding 15 m in height  $\pm 1/1000$  of column

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	20 mm	height in mm or $\pm$ whichever is less
less	Deviation in straightness in longitudinal and transverse planes of column at any point along the height	$\pm 1/1000$ of column height or $\sim 10$ mm whichever is less
	Difference in erected position of adjacent pairs of columns along length or across width of building, prior to connecting trusses/beams with respect to true /distance	$\pm 10$ mm
	Deviation in any bearing or seating level with respect to true level	$\pm 5$ mm
	Deviation in differences bearing levels of a member on adjacent pair of columns both across and along the building	$\pm 10$ mm
<b>Beams:</b>		
	Deviation in difference of bearing levels of beams from the true difference	Depth $< 1800$ mm i 6 mm Depth $> 1800$ mm i 10 mm
	Deviation in sweep of beams in the subject horizontal plane 10 mm	$1/1000$ of span in mm to a maximum of 10 mm
<b>Crane girders and rails:</b>		
	Shift in the centreline of crane rail with respect to centreline of web of crane girder	$\pm 5$ mm
	Shift in plan of alignment of crane rail with respect to true axis of crane rail at any point	$\pm 5$ mm
	Differences in alignment of crane rail in plan measured between any two points 2 metres apart along rail	$\pm 1$ mm
<b>Deviation in crane track with respect to true gauge:</b>		
	For track gauges up to and including 15 metres	$\pm 5$ mm
	For track gauges more than 15 metres	$\pm [5 + 0.25 (S - 15)]$ mm where S is true gauge

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Deviation in the crane rail level at any distance point from true level less	$1/1200$ of the gauge or +10 mm whichever is
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Difference in the crane rail actual levels between any two points 2 metres apart along the rail length	$\pm 2$ mm
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Difference in levels between crane tracks rails at:

Supports of crane girders	$\pm 15$ mm
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Mid span of crane girders	$\pm 20$ mm
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Relative shift of crane rail surfaces at a joint in plan and elevation smooth transition	2mm subject to grinding of surfaces for
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Relative shift in the location of crane stops (end buffers) along the crane tracks with track gauge S in m	$1/1000$ of track gauge S subject to maximum of 20mm
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## **16 Anchor Bolts**

### **16.1 Materials**

Anchor bolt materials shall be as specified in the table below.

#### **Anchor Bolt Materials**

Material	Specification
Steel bolts	ASTM A307, Grade A
Fabricated steel bolts	ASTM A36
Stainless steel bolts, nuts, washers	ASTM A320, Type 304/316 as required

Anchor bolts for equipment frames and foundations shall be designed in accordance with the project seismic zone requirements.

Anchor bolt holes in equipment support frames shall not exceed the bolt diameters by more than 25 percent, up to a limiting maximum over sizing of 6 mm. Minimum anchor bolt diameter shall be 12mm. Anchor bolts for equipment mounting and vibration isolation systems shall be provided as required.

Tapered washers shall be provided where the mating surface is not square with the nut.

Expansion, wedge or adhesive anchors set in holes drilled in the concrete after the concrete is placed will not be permitted in substitution for anchor bolts except where otherwise specified. Upset threads are not acceptable.

The following information shall be provided for all bolt systems not cast-in-place:

- 1 Data indicating load capacities.
- 2 Chemical resistance
- 3 Temperature limitations
- 4 Installation instructions
- 5 Evaluation report for expansion and wedge type anchors.

### **16.2 Execution**

#### **General**

A Fieldwork, including cutting and threading, shall not be permitted on galvanized items. Dissimilar metals shall be protected from galvanic corrosion by means pressure tapes, coating or isolators, grouting of anchor bolts with non epoxy grouts as required.

#### **16.2.1 Cast-In Place Anchor Bolts**

Anchor bolts to be embedded in concrete shall be placed accurately and held in correct position while the concrete is placed or, if specified, recesses or blackouts shall be formed in the concrete and the metalwork shall be grouted in place in accordance with Section 13. The surface of metalwork in contact with concrete shall be thoroughly cleaned.

After anchor bolts have been embedded, their threads shall be protected by greasing and placing the nuts.

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### **16.2.2 Adhesive Anchor Bolts**

Use of adhesive or capsule anchors shall be subject to the following conditions;

- 1 Use shall be limited to locations where exposure, on an intermittent or continuous basis, to acid concentrations higher than 10 percent, chlorine or to machine or diesel oils, is extremely unlikely.
- 2 Use shall be limited to applications where exposure to fire or exposure to concrete or rod temperature above 120°F is extremely unlikely. Overhead applications (such as pipe supports) shall not be allowed because of the above concerns.
- 3 Approval from the Employer's Representative for specific application and from the supplier of equipment to be anchored, if applicable.
- 4 Anchors shall be threaded or deformed for the full length of embedment and shall be free of rust, scale, grease and oils.
- 5 Embedment depth shall be as per manufacturer's recommendations. Adhesive capsules of different diameters may be used to obtain proper volume of the embedment, but no more than two capsules per anchor may be used. When installing different diameter capsules in the same hole, the larger diameter capsule shall be installed first. No extension or protrusion of the capsule from the hole is acceptable.
- 6 All installation recommendations by the anchor system manufacture shall be followed carefully.
- 7 Holes shall have rough surfaces.
- 8 Holes shall be cleaned with compressed air and be free of dust or water prior to installation.
- 9 Anchor shall be left undisturbed and unloaded for the adhesive curing period.
- 10 Concrete temperature (not air temperature) shall be compatible with curing requirements of the adhesives.

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## **17 Painting and Protective Coating**

### **Applications for Anti-Corrosive Internal Lining (Epoxy Coating) protection of Concrete Surfaces**

- 17.1** Application limits of Anti-Corrosion Internal Lining and/or coatings of appropriate material and thickness – to be approved by Employer for Concrete Surfaces contact with sewage and/ or sludge upstream of the Aeration Basins. This also applies to all concrete structures in contact with any type of sewage sludge anywhere in the plant.
- 17.1.1** All units upstream of and including Primary Clarifiers will have to be provided with internal lining for the full internal surface area (Walls and base slab).
- 17.1.2** For Aeration Basins, interior lining shall extend from the top of wall down to 1.0 meter below the lowest operating liquid level.
- 17.1.3** This also applies to all concrete structures in contact with any type of sewage sludge anywhere in the plant.
- 17.1.4** For the units handling the solids part such as: Gravity Sludge Thickener, Anaerobic Sludge digester and Digested Sludge Storage tank, internal lining shall be provided for the entire internal surface area.

## **17.2 General**

### **17.2.1 Surfaces to be Painted**

The following, in general, are the surfaces to be painted.

- 1 All exposed piping and other metal surfaces, interior and exterior.
- 2 All submerged metal surfaces.
- 3 All Structural and Miscellaneous steel, including tanks.
- 4 Exterior, above ground concrete and brick masonry as specified.
- 5 The interior of structures as specified.
- 6 Equipment furnished with and without factory finished surface except as specified hereafter.
- 7 Door woodwork and architectural trim work.

### **17.2.2 Surfaces Not to be Painted**

Unless otherwise approved by the Employer's Representative, the following surfaces shall in general not be painted.

- 1 Concrete surfaces subject to pedestrian traffic
  - 2 Plastic surfaces, except for colour code labelling.
  - 3 Non-ferrous metals (galvanised metal shall not be considered as a non-ferrous metal in this context).
  - 4 Mechanical equipment and electrical equipment with approved factory finishes.
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5 Non-ferrous piping.

6 Chain link fencing

### **17.3 Products**

#### **17.3.1 Materials**

Paints, oils, varnishes etc of approved brand and manufacture shall be used. Ready mixed paints as received from the manufacturer without any admixture shall be used.

If for any reason, thinning is necessary in case of ready mixed paint, the brand of thinner recommended by the manufacturer or as instructed by the Employer's Representative shall be used. Approved paints, oils or varnishes shall be brought to the site of work by the Contractor in their original containers in a sealed condition. The materials shall be brought in at a time in adequate quantities to suffice for the whole work or at least a fortnights work. The empty containers shall not be removed from the site of work until the relevant item of work has been completed and permission obtained from the Employer's Representative.

The Contractor shall consult with the paint manufacturer before commencement of the work to certify the suitability of the surface to receive paint and the paint to be used.

#### **17.3.2 Service Conditions and Applicable Systems – Non-Architectural**

##### **(i) General**

This clause refers to the painting of items other than items of mechanical and electrical plant and equipment.

The painting systems specified herein have been chosen with regard to the different service conditions and shall not be changed except with the explicit permission of the Employer's Representative. All paint materials shall be first quality products of the required type and composition. Trade names, where given; are only meant to clarify the quality required and are not meant to be restrictive in any other sense. Products of other reputed manufacturers complying with the following requirements shall be eligible for use.

##### **(ii) Service Condition A**

Service condition A includes ferrous metals other than stainless steel, subject to corrosive moisture or atmosphere and condensation.

Surface preparation shall be carried out so that all metal surfaces are field sand blasted to near-white metal blast cleaned quality. Weld surfaces, edges and sharp corners shall be ground to a curve and all weld splatter removed.

A near-white metal blast cleaned surface finish is defined as a surface with a grey-white, uniform metallic colour, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed without magnification, shall be free of all oil, grease, dirt, visible mill scale, rust, corrosion products, oxides, paint or any other foreign matter.

Coat	Description	Thickness
Primer	Zinc rich epoxy primer, equal or superior to Apcodur CP 686 of Asian paints or Epilux 4 zinc rich primer	50 microns
Intermediate	Universal type primer, same as above acceptable	50 microns
Finish	Epoxy enamel, equal or superior to Apcodur CF 697 or Epilux 4 High Build.	100 microns

Total Minimum Thickness	200 microns
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A minimum of 12 hours shall elapse prior to the application of additional coats to the prime coat. A minimum of 2 hours shall elapse prior to the application of the intermediate coat and a minimum of 2 hours for the finish coat.

**(iii) Service Condition B**

Service condition B includes ferrous and other metals other than stainless steel, not subject to chemical attack, normal indoor and outdoor exposure, except as specified for buildings.

Surface preparation shall be carried out so that all surfaces shall be free of dirt, dust, grease and other foreign matter before coating. Surfaces shall be cleaned to brush-off blast cleaning quality and weld surfaces and rough edges shall be ground and weld splatter removed.

Coatings shall include the following:

Coat	Description	Thickness
Primer	Zinc rich epoxy primer, equal or superior to Apcodur CP 686 of Asian paints or Epilux 4 zinc rich primer	50 microns
Intermediate	Universal type primer, same as above acceptable	50 microns
Finish	Epoxy enamel, equal or superior to "Apcodur CF 697" or "Epilux 4 High Build	100 microns
Total Minimum Thickness		200 microns

Coatings shall be applied in strict accordance with the manufacturer's recommendations. All sharp edges, nuts bolts and other items difficult to coat shall receive a brush-applied coat of the specified coating prior to application of each coat.

**(iv) Service Condition C**

Service condition C includes ferrous metals and other metals other than stainless steel wholly or intermittently submerged in water or corrosive liquid.

Surface Preparation shall be carried out so that all metal surfaces shall be field sand blasted to near-white metal blast cleaned quality. Weld surfaces, edges and sharp corners shall be ground to a curve and all weld splatter removed and welds neutralized with thinner.

Coatings shall include:

Coat	Description	Thickness
Primer	Zinc rich epoxy primer, equal or superior to Apcodur CP-686 or Epilux 4 zinc rich primer in 2 coats aggregating 75 microns.	75 microns
Intermediate	Coal tar epoxy polyamine coating equal or superior to Apcodur CF 651 or Epilux 5	Adequate coats to aggregate dry film thickness
Finish	As intermediate	400 microns
Total Minimum Thickness		475

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microns

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Coatings shall be applied in strict conformance with the manufacturer's recommendations. All sharp edges, nuts, bolts and other items difficult to coat shall receive a brush-applied coat of the specified coating prior to application of each coat.

**(v) Service Condition D**

Service condition D includes concrete surfaces subject to intermittent submergence including the entire interior surfaces of wet wells and manholes.

Coatings shall include:

Coat	Description	Thickness
Primer	Not required	
Intermediate & Finish Coats	Coal tar epoxy polyamine coating equal or superior to Apcodur CF 651 or Epilux 5 adequate number of coats to give total dry film thickness	400 microns
Total Minimum Thickness		400 microns

**(vi) Service Condition E**

Service condition E includes exterior or interior concrete surfaces exposed to view, not subject to immersion and designated for painting and not covered under architectural painting.

Surface preparation shall be carried out so that all surfaces shall be free of dust, grease and other foreign matter before coating. Cracks and voids shall be repaired or filled with suitable material compatible with the paint used.

Coatings shall include:

Coat	Description	Thickness
1 <sup>st</sup> Coat	Equal or superior to Snowcem, or Durocem	224 microns
Intermediate Coat	Best quality plastic emulsion paint available dry film thickness of not less than 38 microns.	38 microns
Finish Coat	As above	38 microns
Total Minimum Thickness		400 microns

Time between coats -The filler coat may be recoated in 12 hours, the finish coat if dry for a recoat in 2 hours.

A minimum of 12 hours shall elapse prior to the application of additional coats to the filler coat, a minimum of 2 hours shall elapse prior to the application of the finish coat.

**(vii) Service Condition F**

Service condition F includes interior and exterior metal not painted under service conditions A, B and C, but designated for painting.

Surface preparation shall be:

- 1 Ferrous Metals - Prepare surface as for Service Condition B.
-



## 2 Non-Ferrous Metals - Wash surfaces with solvent thinner

### Coatings for Ferrous Metals shall include:

Coat	Description	Thickness
Primer	Red lead primer, equal or superior to Bisow Synthetic Red Lead Primer	50 microns
Intermediate	Exterior synthetic enamel equal or superior to Apcolite or Luxol	50 microns
Finish	As intermediate	50 microns
Total Minimum Thickness		150 microns

### Coatings for Non-Ferrous Metals shall include:

Coat	Description	Thickness
Primer	A wash primer equal or superior to Apconil WP-636 or Bison Wash Primer	10 microns
Intermediate and Finish	As for ferrous metals above, adequate coats to give 140 microns	140 microns
Total Minimum Thickness		150 microns

#### (viii) Service Condition G

Service Condition G includes plastic pipes, coating for purpose of colour coding and label-stencilling. Coatings to be used for this category shall be certified by pipe manufacturer and to be completely acceptable and non-injurious to pipe.

Surface preparation shall be to lightly sand the pipe and wipe with a solvent to degrease and clean surface.

Coating shall include two coats of paint approved by the Employer's Representative and certified by pipe manufacturer as non-injurious to the pipe, of total dry thickness not less than 150 microns.

Application shall be in strict accordance with manufacturer's recommendations.

#### (ix) Service Condition H

Service condition H includes interior and exterior wood. Unless already properly hand-sanded, surface preparation shall include sand-paper smooth by hand and clean off dust. Neatly fill nail holes, cracks and depressions with approved filler, coloured to match the wood. When dry, sandpaper smooth and flush.

Coatings shall include:

Coat	Description	Thickness
Primer	White or pink primer equal or superior to Parrot Wood Primer or Woodrite	n/a
Intermediate	Synthetic enamel coating equal or superior to Apcolite or Luxol High Gloss	50 microns
Finish	As intermediate	50 microns
Total Minimum Thickness		100 microns

### 17.3.3 Coating Schedule

The following list specifies the coating system required for each item. The list shall not be construed as complete, list of all surfaces to be coated but as a guide as to the coating systems applicable.

Where reference is made to ferrous metal in this schedule it does not include stainless steel and galvanized iron pipes. Coatings and finishes for architectural work and items are given separately on the drawings.

Description	Service Condition
<b>General</b>	
Exposed ferrous metal	A
Exposed plastic pipe	G
Galvanized metals to be painted	F
Designated Interior concrete walls	E
Designated Exterior concrete walls	E
Submerged ferrous metals	C
All non-submerged structural steel and miscellaneous metals	B
<b>(Unless A is specified)</b>	
Interior of surge tanks	D
<b>Screenings and wet well Area</b>	
Structure above floor level	A
Screenings hopper	A
Interior of wet wells and all Screen Chambers	D
Walls and roof slabs of all channels	D
Exposed ferrous metals	A
	F
<b>Pump Rooms</b>	
Exposed ferrous metals	A

### 17.3.4 Painting and Coatings - Architectural

#### (i) General

The painting and coatings required for architectural work including doors windows and trim work. The systems required for different items and service conditions are given below.

#### (ii) Service Condition I

Service condition I includes un-plastered interior or exterior concrete surfaces designated for painting shall conform to requirements of service condition E.

### (iii) Service Condition J

Service Condition J includes interior plastered brickwork and concrete surface or concrete block work. All concrete block surfaces to be painted shall be filled with putty of a composition approved by the manufacturer of the paint to be used. Service condition K includes five alternative specifications

Alternative 1 is for synthetic enamel paint and is specified below:

- 1 Surface preparation shall be that all surfaces shall be free of dirt, dust, grease and other foreign matter before coating. Cracks and voids shall be repaired with a suitable compound compatible with the paint to be used.
- 2 Coating shall include:

Coat	Description	Thickness
Primer	Cement primer, equal or superior to Decoprime or Bison cement primer solvent or water thin-able.	Total dry film thickness
Intermediate	Synthetic enamel paint with matt finish equal or superior to Apcoliteor a Luxol synthetic enamel paint	not less than 75 microns
Finish	As intermediate	
Total Minimum Thickness		75 microns

- 3 Each coat shall be completely dry before subsequent coat is applied

Alternative 2 is for emulsion paint and shall be as specified below:

- 1 Surface preparation: As for Alternative 1.
- 2 Coatings: Three coats of an emulsion paint equal or superior to Pentalite Emulsion Paint A 383 line or Luxol Silk Acrylic Emulsion. Total dry thickness should not be less than 190 microns.
- 3 Application: as for Alternative 1 and conforming to requirements of the manufacturer.

Alternative 3 is for an approved brand of oil-bound distemper or vinyl wall paint. Surface preparation, application and minimum dry thickness shall be as for Alternative 1. The paint shall be of a quality acceptable to the Employer's Representative and shall have been used extensively under similar circumstances satisfactorily.

Alternative 4 is for an approved brand of water-bound distemper such as Castle Dry Distemper. Surface preparation, application and minimum dry thickness shall be as for Alternative 1. The minimum dry film thickness shall be 100 microns, obtained by applying an adequate number of coats.

Alternative 5 is for colour wash of approved tint. The surface shall be prepared as for Alternatives 1 and an adequate number of coats of an approved tint of colour wash shall be applied in accordance with the best current practice to ensure a minimum dry film thickness of 100 microns.

### (iv) Service Condition K

Service Condition K is for exterior plastered brickwork and concrete surfaces or concrete block work and is specified below:

- 1 Surface Preparation - The preparation of surface shall be as for Service Condition E.

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- 2 Coatings - Shall be the same as for Service Condition E.
  - 3 Application - Shall be as recommended by the paint manufacturer.

**(v) Service Condition L**

Service Condition L is for the woodwork of doors and windows and is as for Service Condition H unless woodwork is to be varnished or French polished.

Where varnishing is specified, the varnish used shall be the best quality copal varnish mixed with turpentine if required and applied in three even coats.

French polishing, if specified, shall be in accordance with the requirements of I.S 348 French polish.

**17.4 Execution**

**17.4.1 Manufacturers Recommendations**

Unless otherwise specified or approved by the Employer's Representative, the paint and coating manufacturer's printed recommendations and instructions for thinning, mixing, handling applying and protection of the coating materials, preparation of surfaces for coating and for all other procedures relating to coating shall be strictly observed.

**17.4.2 Delivery and Storage**

Materials shall be delivered in manufacturer's original sealed containers, with labels and tags intact and decipherable. Coating materials and equipment shall be stored in designated areas. Coating containers shall be opened only when required for use. Coating shall be thoroughly stirred or agitated to uniformly smooth consistency and prepared and handled in a manner to prevent deterioration and inclusion of foreign matter. Unless otherwise specified or approved, no materials shall be reduced changed, or used except in accordance with the manufacturer's instructions.

**17.4.3 Safety Requirements**

Respirators shall be worn by all persons engaged in and assisting in spray painting.

Cloth and cotton waste that might constitute a fire hazard shall be placed in closed metal containers or destroyed at the end of each day's work.

**17.4.4 Storage Mixing and Thinning**

Paint and coating materials shall be shall be thoroughly stirred, strained and kept at a uniform consistency during application. Materials of different manufacturers shall not be mixed together. Packaged materials may be thinned immediately prior to application in accordance with the manufacturer's directions.

**17.4.5 Preparation for Painting and Protective Coating**

All surfaces to receive paint and protective coating shall be cleaned as specified prior to application of coating materials. The Contractor shall examine all surfaces to be coated and shall correct all surface defects before application of any coatings. All marred or abraded spots on shop-primed and factory finished surfaces shall be touched –up prior to application of any other coating.

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#### **17.4.6 Workmanship**

**Skilled craftsmen and experienced supervisor shall be employed on all work.**

All paint and coatings shall be applied in a workman like manner to produce an even film of specified uniform thickness. Edges, corners, crevices and joints shall receive special attention to ensure that they have been thoroughly cleaned and receive an adequate thickness of paint. The finished surface shall be free of runs, drops, ridges, waves, laps, brush marks and variations in colour, texture and finish. All coats shall be applied to produce a film of uniform thickness. Special attention shall be given to ensure that edges, corners, crevices, welds and similar areas receive a film thickness equivalent to adjacent areas. Installation shall be protected by the use of drop cloths or other approved precautionary measures.

Painting, except the priming coat, shall generally be taken in hand after all other builders work is completed.

The rooms should be thoroughly swept and the entire building cleaned at least one day in advance of the paint work being started.

Hardware, hardware accessories, machined surfaces and similar items not to be coated but which are in contact with coated surfaces shall be removed or masked prior to surface preparations and painting operations. Following completion of coating of each area or unit, removed items shall be re-installed by workmen skilled in the respective trades.

Doors, windows, floors, articles of furniture and such items not to be painted or coated shall be protected from being splashed. Splashes and droppings, if any, shall be removed by the Contractor and the surfaces cleaned.

#### **17.4.7 Application**

Each paint application shall be carried out strictly in accordance with the manufacturer's instructions.

#### **17.4.8 Application of Protective Coating**

##### **(i) Shop Coatings**

Fabricated metal work and equipment which requires coating may be shop-primed with specified primer. Any such work delivered to the site with any other shop coat shall have this coat removed and the specified coating applied in the field if so instructed by the Employer's Representative. Manufactured equipment with approved corrosion resistant factory finishes and galvanized finishes shall be exempt from this requirement.

#### **17.4.9 Thickness of Coating**

Where a dry film thickness (in micron) has been specified, such thickness shall be achieved and verified for each coat.

#### **17.4.10 Testing and Inspection**

The Contractor shall conduct thickness measurements and inspection of the coated surfaces with equipment supplied by him and acceptable to the Employer's Representative and shall recoat and repair as necessary for compliance with these specifications.

Any surfaces or parts thereof found to be unsatisfactory shall be rectified by the Contractor to the satisfaction of the Employer's Representative.

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## **18 Design Submissions**

**18.1** Complete detailed design calculations of foundations and superstructure together with general arrangement drawings and explanatory sketches shall be submitted by the Contractor to the Engineer. Separate design calculations for foundations or superstructures submitted independent of each other shall be deemed to be incomplete and will not be accepted by the Engineer.

**18.2** Submissions of detailed design calculations and Good for Construction drawings shall include the following as a minimum:

### **18.2.1 Detailed Design Calculations**

- a) One (1) Copy of a Compact Disc (CD) containing electronic files relevant to the structure's modelling, analysis and design calculations (Microsoft Excel, Staad Pro, etc) Files submitted shall be in editable format.
- b) Print copy (6 Copies) of the contents as submitted in the Compact Disc.

### **18.2.2 Good for Construction Drawings**

- a) One (1) Copy of a Compact Disc (CD) containing AutoCAD files (Civil General Arrangement, Structural Dimensions and Reinforcement Details) pertaining to the structure. Files submitted shall be in editable format.
- b) Print copy (6 Copies) of the contents as submitted in the Compact Disc. Prints to be submitted on A1 Size Sheet as a minimum or A0 Size Sheet when required by the employer.
- c) Bar-bending schedule indicating the number, shape and size of the rebars shall be submitted as part of the Reinforcement Details
- d) Detailed drawing showing the location, number and depth of inserts shall be included for any structural steel inserts/Metal inserts in the structure such as rungs, bolted connections for ladders/railings, etc.
- e) Location of Construction Joints and pour sequence shall be included on the drawing for base slabs, walls and top slabs.
- f) Revised drawings shall be submitted by clouding at the location with the latest revision number and also show the history of revisions in a table format just above the title block.

**18.3** The design considerations described hereunder establish the minimum basic requirements of plain and reinforced concrete structures, masonry structures and structural steel works. However, any particular structure shall be designed for the satisfactory performance of the functions for which the same is being constructed. The Contractor shall also take care to check the stability of partly completed structures.

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## **19 Design Standards:**

**19.1** All the designs shall be based on the latest Bureau of Indian Standard (BIS) Specifications or Codes of Practice. The design standards adopted shall follow the best engineering practice. In case of any variation or contradiction between the provisions of the BIS Standards or Codes and the specifications given along with the tender document, the provision given in this Specification shall be followed.

**19.2** All reinforced concrete structural design shall generally conform to the following publications of the Indian Standards Institution:

I.S. 456	Code of Practice for plain and reinforced concrete
I.S. 875	Code of Practice for design loads for buildings and structures (Part I to V)
I.S. 3370	Code of Practice for concrete structures for the storage of liquids (Part I to IV)
I.S. 1893	Criteria for earthquake resistant design of structures (Part-1)
I.S. 2974	Code of Practice for design and construction of machine foundations (Part 1 to 4)
I.S. 4326	Code of Practice for Earthquake Resistant Design and Construction of Buildings
I.S. 13920	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces- Code of Practice
IRC: 6	Standard specification and Code of Practice for road bridges Loads and Stresses
IRC: 21	Standard specification and code of practice for road bridge, section III Cement Concrete
IRC 78	Standard specification and code of practice for road and bridge, section VII Foundation & Sub-Structures
All structural steel design shall generally conform to the following publications of the Indian Standards Institution	
I.S. 800	Code of Practice for general construction in steel
I.S. 806	Code of Practice for use of steel tubes in general building construction

## **20 Design Life:**

**20.1** The design life of all structures and buildings shall be 60 years.

## **21 Design Loadings:**

**21.1** All buildings and structures shall be designed to resist the worst combination of the following loads/stresses under test and working conditions; these include dead load, live load, wind load, seismic load, stresses due to temperature changes, shrinkage and creep in materials, and dynamic loads:

### **21.2 Dead Load**

**21.2.1** This shall comprise all permanent construction including walls, floors, roofs, partitions, stairways, fixed service equipments and other items of machinery. In estimating the loads of process equipment all fixtures and attached piping shall be included, but excluding contents, shall be considered.

**21.2.2** The following minimum loads shall be considered in design of structures:

a)	Weight of water	:	9.81 kN/m <sup>3</sup>
b)	Weight of soil (irrespective of strata available at site and type of soil used for filling etc). However, for checking stability against uplift, actual weight of soil as determined by field test shall be considered	:	20.00 kN/m <sup>3</sup>
c)	Weight of concrete	:	24.00 kN/m <sup>3</sup>
d)	Weight of reinforced concrete	:	25.00 kN/m <sup>3</sup>
e)	Weight of brickwork (exclusive of plaster)	:	22.00 N/m <sup>2</sup> per mm thickness of brickwork
f)	Weight of plaster to masonry surface	:	18.00 N/m <sup>2</sup> per mm thickness
g)	Weight of granolithic terrazzo finish or rendering screed, etc.	:	24.00 N/m <sup>2</sup> per mm thickness
h)	Weight of MS chequered plates	:	78.5 N/m <sup>2</sup> per mm thickness of plates
i)	Weight of sludge with water	:	10.40 kN/m <sup>3</sup>



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### 21.3 Live Load:

**21.3.1** Live Load (LL) shall include the superimposed loads due to the use/occupancy of the structure/building not including dead, wind or earthquake load. Live loads shall be in general as per I.S. 875 Part (II). However, the following minimum loads shall be considered in the design of structures:

a)	Live load on roofs	:	1.50 kN/m <sup>2</sup>
b)	Live load on floors supporting Equipment such as pumps, valves etc.	:	10.00 kN/m <sup>2</sup>
c)	Live load on all other floors walkways, stairways and platforms	:	5.00 kN/m <sup>2</sup>

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**21.3.2** In the absence of any suitable provisions for live loads in BIS Codes or as given above for any particular type of floor or structure, assumptions made must receive the approval of the Engineer prior to starting the design work. Apart from the specified live loads or any other load due to material stored, any other equipment load or possible overloading during maintenance or erection/construction shall be considered and shall be partial or full whichever causes the most critical condition.

**21.4** Wind Load

**21.4.1** Wind loads shall be as per I.S. 875 Part (III).

**21.5** Earthquake Load

**21.5.1** This shall be computed as per I.S. 1893.

**21.6** Dynamic Load

**21.6.1** Dynamic loads due to working of plant items such as pumps, blowers, compressors, switch gears, travelling cranes, etc. shall be considered in the design of structures.

**21.7** Wheel Load

**21.8** For any structure or pipeline below the roads, Class A loading of IRC 6 (latest) shall be taken.

**22** Joints

**22.1** Movement joints such as expansion joints, complete contraction joints, partial contraction joints and sliding joints shall be designed to suit the structure. However, contraction joints shall be provided at specified locations spaced not more than 7.5 m or as per latest IS codes in both right angle directions for walls and rafts. Expansion joints of suitable gap at suitable intervals not more than 30 m or as per latest IS codes shall be provided in walls, floors and roof slabs of liquid retaining structures.

**22.2** Construction joints shall be provided at right angles to the general direction of the member. The locations of construction joints shall be decided on convenience of construction. To avoid segregation of concrete in walls, horizontal construction joints are normally to be provided at every 2 m height. PVC water-stops of 150 mm width shall be used for walls and 230 mm width for base slabs.

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**23      Design Conditions for Liquid Retaining Structures / Structures containing media**

- 23.1**      All underground or partly underground liquid containing structures / the structure containing media in all types of technology shall be designed for the following conditions:
- 23.1.1**   Liquid / Media depth up to full height of wall: no relief due to soil pressure from outside to be considered;
- 23.1.2**   Structure empty (i.e., empty of liquid, any material, etc.): full earth pressure, Outside water pressure if any and surcharge pressure wherever applicable , to be considered;
- 23.1.3**   Partition wall between dry sump and wet sump : to be designed for full liquid depth up to full height of wall;
- 23.1.4**   Partition wall between two compartments : to be designed as one compartment empty and other full;
- 23.1.5**   Structures shall be designed for uplift in empty conditions with the water table as per latest soil report and all the possibility of the local flooding shall be taken care while designing.
- 23.1.6**   Walls shall be designed under operating conditions to resist earthquake forces from earth pressure mobilization and dynamic water loads;
- 23.1.7**   All underground or partly underground liquid containing structures / the structure containing media in all types of technology shall also be checked against stresses developed due to any combination of full and empty compartments with appropriate ground/uplift pressures from below to base slab (considering water table as per Cl 23.1.5). A minimum factor of 1.2 shall be ensured against uplift or floatation.
- 23.1.8**   All the liquid / media retaining structures in all type of technology shall be designed for maximum design crack widths 0.1 mm for direct tension and flexure.
- 23.1.9**   All civil works in contact with sewage shall be constructed with R.C.C. with Sulphate resistance cement with Epoxy Paint. Corrosion resistance steel with grade of Fe-500D/550D shall be used for reinforcement.
- 23.1.10**   All liquid / media retaining structures shall be designed assuming liquid / media up to the top of the wall irrespective of the provision of any overflow arrangement.
- 23.1.11**   No pressure relieving devices will be permitted in underground structures.
- 23.1.12**   RCC walls of the media retaining structures in all type of technology shall be designed for submerged soil pressure with minimum wall thickness as described in the tender clause of 25.1.15
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## **24 Foundations**

- 24.1** The minimum depth of foundations for all structures, equipment's, buildings and frame foundations and load bearing walls shall be as per IS 1904 but in any case this shall not be less than 1.5 meter in the original soil.
- 24.2** Safe bearing capacity of soil strata shall be taken as determined by the Contractor through his own independent investigations.
- 24.3** Care shall be taken to avoid the foundations of adjacent buildings or structure foundations, either existing or not within the scope of this Contract. Suitable adjustments in depth, location and sizes may have to be made depending on site conditions. No extra claims for such adjustments shall be accepted by the Employer.
- 24.4** Special attention is drawn to danger of uplift being caused by the ground water table. All underground structural slabs shall be designed for uplift forces if water is encounter due to any source.

## **25 Design Requirements**

- 25.1** The following are the design requirements for all reinforced or plain concrete structures:
- 25.1.1** All binding and levelling concrete shall be a minimum 100 mm thick in concrete grade M15.
- 25.1.2** All liquid retaining reinforced concrete structures / the structure containing media in all types of technology, concrete shall be of a minimum M30 grade with a maximum 40 mm aggregate size for footings and base slabs and with a maximum 20 mm aggregate size for all other structural member. All other structures, reinforced concrete shall be of a minimum M25 grade with a maximum 40 mm aggregate size for footings and base slabs and with a maximum 20 mm aggregate size for all other structural member.
- 25.1.3** The reinforced concrete for all structures shall have a minimum cement content, maximum slump and maximum water cement ratio as per latest IS codes.
- 25.1.4** As a design consideration to control crack, though general requirements of IS 3370 shall be followed, All liquid retaining structures / the structure containing media in all types of technology shall be designed based on the serviceability crack width limit state (i.e. 0.1 mm crack width) and other limits including the ultimate limit states.
- 25.1.5** The minimum cover to the main reinforcing bars for different members for non-liquid retaining structures shall be as follows unless stated otherwise:

a)	Slab (Floor, Roof, Canopy, and Staircase)	:	25 mm
b)	Beams (Sides, Bottom & Top)	:	30 mm
c)	Columns	:	40 mm
d)	Pedestals (in contact with earth)	:	50 mm
e)	Basement wall, retaining walls		
i)	Face in contact with earth	:	40 mm

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ii)	Interior face	:	30 mm
iii)	Foundations	:	50 mm

NOTE: The minimum clear cover to all reinforcement including stirrups and links shall be 50 mm for all liquid retaining structures / the structure containing media in all types of technology.

- 25.1.6** The reinforcement for buildings and sewage treatment units shall be HYSD-CRS (Corrosion Resistant Steel) of Grade Fe 500. Further, for all the Sewage Treatment Plant units coming in direct contact with sewage ( including the structure containing media in all types of technology) , Fusion Bonded Epoxy coated reinforcement steel having not less than 175 microns thickness and up to 300 microns to be used for reinforcement of all diameters as per IS : 13620 for RTS rods and the binding wire should be of PVC coated and the exposed portion if any after bar bending work should be covered with the Epoxy paint. All physical and chemical properties of this Fe 500 grade steel shall conform to IS: 1786-2008. Welded wire fabric shall conform to IS: 1566 as shown or specified on the drawing. The CRS (corrosion resistant steel) index shall be at least 1.35 when tested for Salt Spray test as per “ASTM B 117 – 2009 test procedure for 120 hours when compared with the Fe 500 normal reinforcement bars and with same bar diameter. All test results (including physical and chemical properties and salt spray tests) have to be produced for the respective bar diameter for each consignment of steel delivered at site and at a frequency of every 20 Metric Tons.
- 25.1.7** Reinforcement produced using iron ore as the raw material only will be accepted. Reinforcement produced from scrap metal will not be accepted.
- 25.1.8** The amount of reinforcement in each of the two directions at right angles within each surface zone should be as per IS 3370 latest. For all water retaining structures, minimum of 10 mm dia bars shall be used to avoid any deformation of lesser diameter bars under loads prior to construction.
- 25.1.9** All units / structures of the STP shall have a minimum 1 meter wide, 100 mm thick plinth protection paving in M15 grade concrete or stone slabs/tiles. All plinth protection shall be supported on well compacted strata.
- 25.1.10** All pipes and ducts laid below the structural plinth and road works shall be surrounded with concrete of grade M15 having minimum 150 mm thick concrete or D/4 (D = outer dia. of pipe) thickness whichever is more.
- 25.1.11** Use of pressure relief valves to reduce uplift pressure due to ground water table shall not be allowed.
- 25.1.12** Detailing and designing of the reinforcement shall be done as per latest IS-13920.
- 25.1.13** Sliding layer or slip layer shall be provided between sub base and structural slab (Raft) as per IS 3370 : part 1 2009 or latest.
- 25.1.14** Water tightness testing of water retaining structures shall be done in accordance with IS: 3370, Part I. It is described in Clause 1.22. The depth of water for testing shall be up to the soffit of the covering slab.
- 25.1.15** The following minimum thicknesses shall be used for different reinforced concrete members, irrespective of design thicknesses:

a)	Walls for liquid retaining structures / the structure containing media in all types of technology	:	200 mm
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b)	Roof slabs for liquid retaining structures (Other than flat slabs), Launder wall (< 500 mm)	:	150 mm
c)	Bottom slabs for liquid retaining structures	:	200 mm
d)	Floor slabs including roof slabs, walkways, Canopy slabs	:	125 mm
e)	Walls of channel/ cables / pipe trenches, Underground pits, baffel walls etc.	:	170 mm
f)	Column footings	:	300 mm
g)	Parapets, chajja	:	115 mm
h)	Precast trench cover	:	100 mm
j)	Column Dimensions	:	300 mm
k)	PCC floor slab	:	200 mm
From the fire resistance perspective, the minimum thickness of reinforced concrete members will be as per Fig 1 or Table 16A of IS 456.			

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**25.1.16 Structural Steel:**

- a) Wherever a structural steel member like channels, angles, I sections etc used in mechanical equipment, gets in contact with sewage it requires special precautions. The sludge scrapers in the floor of clarifiers are held in position by mild steel angles suspended from the walkway platform of the clarifier. These are partly inside the sewage and partly above it. The wind action of the sewage causes oscillation of the sewage surface. This results in alternate exposure of steel to wetting and drying. This condition accelerates the corrosion. In such cases, the steel member shall be spliced with SS members for 30 cm above and 30 cm below the sewage surface. Epoxy or special polymer painting of the other portions of steel is needed. Before painting, the bare steel shall be sand blasted to SA 2.5 Swedish standard SIS 05 5900 with a surface profile not exceeding 65 microns or the equivalent specifications of ASTM. Where sand blasting is not possible, manual chipping or wire brushing to remove loose rust and scale shall be permitted to ST2 Swedish standard SIS 05 5900. Solvent free epoxy coating shall be for 360 microns and curing shall be done for 7 days, at room temperature if the temperature is less than 15 degree Celsius, the surface shall be warmed up by in candescent lamps, heaters, blowers or infrared lamp.

**26 Materials in General:**

- 26.1** The term "materials" shall mean all materials, goods and articles of every kind whether raw, processed or manufactured and equipment and plant of every kind to be supplied by the Contractor for incorporation in the Works.
- 26.2** Except as may be otherwise specified for particular parts of the works the provision of clauses in "Materials and Workmanship" shall apply to materials and workmanship for any part of the works.
- 26.3** All materials shall be new and of the kinds and qualities described in the Contract and shall be at least equal to approved samples.
- 26.4** As soon as practicable after receiving the order to commence the Works, the Contractor shall inform the Engineer of the names of the suppliers from whom he proposes to obtain any materials but he shall not place any order without the approval of the Engineer which may be withheld until samples have been submitted and satisfactorily tested. The Contractor shall thereafter keep the Engineer informed of orders for and delivery dates of all materials.
- 26.5** Materials shall be transported, handled and stored in such a manner as to prevent deterioration, damage or contamination failing which such damaged materials will be rejected and shall not be used on any part of the Works under this contract.

**27 Samples and Tests of Materials:**

- 27.1** The Contractor shall submit samples of such materials as may be required by the Engineer and shall carry out the specified tests directed by the Engineer at the Site, at the supplier's premises or at a laboratory approved by the Engineer.
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**27.2** Samples shall be submitted and tests carried out sufficiently early to enable further samples to be submitted and tested if required by the Engineer.

**27.3** The Contractor shall give the Engineer seven days' notice in writing of the date on which any of the materials will be ready for testing or inspection at the supplier's premises or at a laboratory approved by the Engineer. The Engineer shall attend the test at the appointed place within seven days of the said date on which the materials are expected to be ready for testing or inspection according to the Contractor, failing which the test may proceed in his absence unless instructed by the Engineer to carry out such a test on a mutually agreed date in his presence. The Contractor shall in any case submit to Engineer within seven days of every test such number of certified copies (not exceeding six) of the test results as the Engineer may require.

**27.4** Approval by the Engineer as to the placing of orders for materials or as to samples or tests shall not prejudice any of the Engineer's powers under the Contract.

**27.5** The provisions of this clause shall also apply to materials supplied under any nominated sub-contract.

**28 Standards:**

**28.1** Materials and workmanship shall comply with the relevant Indian Standards (with amendments) current on the date of submission of the document.

**28.2** Where the relevant standard provides for the furnishing of a certificate to the Engineer, at his request, stating that the materials supplied comply in all respects with the standard, the Contractor shall obtain the certificate and forward it to the Engineer.

**28.3** The specifications, standards and codes listed below are considered to be part of this specification. All standards, specifications, codes of practices referred to herein shall be the latest editions including all applicable official amendments and revisions.

**28.4** In case of discrepancy between the Specification and the Standards referred to herein, the Specification shall govern.

**28.4.1 Materials**

- IS: 269 - Specification for 33 grade ordinary Portland cement
  - IS: 383 - Specification for coarse and fine aggregates from natural sources for concrete
  - IS: 428 - Specification for distemper, oil emulsion, colour as required
  - IS: 432 - Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement (Parts 1 & 2)
  - IS: 455 - Specification for Portland slag cement
  - IS: 458 - Specification for precast concrete pipes (with and without reinforcement)
  - IS: 650 - Specification for standard sand for testing of cement
  - IS: 651 - Specification for salt glazed stoneware pipes and fittings
  - IS: 808 - Specification for dimensions for hot rolled steel beam, column channel and angle sections
  - IS: 814 - Specification for covered electrodes for manual metal arc welding of Carbon and Carbon Manganese steel
  - IS: 1003 - Specification for timber panelled and glazed shutters (Parts 1 & 2)
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- IS: 1038 - Specification for steel doors, windows and ventilators
  - IS: 1077 - Specification for common burnt clay building bricks
  - IS: 1398 - Specification for packing paper, water proof, bitumen laminated
  - IS: 1489 - Specification for Portland pozzolana cement (Parts 1 & 2)
  - IS: 1566 - Specification for hard drawn steel wire fabric for concrete reinforcement
  - IS: 1580 - Specification for bituminous compounds for water proofing and caulking purposes
  - IS: 1786 - Specification for high strength deformed steel bars and wires for concrete reinforcement
  - IS: 1852 - Specification for rolling and cutting tolerances for hot rolled steel products
  - IS: 1948 - Specification for aluminium doors, windows and ventilators
  - IS: 1977 - Specification for structural steel (ordinary quality)
  - IS: 2062 - Specification for steel for general structural purposes
  - IS: 2185 - Specification for concrete masonry units (Parts 1 & 2)
  - IS: 2202 - Specification for wooden flush door shutters (Parts 1 & 2)
  - IS: 2645 - Specification for integral cement water proofing compounds
  - IS: 2750 - Specification for steel scaffoldings
  - IS: 2835 - Specification for flat transparent sheet glass
  - IS: 3384 - Specification for bitumen primer for use in waterproofing and damp proofing
  - IS: 3502 - Specification for steel chequered plates
  - IS: 4021 - Specification for timber door, window and ventilator frames
  - IS: 4350 - Specification for concrete porous pipes for under drainage
  - IS: 4351 - Specification for steel door frames
  - IS: 4990 - Specification for plywood for concrete shuttering work
  - IS: 8112 - Specification for 43 grade ordinary Portland cement
  - IS: 9862 - Ready mixed paint, brushing, bituminous, black, lead free, acid, alkali, water and chlorine resisting
  - IS: 10262 - Recommended guidelines for concrete mix design
  - IS: 12269 - Specification for 53 grade ordinary Portland cement
  - IS: 12330 - Specification for sulphate resisting Portland cement
  - IS: 12709 - Glass fibre reinforced plastics (GRP) pipes, joints and fittings for use for potable water supply

#### **28.4.2 Tests**

- IS: 516 - Method of test for strength of concrete
  - IS: 1182 - Recommended practice for radiographic examination of fusion - welded butt joints in steel plates
  - IS: 1199 - Methods of sampling and analysis of concrete
  - IS: 2386 - Methods of test for aggregates for concrete (Parts 1 to 8)
  - IS: 2720 - Methods of test for soils (Parts 1 to 39)
  - IS: 3025 - Methods for sampling and test (physical and chemical) for water and wastewater (Parts 1 to 59)
  - IS: 3495 - Method of test for burnt clay building bricks (Parts 1 to 4)
  - IS: 3613 - Acceptance tests for wire flux combination for submerged arc welding
  - IS: 4020 - Methods of tests for wooden flush doors shutters: Type tests
  - IS: 4031 - Methods of physical tests for hydraulic cement (Parts 1 to 15)
  - IS: 5807 - Method of test for clear finishes for wooden furniture (Parts 1 to 6)
  - IS: 7318 - Approval tests for welders when welding procedure approval is not required (Parts 1 and 2)
  - IS: 13311- Methods of Non-destructive testing of Concrete- Part 1 & Part 2
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### 28.4.3 Codes of Practice:

- IS: 456 - Code of practice for plain and reinforced concrete
  - IS: 783 - Code of practice for laying of concrete pipes
  - IS: 800 - Code of practice for general construction in steel
  - IS: 806 - Code of practice for use of steel tubes in general building construction
  - IS: 816 - Code of practice for use of metal arc welding for general construction in mild steel
  - IS: 817 - Code of practice for training and testing of metal arc welders
  - IS: 875 - Code of practice for design loads (other than earthquake) for building structures (Parts 1 to 5)
  - IS: 1081 - Code of practice for fixing and glazing of metal (steel and aluminium) doors, windows and ventilators
  - IS: 1172 - Code of practice for basic requirements for water supply, drainage and sanitation
  - IS: 1477 - Code of practice for painting of ferrous metals in buildings (Parts 1 & 2)
  - IS: 1597 - Code of practice for construction of stone masonry (Parts 1 & 2)
  - IS: 1742 - Code of practice for building drainage
  - IS: 1893 - Criteria for earthquake resistant design of structures
  - IS: 1904 - Code of Practice for Design and Construction of Foundation in Soils: General Requirements.
  - IS: 2065 - Code of practice for water supply in buildings
  - IS: 2212 - Code of practice for brickwork
  - IS: 2338 - Code of practice for finishing of wood and wood based materials (Parts 1 & 2)
  - IS: 2394 - Code of practice for application of lime plaster finish
  - IS: 2395 - Code of practice for painting, concrete, masonry and plaster surfaces (Parts 1 & 2)
  - IS: 2470 - Code of practice for installation of septic tanks (Parts 1 & 2)
  - IS: 2502 - Code of practice for bending and fixing of bars for concrete reinforcement
  - IS: 2571 - Code of practice for laying in-situ cement concrete flooring
  - IS: 2595 - Code of practice for radiographic testing
  - IS: 2751 - Recommended practice for welding of mild steel plain and deformed bars for reinforced construction
  - IS: 2974 - Code of practice for design and construction of machine foundations (Parts 1 to 4)
  - IS: 3114 - Code of practice for laying of Cast Iron pipes
  - IS: 3370 - Code of practice for concrete structures for the storage of liquids (Parts 1 to 4)
  - IS: 3414 - Code of practice for design and installation of joints in buildings
  - IS: 3558 - Code of practice for use of immersion vibrators for consolidating concrete
  - IS: 3658 - Code of practice for liquid penetrant flaw detection
  - IS: 3935 - Code of practice for composite construction
  - IS: 4000 - Code of practice for High strength bolts in steel structures
  - IS: 4014 - Code of practice for steel tubular scaffolding (Parts 1 & 2)
  - IS: 4111 - Code of practice for ancillary structures in sewerage system (Parts 1 to 4)
  - IS: 4127 - Code of practice for laying of glazed stoneware pipes
  - IS: 4326 - Code of practice for Earthquake Resistant Design and Construction of Buildings
  - IS: 4353 - Recommendations for submerged arc welding of mild steel and low alloy steels
  - IS: 5329 - Code of practice for sanitary pipe work above ground for buildings
  - IS: 5334 - Code of practice for magnetic particle flaw detection of welds
  - IS: 5822 - Code of practice for laying of welded steel pipes for water supply
  - IS: 7215 - Tolerances for fabrication of steel structures
  - IS: 9595 - Recommendations for metal arc welding of carbon and carbon manganese steels
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IS: 10005 - SI units and recommendations for the use of their multiples and of certain other units

**28.4.4 Construction Safety:**

IS: 3696 - Safety code for scaffolds and ladder (Parts 1 & 2)  
IS: 3764 - Safety code for Excavation work  
IS: 7205 - Safety code for erection of structural steel work

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## **29 General Arrangement of Plant:**

**29.1** The following general guidelines shall be followed in the preparation of general arrangement of Plant:

**29.1.1** Sufficient room shall be allowed between items of plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance;

**29.1.2** An area adjacent to all mechanical Plant shall be provided as maintenance lay down area;

**29.1.3** fixed runways, lifting eyes or other means shall be provided to permit the removal of Plant that may be required to be removed during the course of its normal operational life for maintenance or any other purpose;

**29.1.4** areas where leakage is likely to occur whether in normal use or during maintenance shall be provided with covered drainage channels which shall direct spillage either to a suitable plant drain or to a sump from where it can be pumped to plant drain;

## **30 Orientation of Works:**

**30.1** The works shall be laid out within the confines of the Site in order to interface to the existing infrastructure of roadways and inlet and outlet pipe work. Underground services requiring to be relocated in order to accommodate the proposed site layout shall, with the approval of the Engineer, be relocated by the Contractor.

**31 Buildings and Structures-** All the building and structure works shall generally comply with the following Employer's Requirements unless otherwise specified elsewhere:

**31.1** All building works shall be of reinforced concrete framework.

**31.2** All internal and external walls shall be in solid cement concrete blocks of concrete grade M15 and shall be provided as per IS: 2185 (Latest Revision) and shall be 200 mm thick or 230 mm thick brick masonry walls.

**31.3** Toilet partition walls shall be in 150 mm thick solid concrete block or 115 mm thick brick masonry walls.

**31.4** For quantity of cement to be used per unit quantity of work refer R & B Department's circular STANDARDS FOR CEMENT CONSUMPTION FOR DIFFERENT ITEMS OF WORK published by Government of Gujarat dated 11.05.2017.

**31.5** Finishes to concrete structure:

**31.5.1** Finishes to concrete liquid retaining structures shall be :

- |    |   |   |
|----|---|---|
| F1 | - | External surfaces, buried                                     |
| F2 | - | External surfaces exposed and up to 300 mm below ground level |
| F2 | - | Internal surfaces   |
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**31.5.2** Finishes to other concrete structures shall be:

- F1 - Buried
- F1 - Exposed, where plastering is specified
- F2 - Exposed

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- 31.6** All internal masonry surfaces finish shall have 12 mm thick plain faced cement plaster in cement mortar (1:4) with neat cement finish on top. Over this, one coat of primer and two coats of plastic emulsion paint of approved quality and shade shall be provided.
- 31.7** All external masonry and concrete with rough board finish shall have 20 mm thick sand faced cement plaster in two coats, base coat 12 mm thick in cement mortar 1:4 and finishing coat 8 mm thick in cement mortar 1:4. Waterproofing compound of approved make and quality shall be added to the cement mortar in proportions as specified by the manufacturer.
- 31.8** All external surfaces above ground level shall have one coat of primer and two coats of waterproof cement based paint of approved quality and shade. A coat of silicone water repellent paint shall also be applied thereon.
- 31.9** Toilet areas, walls and ceilings, shall have one coat of primer and two coats of plastic emulsion paint.
- 31.10** Toilet floor slab shall be filled with brick bat coba (broken bricks in lime) and provided with waterproofing as per the specifications of an approved specialist waterproofing company.
- 31.11** The finished floor level in toilet areas shall be 25 mm below general finished floor level elsewhere in the building.
- 31.12** The flooring in all areas except toilets, staircases, pumping stations, chlorination building, centrifuge building, workshop, D.G. Room shall be in 250 mm x 250 mm x 20 mm thick marble mosaic tiles of approved make unless otherwise specified, shade and pattern and placed in cement mortar 1:4 to give overall thickness of 50 mm. Half tile skirting shall also be provided in these areas.
- 31.13** The flooring in the pumping stations, chlorination building, sludge dewatering building, maintenance workshop, D.G. Room shall be 60mm thick cement flooring with Metallic concrete hardener topping, under layer of 42mm thick cement concrete 1:2:4 (1 cement : 2 coarse : 4 graded stone aggregate 16mm thick nominal size) and top layer of 18mm thick metallic concrete hardener consisting of mix 1:2 (1 cement : 2 stone aggregate 6mm nominal size) by volume & mixed with metallic hardening compound of approved quality @ 3 kg/m<sup>2</sup>. Including cement slurry and rounding off edges.
- 31.14** Chlorine and chemical buildings should be acid resistant.
- 31.15** The flooring in operator's room, loading/unloading bay, MCC cum Panel room shall be in 25mm thick Kota stone slab of approved shade and pattern and placed over 20 mm thick base of cement mortar 1:4 to give overall thickness of 45 mm. Half tile skirting shall also be provided in these areas.
- 31.16** Toilet areas shall have 450 mm x 450 mm x 25 mm thick polished Kota stone tiles placed in cement mortar 1:4 to give an overall thickness of 50 mm. 2100 mm high dado, in 150 mm x 150 mm x 6 mm thick glazed tiles (approved make, shade and pattern) placed in cement mortar 1:3 shall also be provided in these areas.
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- 31.17** The flooring along with skirting in administration cum laboratory building shall be 20 mm thick mirror polished, machine cut granite slab of approved shade and pattern placed in cement mortar (1:4). 150mm high skirting shall be provided in these areas. Granite stone shall be provided for laboratory platforms fixed over double sandwiched cuddappah support as directed and the edges of granite is to be embedded into the wall.
- 31.18** The toilet facilities shall include at least:
- 31.18.1** 2 Nos. Water closets with white porcelain Orissa pan minimum 580 mm long with low level flushing cistern of 10 litres capacity.
- 31.18.2** 2 Nos. Urinals of sizes 600 mm x 400 mm x 300 mm flat back type in white porcelain separated by a marble partition of size 680 mm x 300 mm.
- 31.18.3** 2 Nos. Wash Basins of size 510 mm x 400 mm in white porcelain with inlet, outlet and overflow arrangements.
- 31.18.4** 2 Nos. mirror of size 400 mm x 600 mm wall mounted type fitted over wash basins.
- 31.18.5** 2 Nos. plastic liquid soap bottles.
- 31.18.6** 2 Nos. chromium plated brass towel rails minimum 750 mm long.
- 31.18.7** All stopcocks, valves and pillar cocks shall be heavy duty chromium plated brass.
- 31.18.8** All fittings such as 'P' or 'S' traps, floor traps, pipes, down take pipes etc.
- 31.18.9** The sewage from toilet blocks shall be led to the wet well of terminal sewage pumping station if present or included under this contract or to the closest gravity sewer.
- 31.19** All staircases shall have 25 mm thick chequered mosaic tiles for treads and 25 mm thick plain mosaic tiles for risers of approved make and shade and half tile skirting set in cement mortar in 1:4 to give an overall thickness of 50 mm.
- 31.20** All concrete stairs shall have aluminium nosing over 2 mm thick rubber strip of width same as nosing for the full length of the tread. Nosing shall be fixed with countersunk screws.
- 31.21** Stairways shall be provided to permit access between different levels within buildings. Staircase shall be minimum 1000mm wide unless specified otherwise. Staircases in general shall not be steeper than 40°. Staircases having space constraints may be steeper than 40°. The maximum vertical run for a single flight of stairs shall be 3.0 M.
- 31.22** All roof tops and overhead tanks shall be made accessible with ladder provision. Vertical step ladders fitted with landing point extensions will be permitted where considered appropriate by the Engineer to access areas not frequently visited.
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- 31.23** Steel staircases shall be constructed of standard channel stringers with M.S. grating treads 25mm thick with non skid nosing. Steel Ladders shall be minimum 600mm wide and shall not exceed 6m of straight run. The ladders shall be painted with epoxy paint.
- 31.24** Hand railing (3-rail) for the building shall be provided with 6063-T6 Aluminium Alloy with an ultimate tensile strength of at least 207 MPa and yield strength of at least 172 MPa. The minimum height of hand railing shall be 1m and maximum spacing of verticals shall be 1.5 m.
- 31.25** The reinforced concrete roofs shall be made waterproof by application of an approved roof polythene / bitumen membrane / brick bat coba. The finished roof surface shall have adequate slope to drain quickly the rain water to R.W down take inlet points.
- 31.26** All roof floors shall have minimum 750 mm height solid concrete block / brick wall parapet wall where accessible is provided and shall have minimum 300 mm height solid concrete block/brick wall parapet wall where accessible is not provided.
- 31.27** For roofing drainage, cast iron or uPVC rainwater down takes with C.I. bell mouth or uPVC bend and C.I. or uPVC grating at top shall be provided. For roof areas up to 40 sq m minimum two nos. 100 mm diameter down take pipes shall be provided. For every additional area of 40 sq m or part thereof, at least one no. 100 mm dia. down take pipe shall be provided.
- 31.28** Top surfaces of chajjas and canopies shall be made waterproof by providing a screed layer of adequate slope or application of an approved roof membrane and sloped to drain the rain water.
- 31.29** Building plinth shall be minimum 600 mm above average finished ground level around building or high flood level whichever is more.
- 31.30** All doors, windows, rolling shutters shall have lintels above. Chajja protection to lintels on external walls shall be such as to prevent the rain water splashing into the building. Chajja projection of minimum 750 mm for rolling shutters, 600 mm for doors and 450 mm for windows shall be provided to prevent the rain water splashing into the building. Chajja shall be projected 150 mm on either sides from size of doors/windows/rolling shutters. Continuous lintel should be provided if the height of the wall should be exceed 2.9m.
- 31.31** All windows and ventilators shall have 25 mm thick Kota stone sills bedded in cement mortar (1:3).
- 31.32** All doors and windows shall be painted with two coats of synthetic enamel paint over a priming coat (ready mixed Zinc Chromate Yellow primer of approved brand and manufacturer confirming to I.S.: 127-106, 341 and 340).
- 31.33** All doors, windows and ventilators shall be made of aluminium confirming to latest version of IS: 1948. All fixtures for doors, windows and ventilators shall also be of aluminium. Aluminium grills shall be provided in all the windows. Doors shall be in two panel and both panels shall be glazed/unglazed. Minimum weight of aluminium doors & windows shall be as follows
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### **31.33.1 Single Glazed Window: (Weights indicated shall be aluminium)**

#### **a) Openable**

Outer Frame	:	Weight 0.70 kg/Rmt
Shutter Frame	:	Weight 0.97 kg/Rmt
Intermediate Mullion	:	Weight 0.97 kg/RMt
Beading	:	Weight 0.31 kg/Rmt
Fixing Louvers windows/ventilators		
Outer Frame	:	Weight 0.46 kg/Rmt

### **31.33.2 Double Glazed Window**

Outer Frame	:	Weight 0.72 kg/Rmt
Shutter Frame	:	Weight 0.97 kg/Rmt
Intermediate Mullion	:	Weight 0.98 kg/Rmt
Beading	:	Weight 0.31 kg/Rmt

### **31.33.3 Sliding Windows**

Bottom & Top Frame	:	Weight 0.70 kg/m
Shutter Frame	:	Weight 0.42 kg/m
Interlocking Section	:	Weight 0.47 kg/m

### **31.33.4 Aluminium Door**

Outer Frame	:	Weight 2.508 kg/Rmt
Shutter Frame	:	Weight 2.508 kg/Rmt
Bottom Stile	:	Weight 2.508 kg/Rmt
Glazing shall be 5.5 mm thick glass.		

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- 31.34** Openings of the windows & ventilators shall be minimum 25% of the external wall area.
- 31.35** Ventilator shall be provided where height of floor is more than 3m.
- 31.36** All windows and ventilators shall have wire mesh. Frame of doors, windows and ventilators shall be of aluminium of standard rolled section. Doors, Windows and Ventilators shall be of size as per schedule to be submitted by the Contractor for approval of Engineer. The minimum size shall be as per below:
- Door of opening size 1.2m x 2.1m
- Door of opening size 0.75m x 2.1m for toilets
- Glazed windows of minimum size 1.2m x 1.2m
- Ventilators of minimum size 0.6m x 0.6
- 31.37** Rolling shutters shall be made of 80 x 1.25 mm MS laths. Rolling shutter shall be of minimum size 3m wide x 3.0m high. Rolling shutter shall be provided in MCC cum panel room, chlorine tonner shed, at entry and exit of the pump house for access to pumps, motors, valves, panels and as wherever required.
- 31.38** All concrete channels and ducts used for conveying liquid shall have inside finish of type F2. The width of concrete channels shall not be less than 500 mm. All open channels shall be provided with G.I. / Aluminium hand railings (3-rail) or concrete walls to a minimum height of 1 m from the access surface elevation. All concrete surfaces of structures conveying raw sewage or primary effluent upstream of the aeration tanks shall be protected from corrosion with an approved internal epoxy lining.
- 31.39** RCC Kerbs to be provided below the hand railing on the catwalks/pathways should be as per relevant sections of Factory Act. It shall not be less than 150mm.
- 31.40** All exposed surfaces of inserts embedded in concrete shall be painted with two coats of enamel paint over one coat of red oxide zinc chrome primer. Surfaces in contact with concrete shall not be painted.
- 31.41** All structural steel members shall be painted with two coats of enamel paint over one shop and one field coat of red oxide zinc chrome primer.
- 31.42** All rooms in the treatment plant buildings shall be provided with appropriate sign boards indicating the function of the rooms involved written in Gujarati and English Languages.
- 31.43** The design of buildings shall reflect the climatic conditions existing on site. Process buildings shall as far as possible permit the entry of natural light , and the use of glazed panelling shall be kept to a minimum and preference given to wall openings protected by weather canopies.
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- 31.44** Emergency exit doorways shall be provided from all buildings in order to comply with local fire safety regulations .Stairways and paved areas shall be provided at the exit points.
- 31.45** Toilet blocks in process buildings and control blocks shall be provided with a sink with two drinking water taps of 20 mm size with adequate inlet and outlet connections.
- 31.46** All the walkways shall have minimum 1.2 m width with kerb and shall be covered with mosaic tiles. Walkways to be provided with G.I / 6063-T6 Aluminium Alloy hand railings.
- 31.47** Anaerobic Sludge Digesters and Sludge Tank shall be built in RCC. A top dome of digesters shall be made of M.S. Steel work with inside surface of the dome shall be coated with Epoxy Coating as approved by Engineer and top surface Ring Beam and top 2m wall of the digester shall also be coated with Epoxy Coating. Contractor may submit his proposal for the alternative materials which can be used for digester dome along with all technical details. Employer will approve the type of material which shall be used for the construction digester domes depending upon the durability, corrosion resistivity, strength, ease in operation, functional requirements, economy, etc.
- 31.48** All concrete structures in contact with sewage and/or sludge upstream of the Aeration Basins shall be provided with full interior corrosion protection linings and/or coatings of appropriate material and thickness – to be approved by Employer. This also applies to all concrete structures in contact with any type of sewage sludge anywhere in the plant. For Aeration Basins, interior lining shall extend from the top of wall down to 1.0 meter below the lowest operating water level.
- 31.49** For structures containing water or process liquid, the top of the wall shall be atleast 0.5m higher than the maximum water surface level calculated at peak plant flow.
- 31.50** The top level of internal plant roads and approaches shall be at least 0.5m above the site High Flood Level. If the High flood level is more than Ground Level then road shall be constructed on the earthen embankment. Earthen embankment shall be constructed with side slope of at least 2 horizontal to 1 vertical. Stone pitching shall be provided at both sides of the embankment as per IS: 8237. Top width of embankment shall be taken as 6.0m. Top level of embankment shall be 0.5m above high flood level. Excavated earth from the plant can be used for embankment construction and if required, extra earth can be borrowed from the borrow pit as approved by Engineer.
- 32 Site Drainage-** The Contractor shall provide a site drainage system. The system shall comprise of the following:
- 32.1 Storm Water Drainage**
- 32.1.1** Storm water drains adjacent to the existing and proposed roads (under this Contract) shall be sized for a rainfall intensity of 50 mm/hr, allowing for 100% runoff. Drains adjacent to roads shall be in stone masonry in CM (1:4) of appropriate thickness, topped with 75 mm thick M10 concrete and internally flush pointed in cement mortar (1:4), 20 mm thick. The minimum width of drain shall be 450mm.
- 32.1.2** The storm water drainage system shall also be designed to cater the run-off from the existing plot areas and structures, if necessary depending upon the site topography.
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## **32.2 Foul Drainage**

- 32.2.1** The foul drainage system shall accept discharge from toilets, washrooms, offices and the laboratory. The foul drainage system shall be conveyed to either wet-well of the terminal sewage pumping station wherever exist or proposed under this contract or nearest public sewer wherever exist.

## **33 Cable and Pipe work Trenches**

- 33.1** Cable and pipe-work trenches shall generally be constructed in reinforced concrete. However, 500 mm x 500 mm size or smaller trenches, not on fill may be constructed in 200 mm thick solid cement concrete blocks / 230 mm thick brick work over 150mm thick M 15 PCC base. The trenches will be 20mm thick plastered internally with cement mortar (1:4) and externally in cement mortar (1:3).
- 33.2** All floor cut-outs and cable ducts, etc. shall be covered with M20 precast concrete covers (Heavy Duty) or MS grating as per direction of Engineer in outdoor areas and M.S. chequered plates, suitably painted of adequate thickness in indoor areas. All uncovered openings shall be protected with hand railing. The pipe, cable trenches shall be suitably sloped to drain off rainwater to a suitable location.
- 33.3** Layout of trenches outside the buildings shall allow space for construction of future trenches where necessary with due consideration for planning for future developments. This aspect shall be brought to the notice of the Engineer while planning the works.

## **34 Pipes and Ducts**

- 34.1** R.C.C ducts for drainage shall have minimum 1 metre pre-cast cover (M20 concrete, Heavy duty) while laid under roads. Access shafts of size not less than 600 mm x 1000 mm shall be provided.
- 34.2** All drains (except storm water drains adjacent to roads) shall be covered and designed structurally for appropriate loads.
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## **35 Main Gate**

- 35.1** Each proposed treatment plant shall have one main gate to access the plant irrespective of existing gate at the premises of existing plant site. Minimum width of main gate shall be 6m. Main gate shall have 1.5m wide wicket gate. Main gate shall have as external framework of GI pipes and internal framework of MS flats. Gate shall be fixed on RCC columns of min 350 X 350 mm size. The design and pattern of gate with drawing shall be submitted for approval of the Engineer. The gate shall have all necessary hinges, locking arrangement, rolling arrangement and painting complete, as approved by the Engineer.
- 35.2 Tree Planting-** Pits dug a few days in advance of actual planting shall be allowed to weather and be filled with top soil mixed with manure. Size of the pit shall be as per standard requirement. Only one tree shall be planted in each pit. A guard made of bamboo with wire mesh or bricks or M.S. ring as approved by Engineer, shall be provided.

## **36 Hydraulic Testing of Liquid Retaining Structures**

- 36.1** In addition to the structural test of structures, the liquid retaining structures shall also be tested for water tightness test at full supply level as described in 10.1.1, 10.1.2 and 10.1.3 of latest revision of IS 3370 (Part I).
- 36.2** On completion of the structure and before its commissioning, the Contractor shall carry out a water tightness test for the maximum water head condition i.e. with the water standing at Full Supply Level (FSL). This test shall be carried out preferably in dry season and prior to internal lining in accordance with the procedure given below:
- 36.3** The water tightness test shall be carried out when the construction of liquid retaining structure is done and when it is possible to fill the structure and ensure that uniform settlement of the structure as a whole or as directed by the Engineer. Before the filling operations are started the structure shall be inspected by the Engineer and the Contractor's Representative and the condition of surfaces of walls, contraction joints shall be noted and it shall be ensured that the jointing material filled in the joint is in position and all openings are closed. The Contractor shall make necessary arrangement for ventilation and lighting of the structure by way of floodlights, circulators etc. for carrying out proper inspection of the surfaces and inner conditions if so desired by the Engineer. Records of leakages starting at different levels of water in the reservoir, if any, shall be kept.
- 36.4** The liquid retaining structure once filled shall be allowed to remain so for a period of seven days before any readings of drop in water level are recorded. The level of the water shall be recorded against the subsequent intervals of 24 hours over a period of seven days. The total drop in surface level over a period of seven days shall be taken as an indication of the water tightness of the structure, which for all practical purposes shall not exceed 40 mm. Also there shall be no indications of the leakages around the opening or on the walls.
- 36.5** If the structure does not satisfy the condition of test and the daily drop in water level is decreasing, the period of test may be extended for a further period of seven days and if the specified limit is then reached the structure may be considered as satisfactory.
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- 36.6** The external faces of structure shall not show any signs of leakage and shall remain apparently dry over the period of observation of seven days after allowing a seven day period for absorption after filling.
- 36.7** In case the drop in level exceeds the permissible level limit and signs of leakage with the stipulated period of test, the Contractor shall carry out such additional works and adopt such measures as may be directed by the Engineer to reduce the leakage within the permissible limits. The entire rectification work that shall be carried out in this connection shall be at the Contractor's cost. The water required for subsequent testing shall be supplied to the Contractor free of cost, if the same is available near the site. Contractor shall have to make arrangement for filling emptying the structure at his own cost.
- 36.8** If the test results are unsatisfactory, the Contractor shall ascertain the cause and make all necessary repairs and repeat the water retaining structures test procedures, at his own cost. Should the re-test results still be unsatisfactory after the repairs, the structure will be condemned and the Contractor will dismantle and reconstruct the structure, to the original specification, at his own cost.
- 36.9** During testing and during defect liability period the impression marks created due to seepage shall be rectified and made good.
- 36.10** No separate payment shall be made for water tightness test and the cost thereof shall deem to be covered in the price quoted of different items of work of Sewage Treatment Plant.
- 37** **Compound Wall-** The compound wall (TYPE A or TYPE B) shall be constructed along the boundary of STP site (considering plant layout for intermediate and ultimate build out capacity and 33% landscaping area).
- 37.1** **TYPE A-**
- 37.1.1** Compound wall shall be of stone masonry / locally available material of approved quality and type. The wall shall be min. 300mm thick for stone masonry and min. 230 mm thick for brick masonry, the height shall be 2 meter above natural ground level. Minimum foundation depth shall be 1.0m for rock or up to good soil below ground level. Necessary expansion joints shall be provided as per latest IS standard or approved drawing.
- 37.1.2** Pilasters / Rectangular R.C.C. Column of 300 mm X 300 mm size at min. 3 meters spacing shall be provided along the length of the compound wall. Necessary tie beam / masonry foundation between the R.C.C column shall be provided to support the wall. Also coping, broken glass set, fabricated MS angles, GI barbed wire fencing 0.75 meter high on wall top shall be provided, all as approved by the Employer's Representative. Cement Mortar Pointing (CM 1:4) shall be provided on both side of the wall.
- 37.2** **TYPE B**
- 37.2.1** Compound wall shall consist of RC precast slab panels (M25), RC post at regular intervals including plinth beam as supports for the panels and necessary RC foundation system for the same along with barbed wire stretched between MS angles fixing at the top of the precast panels with necessary fixtures etc., (Typical Drawing enclosed).
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**37.3** All structural designs and Specifications shall confirm to relevant Codal provisions.

## **38 Pipes & Specials**

### **38.1 Unplasticized Poly Vinyl Chloride (uPVC) Pipes:**

- a) The latest versions of IS shall be adhered to for the design, manufacturing, inspection, factory testing, packing, handling and transportation, laying and jointing of the uPVC pipes. The rubbers shall be vulcanized from Ethylene Propylene (EPDM) confirming to IS 5382. The uPVC shall be of minimum 4 kg/cm<sup>2</sup> and as per IS 4985 and the pipes for plumbing work in office buildings shall be SWR (type B0 as per IS 13592, with electrometric sealing rubber ring joints. The method of sampling of rubber rings should be as per IS 5382.
- b) The material from which the pipes are made shall consist substantially of unplasticized PVC as per IS 10151, to which only those additives shall be added that are absolutely needed to facilitate the manufacture of the polymer and the production of sound, durable pipes of good surface finish, mechanical strength and opacity. The total quantity of additives like plasticizer, stabilizer, lubricants and fillers shall not exceed more than 7 %. The bulk density of uPVC pipes shall be 1.39 to 1.44 gm/cm<sup>3</sup>. The PVC resin suspension grade K-66/K-67 shall be used for extrusion of uPVC pipe. The uPVC fittings shall be fabricated from Class 4 uPVC as per IS 4985.

**38.1.1** Tests on Material: Following in house tests shall be carried out on the raw material:

- a) Grade (K-value)
- b) Particle size Distribution
- c) Bulk density of resin
- d) Bulk density of compound

**38.1.2** Acceptance Test on Pipes: The acceptance test shall be conducted in accordance with IS 4985 and presence of the Engineer's representative.

- a) Visual and dimensional Check
- b) Reversion test
- c) Vicat softening test
- d) Ash content
- e) Bulk density
- f) Resistance to external blows
- g) Internal Hydrostatic pressure test for pipes and joints
- h) Opacity

**38.1.3** Marking on Pipes- Each pipe shall be clearly marked as indicated below:

- a) Manufacturer's name and trade mark
  - b) outside dia in mm
  - c) Class of the pipe and pressure rating
  - d) Month and year of manufacturing
  - e) Length of pipe
  - f) Marking of insert depth of spigot
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**38.1.4** Marking on Rubber ring- Each sealing ring shall be permanently marked with:

- a) Manufacturer's name and trade mark
- b) Month and year of manufacturing
- c) Diameter of pipe for which the ring is suitable
- d) Type of rubber material

**38.1.5** Tests on Rubber Ring- Following tests shall be conducted on rubber rings conformity:

- a) Hardness
- b) Tensile strength
- c) Elongation at break
- d) Compression test
- e) Accelerated ageing
- f) Water absorption
- g) Stress relaxation

**38.2** Ductile Iron (DI) Pipes

- a) The DI pipes shall be centrifugally cast(spun) for water and sewage application and conforming to IS 8329-2000. The pipes used shall be both gasket joints and flanged joints. The minimum class of pipe to be used shall be class K-9 as per IS 8329. In general, pipes inside the buildings and below structures shall be jointed as double flanged pipes and those outside the building can either EPDM gasket as per IS 5382 and manufactured by the pipe manufacturer only.
- b) The pipes shall be supplied in standard length of 5.5 m and 6.00 m length with suitably rounded chamfered ends. Any change in the stipulated length should be approved by the engineer's representative. The flanged joint shall be as per IS 8329. The pipe supply will also include one rubber gasket for each flange.

**38.2.1** Inspection and testing- The pipes shall be subjected to following tests for acceptance.

- a) Visual and dimensional check as per IS 8329
- b) Mechanical tests as per IS 8329
- c) Hydrostatic tests as per IS 8329
- d) The test reports for the rubber gaskets shall be as per acceptance test of the IS 5382.
- e) Sampling shall be done as per IS 8329

**38.2.2** Marking- All pipes shall be marked as per IS 8329 and as show in below:

- a) Manufacturer's name /stamp
- b) Nominal diameter
- c) Class reference
- d) A white ring line showing length of insertion at spigot end

**38.2.3** Packing and Transport

- a) The pipes should be preferably transported by road from factory and stored as per the manufacturer's specifications to protect them from damage.
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#### **38.2.4** Specials for DI pipes

a) The DI specials shall be manufactured and tested as per IS 9523 or BS 4772. the mechanical test and hydrostatic test shall be as per IS 9523. The tolerances on the dimensions shall be as per Is 9523. The manufacturer of the pipes shall supply the fittings.

#### **38.2.5** Supply

a) All the DI fittings shall be supplied with rubber rings for each socket. The rubber ring shall be as per IS 12820 and IS 5328. flanged fittings shall be supplied with one rubber gasket per flange and the required numbers of nuts and bolts.

### **38.3** Reinforced Cement Concrete (RCC) Pipes

#### **38.3.1** Design

a) Design of RCC pipes including reinforcement details and the ends of pipes shall be in accordance with the relevant clauses of IS: 458.

#### **38.3.2** Manufacturing

- a) The method of manufacture shall be such that the form and the dimensions of the finished pipes are accurate within the limits specified in relevant clause of IS: 458. The surfaces and edges of the pipes shall be well defined and true, and their ends shall be square with the longitudinal axis. The ends of the pipes shall be further reinforced by an extra ring of reinforcement to avoid breakage during transportation.
- b) The RCC pipes and collars/rubber rings shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality.
- c) The Engineer shall at all reasonable times have free access to the place where the pipes and collars/rubber rings are manufactured for the purpose of examining and testing the pipes and collars/ rubber rings and of witnessing the test and manufacturing.
- d) All tests specified either in this Employer's Requirements or in the relevant Indian standards shall be performed by the supplier/contractor at his own cost and in presence of the Engineer if desired. For this, sufficient notice before testing of the pipes and fittings shall be given to the Engineer.
- e) If the test is found unsatisfactory, the Engineer may reject any or all pipes of that lot. The decision of the Engineer in this matter shall be final and binding on Contractor and not subject to any arbitration or appeal.

#### **38.3.3** Manufacturing

- a) For all materials Factory's test result, and written guarantee document with necessary analysis data shall be submitted to obtain the approval of the Engineer before carrying to sites.
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**38.3.4 Cement**

- a) Cement used for the manufacture of RCC pipes and collars shall conform to relevant IS codes. The use of pozzolana as an admixture to Portland cement shall not be permitted.

**38.3.5 Aggregates**

- a) Aggregates used for the manufacture of RCC pipes and collars shall conform to IS: 383. The maximum size of aggregate should not exceed one third the thickness of the pipe or 20mm, whichever is smaller.

**38.3.6 Mixing and Curing Water**

- a) Water shall be clean, colour less and free from objectionable quantities of organic matter, alkali, acid, salts, or other impurities that might reduce the strength, durability or other desirable qualities of concrete and mortar. Contractor shall submit water quality report before using it.

**38.3.7 Reinforcement**

- a) Reinforcement used for the manufacture of the RCC pipes and collars shall be mild steel Grade I or medium tensile steel bars conforming to IS:432 (Part-1) or hard-drawn steel wire conforming to IS: 432 (part-2). Reinforcement cages for pipes and collars shall be as per relevant requirement of IS:458.

**38.3.8 Concrete**

- a) Concrete used for the manufacture of RCC pipes and collars shall conform to IS: 456. The minimum cement content and minimum compressive strength of concrete shall be as per relevant requirements of IS: 458. Compressive strength tests shall be conducted on 15 cm cubes in accordance with the relevant requirements of IS: 456 and IS: 516.

**38.3.9 Curing**

- a) Pipes manufactured in compliance with IS: 458 shall be either water cured or steam cured in accordance with the relevant requirements of IS: 458.

**38.3.10 Dimensions**

- a) The internal diameter, wall thickness and length of barrel and collar of pipes, reinforcement (longitudinal and spiral), type of ends and minimum clear cover to reinforcement and strength test requirements shall be as per the relevant clauses / tables of IS:458 for different classes of pipes.
- b) The tolerances regarding overall length, internal diameter of pipes or sockets and barrel wall thickness shall be as per relevant clause of IS: 458.

**38.3.11 Workmanship and Finish**

- a) Pipes shall be straight and free from cracks. The ends of the pipes shall be square with their longitudinal axis so that when placed in a straight line in the trench no opening between ends in contact shall exceed 3 mm in pipes up to 600mm diameter (inclusive), and 6 mm in pipes larger than 600 mm diameter.
  - b) The outside and inside surfaces of the pipes shall be smooth, dense and hard, and shall not be coated with cement wash or other preparation unless otherwise agreed to between the Engineer and the manufacturer or supplier.
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- c) The pipes shall be free from defects resulting from imperfect grading of the aggregate, mixing or moulding.
  - d) The pipes shall be free from local dents or bulges greater than 3 mm in depth and extending over a length in any direction greater than twice the thickness of barrel.
  - e) The deviation from straight in any pipe throughout its effective length, tested by means of rigid straight edge parallel to the longitudinal axis of the pipe shall not exceed, for all diameters 3 mm for every meter run

#### **38.3.12 Testing**

- a) All pipes for testing purposes shall be selected at random from the stock of the manufacturer and shall be such as would not otherwise be rejected under the criteria of tolerances as mentioned in IS: 458. Engineer reserve the right to attend all testing.
- b) During manufacture, tests on concrete shall be carried out as per IS: 456. The manufacturer shall supply, when required to do so by the Engineer the results of compressive tests of concrete cubes and split tensile tests of concrete cylinders made from the concrete used for the pipes. The manufacturer shall supply cylinders or cubes for test purposes required by the Engineer and such cylinders or cubes shall withstand the tests prescribed as per IS: 458. Every pressure pipe shall be tested by the manufacturer for the hydrostatic test pressure. For non-pressure pipes, 2 percent of the pipes shall be tested for hydrostatic test pressure.
- c) The specimen of pipes for the following tests shall be selected in accordance with relevant clause of IS: 458 and tests in accordance with the methods described in IS: 3597.
  - I. Hydrostatic test
  - II. Three edge bearing test
  - III. Absorption test
  - IV. Visual Examination

#### **38.3.13 Sampling**

- a) In any consignment, all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of this Employer's Requirements shall be ascertained on the basis of tests on pipes selected from it.
  - b) The number of pipes to be selected from the lot for testing shall be in accordance with Table 15 of IS: 458.
  - c) Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every pipe be selected till the requisite number is obtained, or being the integral part of  $N/n$  where  $N$  is the lot size and  $n$  is the sample size.
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- d) All pipes selected shall be inspected by Engineer for dimensional requirements, finish and deviation from straight. A pipe failing to satisfy one or more of these requirements shall be considered as defective.
  - e) The number of pipes to be tested shall be in accordance with column 4 of Table 15 of IS:458. These pipes shall be selected from pipes that have satisfied the requirements mentioned in the above clause.
  - f) A lot shall be considered as conforming to the requirements of IS:458 if the following conditions are satisfied.
  - g) The number of defective pipes shall not be more than the permissible number given in column 3 of Table 15 of IS: 458.
  - h) All the pipes tested for various tests shall satisfy corresponding requirements of the tests.
  - i) In case the number of pipes not satisfying requirements of any one or more tests, one or two further samples of same size shall be selected and tested for the test or tests in which the failure has occurred. All these pipes shall satisfy the corresponding requirements of the test.
  - j) All result of tested data must be prepared by contractor at site so that the Engineer shall make decision of “fail or pass” at once. All cost for the test shall be borne by the Contractor.

**38.3.14 Marking** The following information shall be clearly marked on each pipe:

- a) Internal and External diameter and length of pipe
- b) Class of pipe
- c) Date of manufacture and
- d) Name of manufacturer or his registered trade-mark or both.

**38.3.15 Joining- General**

- a) Jointing of RCC pipes shall be done as per the requirements of following Employer's Requirements and as per the relevant IS standard. After jointing, extraneous material, if any, shall be removed from the inside of the pipe and the newly made joints shall be thoroughly cured. In case, rubber sealing rings are used for jointing, these shall conform to IS: 5382. The pipe joint work must be done neatly and keep even slope and level for pipe laying works.

**38.3.16 Spigot and Socket Joint**

- a) The spigot of each pipe shall be slipped home well into the socket of the pipe previously laid and adjusted in the correct position. The opening of the joint shall be filled with stiff mixture of cement mortar which shall be rammed with caulking tool. This joint is used for low pressure pipe line.

**38.3.17 Collar Joint**

- a) After laying the RCC pipes at proper alignment and gradient their abutting faces shall be coated with hot bitumen in liquid condition by means of a brush. The wedge-shaped groove in the end of the pipe shall then be filled with a tarred gasket in one length for each joint. The collar shall then be slipped over the end of the pipe and the next pipe butted well against the tarred gasket by suitable appliances approved by the Engineer so
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as to thoroughly compress the tarred gasket into the grooves, care being taken that the concentricity of the pipes and levels are not disturbed during this operation.

- b) The collar shall then be placed symmetrically over the end of the two pipes and the space between the inside of the collar and the outside of the pipe filled with a mixture of cement and sand to withstand any stress and prevent any water leakage, tempered with just sufficient water to have a consistency of the semi-dry conditions, well packed and thoroughly rammed with caulking tools. The joints shall be finished off with a fillet sloping at 45° to the side of the pipe. The finished joints shall be protected and cured thoroughly as directed by the Engineer. Any plastic solution or cement mortar that may have been squeezed into the inside of the pipe shall be removed so as to leave the inside of the pipe perfectly clean.

#### **38.3.18 Flush Joint (Internal)**

- a) This joint shall be generally used for culvert pipes of 900 mm diameter and over. The ends of the pipes are specially shaped to form a self-centring joint with an internal jointing space 13 mm wide. The finished joint is flush with both inside and outside with the pipe wall. The jointing space is filled with cement mortar mixed sufficiently dry to remain in position when forced with a trowel or rammer.

#### **38.3.19 Flush Joint (External)**

- a) This joint is suitable for pipes which are too small for jointing from inside. This joint is composed of specially shaped pipe ends. Each end shall be butted against each other and adjusted in correct position. The jointing space shall then be filled with cement mortar sufficiently dry and finished off flush. Great care shall be taken to ensure that the projecting ends are not damaged as no repairs can be readily effected from inside the pipe.

#### **38.3.20 Spigot and Socket (Semi Flexible)**

- a) This joint is composed of specially shaped spigot and socket ends on the RCC pipes. A rubber ring shall be lubricated and then placed on the spigot which is forced into the socket of the pipe previously laid. This compresses the rubber ring as it rolls into the annular space formed between the two surfaces of the spigot and socket, stiff mixture of cement and mortar shall then be filled into the remaining annular space with a caulking tool.

#### **38.3.21 Collar Joint (Semi-flexible)**

- a) This joint is made up of a loose collar which covers two specially shaped pipe ends. Each end shall be fitted with a rubber ring which when compressed between the spigot and collar, seals the joint. Stiff mixture of cement mortar shall then be filled to withstand stress and prevent any water leakage, into the remaining annular space and rammed with a caulking tool.

#### **38.3.22 Spigot and Socket Joint (Flexible)**

- a) The RCC pipe with the rubber ring accurately positioned on the spigot shall be pushed well home into the socket of the previously laid pipe by means of uniformly applied pressure with the aid of a jack or similar appliance. The RCC pipes shall be of spigot and socket type and rubber rings shall be used, and the manufacturer's instructions shall be deemed to form a part of these Employer's Requirements. The rubber rings shall be lubricated before making the joint and the lubricant shall be soft soap water or an approved lubricant supplied by the manufacturer.
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#### **38.3.23 Cleaning of pipes**

- a) As soon as a stretch of RCC pipes has been laid complete from manhole to manhole or for a stretch as directed by the Engineer, Contractor shall run through the pipes both backwards and forwards a double disc or solid or closed cylinder 75 mm less in diameter than the internal diameter of pipes. The open end of an incomplete stretch of pipe line shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.
- b) If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipe lines, he shall be entitled to order the stretch to be tested immediately. Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.
- c) It shall also be ascertained by contractor that each stretch from manhole to manhole or the stretch as directed by Engineer is absolutely clear and without any obstruction by means of visual examination of the interior of the pipe line suitably enlightened by projected sunlight or otherwise.

#### **38.3.24 Testing at work site**

- a) After laying and jointing of RCC pipes is completed the pipe line shall be tested at work site as per the following Employer's Requirements and as directed by the Engineer. All equipment for testing at work site shall be supplied and erected by contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be contractor's responsibility and shall be rectified by him to full satisfaction of the Engineer. Water used for the test shall be removed from pipes and not released to the excavated trenches.
  - b) After the joints have thoroughly set and have been checked by the Engineer and before back filling the trenches, the entire section of the sewer or storm water drain shall be proved by the contractor to be water tight by filling in pipes with water to the level of 1.50m above the top of the highest pipe in the stretch and heading the water up for a period of one hour. The apparatus used for the purpose of testing shall be approved by the Engineer. Contractor if required by the Engineer shall dewater the excavated pit and keep it dry during the period of testing. The loss of water over a period of 30 minutes should be measured by adding water from a measuring vessel at regular 10 minutes intervals and noting the quantity required to maintain the original water level. For the approval of this test the average quantity added should not exceed 1 liter/ hour/100 linear metres / 10mm of nominal internal diameter. Any leakage including excessive sweating which causes a drop in the test water level will be visible and the defective part of the work should be removed and made good.
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## **39 Gates and Valves :**

### **39.1 Sluice Gates**

#### **39.1.1 Design requirement and construction features**

The construction of the sluice gate shall be in accordance with the specification and generally as per AWWA C 560-00 / IS: 13349-1992 or other applicable standard. All sluice gates shall be of the rising spindle type. The sluice gates shall be capable of performing the duties set in this specification without undue wear or deterioration. They shall be constructed so that maintenance is kept to a minimum. All parts of sluice gate, including lifting mechanism components shall be designed for the heads required with a minimum safety factor of five.

#### **39.1.2 Frame**

- a) Guide shall be bolted to the frame of cast integrally with it and shall be machined on all bearing and contact faces.
- b) The length of guide shall be such that it should support the gate upon the horizontal line of stem nut pocket.
- c) Arrangement shall be made to prevent lateral movement of bolted on guides. they shall be capable of taking the entire thrust produced by water pressure and wedging action. Wedges or wedge facings shall be attached securely to the guides at points where, in the closed position, they will make full contact with the wedging surface on the slides.

#### **39.1.3 Seating Faces**

- a) Seating faces shall be made of full width, solid section; dove-tail strips of stainless steel. They shall be secured firmly by means of counter sunk fixing in finished dove-tail grooves in the frame and slide faces in such a way as to ensure that they will remain permanently in the faces shall be of ample section and finished smooth.

#### **39.1.4 Wedging Devices**

- a) Sluice gates shall be equipped with adjustable side, top and bottom wedging devices as required providing contact between the slide and frame facing when the gate is in closed position. All faces shall be machined accurately to give maximum contact and wedging action. wedges shall be fully adjustable screws and locknuts and so designed that they will remain in the fixed position after adjustment.

#### **39.1.5 Lifting Mechanism**

- a) Sluice gate shall be operated through suitable lifting mechanism which shall incorporate suitable gearing if required.
  - b) Lifting mechanism shall be suitable for operation by one man under all conditions. lifting mechanism shall incorporate a strong locking device suitable for use with a padlock or padlock and chain.
-



- c) The manual operation shall be of the hand wheel crank operated type and shall have a lift nut threaded to fit the operating stem. Crank shall be removable. Ball or roller thrust bearing shall be provided above and below the flange on the lift nut to take the load developed in opening and closing the gate with torque of 14 kg-m on the crank. Fitting shall be provided to lubricate gears and bearing.
- d) The design of the lifting mechanism of the hand operated gates shall be such that the slide can be operated with a torque of not more than 7 kg-m on the operator after the slide is unseated from wedges based on the operating head. the maximum crank radius shall be 380 mm.
- e) All gear and bearings shall be enclosed in cast iron housing with labyrinth seals. The lifting mechanism shall be with a cast iron pedestal, machined and drilled to receive the gear housing and suitable for bolting to the operating floor. The gates shall close with clockwise rotation of the crank. The direction of rotation to close the gate shall be indicated on the lift mechanism.
- f) A suitable means shall be provided for lubricating the stem threads directly adjacent to the lift nut. An inspection cover shall be provided to access the lift nut and gearing.
- g) Stem shall be provided with a GI pipe cover shall be fixed to the headstock.
- h) Lift mechanism shall be provided with a suitable position indicator to show the position of the gate at all times.

#### **39.1.6 Wall Thimbles**

- a) Wall thimbles shall be made of CI and shall be supplied along with the gate. The wall thimbles shall provide a rigid mounting, designed to prevent warping of the gate frame during installation.
- b) The cross section of the thimble shall have the shape of the letter 'F'. The front, or mounting flange, shall be machined and shall be drilled and tapped to the same template used for its particular gate frame. the frame shall be attached to the thimble with bolts of studs. The depth of the wall thimbles shall not be less than 300 mm.
- c) To permit entrapped air to escape as the thimble is being encased in concrete, holes not lesser than 35 mm diameter at not more than 600 mm span, shall be cast or drilled in each entrapment zone formed by the reinforcing ribs or the flange and water stop.

#### **39.1.7 Lifting Lugs- Lifting lugs shall be provided for all gates.**

#### **39.1.8 Flush Bottom Seal**

- a) When sluice gate are provided with flush bottom seals, the wedging device and facing along the bottom edge of the slide and frame shall be omitted.
  - b) A solid square cornered, resilient rubber seal shall be provided on the bottom facing of slide. The seal shall be securely fastened to the bottom face of the slide by a retainer bar and corrosion resistant metal fasteners. The top surface of the bottom facing of frame shall be flush with invert of the gate opening. Bottom facing of the slide shall be accurately machined to make contact with the seal when the slide is closed.
  - c) Suitable arrangement shall be made for on all the sluice gates or actuators such that the portable electrical actuator is capable of operating all sizes of sluice gates.
-

- d) One No. of portable type electrical actuator for closing and opening of sluice gates shall be provided at each STP, so that the closing and opening operation time shall be maximum of 10 min.
- e) Suitable arrangement shall be made on all the sluice gates or actuators such that the actuator is capable of operating all sizes of sluice gate, under this contract.
- f) Pipe hood shall be provided on the top of headstock to protect the spindle from damage dirt, dust, water etc. The hood shall be made of transparent fracture resistant polycarbonate material. The hood shall have vent holes to prevent condensation.
- g) The material of construction of sluice gate shall be as follows:

Component	Material
Wall thimble	CI: IS 210 Gr. FG 260
Frame & Slide	CI: IS 210 Gr. FG 260
Seating Faces	SS : ASTM Countersunk Fixing A276 type 316
Wedge	CI: IS 210 Gr. FG 260
Stem	SS: ASTM extension A276 type 316
Stem guide bracket	CI: IS 210 Gr. FG 260
Stem nut	SS : ASTM A743 CF8M
Stem Coupling	SS: ASTM A276 type 316
Fasteners, Anchor	SS: ASTM A276 type 316
Lifting Mechanism, pedestal gear house cover and stem guide	CI: IS 210 Gr. FG 260
Lift nut	Bronze : ASTM B 148 (CA 952, CA 954 or CA958)
Headstock Body	CI: IS 210 Gr. FG 260

### 39.2 Open channel Gates

- a) The manufacture of open gate channel shall be in accordance with manufacturer's standard.
- b) All open channel gate shall be of the rising spindle type and manually operated.
- c) Open channel gates shall be tested as per manufacturer's standard.
- d) The open channel gates for pumping station shall be CI sluice gates. All other gates shall be of marine grade aluminium alloy gates.
- e) The material of construction shall be as follows.

Components	Material	Specification	Grade
Gate frame, Shutter, headstock, Flush bottom seal support bar, stop nut	Cast Iron	IS 210-1993	FG:260
Sealing Faces / Seat Facings	SS	ASTM A276	AISI: 316
Resilient rubber seal	Natural Rubber EPDM		

	Rubber Neoprene Rubber		
Seal retainer bar	SS	ASTM A276	AISI: 316
Stem/Spindle	SS	ASTM A276	AISI: 316
Operating Nut/Stem nut	Leaded Tin Bronze	IS:318-1981	LTB 1, LTB 2
Fasteners	SS	ASTM A276	AISI: 316
Anchor Bolts	SS	ASTM A276	AISI: 316
Yoke	MS	IS: 2062- 1992	Grade A

### 39.3 Valves

#### 39.3.1 Sluice Valve

- a) Sluice valves shall be of rising spindle type. The valve shall be furnished with a bushing arrangement for replacement of packing without leakage. Shoe and channel arrangement shall be limited to valves of 450 mm and above. The gap between the shoe and channel shall be limited to 1.5 mm.
- b) Valves of 450 mm and above shall be provided with thrust bearing arrangement for ease of operation.
- c) Valves of Dia 450 mm and above shall be provided with enclosed gear arrangement for ease of operation. The operation gear of all valves shall be such that they can be opened and closed by one man against as unbalanced head 15% in excess of the maximum specified rating. Valves and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 400 N.
- d) All valves, spindles and hand wheels shall be positioned to give good access for operational personnel.
- e) All the hand wheel shall be arranged to turn in a clockwise direction to close the valve. the direction of rotation of opening and closing of the valve shall be indicated on the hand wheels.
- f) The material of construction of Valve shall be as follows:

Sr. No.	Component	Material
1	Body and Doors	CI IS 210 Gr. FG 260
2	Spindle	SS BS : 970 Gr 431
3	Seating rings	SS BS: 970 Gr 316
4	Back Seat Bush	Bronze IS:318 Gr LTB2
5	Shoe and channel linings	SS BS: 970 Gr 316

#### 39.3.2 Knife Gate Valves

- a) The valve shall meet the requirements of MSS SP 81 / AWWA C520-10.

- b) Outer body shall be provided with inner liner in corrosion resistant SS which shall extend into gland. The body shall be devoid of any wedge/dead pockets to avoid setting of suspended particles and solids in the service fluid. MOC & Design may be offered as per AWWA C 520-10 also.
- c) The gate/plate shall be precision buffed and the edge contoured to a knife edge. The gate shall move along / be guided by the seat ring to ensure that it scrapes any deposit / scale, enabling smooth uninterrupted movements.
- d) Seat shall be so designed that there is no recess / relieved groove to harbour deposition that could build-up and swamp the valve. The design to also incorporate bosses that guide the gate and avoid deflection, ensuring positive shut off.
- e) The stem shall have double start threads cut in order to ensure smooth and speedy operation.
- f) Gland packing shall offer minimal frictional resistance and precludes external lubrication. As positive sealing element, the packing shall also include a resilient rubber ring.
- g) The knife edge and seat face in flow path shall be hard faced to a hardness of 400 to 450 BHN to counter erosion. In such cases, provision shall also be made ensure the fluid contact with the seat ring minimal.
- h) The material of construction of valve shall be as follows:

Sr. No.	Component	Material
1	Body	CI IS:210 Gr FG 260
2	Inner Lining	SS BS:970 Gr 316
3	Knife gate/plate	SS BS:970 Gr 316
4	Stem	SS BS:970 Gr 316
5	Seat ring/Boss	SS BS:970 Gr 316
6	Gland Housing	DI BS:2789 Gr 500
7	Gland Packing	Teflon Impregnated with the asbestos + rubber

### 39.3.3 Butterfly Valves

- a) This valves shall be installed at the pipe-line to seal the water or air and to adjust the flow.
- b) Valves shall be used suitable for throttling operations and for infrequent operation after period of inactivity.
- c) The body of the valve shall be made from cast iron of ductile iron.
- d) Valves shall have fabricated steel, cast iron or ductile iron discs with a resilient rubber sealing ring.

- e) Valves stem, shall be if stainless steel designed for both torsion and shearing stresses when the valve is operated with permanently self-lubricated shaft stub bearing, sized to withstand bearing loads.
- f) Butterfly valves shall be provided with hand-wheels and rack and pinion gearing operation. the valves shall be open by turning the hand wheel in an anticlockwise direction. the direction of valve opening and closing shall be marked on the hand wheel casing.
- g) The valve shall be designed to hold the disc in any intermediate position between fully opened to fully closed without creeping or fluttering by manual or electrical operation.
- h) The material of construction of valve shall be as follows:

Sr. No.	Component	Material
1	Body	CI IS 210 Gr. FG 260
2	Disc	CI IS 210 Gr. FG 260
3	Stem	SS 316
4	Seat	Rubber or Equivalent

#### 39.3.4 Non Return Valves

- a) The internal parts of the valves shall be easily accessible for inspection through inspection hole.
- b) Hydraulic passages and door shall be designed to avoid cavitations.
- c) Valves shall be of swing type or ball type. Ball valves must house a freely moving ball in such a way that return flow is effectively prevented.
- d) Valves shall be quick closing type with non-slam characteristics. In case of swing type, the non slam characteristics shall be achieved by providing suitable combination of door and hydraulic passages without any external level/damping arrangement.
- e) Valves of 450 mm and above shall be provided with supporting foot
- f) Swing door valves of size 600 mm and above shall be of multi door type.
- g) Direction of the flow shall be clearly embossed on the valve body
- h) Maximum pressure drop across the valve shall be 0.4 mm WC
- i) Maximum allowable leakage rate shall be 7 cc/hr/mm diameter.
- j) The material of construction of valve shall be as follows

Sr. No.	Component	Material
1	Body & Door	CI IS 210 Gr. FG 260

2	Body and door Ring	SS ASTM A743 CF8, BS 970 Gr. 316 S11
3	Hinge Pin	SS BS 970 431 S49
4	Bearings	Teflon

### 39.3.5 Telescopic Valve

- The telescopic valve shall be a proprietary item of proven design manufactured in CI and adjustable to cater for 1000 mm variation in level.
- The bell mouth height shall be controlled by a hand wheel operated from top of the chamber.
- The bell-mouth, pipe work, spindle and headstock shall be robustly constructed with adequate brackets of cast iron.
- The ball mouth shall be connected by swept tees to a CI sludge outlet pipe of 300 mm diameter.
- Material of construction shall be as follows.

Sr. No.	Component	Material
1	Bell Mouth	CI IS : 210 Gr. FG 260
2	Piping	CI IS 210 Gr. FG 260
3	Spindle	SS 316
4	Hand Wheel	CI IS 210 Gr. FG 260

### 39.3.6 Pressure / Vacuum relief Valves

- Pressure relief valves shall be capable of relieving pressure in the system to prevent the system being pressurized in excess of a present maximum allowable pressure. the valves shall be drops tight under no flow conditions.
- Vacuum relief valves shall be capable of preventing the vacuum pressure to be developed in the system by allowing air entry. The valves shall be drops tight under no flow conditions.
- The valve operation shall be achieved by the interaction of the inlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valve.
- The pilot valve or relay system shall be actuated by a diaphragm connected to the inlet pressure on its underside and a constant pressure on its upper side derived either from weights or from a spring.
- Body ends shall be flanged and drilled to BS 4504.

**Section – 5c**  
**Technical Specifications for Mechanical Works**

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<b>Sr. No</b>	<b>Description</b>
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2	General
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4	Pumps and Mixers
5	Induction Motor
6	Material Handling Equipment
7	Auxiliary Equipment

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## **1. INTRODUCTION**

- 1.1.** This part of Owner's requirements sets out the general standards for mechanical equipment to be used by the contractor for the works. Any item not mentioned herein but required for completion of work shall have to be taken into account by the contractor. Reference to any specific items does not necessarily imply that it is to be included in the works. All equipment used for the works shall, unless otherwise specified, comply with the provisions of this chapter. Successful Bidder has to submit the list and schedule of all design / drawings / calculation / QAP/ etc within 1 month of issue of LOI.

## **2. GENERAL**

### **2.1. Material**

All materials incorporated in the works shall be the most suitable for the duty concerned and shall be new & from reputed/approved make or approved quality and of first class commercial quality, free from imperfection and selected for long life and minimum maintenance. Destructive/Non-destructive tests, if called for, shall be carried out. All the moving parts of the plant, or shaft and spindles or faces etc. In contact with them shall be of corrosion resistance materials. All parts directly in contact with various chemicals, shall be completely resistant to corrosion, or abrasion by these chemicals, and shall maintain their properties without aging due to the passages of time, exposure to light or any other causes. All material shall conform to the material as per BIS or any equivalent standard. All stainless steel materials used shall be of SS 316 unless otherwise specified.

### **2.2. Workmanship**

Workmanship and general finish shall be of first class quality and in accordance with best workshop practice. All welds shall be as per BIS or any equivalent standards. All tolerances and clearance shall be as per good and sound engineering practice. Should the owner's representative not consider any material acceptable, it shall be replaced.

### **2.3. Design Features**

- a) As far as practicable, all proposed designs shall be as per latest proven concepts and practices. The equipment shall be new, of robust design for long reliable operating life. These shall be capable of 24 hours operation in a day for 365 days in a year for continuous operation for a long period in the climatic and working conditions prevailing at the site and with a minimum of maintenance. Particular attention shall be given to extra temperature and the rating of electrical and mechanical equipment, cooling systems and choice of the lubricating system.
- b) The equipment shall be designed to provide easy access to and replacement of the component/parts which are subjected to wear without the need to replace whole units. All parts in contact with water/sewage/chemicals shall have a life from new to replacement for 15 years minimum and new to repair of not less than five years. Design features shall include the protection of equipment against damages caused by vermin, dirt, dust and dampness and to reduce the risk of fire. Equipment shall operate without undue vibration.
- c) The noise level produced by any equipment like pump sets, compressor sets,

blowers etc., shall not exceed 85 dB(A) measured at a distance of 1.86 m from outer surface of source. At the time of operation, the mechanical vibration shall not exceed the limit given in the **Table 2-1**, at recommended points of the measurement as per ISO 10816:1995.

- d) During the commissioning of the plant/equipments if noise level/vibrations found beyond the permissible limit, contractor to rectify/replace the particular equipment at no extra cost with in mutually agreed time limit. During the O&M period (O&M is done by contractor) if noise/vibration of equipment found beyond the permissible limit, rectify/replace of the particular equipment shall be responsibility of contractor.

- e) **Table 2-1** : Permissible Equipment Velocity of vibration (in mm/sec)

Sr. No.	Equipment	Permissible Velocity of Vibration (in mm/sec)
1	All rotating equipment without reciprocating parts of motor rating $\leq 15$ kW	1.12
2	All rotating equipment without reciprocating parts of motor rating $> 15$ kW & $\leq 75$ kW	1.8
3	All rotating equipment without reciprocating parts of motor rating $>75$ kW	2.8

- f) Parts shall be design to withstand the maximum stresses under the most sever conditions of normal service. All rotating elements shall be dynamically and statically balanced.

#### 2.4. Lubrications

- a) The equipment shall be lubricated by long life lubricants such that working life is not less than 3000 operation hours or as per recommendation of the equipment manufacturer.
- b)
- c) A complete schedule of recommended oils and other lubricants shall be furnished by the bidder. The number of different types of lubricants should be kept to minimum. The schedule and the name of the supplier of the lubricant shall be submitted to the owner's representative for approval.
- d)
- e) Lubricants shall be oil and grease. The contractor shall indicate indigenously available equivalent lubricants with complete specifications.
- f)
- g) Where the lubricant is grease, preference shall be given to a pressure system which does not require frequent adjustment or recharging. Preferably, life lubricated grease packed bearings shall be used. Grease gun for each type of grease used shall be supplied.

#### 2.5. Name Plates

Each equipments of the plant shall have permanently attached to it a nameplate and rating plate in a conspicuous position, upon these shall be engraved or stamped, the manufacturer's name, type and serial number of the equipment, details of the loading and duty at which the equipment has been designed to operate, and such diagrams as may be required by the owner's representative. All indicating and operating devices shall securely attach to them or marked upon them designations as to their

function and proper manner of use.

## **2.6. Painting**

### **2.6.1. At Manufacturer's Work**

- a) The contractor shall be responsible for the cleaning, preparation for painting and priming or otherwise protecting, as specified, all parts of the plant/equipment at the place of manufacture prior to packing.
- b) Parts may be cleaned but surface defects should not be filled in before testing at manufacture's work. Parts subjected to hydraulic test shall be tested before any surface treatment. After testing, all surfaces shall be thoroughly cleaned and dried out, if necessary by washing with as approved dewatering fluid prior to surface treatment. Except where the specification provides to the contrary, all painting materials shall be applied in strict accordance with the paint manufacturer's instructions.

Steel and cast iron parts shall be sand blasted to near white cleaning before painting. Edges, sharp corners etc. Shall be grounded to a curve before sand blasting. A primer coat of a zinc rich epoxy resin based coating with at least 75 microns dry film thickness is to be provided. In addition, the parts for wet duty are to be provided with an adequate number of coats of coal tar epoxy polyamine coating to a dry film thickness of 175 microns excluding primer coating.

### **2.6.2. At Site**

- a) Immediately on arrival at the site, all items of the plant shall be examined for damage to the paint coat applied at the manufacturer's work. Any damaged portions shall be cleaned down to the bare metal, all rust removed, and the paint coat made good with similar paint. After erection, such equipment/items which are not finish painted shall be done so. Items that have been finished painted at the manufacturer's work shall be touched up for any damaged paint work. Damaged paint during erection shall be made good with similar paint.
- b) For finish painting, two coats of synthetic enamel conforming to IS: 2932 shall be applied. Dry film thickness of each coat shall be at least 25 microns. The dry paint film thickness shall be measured by Elcometer or other instruments approved by the owner's representative. In order to obtain the dry film thickness specified, the contractor shall ensure that the coverage rate given by the paint manufacturer will enable this thickness to be obtained. Strength of adhesion shall be measured with an adhesion tester and this value shall not be less than 10 kg/cm<sup>2</sup>.
- c) Painted fabricated steel work which is to be stored prior to erection shall be kept clear of the ground and shall be laid out or stacked in an orderly manner that will ensure that no water or dirt can accumulate on the surface. Suitable packing shall be laid between the stacked materials. Where cover is provided, it shall be ventilated.

## **2.7. Galvanizing**

Wherever galvanizing has been specified the hot dip process shall be used and electro galvanized parts, equipments shall not be permitted. The galvanized coating shall be of uniform thickness. Weight of zinc coatings for various applications shall not be less than those indicated below:

- i) Fabricated Steel : 460 gm/m<sup>2</sup>
  - ii) Fasteners : 300 gm/m<sup>2</sup>
- b) Galvanizing shall be carried out, after all drilling; punching, cutting, bending and welding operations have been carried out. Burrs shall be removed before galvanizing. Any site modification of galvanized parts should be covered well by zinc rich primer and aluminum paint.

## **2.8. Wet Well**

- a) In order to prevent surcharging of sewers, the maximum level of sewage in the suction/wet well of the TSPS/ISPS shall be limited to 500 mm below the invert of the lowest incoming sewer.
- b) For the TSPS/ISPS, in order to prevent sewage from turning septic, maximum retention of sewage in the wet / suction well shall not exceed 30 minutes for the average flow.

The depth of sump shall be such that it provides at least 15 % margin over the minimum required pump submergence calculated at duty point on the basis of the Hydraulic Institute Standard.

- d) The wet well effective operating volume (volume between low level where all pumps are shut off and high level where all pumps except standby are operating) shall be such that the hydraulic retention time in this volume at peak flow is not less than 5 minutes and the number of starts per hour does not exceed 6 for any single pump under any circumstances.
- e) Appropriate baffles shall be provided in the wet/suction well to prevent the excessive turbulence and air entrainment when free fall of material to be pumped occurs.
- f) Benching shall be provided at the bottom of the wet well towards the suction bell mouth to ensure that the pumps can be used to completely drain the wet well. The wet well design shall incorporate corner fillets and ogees as appropriate to eliminate dead spots, prevent accumulation of solids or debris, and to ensure that the wet well is fully self-cleaning – automatically cleaned by the hydraulics of the flow.
- g) Priming of pumps shall be ensured by providing positive suction head.
- h) Operation of sewage pumps shall be automatic based on the sewage levels in the wet well.
- i) Standby unit of each type and size of pump employed shall be provided as specified in particular mechanical requirement and these shall be minimum requirement.
- j) The clearance between pumps outer periphery (or pump foundations) shall be not less than 1000 mm.
- k) Sequence of operation of raw sewage pumps shall be changed every 8 hours to avoid accumulation of solids in the wet/suction well.
- l) 5% margin on the pump capacity shall be provided for all the pumps.

- m) The total head of the pump shall be selected considering peak flow and maximum design level in the wet well for normal conditions of operation and checked for satisfactory operation under extreme conditions of operation; the selected head to be revised if required.
- n) The minimum permissible velocity in the pumping mains shall be 0.5 m/sec. The maximum velocity in the pumping main shall not exceed 2 m/sec.
- o) All dry well pumping stations shall be provided with a pit and drain pumps (1 working + 1 standby) to automatically empty the stuffing box drain.
- p) Ventilation shall be provided for the pumping station based on 10-12 air changes per hour.
- q) For TSPS/ISPS, mechanical rake coarse bar screen shall be provided upstream of the pumping station wet well. Provisions shall be made to allow lifting of screenings by belt conveyor.
- r) Appropriate lifting devices shall be provided for safe and easy retrieval and/or removal of the pumps from wet well or dry well for maintenance or any other purpose at all pumping stations.

### **3. VALVES & BELLOWS**

#### **3.1 Sluice Valve**

Sluice valve shall conform to IS 14846-2000 or relevant internationally recognized standards.

The valve shall be of non-rising spindle type. The valve shall be furnished with a bushing arrangement for replacement of packing without leakage. They shall also have renewable channel and shoe linings. The gap between the shoe and channel shall be limited to 1.5 mm.

The gate face rings shall be securely pegged over the full circumference.

Valve of 450 mm and above shall be provided with thrust bearing arrangement for ease of operation.

Valve of diameter 400 mm and above shall be provided with enclosed gear arrangement for ease of operation. The operation gear of all valves shall be such that they can be opened and closed by one man against an unbalanced head 15% in excess of the maximum specified rating. Valve and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 400N.

All valves, spindles and hand wheels shall be positioned to give good access for operational personnel.

All hand wheels shall be arranged to turn in a clockwise direction to close the

valve, the direction of rotation for opening and closing being indicated on the hand wheels.

### 3.1.1 Specific requirement

- i. Fluid to be handle: Raw Sewage
- ii. Nominal Size of Valve: As per Piping and Instrumentation diagram
- iii. Nominal design pressure: PN 1.6
- iv. Material of Construction: For major component refer Table 3.1, for remaining component applicable IS code to be followed
- v. Flange Dimensions: As per applicable IS code
- vi. Body Type: PD type short body
- vii. Marking: As per applicable IS code
- viii. Additional marking: "GWSSB" or as per approved QAP & shut and open direction on hand wheel
- ix. Testing: As per applicable IS code
- x. Mode of operation: Manual Hand wheel operated for below 400 mm size & For 400 mm and above manual hand wheel operated with gear arrangement

Table 3.1: Material of construction for Sluice Valve

Sr. No.	Component	MOC
1	Body, Bonnet, Dome, Stool Cover, Wedge, Stuffing Box, Gland, thrust plat, Cap, Hand Wheel, Gear Housing	IS:210, FG 260
2	Stem	SS AISI 410
3	Wedge Nut, Shoe, Channel, Body seat ring, wedge facing ring & Bushes	IS : 318, LTB-2
4	Gasket, Gland packing	IS: 638, Type B
5	Gear	IS: 1865, Gr 500/7
6	Pinion & Pinion Shaft	IS:1570, part 3, C55Mn75
7	Fasteners	SS 304

### 3.2 Non return Valve

ISI marked Non return valve as per IS: 5312 are to be provided. The valve shall be suitable for mounting on a horizontal pipeline and flow direction shall be clearly embossed on the valve body.

#### 3.2.1 Specific requirement

- i. Fluid to be handle: Raw Sewage
- ii. Nominal Size of Valve: As per Piping and Instrumentation diagram
- iii. Nominal design pressure: PN 1.6
- iv. Material of Construction: For major component refer Table 3.2, for remaining component applicable IS code to be followed
- v. Flange Dimensions: As per applicable IS code
- vi. Marking: As per applicable IS code
- vii. Additional marking: "GWSSB" or as per approved QAP
- viii. Testing: As per applicable IS code

Table 3.2: Material of construction for Non return Valve		
Sr. No.	Component	MOC
1	Body, Cover Door, bearing housing, Hinges	IS:210, FG 260
2	Hinge Pin, Door Pin, door suspension pin	SS AISI 410
3	Door seat ring, Door face ring, bearing bushes / block, Plugs for hinge	IS: 318, LTB-2
4	Gasket	IS: 638, Type B
5	Fasteners	SS 304

### 3.3 Dual Plate Check Valve

The valve shall be suitable for mounting on a horizontal pipeline and flow direction shall be clearly embossed on the valve body.

Valves shall possess high speed closing characteristics and be designed for minimum slam condition when closing.

Dual plate check valves shall conform to IS: 5312 They shall have metal to metal sealing. The spring action shall optimize the equal closing rates of each plate especially when the friction coefficients are uneven due to one plate resting upon one another. The plates shall not drag on the seat while opening. The plates shall not vibrate under full or partial flow condition.

In case of the nozzle check valve, the disc shall be correctly positioned at all times to achieve fully non-slam closure. The spring shall be fully shielded from the flow stream by the central flow diffuser.

Tilting disc non-return valve shall incorporate a double offset shaft with a variable angle tilt disc configuration. Sealing shall be metal to metal. The disc shall be stable and shall not vibrate under full or partial load conditions.

Valve of diameter greater than 450 mm shall be provided, in addition to others, feet and jacking screws. Hinge pins / shaft shall preferably be square in section to ensure positive location of flaps and provide for secure fixing.

#### **Hydro test Pressure as per IS-5312(Part – I):2000**

Rating	Test for	Test Pressure
PN 1.0	Body	15 kg / cm <sup>2</sup> (1.5 MPa)
	Seat	10 kg / cm <sup>2</sup> (1.0 MPa)
PN 1.6	Body	24 kg / cm <sup>2</sup> (2.4 MPa)
	Seat	16 kg / cm <sup>2</sup> (1.6 MPa)

#### **Materials of Construction for DPCV**

Sr. No.	Component	Material
(a)	Body Cast Iron:	IS 210 Gr. FG 260
(b)	Disc	Aluminium Bronze
(c)	Stop & hinge pin	SS AISI-410
(d)	Seat ring (Disc)	EPDM Rubber
(e)	Bearings (Body& Plate lug)	PTFE
(f)	Body Seat	SS AISI-410
(g)	Spring	Spring steel

### **3.4 Air Valve**

Air valve (as per IS 14845) with sluice valve for isolation to be provided. For Sluice valve Specification as per clause 2.1 is to be followed.

#### **3.4.1 Specific requirement**

Fluid to be handle: Raw Sewage



- Nominal Size & Type of Valve: As per BOQ  
Nominal design pressure: PN 1.6
- Material of Construction: For major component refer Table 3.4, for remaining component applicable IS code to be followed
- Flange Dimensions: As per applicable IS code
- Marking: As per applicable IS code
- Additional marking: "GWSSB" or as per approved  
QAP Testing: As per applicable IS code

Table 3.4: Material of construction for Air Valve		
Sr. No.	Component	MOC
1	Body, cover, valve disk, stuffing box, valve guide, cowl, gland, cap, joint support ring	IS:210, FG 260
2	Float (both)	SS AISI 304
3	High pressure orifice, Float guide	IS: 318, LTB-2
4	Gasket	IS: 638, Type B
5	Fasteners	SS 304

### 3.5 Expansion Below

The metallic single expansion bellows with all parts shall be manufactured as per EJMA standards. The rating of metallic expansion bellows is PN 1.6. The bellow shall have both flanged ends as per applicable IS code. Bellow shall have minimum axial extension of 5 mm & minimum axial compression shall be 15 mm. It adequate capacity to compress and expand within the limit mentioned in its entire life cycle of minimum 7000 cycles. It shall be retained for the entire design period. The period shall have to be mentioned by the bidders.

#### 3.5.1 Specific requirement

Fluid to be handle: Raw Sewage

- Nominal Size & Type of Valve: As per BOQ  
Nominal design pressure: PN 1.6
- Material of Construction: For major component refer Table 3.4, for remaining component applicable IS code to be followed
- Flange Dimensions: As per applicable IS code

- Marking: As per applicable IS code
- Additional marking: “GWSSB” or as per approved QAP Testing: As per applicable IS code
- Testing: Hydro test at 24 kg/cm<sup>2</sup> for 30 minutes

Table 3.5: Material of construction for Expansion Bellow

Sr. No.	Component	MOC
1	Bellows / Collar / Internal sleeve	SS AISI 304
2	Limit Rods	SS AISI 304
3	Fasteners	SS AISI 304
4	Lugs / Flanges / Welded	SS AISI 304

#### **4. PROCESS EQUIPMENTS:**

##### **4.1. Mechanically Medium Bar Screen**

###### **4.1.1. Purpose**

- a) Mechanical screens should be suitable for installation in Sewage treatment plant for removal of floating wastes coming along with sewage. These screens should be capable to screen out most of the medium and large floating material such as plastic bags, floating debris, weeds, paper wastes, clothes and rags etc. Which are generally clogging the impellers of the pumps installed downstream of the screens.
- b) The operation of the screen shall be automatic. An ultrasonic type differential level controller shall be provided to sense the head loss through the bar and give the signal to the travelling raking mechanism to start its operation. The sensor will signal the raking mechanism to operate continuously till the head loss is reduced to a present level.
- c) A complete electrical control system shall be supplied with each screen and shall be mounted independently near to the screen installation. The system shall provide for total automatic operation of the screen with the feedback from the level controller.

###### **4.1.2. General**

- a) The screen shall be of the front raking type with aperture size of 60 mm. All the materials and sub-assemblies used shall be suitable for outdoor application. They shall be constructed so that maintenance is kept to a minimum. There shall not be any moving part, sprocket, bearing, etc. Continuously immersed in sewage. All lubricating points shall be conveniently accessible from the deck level.
- b) The screen shall be suitable for discharging 75% of the screened material lifted from the screen in to chute. The screen shall be designed such that in case of heavy accumulation of solids, the same is to be removed gradually without overloading or damaging the screen bars or mechanism.

###### **4.1.3. Scope:**

- a) Contractor shall furnish and install mechanically cleaned bar screens with multiple rake blades. Each screen shall be manufactured from SS 316 stainless steel shapes. Fabrication and assembly shall be in conformance with this specification.
  - b) Each screen shall be furnished complete with bar rack, dead plate, discharge chute, side frames, covers, rake blades, drive chains, sprockets and bearings , scraper assembly, drive motor, gear reducer, anchor bolts, controls and all accessories and appurtenances specified or otherwise required for complete and properly operating installation.
  - c) Contractor shall coordinate all details of the equipment with other related parts of the work. He shall verify that all structures, piping, wiring, and equipment
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components are compatible. Contractor shall be responsible for all structural and other alternations required to accommodate equipment differing in dimensions or other characteristics from these specifications and drawings.

- d) Contractor shall install the equipment according to instructions and recommendations of the equipment manufacturer.
- e) Power supply is 400Volts, 50Hz, 3-phase.

#### **4.1.4. Material**

- a) Screen shall be manufactured from AISI 316 stainless steel shapes (rods, angles, and channels), pipes and sheets. In particular, side frames and guides, bar rack, rake assembly, scraper assembly, shafting, discharge chute, fasteners and anchor bolts shall be made of this material.
- b) Screen shall be manufactured in a stainless steel factory only to prevent contamination of the stainless steel with rusty dust.
- c) All stainless steel components and structures shall be submersed in a chemical bath of nitric acid and hydrofluoric acid (pickling bath) to remove any residues that may be present on the material as a result of forming, manufacture, or handling. After removal from the pickling bath, the equipment must be washed with a high-pressure wash of cold water to remove any remaining surface debris and promote the formation of an oxidized passive layer which is critical to the long life of the stainless steel.
- d) Chains and sprockets shall be made of SS 316.
- e) Lower sprocket bearing shall have a stainless steel casing including a shaft made of white cast iron and a ceramic (calcium carbide) friction bushing.
- f) Upper sprocket bearings shall have a paint coated cast iron casing and include ball bearings that are greased for life and shall be double-sealed with Nilos rings.

#### **4.1.5. Performance & Design Requirements**

- a) Separation of floating, settling and suspended material from wastewater by means of an inclined bar rack installed within the channel.
  - b) Both ends of the cleaning elements are connected to drive chains.
  - c) Each chain is driven by a sprocket on a common shaft and a flange mounted gear motor.
  - d) Furthermore, defined meshing of the cleaning rakes with bar rack ensures a high operating reliability.
  - e) The cleaning elements, attached to the chain system, should be adjustable.
  - f) The cleaning elements, consisting of the rake and comb plate, are screwed and thus independently replaceable.
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- g) If the screen operation is blocked, the electromechanical torque control reliably protects the screen against damage caused by overload.

#### **4.1.6. 1 Frame work**

- a) The frame work of the screen should be such that it should mount on the top of the channel wall. Screen construction should be such that, it should mount only on top of the channel wall. The frame will rest on the special supports installed on the wall along the depth of channel. In case of maintenance, screen should be able to be lifted out from the top with crane. No personnel should go inside the screen chamber for any type of maintenance or repair work.

#### **4.1.7. 1 Screens Construction**

- a) The bar Screen shall remove floating materials from the incoming wastewater by means of a positively cleaned bar rack that is installed in a concrete channel. The screen shall retain floating materials at the bar rack.
  - b) A multitude of rake blades shall remove and lift the floating materials to a discharge mechanism.
  - c) The bar rack shall be cleaned by a serious rakes engaging the bar rack from the upstream side at the bottom of the channel and then moving up along the bar rack.
  - d) The floating materials shall be lifted above the channel and dropped on a discharge chute at the downstream side of the screen.
  - e) Screens with single rakes shall not be approved.
  - f) The bar rack shall consist of equally spaced, straight bars that are inclined from the horizontal with the inclination angle specified above.
  - g) The lower ends of the bars shall be provided with a minimum 4 mm thick curved base plate such that the rakes positively remove all screenings from the bottom of the bar rack.
  - h) Bars shall have Tear Drop profile with a cross section of 12 mm (front width/Tear Dia) X 10 mm(back Width) X 50 mm (Depth).
  - i) The bar rack shall be securely fastened to the frame of screen and be readily removable.
  - j) The bar screen shall be provided with a dead plate extending from the bar rack to the discharge chute.
  - k) The dead plate shall be made of a minimum or 4 mm thick stainless steel plate and shall be stiffened by structural members so that it is flat without undulation so that the tips of the rake's teeth ride at a distance between 1 to 2 mm over the dead plate.
  - l) The dead plate shall be securely fastened to the side frames.
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- m) A Discharge chute shall be provided that fully encloses the discharge section of the screen. An access hatch with hinges and a handle shall be provided in the chute permitting easy access. The discharge chute shall be mounted to direct screenings into the appropriate receiving container or conveyor.
  - n) The chute shall have a slope of minimum 45 degrees. The discharge chute shall be made of a minimum 4 mm thick stainless steel plate.
  - o) A frame shall be provided supporting all required loads. Side frames shall be made of 4 mm thick 316 stainless steel plates with a minimum of four axial edges. The side frames shall be connected with each other through channels having a minimum thickness of 4 mm and a minimum cross section of 108 X 49 mm. The side frames shall be connected to support frames. The support frames shall be securely anchored onto the operating floor.
  - p) The screen shall be provided with easily removable, sufficiently, stiffened covers made of 1.5 mm thick stainless steel plates with edges on all sides. The covers shall be provided with turn locks and handles.
  - q) Each side frame shall include separate roller tracks to guide the rakes. The roller tracks shall be bolted to the frame so that they can easily be replaced. The roller tracks shall be made of 4 mm thick L-profiles
  - r) Drive chains for the rakes shall be roller type chains and be made of hardened steel and shall be zinc and chrome electroplated.
  - s) Each chain shall have strength of 125 kN. Drive chains, chain guides, sprockets and their bearings shall be replaceable without removing the screen from the channel.
  - t) The sprockets shall be made of minimum 29 mm thick hardened steel plates and shall be Zinc galvanized and chrome plated. Rakes shall include rake bars made of 6 mm thick channel profile having a cross section of 105 x 60 mm.
  - u) The rake blades shall have teeth matching and engaging the bars of the bar rack. The rake blades shall each consist of several pieces with teeth such that only one piece needs to be replaced in case that a tooth should be damaged.
  - v) A pivoting scraper mechanism shall be positioned at the point of discharge and shall be attached to the side frames. The scraper shall clean the rake on each pass and return to its rest position with minimal shock. The scraper shall be designed such that screenings do not wrap around the rake or scraper. The scraper shall be provided with a scraper bar made 4 mm thick channel profile with a minimum cross section 39 x 68 mm and an adjustable 10 mm thick wiper made of polyethylene. The scraper shall be connected with the frame through a pair of minimum 500 mm long scraper arms that shall be made of 4 mm thick channel profile with a minimum cross section 68 x 59 mm.
  - w) A pair of shock absorber elements made of neoprene shall be provided.
  - x) The drive shaft shall have a diameter of minimum 80 mm and a wall thickness of minimum 5 mm.
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- y) The drive shaft includes an integral rocker arm assembly on the drive end that flexes if the screen rakes get jammed.
  - z) The rocker arm assembly shall consist of a drive unit mounted to a stainless steel arm. The stainless steel arm will be held in place by a flanged roller bearing connected to the drive shaft and two heavy duty tension springs. The flange bearing shall be connected to the rocker arm by four bolts. The rocker arm shall be maintained in the standard operating position by the two tension springs. If the screen rakes experience a jam, the force will cause the rocker arm to rotate around the drive shaft, compressing one of the tension springs. This motion shall be limited by a rocker guide. When the rocker arm rotates out of the normal operating position a proximity sensor will send a signal to the PLC causing the motor to enter a self cleaning mode. If the self clearing mode should prove unsuccessful then the system shall initiate an alarm signal.
  - aa) All stainless steel parts must be completely passivated and submerged fully in Pickling Bath.
  - bb) Rake screen must be full flexible to make the cleaning frequency to the requirements on site. To do so, the quantity of rakes installed on the screens. The quantity of rakes can be increased to meet the necessary screenings conveying capacity.
  - cc) Motor can be equipped to run on frequency converters; therefore can adjust the speed of the rakes to meet the necessary screenings conveying capacity.
  - dd) Rake screen must be using stainless steel covers as a standard.
  - ee) Rake screen bar rack is put together with segments. A segment has a higher stiffness instead a single bar. In case of damage, only the damaged segment has to be changed, not the whole bars rack.
  - ff) Rake screen should be with front rake system with no of rakes should be minimum 8 considering channel depth
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#### **4.1.8. Screen Drive**

- a) TEFC motor with protection grade IP 65.
- b) Explosion protection in accordance with II2GExeIIIT3

#### **4.1.9. Control & Instrumentation**

- a) The screen shall be pre-wired so that the tenderer is only required to make electrical connections to the control panel and from the control panel to a junction box at the screen.

##### **Local control on Screen:**

- i). One proximity switch for monitoring of the rocker arm position.
- ii). One local control station.

#### **4.1.10. Water Level Sensors**

Tenderer shall provide one transducer and electronics package for continuously monitoring of the upstream water levels for control of screen operation. The transducer shall be rated for hazardous locations and shall be intrinsically safe without the use of additional barriers, complete with built-in temperature compensation and submerged shield. The transmitter shall be mounted in the control panel. Tenderer shall install the transducers and provide wiring to the control panel.

#### **4.1.11. Control Panel**

- a) A single main control panel shall be furnished with a lockable corrosion-resistant stainless steel enclosure together with 8 local push button stations rated for a hazardous environment.
- b) Control panel shall contain all power and control devices necessary for the proper function of the screen.

#### **4.1.12. Shop Testing**

- a) The screen shall be factory assembled and subjected to following tests at manufacture's premises.
- b) Dimensional check: The overall dimension of the screen shall be confirming to the approved drawings.
- c) Operational Test: The Complete screen including its carriage, rake, drive system and brake motor shall be mechanically operated and tested to verify interference free movement and satisfactory operation.

#### **4.1.13. Inspections & Tests**

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- a) The Purchaser & its representative shall have the right to inspect and / or to test the Goods (major equipments as specified in scope of work) to confirm their conformity to the Contract. The special conditions of contract and / or the Technical Specification shall specify what inspections and tests the Purchaser requires and where they are to be conducted.
  - b) The Purchaser shall notify the Supplier in writing of the identifying of any representatives retained for these purposes.
  - c) All the expenses related to inspection at manufacturer's works & at site viz. Lodging & boarding, transportation; all facilities including third party inspection (TPI) fees and other related commercial expenses as and where required shall be borne by the successful bidder.
  - d) Offered items for testing at manufacturer's premises & at site shall be done by third party inspection and owner's (client's) representative deputed by purchasers.
  - e) Also major equipments as specified in Scope of Work shall be tested at manufacturer's works. The inspections and tests may be conducted on the premises of the Supplier or its subcontractor(s), at point of delivery and / or at the Good's final destination.
  - f) Should any inspected or tested Goods fail to conform to the Specifications, the Purchaser may reject them and the Supplier shall either replace the rejected Goods or make all alterations necessary to meet specification requirements free of cost to the Purchaser.
  - g) The bidder shall be responsible for communication & co-ordination between all supplier for the compatibility of the various electrical & mechanical equipments. The Purchaser's right to inspect, test and, where necessary, reject the Goods after the Good's arrival in India shall in no way be limited or waived by reason of the Goods having previously been inspected, tested and passed by the Purchaser or its representative prior to the Goods' shipment from the country of origin.
  - h) Approval of Documents: - It will be in the scope and responsibility of the Contractor to get the documents (drawing, data sheet and QAP) approved by the client /PMC prior to manufacture.
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#### **4.1.14. Conveyor System**

- a) For the disposal of screenings, a motor driven endless belt conveyor shall be provided. The conveyor shall be designed in accordance with IS 11592 or equivalent. The conveyor and chutes shall be suitable for handling occasional heavy objects, which may cause shock loads. The capacity of the conveyor shall be in accordance with the peak flow.
  - b) The construction of the frame and support shall be robust and torque resistant. Belt conveyor shall be of maximum 20 deg. Trough type complete with drive assembly structures, idlers, pulleys and belt cleaners/Scrapers. Idlers and pulleys shall be provided with anti-friction bearings.
  - c) The belt material shall be three-ply nylon or equivalent with minimum 3 mm neoprene covering on carrying side. Splicing shall be employed to make the belt endless. The belt shall operate over three roll twenty degree, troughing idlers. The idlers shall rotate on precision type, deep groove, and single row ball bearing with built-in close fitting triple labyrinth grease seal. The ends of the outer shell shall be counter bored and a full length centre tube journal led concentricity. The outer shell, centre tube and precision die formed steel ends shall be brazed into an integral unit to provide concentricity.
  - d) The ends of the centre tube shall be bored concentrically with each other after roll assembly to provide correct bearing alignment and to provide pre-stressing of boring. The centre tube shall be grease fit after assembly. Troughing idlers shall have means of adjustment of ensuring belt tracking. On the return run the belt shall operate over flat roll idlers having bearing, shaft and lubrication arrangements as above for carrying idlers. Spacing of idlers shall be of 1200 mm on carrying side and 2400 mm on return run.
  - e) The width of the belt shall be minimum of 600 mm and speed of the belt shall be between 18-20 metre per minutes.
  - f) The head and tail pulleys shall be manufactured from welded steel/ alloy steel and shall be provided with rubber lagging. Lagging for drive pulleys shall have herringbone grooving. Pulleys shall be equipped with taper lock bushings.
  - g) Shafting for pulleys shall be of heat-treated carbon steel. They shall be forged, ground and polished to obtain close diameter tolerances. The head shaft shall be provided anti friction bearings.
  - h) The belt conveyor shall be driven by a squirrel cage, TEFC motor coupled to the reduction gears. The gears shall have service factor of 2. A V-belt drive arrangement shall be provided between the motor and a helical speed reducer, the latter shall be mounted on the end of the head shaft. The driving pulley shaft shall have backstops to prevent backward movement of the belt.
  - i) 50 mm channel section with 14 gauge steel deck plate between the two runs of the belt and the necessary supports to the floor. The floor supports shall be made out of steel plates having minimum 6 mm thickness. The conveyor shall be protected from weather by a 'dog box' type canopy.
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- j) An adjustable belt scraper shall be provided on the hopper end of the conveyor belt. The scraper and attachments shall be of fibreglass/ fibre reinforced plastic/ PVC.
  - k) The conveyor shall be fitted with an emergency stop operated by wire rope at foot level. Two Nos. Belt sway switches shall be provided on conveyor.
  - l) Screening discharge chutes (Galvanized MS made) shall be provided to transfer screening from the screen to the conveyor and from conveyor to Portable screening container. The discharge chute of conveyor shall extend beneath the belt scraper and shall allow access for maintenance of the belt scraper. Chute shall be design to minimize the accumulation of rags and stringy materials.

#### **4.1.15. Portable Screening container**

Portable screenings containers made of galvanized steel shall be provided to store the screenings until time of pick up/ The container shall have capacity of approximate 2.0 cu.m and shall be of a convenient height to permit the discharge of screenings directly into the container without having to transfer the screenings manually. The container shall have hinged covers and its design shall permit their being lifted by an overhead hoist or packer truck. The container shall be trolley type attachable to tractor. The sides shall be constructed of 12-gauge steel. The bottom of container shall be made of 5 mm steel plate.

The containers shall be reinforced with 50 mm x 50 mm x 5mm angle

#### **4.2. Automatic Drum Screen**

##### **4.2.1. 1 Purpose:**

The construction of Rotary drum screens shall be strictly in accordance with the specifications mentioned hereunder. The rotary drum screens shall be installed in the screens channels of sewage treatment plant for removal of the fine floating wastes which otherwise reduces the efficiency of treatment process. The contractor shall provide the screens manufactured by an ISO: 9001-2008 certified company manufacturing the underspecified product for at least 3 years. The preferred manufacturer shall be stated in data sheet. The specification given hereunder shall supersede other specification in case given elsewhere in tender document.

##### **4.2.2. Scope:**

- a) Design, manufacturing, testing, supply & commissioning of rotary drum screens consisting of following items
    - i) Rotary drum screens complete with perforated drum, drive shaft, collection trough, screw conveyor, water jet, washing & compacting unit.
    - ii) Level sensing instrument to sense the water level.
    - iii) Local control panel installed near screens.
    - iv) Collection bin / flat belt conveyor.
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#### 4.2.3. Design & Constructional details:

- a) The rotary drum screens to be installed at an inclination of 35 degree from horizontal in to the fine screens channels of treatment plant allowing sewage to pass through the open end of the perforated drum so that the solids of the size bigger than bar spacing retained on the surface of drum itself.
  - b) For sewage application rotary drum screens shall be made of **SS 316** with bar spacing of 6 mm and shall be suitable for peak flow, channel width & channel depth given elsewhere in tender document. The fine screens channels must be designed in such a way that sewage water depth at peak flow remains below the centre line of drum.
  - c) The rotary drum screen as a single integrated unit must include rotary drum, drive shaft, collection trough, screw conveyor, water jet and washing & compacting unit. Design involving common screw conveyor for all screens shall not be allowed in any case lest its brake down will hamper working of all screens. The rotary drum screen must be supplied in fully assembled condition after dry run test at plant to eliminate the possibility of improper installation at site.
  - d) This screen must be supplied with a suitable level sensing device so that when water level increases up to a pre-determined level due to the blockage by the retained solids it gives signal to the drive through local control panel resulting in to rotation of drum on its drive shaft. As soon as drum starts its rotation a brush mounted on the brush arm must sweep the drum thereby pushing the solids in to the collection trough at the centre of drum. The screen must be equipped with a high pressure clean water jet to facilitate this removal effectively. The wash water should be clean treated water and must be made available at minimum 2 bar pressure at screen location. All required piping to bring the clean water from source to screens and the hydraulic pumps to deliver water jet with required pressure on screen shall be in contractor scope of supply.
  - e) A screw conveyor placed in collection trough will move solids to the washing & compacting unit where again high pressure jet of clean treated water will wash the solids to remove the soluble components as well as to reduce the odor. The water thus used shall be sent back to wastewater stream through the pipe.
  - f) After washing screw conveyor shall bring solids to compaction zone where they will be de-watered by squeezing before finally discharging from the discharges point to the container /belt conveyor placed below the screen on platform.
  - g) The drive motor shall be TEFC type with IP 55 protection and class F insulation and shall be suitable for operation on 3 phase, 415V +/- 10% and frequency of 50 Hz +/- 5%.
  - h) The control panel shall have IP 65 protection painted with Epoxy paint and shall be comprising of
    - i) Mushroom head emergency stop.
    - ii) Overload relays for motor protection.
    - iii) MCB's.
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- iv) Circuitry to operate screens with level sensor.
- v) Selectors switch to operate the screens on JOG mode.
- vi) The level sensor shall be of upstream type ultrasonic level switch.

#### 4.2.4.

**Eligibility criteria for screen manufacturer:** As rotary drum screens are essentially fabricated item the screen manufacture must full fill the following eligibility criteria to ensure quality & reliability of product:

- a) Must be an ISO: 9001-2008 certified company.
- b) Must have welding PQR, WPS & qualified welders as per ASME section 9.
- c) Must have pickling & passivation facility to eliminate any carbon steel contamination which may have taken place during the course of manufacturing to avoid the rusting at site.

#### 4.2.5.

**Testing:** The rotary drum screens shall be supplied in factory assembled condition after following tests at the manufacturer premises before dispatch

- a) Dimensional check: All important dimension of screen shall be confirming to the approved GAD.
- b) Dry run test: The complete screen in assembled condition shall be mechanically operated in dry condition to verify interference movement & satisfactory working.
- c) Positive material identification (PMI) test: shall be carried out to verify the components made of stainless steel.
- d) Dye penetration test: to be conducted at random for checking the soundness of welding joints during the inspection.
- e) Review of test certificates: Material test report, motor certificate, control panel certificate etc. as per approved QAP to be furnished for review during the inspection.
- f) Review of WPS, PQR & Welders certificate: to be furnished for review during the inspection.

#### 4.2.6. Miscellaneous:

The installation and commissioning of screens must be done in presence of manufacturer representative to avoid any possibility of misalignment and faulty installation.

Packing of screens and allied accessories shall be transit worthy to avoid any possibility of damage during the transportation to site.

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### **4.3. Perforated Filter Band Screens**

#### **4.3.1. Specifications**

- a) The screens shall consist of continuous belt of linked perforated 316 stainless steel plates with 6 mm perforation mounted in the inlet channel at an angle (45° - 75°). Debris and suspended solid present in the wastewater flows shall be retained by these perforated plates. Each end of the perforated plate shall be connected to a drive chain which is driven by chain wheels. Each chain shall be driven by a sprocket on a common shaft and flange mounted geared motor. The screens shall be designed to prevent long fibers from passing through and shall be able to cope with a significant amount of gravel and grit.
  - b) At the turning point where the filter element is about to start its downward journey, wastes are dislodged from the filter elements by a series of high pressure water jets. The waste along with the used water falls on to the in-built chute. From the chute the waste to be collected in to a launder or screw conveyor for separation of waste and wash water and for further disposal.
  - c) The filter elements to have step type perforated plate profile to carry large sized solids and avoids formation of sausage. The filter elements with protruding tines shall not be acceptable.
  - d) Screening removed by the fine screen cleaning mechanism shall be discharged into a launder trough, such that none passes back into the main flow or outside the trough.
  - e) Screenings shall be transported along the launder trough via the flow of wash water, to the screw conveyor for dewatering / compaction and disposal into skips.
  - f) The screens shall be designed so as to facilitate safe inspection, cleaning, lubrication and repair to ensure safe and satisfactory operation under all service conditions. The screens shall be able to tilt by means of a pivot out of the channel to allow the sections normally located below the coping level to be inspected and maintained.
  - g) Electrically actuated open channel gates with 415 V and 50 Hz frequency shall be provided upstream and downstream of each screen for maintenance / repair.
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#### **4.3.2. Frame**

- a) The screens frame shall be stainless steel grade 316 constructions. The frame shall be secured to the coping of the channel. There shall be no fixing below coping level. The screens should be of self-carrying design so that its own weight is sufficient to keep the screen secured in position.
- b) Wear resistant plastic elements shall provide sealing between the travelling screen elements and the frame whilst the perforated plates are moving. The plastic and screening elements shall be easily replaceable. The screen shall be completely enclosed with easy to remove covers for odor control purposes.
- c) The material of construction for the drive chains and sprockets shall be stainless steel grade 304 and chain pins to be made of hardened stainless steel material of special grade. Special grade ceramic bushes are to be provided for lower sprockets to ensure very long operative life. The upper chain tensioning units shall be easily accessible from outside.

#### **4.3.3. Drive Motors**

- a) The headgear of the screens shall include the main drive with associated gear reduction unit and drive shafts.
- b) The drive motor shall be a fully weatherproofed totally enclosed squirrel cage continuously rated motor. The motor shall be rated IP55.
- c) The clutch shall be a friction element clutch on the gearbox output drive shaft.
- d) The drive shaft with 415V and 50 Hz frequency shall be made from 304 grade stainless steel.
- e) Overload equipment shall be provided to limit torque and prevent damage to mechanical components or electric drives in the event of the screen components becoming jammed. Electrical cut-out and volt-free contacts from alarm purpose shall also be incorporated in the overload device.

#### **4.3.4.**

##### **Guards**

- a) Moving parts shall be guarded to at least 150 mm below the coping level or to meet the channel covers. Guards shall be manufactured in clear polycarbonate for inspection purpose and shall be locked into position such that a tool is required to remove them. The guards shall be hinged where possible.
- b) Guards shall be in accordance with all relevant statutory standard and laws. Rotating or moving parts shall be close guarded to prevent injury to personnel.
- c) The side sealing rubber shall be a continuous heavy duty rubber strip with a grade 304 stainless steel cover strip.

##### **a) Spray wash water**

- i) Wash water 210 LPM at 5 bar pressure per screen shall be used to supply the screen spray bar nozzle to facilitate removal of screenings. If treated sewage has less than 55 mg / liter suspended solids with
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maximum particle size being less than 2 mm then it can be used as wash water otherwise clear water will be required as wash water.

- ii) Screens with 2 high pressure nozzle spray system are required. Primary system above discharge level will eject the entrapped screening and secondary wash system will bring any remaining residue through drain pipe back in to the upstream of the channel.

#### **4.4. MECHANICALLY OPERATED STEP TYPE FINE BAR SCREENS**

##### **4.4.1. GENERAL :**

Mechanically operated step screen completely made of Stainless Steel grade 3 having 6 mm average spacing between the bars shall be provided in inlet scre channel(s) for screening out floating materials such as plastic pouches, bags, rag floating debris, weeds, paper wastes and other floating materials from the raw sewa coming from the pumping station / gravity mains.

The screen shall include discharge chute as required to discharge the screenings on the belt / screw conveyor without employing any external mechanism / rake mechanism

##### **4.4.2. SPECIFICATION:**

- **Material of construction:**

The fixed as well as movable bars, link, mechanism, support main frame, dischar chute shall be manufactured from stainless steel grade 316 for long life in the aggressi sewage environment. No component of the screen assembly shall be made of carb steel or any other material, which can get corroded in sewage environment.

- **Screen Construction**

The step screen shall be a complete unit comprising of main frame with an integ mechanism containing movable bars located in between fixed bars without engageme of external mechanism / rake mechanism for pulling out the screened material ensuri minimum movement of the mechanism.

The mechanism comprising of movable bars located between fixed bars shall gradua move the screened material upward in the form of a mat and deliver up to the dischar chute.

The fixed as well as movable bars shall contain a series of steps to prevent t screenings from falling back into the main flow. Fixed bars shall be of 3 mm where movable bars shall be of 2mm thickness.

The mechanism shall be mechanically operated by Geared-motor system and shall suitable for automatic operation controlled by a level sensor.

The screen shall operate automatically when the upstream water level increases beyo a pre-set limit and it shall stop when the upstream level decreases to a preset low lev due to upward travel of screened material.

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The fine bar screen shall be capable of being tilted out of the sewage flow up to horizon position for the purpose of cleaning & maintenance.

The base of the screen shall be fitted with a specially profiled stainless steel plate direct any grit that may be present towards the screen and taken out along with oth screened material thus reducing the possibility of building up of grit in front of the scree

#### Level Sensor

The level Sensor shall be of upstream type Ultrasonic level switch

#### Electrical Motor

The motor shall be TEFC type with IP 55 protection & Class F insulation and shall suitable for operation on 3 phase, 415V  $\pm$  10% and frequency of 50Hz  $\pm$  5%.

#### Control Panel

The Control Panel shall have IP 65 protection, painted with Epoxy paint and shall comprising of

- Mushroom Head Emergency stop.
- Overload relays for motor protection.
- MMCB's, HRC Fuses and Glass Fuses.
- Circuitry to operate the screen with level sensors.
- Selector Switch to operate the screen on JOG mode.

The specification given hereunder shall supersede other specification in case given elsewhere in tender document.

#### 4.4.3. TESTING:

The Fine bar screen shall be Factory assembled and shall be subjected to following tests at the manufacturer's premises before dispatch.

- **Dimensional Check:** The overall dimensions of the screen shall be conforming to the approved drawing.
- **Operational Test:** The complete screen including its mechanism, Electro-mot hydraulic operating mechanism and control panel shall be integrated a mechanically operated in dry condition to verify interference free movement a satisfactory working.
- **Positive Material Identification (PMI) test:** To ensure that Screens are actua made of Stainless Steel Grade 316 positive material identification (PMI) test to conducted for all important screen components like Bars & Frame during inspecti and PMI reports to be submitted to client / corporation along with joint inspecti report.
- **Review of test certificate:** Material test report / certificate, Motor certificate, Contr Panel certificate to be furnished for review during the inspection.

#### MISCELLEANOUS:

- The installation and commissioning of screens shall be carry out in the presence manufacturer's representative(s) so as to avoid any possibility of misalignment a faulty installation.
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- Packing of screens and allied accessories shall be transit worthy to avoid a possibility of damage during the transportation to the site(s).

#### **4.5. Grit Removing Equipment**

**4.5.1.** For STP initially the sewage shall be subjected to pre-treatment which includes removal of floating material through screen and grits with the help of grit removal mechanism. From the inlet chamber, the sewage will overflow to screen chambers, each screen channel comprising of mechanical fine perforated plate screen suitable for design peak flow shall be provided. Perforated plate screens shall be provided for removal of floating materials, etc. Shall be provided in each screen channel. After screening, the sewage shall overflow to grit chambers for removal and washing of grits from the sewage. Each grit chamber shall have grit separating system and grit washing system. The grit will be collected and transferred to the collector via screw conveyor.

#### **4.5.2. Grit chamber**

- a) The flow from the screen channel shall be allowed into the grit chamber for the removal of grit/inorganic matter by means of RCC tank designed as per relevant IS code of practice.
  - b) There shall be 2 no. Mechanical vortex type grit chamber. Grit chambers shall be designed for peak + other flow.
  - c) Mechanical grit chamber shall be capable of removing grit of particle size of 100 micron and above and sp. Gravity of 2.65.
  - d) The surface loading rate, settling velocity and other design parameters shall be as stated earlier. The grit chamber shall be of RCC M30 grade construction with suitable RCC foundation with necessary water tightness test.
  - e) The inside surface of the grit chamber shall be provided with 20 mm thick water proof plaster in cement mortar 1:3. The bottom of the chamber shall be provided with 40 mm thick ips screeding. The outside surface shall be provided with 20 mm thick double coat sand faced plaster in cement mortar 1:3 with exterior emulsion as per civil specification.
  - f) Chamber should be curved the vortex in shape. The mechanical grit chamber shall be of curved vortex type so the screened wastewater enters at the bottom of the grit chamber will rotate tangentially.
  - g) The grit chamber shall be equipped with constantly rotating stirrer which helps the wastewater circulation within the grit chamber ensuring a constant velocity of rotation within the complete grit trap system even under dry weather conditions.
  - h) Due to the constant radial rotation the solids are very quickly collected within the centre of the grit chamber from where they then pass into the bottom of the grit collection tank.
  - i) The grit-free wastewater then exits and flows onto the next treatment step.
  - j) Centrifugal or airlift pumps can then deliver the collected solids from the grit collection tank into a grit classifier or grit washer where the solids can then be subsequently separated and dewatered and organic particles removed.
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#### **4.5.3. Mechanism**

- a) 4 piece Stainless steel paddles with hard cast iron welding, fixed on the drive shaft. The paddles should be adjustable in all directions, interlocked with counter screws.
- b) Central tubing prearranged for air lift pump with funnel in the grit discharge area.
- c) The central shaft is ending with a flange. Removable floor plate over grit storage chamber with minimum opening 75 mm to storage chamber, design plate assembly in two sections with lifting lugs, plate thickness minimum 10 mm.
- d) Totally enclosed squirrel cage motor with at least IP55 protection in accordance to IS standards.
- e) Gear reducer to include anti-friction bearings with high overhung load properties, and double lip oil seals. Drive unit and motor bearings have a minimum bearing life of 100.000 hours.
- f) Turnable bearings supporting the paddles assembly have a minimum bearing life of 20 years. Grit from grit washing unit should be guided with the help of screw conveyor to the grit collector

#### **4.5.4. Degritting Tank Mechanism, Classifier and Washing of Grit**

- a) Removing different type of grit, clay, sand, metal etc. From tank mechanism, classifier and washing of grit etc. It shall incorporate following.
  - i). Removing different type of grit, clay, sand, metal etc. From tank mechanism:
  - ii). The different type of grit, clay, sand, metal etc. Settled in a tank shall be scrapped a collection point by a scrapper mechanism.
  - iii). It shall be designed for continuous operation. The mechanism will be coupled to a suitable motor-gear- box assembly.
  - iv). The collected grit shall be elevated to the top of tank by the help of a classifier. While the grit is being elevated from the tank bottom, suitable arrangement for grit washing by plain tap water shall be made.
  - v). All moving parts shall be abrasion resistant.

#### **4.5.5. Grit Washer**

- a) The grit mechanism will be suitable for installation in a tank and will comprise of the following:
    - i). Grit collection mechanism.
    - ii). Organic return pump.
    - iii). Classifier cum washing mechanism.
  - b) The grit contained in waste water is usually removed in grit traps by gravity or centrifuge force to protect downstream equipment.
  - c) No additional screening must take place upstream of the grit washer. The plant must be able to handle mineral grain sizes up to 30 mm.
  - d) The grit/water mix must centrally flow into the grit washer.
  - e) Grit classification and washing must take place in one tank, i.e. preceding longitudinal grit traps are not permitted.
    - i). Surface overflow rate (incl. Wash water) must be < 25 m/h.
    - ii). The grit washer must be equipped with a circumferential overflow weir on the outside.
    - iii). Overflow weir load must be < 15 m<sup>2</sup>/h.
    - iv). The combined addition of water and air or fixed bed plants is not permitted.
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- v). The grit washer must have a separate organics discharge  $\geq$  dn 100.
  - vi). The grit washer must have a clogging-free perforated membrane sandwich-plate at the lowest point of the wash cylinder for best water distribution in order to achieve best wash results.
  - vii). Grit level measurement must be carried out by means of a hydrostatic pressure probe.
  - viii). The grit washer must remain in full function (wash and discharge grit) even during feeding from the grit trap.
  - ix). The grit removal screw must be a stainless steel screw supported on both ends.
  - x). Shaftless spirals or screws made of "special steel" are not permitted.
  - xi). The grit removal screw trough must not have guide bars or plastic shells.
  - xii). The grit washer must be acid treated in a pickling bath and passivated
  - xiii). The complete grit washer must be made of at least 1.4307 stainless steel materials.
  - xiv). The stirrer must be made of at least 1.4307 full stainless steel materials.
- f) The grit washing machine should achieve high grit separation efficiency through optimum utilization of the tank volume due to the defined and calculable flow path based on the coanda effect in the inlet combined with the preceding vortex chamber.
  - g) After solids separation the organic particles are washed out in the bottom part of the tank by means of a grit fluidized bed.
  - h) The wash water is added across the entire wash zone cross section. To achieve constant washing results, the system should work with a uniform, constant up flow velocity in the wash zone.
  - i) Washout is supported by a slowly running stirrer. As a result, the lighter organic particles are separated from the dense mineral particles.
  - j) Organic material should be additionally removed via a separate automatically actuated organics discharge located above the grit fluidized bed.
  - k) The washed grit should be removed and at the same time dewatered by a sturdy grit transport screw supported on both ends in a trough. There should be special arrangement of the screw flights for plug-free operation. The screw should be impulse-pause operated in dependence of the fed amount of grit, which is measured by a pressure probe.
  - l) Organic loss should be less than 3%
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#### **4.5.6. Classifier Mechanism**

- a) The classifier mechanism shall comprise of a screw driven by a suitable motor. The material of construction of the mechanism shall be SS 316 and the diameter shall be minimum 400 mm. The length of screw shall be such that the grit can be elevated up to the discharge end. SS puddle pipe shall be provided in the concrete trough at the discharge point of wet grit.
- b) The classifier mechanism shall consist of the following:
  - i). Chain and sprocket with guard.
  - ii). Reciprocating rake with hangers of screw mechanism.
  - iii). A.C. Motor.
  - iv). Local push button shall be provided.

#### **4.5.7. Organic return Pump**

- a) Vertical Propeller pump with suitable motor, starter, etc. Shall be provided. The design of the pump and the piping on the inlet and outlet side has to be such that there are minimum numbers of bends as they are liable to be choked with organic matter.
  - b) One set of push button shall be provided near the pump set and one starter in the terminal sewage pumping station. The suspended organic matter washed in the de-gritting system will be returned to the distribution chamber. Impeller shall be of SS CF8M and shaft shall be of SS 316.
  - c) In the event of tripping of working grit removing equipment (motor), the sizing of this equipment (including motor) shall be done in such a way that it shall take the overhead to remove the excess grit collected after starting of the tripped grit removal equipment.
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#### **4.6. Primary & Secondary Clarifiers:**

Circular (radial), fixed bridge with scum collector, central turns table type or peripheral drive type, collecting effectively with proper circumferential speed, clarifiers shall be provided. The clarifier shall be rugged and robust in design and shall be provided with high capacity drive head and induction motor having high torque rating, centrally or peripherally located, with positive sludge raking by means of one or more raking arms. Both the raking arms should have scraper blades fitted at the bottom, so that the sludge from scraper blades is pushed to the sump on every rotation.

- a) The drive head mechanism arrangements shall consist of a turn table base casing mounted on top of the centre pier and shall have an angular ball bearing mounted internal gear that supports the underwater mechanism. The pinion meshing with the internal gear should be driven through a worm gear reduction unit mounted on top of the turn table drive unit. The balls should ride on hardened steel strips set into grooves in the base and gear casing so that they can be readily replaced whenever required.
  - b) The unit will have mechanical overload arrangement with a torque indicating arrangement along with necessary contacts for tripping the motor in the event of overloading. This condition shall be enunciated. The unit shall have push button station near the motor and starter with push button shall be provided in the control room, i.e. the return activated sludge pump house along with necessary switches. The clarifier unit should also be provided with necessary M.S. scum trough, scum baffles, skimmer assembly, M.S. rake blades, arms and brass squeezes. The V-notch weirs shall be 6mm thick of reinforced fiber glass with clamps etc. For making the necessary adjustments.
  - c) The bridge connecting the periphery of the tank to centre pier shall have walkway covered with chequered plates and provided with hand railing on both sides.
  - d) Corrosion allowance of 2mm shall be taken in the structural sections of scraper arm, bridge etc.
  - e) Structural design calculations shall be submitted for all structures including scraper arm, bridge etc.
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#### 4.7. Decanter Assembly

- a) Mechanical floating decanter and related equipment accessories as described herein for each basin. Each decanter shall consist of an integral flotation unit, a stainless steel movable weir assembly, and an electric motor-driven actuator to open and close the weir.
  - b) Performance-Each decanter shall be capable of withdrawing decant fluid beneath the liquid surface, regardless of liquid depth, down to the minimum allowable water level. The decant liquid shall be drawn through an adjustable weir. The weir shall be circular in shape and permit liquid to enter the decanter from the entire 360 degrees without obstruction or equivalent.
  - c) Weir actuator shall include a reversible electric motor operated linear actuator. The actuator shall be capable of operating with a closing force and shall operate from a 415 volt, single phase, 50 hertz source. Adjustable limit switches shall be included to permit adjustment of the weir opening. A spring shall be included to provide for travel after the weir has closed and provide desired closure pressure. A corrosion resistant removable cover shall be included to provide protection to the actuator and motor during normal operation. The power section is painted steel. Power cable shall be provided from the NEMA 4X junction box of the unit to the basin wall. Supply of junction box/disconnect at the basin wall shall be the responsibility of the installing contractor.
  - d) The weir shall be constructed of 316 stainless steel, be circular or rectangular in shape, and shall include vortex control baffles permanently affixed to the weir. The weir shall be attached to the actuator through a removable single shaft or linkage which shall also function as the torque restraint.
  - e) Flotation-Each unit shall be equipped with a modular float constructed of fibre reinforced polyester filled with closed cell polyurethane foam having a minimum 2.0 lbs./ft<sup>3</sup> density. Float shall be completely sealed to prevent the foam from being in contact with the external environment. Float shall have appropriate eight reserve buoyancy to ensure stability and to provide support flotation required during decanter servicing. A urethane type or equivalent seal shall be moulded into the bottom of the float assembly to receive the decanter weir.
  - f) Decanter Discharge Pipe -Each decanter shall include a 316 stainless steel elbow flange and 316 stainless steel flanged flexible joints and others. The installing contractor shall provide a valve with hose connection on the decant line between the decanter and the decant valve. All piping, supports, gaskets, and hardware beyond the terminating flange of the decant pipe flexible joint shall be supplied by the installing contractor.
  - g) Decanter Restrained Mooring System-Each decanter shall include a stainless steel mooring frame attached to the float. Stainless steel mooring post assembly with base plate shall be provided to assure consistent location of the decanter in the basin. Mooring post shall be filled with concrete by the installing contractor.
  - h) Stainless steel dewatering support posts consisting of vertical pylons with base plates and pipe dewatering support post with pipe saddle and base plate shall be provided. Each support with base plate shall be affixed to the basin floor with 316 stainless steel adhesive anchors. Top and bottom mooring post supports constructed of stainless steel shall be provided for attachment to the basin wall by the installing contractor.
- Decant Flow Control Valve-Furnish one electrically operated butterfly valve for each basin to control the decant rate. Valves shall be electrically operated butterfly valves with ANSI Class 125# flanged end ASTM A-536 ductile iron body, ductile iron disk with a 316 stainless steel edge, fully lined EPDM seat vulcanized in the body, 316 stainless steel shaft assembled and tested with 415
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volt, three phase, 50 cycle open/close service electric actuator. Valve actuator shall include a compartment heater. Each valve shall include a manual override with limit switch feedback to the microprocessor in both the open and closed positions. Field wiring and junction/box disconnect shall be provided by the installing contractor.

### **Moving weir decanters**

One or more pneumatically / electrically actuated variable speed moving weir decanters shall be provided in each tank which function under a controlled (but variable) constant lowering rate.

During aeration and settlement, the decanter collection weir shall be situated (parked) above the top water level of the reactor. The decanter shall automatically operate as a high level overflow in the event of an emergency.

The initial rate of travel of the decanter shall be adjustable and shall have an initial high rate of travel until entry into the liquid surface, at which point the rate of travel of the decanter shall be automatically reduced to a calculated rate of operation. The drive mechanism or actuator will be designed for a continuous duty, variable speed mode of operation thereby producing a uniform effluent flow rate until the decanter weir reaches BWL at the end of the decanter phase, thereby maximizing settling time.

The rate of operation shall be calculated for each cycle and shall be determined by the volume of treated effluent to be discharged per cycle. The calculation of decanter travel shall ensure that the volume of treated effluent shall be discharged throughout the designated decant phase of the process cycle.

Upon reaching the designated BWL, the decanter shall be returned to its parked position travelling at the same rate of travel as the initial high downward rate. The decanters will be parked above the design TWL during aeration and settling phases, thereby eliminating any possibility of solids carryover during these phases.

At the parked position, the decanter will provide fail safe overflow protection in the event of a power failure. Settled supernatant will flow via gravity, under the scum guard, over the weir, and into the decanters.

If more than one decanter is provided per tank, the Contractor shall describe the method of decanter control by which an even distribution of flow is provided between the decanters during operation.

The decanters shall be designed to prevent solids entering the decanting device during the aeration phase.

Each decanter shall be fitted with a moving scum retention mechanism to prevent discharge of surface scums and floatables during decanting and overflow operation.

Blower operation and automatic valves will be interlocked with the decanter controls through the process control center to prevent operation during settling and decanting.

Each decanter drive mechanism shall consist of an electric motor, actuator/gearbox and travel position limit switches. Four (4) limit switches shall be provided for each decanter to ensure reliable operation at HI level (parked position), LO (design BWL) and HI-HI and LO-LO level to detect over-travel operation.

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Each decanter shall include local control panel with manual operation selection and function buttons, parked and BWL indicator lights, emergency stop button, and communications to the SBR control PLC.

All critical decanter components that may require routine inspection or maintenance (including motors, actuators, and limit switches) shall be easily accessible from an access platform or walkway at tank coping level without taking a tank out of service or draining or partially draining the tank.

It shall be possible to carry out decanter maintenance activities without interrupting normal operation of the tank while the decanter is at its parked position during aeration and settling phases.

Stainless steel decanters shall be provided. All in-tank welded decanter components, except seals and bearings, shall be constructed of corrosion and ultra-violet resistant 316 stainless steel. All fasteners shall be constructed of 316 stainless. Site fabrication of decanters shall not be allowed.

All decanter seals and bearings shall be constructed of maintenance free, synthetic materials for longest possible service life. All seals and bearings shall be shipped factory assembled, simplifying installation.

The decanter weir shall always be visible from the tank walkway to provide the operator with a visual check of the effluent quality.

Support the decanter by a minimum of two (2) concrete support piers. Design the support pier to provide full support of the decanter. Attach the decanter to the support piers by means of stainless steel anchor bolts with nuts and washers. Integrally link the electro-mechanical drive mechanism to the support frame and the rotating member of the decanter. Direct attachment of the drive mechanism to the end wall of the tank shall not be permitted.

### **Diffused Air Aeration system**

- i) This section of the specification sets out the minimum requirements of the design and selection of diffused air aeration system equipment.
    - a) The pipe works, instrumentation and the diffusers shall be correctly sized to deliver the required quantity of air at the available pressure to meet all operating conditions. The pipe work to the tank shall be sized for 110% of the required oxygen transfer capacity to cater for the higher loadings.
    - b) The aeration header shall be design for removal/replacement from/to the reactor without taking the reactor off-line or dewatering the reactor. The operator shall be required to demonstrate removal and replacement of the headers with the reactor on-line.
  - ii) **Aeration Diffusers**
    - (a) Air diffuser system consist of Tube/ Disc type porous membrane of Acid resistant with Outer Diameter (OD) as per bidder's/ supplier's design with support Tube/ Disc, SS Clamps.
    - (b) Entire diffuser has to be manufactured, assembled, tested in factory premises & no site work is permitted.
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- (c) Flat surface facing upwards as membrane shall not be accepted.
- (d) The aeration tank is used to remove oxygen consuming organic matter from the effluent by biological treatment. Diffused aeration is used for air supply. The bubbles produced from the diffuser are of extremely small size between 0.5-0.8 mm, thus the total surface area that interacts is large and the contact time of bubble is large due to slow rise of bubbles. The system is thus extremely power efficient in terms of oxygen transfer efficiency. The flow of fine bubble of 0.8 mm in size provides a gentle mixing, which prevents flock shear.
- (e) Fine Bubble diffuser consists of a porous membrane made of acid resistant silicon based rubber. Each diffuser is fully supported over the length and circumference on the single piece injection molded polypropylene (PP) tube with a RIDGE on the top to hold the membrane in position against the velocity generated in the wastewater.
- (f) No drilled holes on the supports tubes are permitted and only channel type of arrangement for entry of air into membrane is desired. Air opening on the membrane should be 0.8-1 mm with staggered perforation.
- (g) The diffuser will be retained in place by two clamps. It is fitted to the pipe lateral by CLIPIN arrangement. The Laterals are connected to a pipe header. The wetted parts of the system shall be made of Non-corrosive material specifically SS 316. During power shutdown at the STP the membrane will contract and lose around the PP support pipe and means shall be provided to prevent any back flow.
- (h) Each diffuser (respective of diffuser type chosen) shall consist of the following:
  - i) Outer Diameter as per bidder's/supplier's design PP injection moulded type.
  - ii) Porous membrane made of silicon based rubber lateral.
  - iii) RCC support block with SS 316 clamping.
  - iv) Flexible hose pipe (Drop pipe for each diffuser assembly)
  - v) PP ropes for lifting and guide position.
  - vi) Hose clamp
  - vii) pipe connector
  - viii) GI barrel nipple with connector for connection with pipe
- (i) All hardware accessories including clamps, fasteners, fan-hooks, eye bolts, should be of SS 316 material only.

### **iii) Air supply Pipe Work**

- (a) Many factors need to be incorporated in the design of the air distribution pipe work to minimize the potential of noise problems occurring. Factors to be considered in the design of the air pipe work to be minimize noise level shall includes:
  - i) The diameter of the pipe work, to keep velocity low.
  - ii) The connection of the blower discharge pipes to the manifold should be "wye", not at right angles.
  - iii) No blind flange at the end of the manifold.
  - iv) The manifold shall be design to ensure air travels in one direction.
  - v) The air pipe work shall be designed to minimize changes of direction and use large radius bends.
  - vi) Flexible connections shall be provided between the diffuser assembly nits and the main air supply pipe work to allow for any differential movements.
  - vii) Expansion and contraction shall be fully allowed for in the design and installation of the air distribution pipe work.

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- viii) Rain taps shall be provided on the air pipe work to allow draining of moisture.
  - ix) The pipe work and the support brackets shall be galvanized steel.
  - x) Pipe work shall have inbuilt flexibility such as packer flanges for reasonable construction tolerances on the structures to which it is attached.
- (b) Pipe shall be designed to ensure the efficient operation of the aeration system and compliance with the noise limitations. All valves in the air delivery system shall be correctly selected for the duty. Calculations of Cv (Head loss co-efficient) values for the range of flows and pressure losses across each valve should be prepared to ensure that each valve has adequate range of controllability for the duty.
- (c) However the air piping submerged in sewage has to be in SS316 conforming to IS specification. Material of Construction (MOC) of diffuser laterals shall be SS 316. Two spare drop pipes with diffuser elements shall be supplied by the Operator one for each compartment. This will be used to replace the choked diffusers drop pipe or on preventive basis on rotation. The choked one will be attended to and used as spare drop pipe.

**iv) Air supply Headers**

- (a) The air supply headers run from the main air distribution pipe work to the down comers. Pipe work shall have inbuilt flexibility such as packer flanges for future modifications and to allow for reasonable construction tolerances on the structures to which it is attached.
- (b) An isolation valve for each main air supply pipe shall be installed at the point of connection to the main distribution pipe work. The design of the main air supply header shall incorporate all components necessary to enable the easy connection of the main distribution pipe work to the main air supply header.

**v) Blower Discharge Pipe Work**

The Discharge pipe work from each blower shall be connected to a common manifold. Flexible connections shall be provided between the blower assembly units and the discharge pipe work to allow for any differential movements. The design of the manifold pipe work shall incorporate all components necessary to enable the easy connection to the main distribution pipe work.

**vi) Air Flow Measurement**

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- (a) The amount of air being supplied to each air supply header shall be measured by the installation of flow measuring devices. The flow measuring devices shall be suitable for the intended application. The sensor assembly shall be supplied with suitable fittings which shall enable easy removal during maintenance. The installation shall provide adequate length of straight pipe upstream and downstream of the flow meter to ensure the accuracy of the meter is attained.
- (b) Pressure and temperature sensors, shall be provided to measure the pressure and temperature of the air in the pipe, upstream of the flow measurement device.
- (c) Pressure and temperature compensation measurements shall be provided for volumetric correction if the control air is based on airflow rate.

**vii) Pressure Gauges**

Pressure gauges of an approved type shall be installed on each main distribution pipe work and main header.

**viii) Leak & Pattern testing Diffuser System**

- (a) The diffuser system shall be visually tested by filling the tanks with clean water to level 1 m above the top of the diffuser assembly units. Air shall then be passed through the diffusers and a visual assessment of the diffuse operation shall be made. The visual assessment shall include the following minimum inspection:

- i) Checking all diffusers for installation level within the required tolerances.
- ii) Checking that all joints along the diffuser headers have been made airtight
- iii) Checking the required air distribution of diffused air is achieved across the entire tank floor.

**b) Aspirating Aerator**

- i) The Supplied equipment must be in operating condition in India for minimum of three years in any Government plant with minimum three successful installations and documentary proof of performance certificates of the same shall be produced to approving authority. The client reserves the right to inspect any one of the successful installation at the referred site; in case found not satisfactory, vendor shall be disqualified.
- ii) Aspirator aeration shall consist of motor driven aspirator Draft tube/Air Suction Inlet/blower. The Device shall draw air through a hollow tube and inject it underwater where both high velocity and propeller action create turbulence and diffuse the air bubbles.

The assembly shall consist of electric motor connected to a hollow shaft with a protective housing positioned at a suitable angle downward into the water. The hollow shaft shall drive a mixing propeller and diffuser beneath the water surface to effect fine bubble diffused aeration.

**iii) Aerator/ Mixer Components**

- (a) Aerator Drive Motor
  - i) Motor shall be suitable to operate at 3phase, 415 volts, 50Hz supply. Motor shall conform to IS 325.
  - ii) Motor shall be provided with suitable starter and starter panel as per tender specifications.
  - iii) Motor enclosure configuration shall be totally enclosed, fan cooled TEFC and meet IP65 specifications.

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- iv) Motor shall be suitable for S1 duty, shall have class F insulation and temperature rise to class B.
  - v) Efficiency class of motor shall be IE -2 as per IS-12615.
  - vi) Winding, bearing, temperature detector shall be provided for motors above 200kW. Space heater shall be provided for motor above 30kW.
  - vii) Motor frame shall be made-up of cast iron end brackets and cast iron body. Fan material shall be propylene with metal hub. Fan cover shall be carbon steel.
  - viii) Total motor shall be epoxy painted – Final Total Dry film thickness of minimum 180 microns.
  - ix) The noise level of the motor shall be within acceptable limit (<85dB) in accordance with IEC specifications.
- (b) Blower/ Draft Tube/ Air Suction Inlet-The equipment shall include a high efficiency regenerative blower/Draft Tube/Air Suction Inlet sized to provide sufficient airflow to yield the rated oxygen transfer capacity. Such Device shall include the following features:
- x) Maintenance free and CE compliant – Declaration of Conformity on file
  - xi) Aluminum alloy construction
  - xii) Inlet and outlet sound attenuating silencers/acoustic hood to minimize noise, if applicable.
  - xiii) Inlet filters with epoxy-coated wire mesh media rated for 150 microns or better, if applicable.
  - xiv) The blowers shall be tropical zed for corrosion resistance and motors should be suitable for 415V, 50Hz cycle, 3 phase service and with IP65 rating.
- (c) Bearing-The aerator shall be supplied with a field replaceable water lubricated lower support bearing /Grease Lubricated Bearing. The bearing shall be constructed of an appropriate material for the application inside a fibre backing. The bearing shall be press-fitted into the housing to allow ease of replacement.
- (d) Sleeve- The sleeve shall be solid, homogeneous and replaceable hardened non-metallic sleeve
- (e) Propellers:
- i) The stainless steel mixing propeller shall be specifically designed to maximize oxygen transfer and mixing characteristics. Propellers shall be self-tightening such that the propeller threads tighten on the shaft threads during normal operation. The entire flow of air shall pass through the propeller via the hollow drive shaft along the axis of the propeller hub.
  - ii) The propeller design shall be tested in clean water and shown to draw a minimum of 85% of the recommended full motor amperage load at nameplate voltage and power factor. The propeller shall be designed to allow easy removal and replacement in the field.
- (f) Flotation
- i) The aerator flotation assembly shall consist of suitable number of pontoons/Suitable Floating arrangement. Galvanized or stainless steel structural members to be used to prevent corrosion. To allow for servicing by not removing the aerator from the flotation, the flotation assembly shall be designed so the aerator may be rotated completely out of the water and taking care of water level fluctuations.
  - ii) The Floating Arrangement may not be applicable in Fixed type Installation for Aerator.
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- (g) Bridge mount-The fixed bridge mount shall be made of Galvanized steel. The recommendation of the Float and Fixed mount shall be as per recommendation of the client according to the site conditions.
  - (h) Electrical Service Cable-Cable shall be IEC/IS/CSA/UL approved for severe environments, suitable for underwater service and one continuous length based on the site condition. The cable shall be jacketed, flexible stranded cable with individually wrapped conductors.
  - (i) Particular requirement :
    - i) Contractor shall explain the technology by suitable simulation software to explain the bubble formation and zone of aeration to ensure total aeration basin shall get uniform oxygen zone is created.
    - ii) Float and Fixed mount both are acceptable and shall be provided with 100% installed/ shelf standby for the total system.
    - iii) Staad Pro model along with structural calculation shall be provided for Float or/and Fixed mounting.
    - iv) The bidder shall provide support documents/certificates to testify the claimed oxygen transfer efficiency achieved by the aerator for minimum 5m depth in line with tender specifications, for example- inspection report by competent third party or/and certified lab reports.

**c) Air Blowers (Roots Type)**

- i) The Blowers shall be sized for providing adequate oxygen into the reactor tank for aeration. The blowers shall be capable of developing the required total pressure at the process unit rated capacity for continuous operation.
  - ii) Compressor blowers shall be Roots type, each provided with inlet filter and silencer, automatic load-unload valves, pressure gauges, pressure relief valve, drain, air flow indicator and acoustic bend of silencer in the delivery branch. Bearings and gear boxes shall be separated from the blower housing by air spaces. The units shall be complete with a self contained oil cooling system for the bearings. The blowers shall be housed in a separate sound proof room to reduce the noise level or inside acoustic enclosure. The noise level shall not exceed 85 dBA at 1.86 m from blower.
  - iii) The Bearing shall be generously designed to give long operational life. Bearing at the drive end may be oil or grease lubricated. The gears and bearings at the non-drive end shall be oil lubricated. Bearings shall be provided with oil throwers to prevent leakage of oil. The delivery velocity not exceeding 25 m/s and each blower shall be provided with following components but not limited to:
    - (a) Common base frame for blower & Motor
    - (b) Inlet silencer and filter
    - (c) Discharge silencer & non-return valve in delivery branch
    - (d) Butterfly valve in delivery branches
    - (e) Pressure relief valve or excess pressure safety device
    - (f) Bellows type couplings on inlet and delivery branches
    - (g) Acoustic Enclosure
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- (h) Motor-Blower Direct Coupling
  - (i) Isolating valves, Automatic load-unload valve
  - iv) The interconnecting pipe work shall be flanged to BS EN 1092-1. A drain cock shall be provided at the lowest point in the each delivery pipe work along with reflux valve. Individual stop valves and safety valves shall be provided for each unit.
  - v) Blower shall be driven by squirrel cage motor through direct coupling. Blowers shall not run above 1000 rpm.
  - vi) Each delivery branch shall include a drain at the lowest part and a reflux valve.
  - vii) The blower equipment specified herein is standard equipment for blowers handling ambient air for use in aeration tank diffusers.
  - viii) **General Design Requirements**
    - (a) The air blowers shall be such design as to achieve energy efficient operation continuously over the range of design airflow rates at the discharge pressure that shall remain practically constant.
    - (b) Each blower shall be fitted with a variable speed motor and be capable of operating between 80 % and 110% of its nominal peak airflow demand.
    - (c) The discharge pressure shall be calculated by the operator dependent on the final design layout of the aeration system and of the delivery manifold.
    - (d) The blower shall be capable of supplying the design “mass flow” rate at maximum ambient inlet temperature of 50 deg C.
    - (e) Each of the blowers shall be capable of operating without surge in parallel with the other duty blower at the maximum mass flow against design maximum gauge pressure at the outlet pipe. The operator shall demonstrate this during testing and commissioning.
    - (f) Performance curves for the blower system shall be submitted. Standard certified factory test sheets showing the results of each test shall be supplied to the Engineer prior to Delivery of the blowers. The blower unit shall be capable to operate at maximum duty for continuous operation.
  - ix) **Blower General Arrangement** The blower arrangement shall have the following features:
    - (a) The blowers shall be roots type units
    - (b) Blower type: Rotary lobe PD or turbo/ single stage centrifugal type air blower with Variable frequency drive (VFD) for all blowers with acoustic enclosure. The arrangement shall be such that all blowers are accessible for operation and maintenance and the installation of additional blowers in the future is possible.
    - (c) The inlet air to the blower house shall be filtered to suit the blowers and aeration diffusers selected.
  - x) **Ancillary Equipment for Blowers**-The blowers shall be provided with the usual ancillary equipment for aeration duty, including:
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- (a) Acoustic enclosure with fan cooling
  - (b) Discharge pressure switch
  - (c) Discharge pressure relief valve
  - (d) Discharge automatic loading-unloading valve
  - (e) Discharge check valve
  - (f) Discharge isolation valve
  - (g) Discharge silencer, designed to minimize noise propagation along the pile work
  - (h) Vacuum switch, pressure switch, oil level indicator and any other monitoring device shall be mounted outside the acoustic enclosure
  - (i) Inlet and outlet pressure gauge shall be mounted outside the acoustic enclosure
  - (j) Vibration absorbing mounting pads

**xi) Blower Noise Limits**

The blowers supplied under this contract shall be quiet in operation. The operator shall guarantee that the total sound power noise emission for the aeration system shall be broad band and free from any total or intermittent components. Under any loading condition from no load to full rated, the blower supplied shall comply with the noise requirements.

**xii) Materials of Constructions & Tests**

- (a) The material of construction for the blowers shall be at least equal in quality to the following:

Casing	CI Conforming to IS : 210 Gr FG 260
Rotor	Alloy Steel
Shaft	Carbon Steel C40/EN 24/19
Timing gear	Cast Alloy steel
Pulley and gear side Plates and covers	CI conforming to IS 210 Gr FG 260
Impeller	As per Manufacturer's std.
Base Plate	Steel, Galvanized
Nuts and Bolts	SS



(b) Following testing shall be carried out

1	Hydrostatic Test	Twice the maximum working pressure
2	Performance test	As per BS: 1571
3	Strip test	Clearances with tolerance limit
4	Mechanical Balancing	ISO 1940 Gr. 6.3 or better
5	Visual Inspection	Before Painting

**xiii) Filters and Silencers**

- (a) The filters shall be used to remove dust, etc. Contained in the suction air. For this purpose, a filter shall be mounted directly on the suction silencer of each blower. The filter element shall be non-textile cloth or equivalent, and the element passage speed shall be 2 m/s max. The operator shall indicate the useful life period for the diffuser.
- (b) The blower shall receive filtered air individual replaceable filter elements suitable for the intended duty.
- (c) The filter element shall be housed in an airtight housing which shall allow easy replacement of the filter elements. Replacement of elements shall be possible without use of tools.
- (d) If the filters/silencer elements supplied are located out of doors, a weatherproof cover shall be provided for protection from rain.
- (e) The filter unit shall be fitted with suitable vacuum gauges to indicate the suction pressure into each blower. The gauge shall be industrial Bourdon of Schaffer type gauge with a nominal diameter 150 mm. The scale shall be suitably selected and shall include a red line to indicate the point at which the filter elements require renewal.
- (f) Each blower intake shall be fitted with a differential pressure switch, which shall indicate an alarm signal in the event of excessive pressure drop in the blower intake.

**xiv) Flexible Connections**

- (a) The blower discharge shall be fitted with an approved flexible sleeve with fixing clamps and a flanged outlet spigot for connection to site pipe work. If the blower inlet is via a common plenum the inlet pipe shall be also fitted with a flexible connection.
- (b) Flanges shall be drilled to Table D and shall comply with the required standard. Sleeves shall be manufactures from an approved non-metallic material suitable for the duty and location in which the blower are to be installed.

**xv) Pressure Relief Valve**

- (a) The pressure relief valve shall be sized and adjusted to allow the full flow of the blower to be discharged in the event of a blockage of valve closure in the downstream pipeline and without overloading the drive motor.
- (b) Each blower shall be fitted with a suitable pressure switch, which shall shut down the blower in the event of excessive discharge pressure. The pressure setting shall be lower than the set pressure of the pressure relief valves.

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- (c) The pressure relief valve shall be installed at a height above 2m from floor and away from blower suction point. The pressure relief valve shall be fitted with a silencer.

**xvi) Non-Return Valves-** A non-return valve shall be installed on the discharge pipe work of each blower, upstream of the blower isolation valve.

**xvii) Isolation Valves-** Isolating valves shall be installed on the delivery pipe work of the blowers: such that each blower and all associated pipe work and valves upstream of the common distribution manifold can be dismantled without disruption to the normal operation of the plant.

**xviii) Temperature Measurement-** Temperature sensor completes with gauge of an approved type shall be supplied for each main distribution pipe work and for the blower room.

**xix) Piping Vibration-** If the blower type selected produces a discharge flow with pulsating characteristic, flow pulsation dampers shall be installed on the blower intake and discharge, as required, eliminating excessive noise or vibration from this source.

**d) Air Blowers (Centrifugal Type)**

**i) General:**

- (a) The blower shall be of single-stage centrifugal, and shall be designed integral type. The flow rate should be adjustable by controlling the rotation speed with frequency converter or inlet vane or discharge guide vane according to the inlet temperature and differential pressure to ensure the optimal power consumption. Regulation should be possible in the range of 100-50% of the specified design flows at all project design temperatures and at design pressures.
  - (b) The regulation should be fully automated and contain a program for continuous optimization of blower efficiency with respect to changes in inlet temperature, differential pressure and required flow.
  - (c) The pressure grade of the blower casing shall be minimum PN 1.0. The casing shall be cast and bolted together and allow the impeller to be removed with the casing in situ.
  - (d) The impeller shall be open radial flow type (with backward leaning) and made of aluminum alloy, all surfaces of the vanes should be finish machining.
  - (e) High frequency, variable rotation speed and air-cooling motor should be adopted. The impeller and cooling fan should be directly connected with the motor shaft.
  - (f) The motor shall be equipped with magnetic bearings (If required), which should have the characteristic of magnetic suspension and continuous variable rotation speed. The motor should be installed at a frame with flexible fastening devices.
  - (g) Two radial magnetic bearings and one axial magnetic bearing shall be orientated accurately via the active-bearing controller controlling the rotor. The active bearing controller shall be powered by one DC and one 3 phase AC input. The service life of all bearings should be more than 100000 hours.
  - (h) Appropriate cooling arrangement shall be provided at the blower discharge line so as to bring down the outlet air temperature within tolerable limits, so as to safeguard the life of fine bubble diffusers and satisfactory performance of the same. This cooling arrangement is mandatory with all types of Blowers.
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- (i) The local control cabinet should be equipped with display screen and keypad unit. The running state of the blower should be able to monitor at real time. The displayed data at least include the following:
    - i) Actual flow (%)
    - ii) Running time (hour)
    - iii) Running time (day)
    - iv) MWh counter
    - v) Differential pressure
    - vi) Reference flow (%)
    - vii) Model of the blower
    - viii) Power frequency of the motor (Hz)
    - ix) Current (A)
    - x) Transition temperature
    - xi) Motor temperature
  - (j) When operating, if the control system finds fault, the blower will give an alarm automatically or stop and the fault code will be displayed at the control cabinet.
  - (k) The blower should have the following protection functions (but not limited to):
    - i) Over voltage of the main power supply
    - ii) Under voltage of the main power supply
    - iii) I-phase fault
    - iv) Over voltage/Under voltage of the auxiliary power supply
    - v) Inlet and outlet air pipe blocking
    - vi) Air temperature is higher than the specified limited temperature
    - vii) Cooling air temperature is high than the specified limited temperature

**ii) Accessories**

- (a) Inlet filter and silencer :
    - i) Each blower shall be provided with an inlet filter/silencer mounted directly on the inlet of the Blower via a flexible connection. Such mounting is for the purpose of reducing pressure drop across the inlet appurtenances and of minimizing noise from pipes. Filter/silencer housing shall consist of stainless steel plate and acoustical sound-deadening material on the inside.
    - ii) Filters shall be removable through easily accessible doors and have very high removal efficiency and shall be sized for maximum face of velocity of 2m/sec at peak air flow.
  - (b) Discharge Flex Connector-
    - i) Each blower shall be provided with discharge expansion Bellows joint of SS 316. The expansion joint shall alleviate stress caused by thermal expansion and contraction in the piping system.
    - ii) The expansion joints shall be capable of withstanding the pressure under all operating conditions and shall be rated for temperatures up to 160°C.
  - (c) Discharge Cone Diffuser Silencer-
    - i). Each blower shall be supplied with a combined discharge cone diffuser-silencer to increase the discharge from the blower outlet to the discharge pipe, thus reducing the air velocity to max. 20 m/sec. The length of the discharge cone shall be
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aerodynamically designed in order to recover dynamic pressure head and minimize discharge turbulence.

- ii). The discharge cone shall be constructed of stainless steel plate and acoustical sound-deadening material on the inside, with flanges, and be equipped with a stud for a possible measuring device.
- (d) Blow-off (Bypass) Valve -Each blower shall be provided with a blow-off valve to allow unloaded start-up and unloaded stop. The valve operator shall be motorized, equipped with open/closed limit switches, and shall be suitable for air service at 200°C operating temperature. Controls for the valve shall be mounted in each local blower control cabinet with indicating light.
- (e) Blow-off silencer -Blow-off silencer shall be provided for each blower and mounted on the discharge by-pass line. The blow-off valve silencer shall be constructed of stainless steel and contain sound absorption material encased in an outer shell. The silencer shall have one sleeve inlet connection for mounting onto the end of the bypass line.
- (f) Discharge check valve (Back-flow Barrier) -Each blower shall be provided with one discharge check valve flange ends located in the discharge side pipe work, spring loaded butterfly design for mounting between flanges according BS EN 1092-1/BS: 4504 or Eq. The pressure losses of the fully open valve must not exceed 1.0 kPa. The valves shall be rated for temperatures up to 160°C.
- (g) Noise Protection Cover-The blower and motor should be covered with one Acoustic cover, which should be equipped with electric cooling ventilator.
- (h) Base plate and anchor bolts-Each blower unit shall be furnished with a frame of adequate size to support the blower, motor, magnetic bearing controller frequency converter, control cabinet and other accessories. The base plate shall be constructed of fabricated steel, provided with lifting lugs and of sufficient rigidity to permit lifting by a fork-lift, with all equipment mounted, without distortion or other damage to the base plate or to components parts of the machinery.

**iii) Material of Construction:**

- a) The material of construction shall be considered as following:

Description	Material of Construction
Blower Housing	Ductile (SG) Iron IS 1865 Gr.500/7 or Superior grade
Impeller	Aluminum alloy
Shaft	SS410
Base plate	Profiled steel
Inlet filter, silencer casing	SS 304
Acoustic enclosure	Al-Zn coated steel, insulated with glass wool

Blow-off silencer and motor cooling silencer	SS 304
Inlet cone extension	SS 304
All connecting accessories and anchor bolts	AISI 316

**iv) Control**

- (a) The control system of the blower should be well connected with the control system of the whole plant. All the real time monitor and protection function shall connect with the control software; the remote control shall be carried out with 4-20 mA or network.
- (b) Local control panel and control cabinet shall be combined, that include display screen and keypad, main switch and lock stop push button. The blower operation shall be controlled by the main running switch and keypad.

**v) Performance Guarantee:**

- (a) The Performance of the compressor shall be guaranteed according to the requested project design values subject allowed tolerances on Flow & Pressure: +/- 0%, and Power: 2%.
- (b) Compressor or any portion thereof is liable for rejection, if it fails to give any of the guaranteed performance parameters.

**TURBO AIR BLOWER**

The turbo air blower shall be compact, centrifugal, rotary type single stage, incorporated uni-built / coupled high efficiency Induction / permanent magnet motor and integrated variable speed frequency drive control system with all safety controls required for monitoring the system

It shall be capable or operating preferable within a range of 20,000- 30,000 RPM With normal operating speed being 25,000 RPM, It shall be able to operate under varying pressure and flow Conditions as per process requirement. Minimum turndown ratio should be 50% The Maximum idle time between OFF and ON shall not exceed 30 seconds.

The blower casing shall be volute type of robust construction and made of cast aluminum

Turbo Blower's impeller shall be mounted on the Shaft properly Keyed /locked and made of machined cast stainless steel / cast aluminum and shall be smother, deeper with intricate vane design in order to provide better strength and Stability.

Impeller shall be dynamically balanced individually and again after mounting on the shaft together with rotor with other rotating parts shall be dynamically balanced. Impeller shall be made in one piece.

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The motor shall be maintenance free, air cooled and high efficiency. The rotor of the motor shall be small light weight. Motors shall be suitable for 415 V+10%, 50Hz+-5% 3 phase AC supply.

The motor with aerodynamic fluid film, non contact, non wearing, oil free air foil bearing Shall be preferred.

### **Control Panel**

The Control Panel shall be skid mounted and shall feature the basic functions for start and stop of the turbo blower. Panel shall have following features.

- Controls modes for constant flow mode, constant pressure mode and proportional mode
- PLC integrated with VFD
- Simple touch screen HMI interface
- HMI display for discharge pressure, inlet temperature, discharge temperature.
- Flow rate, Bkw consumed, speed, diff. Pressure across the inlet filters, performance curve with actual operating monitoring.
- Complete system monitoring
- Storage of historical data of all measured parameters for the last 90 days.
- Communications port (Ethernet) for connectivity to main PLC / SCADA
- Ethernet Connectivity (Web based Control)
- UV Protective cover

### **The turbo unit compromise of all required instruments as follows:**

- Inlet air temperature transmitter
- Oil temperature Transmitter (If applicable)
- Oil Pressure Switch

The turbo blower shall be provided as a Complete package in Ready to use (RTU) unit comprising of blower, motor, variable speed motor starter, pressure, relief valve, expansion joint, a suction air filter and silencer, blow off valve, outlet silencer, delivery isolating and non-return valve, cone diffuser, control panel with all safety control and acoustic enclosure of proper design along with all accessories not mentioned here but required for smooth operation of the unit after providing electric connection to the unit and joining delivery header to the discharge cone / flange

A metallic bellow joint shall be provided on the delivery side of each blower.

Noise level should be less than 85 dBA at 1.00 m from blower whereas Vibration level should be less than 1 mm / sec. Vibration of rotating equipment shall be within the limit mentioned below with points of measurement as per ISO-2372-1974 amendment 1-1983.

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**Equipment with prime movers motor  
m/sec**

**Velocity of Vibration per**

KW less than or equal to 15 kw

1.12

15 kw to 75 Kw

1.8

> 75 kw

2.8

Unit shall be with Anti Vibration mounting / pads at foundation level to keep Vibration of the equipment within acceptable limits.

**e) Air Compressors**

- i)** If a compressor system is required for some reason, it shall comprise compressors, after-coolers and air dryers, duty/standby air receivers together with control equipment, oil eliminating filters, flow regulators and oil mist lubricator as required.
  - ii)** Electrically driven air compressor sets shall operate up to minimum 10 bar working pressure.
  - iii)** Compressor sets with at least 1 standby shall be provided complete with the following:
    - (a) Common base frame for compressor & Motor
    - (b) Single stage air cooler unit
    - (c) Isolating valves
    - (d) Air filter and silencer
    - (e) Pressure relief valve of excess pressure safety device
    - (f) Pressure reducing valves
    - (g) Pressure gauges
    - (h) Off loading Piston
    - (i) Automatic changeover (failure of duty unit)
    - (j) Drain pipes
    - (k) V-Belt drive arrangement with belt Guard
    - (l) Stoppers
    - (m) Air receivers
    - (n) Other necessary appurtenances
  - iv)** Compressors shall be arranged for automatic changeover on failure of the duty unit. Failure of the duty unit shall initiate an alarm. Control equipment shall include automatic unloading valves, pressure switches for duty standby and alarm, and lockable changeover switches.
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v) One duty & one standby after cooler shall be provided. Water cooler of air blast types will be considered. Air receivers shall be design and fabricated in accordance with relevant approved standards. They shall be mounted vertically on steel feet so that sufficient space is allowed for each access to the whole outside surface. Receivers shall be provided with drain cocks piped to drain pressure gauges, relief & check valves.

vi) Supply of all necessary electrical components, devices, equipment, control panels, etc. Together with cabling, earthing provisions, etc. Shall be the responsibility of the operator.

vii) Interconnecting pipe work shall be arranged with drain cocks piped to waste.

**f) Chlorination System**

i) Chlorine solution diffusers shall be supplied and installed at the dosing point.

Treated sewage shall be dosed with chlorine gas at concentrations not more than 10 mg/l. Effluent from the chlorine contact tank shall not have more than 1 mg/l of residual chlorine.

**ii) Chlorinators**

(a) Vacuum type chlorinators shall be supplied with one duty and one standby unit.

(b) Chlorinators shall be free-standing, floor-mounted, and shall have a turn down ratio of 10: 1 over the full range of works operation.

(c) The dosing rate shall be manually set and each chlorinator shall be equipped with a 0 to 10 mg/l scale and a manual dose setter over the complete range

**iii) Motive water pumps and Injector**

(a) Motive water pumps (1 working + 1 standby) shall be installed.

(b) The pumps shall draw their supply from bore well/plant water supply.

(c) The pumps shall be installed outside the chlorination room and shall be made from material resistant to corrosion by chlorine.

(d) Two injectors shall be provided, each serving a duty / standby pair of chlorinators. The injectors shall be located near point of dosing i.e upstream of Chlorine contact tank.

**iv) Inline Vacuum/venturi type chlorine injectors**

(a) In line Venturi type which shall mix Cl gas metered from Chlorinator into motive water from Booster Pump

(b) All wetted materials shall be constructed of Grade 2 Titanium (unalloyed). The motor shall be chemical duty type.

v) **Chlorine**-Chlorine shall be supplied as liquid from nominal 1 ton chlorine tonner.

**vi) Tonner Room**

(a) Storage shall be provided for chlorine tonners sufficient for at least one month's usage at normal rates of application.

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- (b) The system shall be designed to prevent freezing of the liquid chlorine at the maximum rate of withdrawal.
  - (c) Tonners on line, tonners on standby and full and empty tonners, shall be stored separately in the tonner room.
  - (d) Four sets of tonner rollers shall be provided. Tonners not in use shall be stored on concrete cradles. Tonner shall be provided with suitable capacity chain pulley block (Min. 2 Ton)
  - (e) The container lifting beam shall be specifically designed for handling chlorine containers and equipped with necessary shackles and hooks.
  - (f) Operation of crane system shall be from the floor level using independent push button pendant controls operating at a 230 volt 50 Hz AC supply.
  - (g) Two lifting beams shall be provided (a duty and a spare) and a one tonner weighed to be suspended from the crane hoist.
  - (h) When the pressure in the duty chlorine tonner falls to less than 1 kg/cm<sup>2</sup> the automatic changeover device shall operate to isolate the empty tonner and to bring the full standby tonner on line.
  - (i) A pit and alkali absorption system shall be provided to contain and neutralize chlorine in the event of a leak. The system shall comprise a pit located in the tonner storage room and accessible by the overhead crane system. The pit shall be surrounded with removable guard railing. The pit shall be kept full with a neutralizing solution of lime. The pit shall be capable of holding side by side two chlorine tonners. A provision shall be made to drain the pit. Tonner shall be provided with suitable capacity chain pulley block (Min. 2 Ton) also Neutralization Pit for the suitable capacity to handle the leakage of Chlorine Tonner to be constructed in the vicinity of the tonner in Chlorine room.
  - (j) Special consideration shall be given to any floor drainage system in the tonner building; adequate traps shall be provided to ensure that chlorine gas cannot escape. All leader tubes carrying cables or pipes out of the building shall be sealed at either end to prevent any chlorine gas leaking out.

**vii) Chlorination Room**

- (a) The chlorination room shall be constructed adjacent to the tonner room but with no interconnecting door or other form of access.
- (b) Gas lines from the tonner room into the chlorination room shall run in ducts to be sealed after installation and prior to commissioning.

**viii) Chlorine Leak Detectors**

- (a) One Chlorine Gas Detector shall be provided with Single Detection Cell located in Chlorine Tonner room
  - (b) Statutory warning notices relating to the storage and handling of chlorine shall be provided. The signs shall be pictorial and provided in Gujarati and English.
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**ix) Ventilation System**

- (a) Each area where chlorine is stored or used as gas or liquid shall be provided with a forced ventilation system. Air intakes shall be sized to allow uniform ventilation and positioned to prevent possible recirculation. Exhaust air shall be ducted from low level and discharged at high level.
- (b) An air change rate of four per hour under normal condition and a minimum of twenty changes of air per hour under shall be used in the event that a chlorine leak is detected.
- (c) Exhaust fans shall be heavy duty industrial pattern manufactured from chlorine resistant materials.
- (d) Ductwork shall be manufactured from U-PVC extruded sheets or circular sections.
- (e) Ducts shall be designed in accordance with relevant Indian standard specifications.

**x) Safety Equipment**

- (a) Materials and equipment necessary to ensure the safety of personnel operating the chlorination plant and others shall be provided.
  - (b) Safety equipment shall include:
    - i) Two sets of approved self-contained breathing apparatus, each comprising an air set, carrying harness, face mask and valves and ancillary equipment. Each set shall be provided with three 1200-liter capacity, 140 mm diameter, air tonners.
    - ii) Two No of Canister type Gas Mask
    - iii) Two sets of approved positive airline breathing apparatus, each comprising body harness, face masks and valves and 30 m of airline with Suitable Air Tonners along with airline hose.
    - iv) Emergency Repair Kit suitable to handle Gas leakage from Chlorine Tonner
    - v) Two 'instant action' resuscitators.
    - vi) Four sets of safety clothing in various sizes, each comprising PVC overalls, wellington boots with steel toe caps, goggles, gloves and safety helmets.
  - (c) All the Safety Equipment should be as per the applicable IS standard for Chlorination as per the CPHEEO and in addition to above list as per the requirement.
  - (d) Each set of safety equipment shall be mounted in a glass-fronted, non-locking PVC coated steel cabinet in approved locations on the outside of the building.
  - (e) Two emergency showers shall be provided and shall be installed outside on either side of the tonner room.
  - (f) Each shower shall be operated automatically by a quick acting hand or foot valve.
  - (g) Four eyebaths shall be supplied. Two eyebaths shall be adjacent to each of the showers.
  - (h) Water for the showers, etc, shall be drawn from the service water supply.
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- (i) A telephone will be provided close by outside the building for emergencies.

**xi) Chlorination Power & Control**

A combined MCC and control panel shall be provided and located in a suitable location protected from the weather and the effects of the process. The control panel provide facilities for :

- (a) Display status and values associated with the chlorination systems;
- (b) Duty pump selection;
- (c) Annunciate alarms associated with the chlorination systems;

**g) Sludge Handling**

**i) General**

As sludge generated from different process units depending upon the process adopted, it is advised to provide sludge handling units and equipment like sludge thickeners, Digesters, centrifuge or vacuum filter press or screw press or bag filter, combo-machine and other ancillary units which is suitable for the process and which is sustainable from Operation & Maintenance point of view. The units and equipment shall be selected accordingly which occupies less power, space, chemicals and maintenance.

**ii) Gravity Thickeners**

- (a) Circular (radial), fixed bridge, central turn table type or peripheral drive type picket fence, collecting effectively with proper circumferential speed, a clarifier shall be provided. The clarifier shall be rugged and robust in design and shall be provided with high capacity drive head and induction motor having high torque rating, centrally or peripherally located, with positive sludge raking by means of one or more raking arms. Both the raking arms should have scraper blades fitted at the bottom, so that the sludge from scraper blades is pushed to the sump on every rotation.
  - (b) The circular reinforced concrete thickeners tapering at bottom shall be provided for thickening process. The sludge laden suspension from Waste water balancing Tank shall be fed to thickeners.
  - (c) Design shall be such that the sludge can become compacted and can be extracted from the bottom. Interstitial liquid flows through peripheral weir at top. Tanks shall be deep enough to allow the sludge to settle. At least 50 cm freeboard shall be provided. Provision shall be made to remove the sludge from top if there is a serious risk. Provision shall be made for collection of thickened sludge and pumping it to Centrifuge.
  - (d) A full diameter bridge with central drive shall be provided with: central platform for the installation of the scrapers and their drives and for the local control panel; a radial scraper system with bottom scraper blades, suspended on the bridge.
  - (e) The thickeners shall have a full diameter fixed bridge complete with 1200mm walkway for personnel access to the center, access stairs to ground level and hand railing, a motor driven sludge scraper complete with all necessary controls, delivery pipe work, a stilling well and overflow steel weir plates. Hand railing, walkways, access steps etc shall be galvanized. Handrails shall be of tubular construction and made of 32NB pipes.
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- (f) The scraping gear shall be supported from the tank base and from a fixed bridge carrying the central electrical drive for the rotating gear. The equipment including driving motor, gears, shafting and scrapers shall be designed for continuous operation and sized for the most arduous operating condition including starting from rest with an accumulation of sludge in the thickeners.
  - (g) The electric motor, gearbox etc., shall be provided with a sunshade.
  - (h) The fixed bridge, hand railing, access steps and the feed well shall be galvanized steel. The main drive shall be cast Iron construction and shall be enclosed in a dustproof enclosure with oil bath lubrication. All underwater hardware shall be of SS316.
  - (i) Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided.
  - (j) The scrapers shall be fitted with rotation monitors and over torque protection to alarm in the event of a failure.
    - i) Corrosion allowance of 2 mm shall be taken in the structural sections of scraper arm, bridge etc.
    - ii) Structural design calculations shall be submitted for all structures including scraper arm, bridge etc. And also the calculation for drive head selection including the Torque Rating.
  - (k) V-notch weir in Reinforced fiber glass construction of size minimum 5mm thick and 200 mm wide shall be provided along the launders for uniform draw-off of the overflow. The weir plate shall be fixed to the launder by means SS316 grade clamping plates and fasteners.
  - (l) The hydraulic equipment will consists of the DI inlet pipe (runs along the bridge) to the central feed well of the thickener; sludge draw-off pipe with an manual & Motorized Knife Gate valve (in SS CF8M material of construction) for intermittent operation according to an adjustable timer; a drain pipe with manually operated gate valve for the complete emptying of the unit; a discharge pipe/channel from the peripheral collecting channel to the main channel leading to the Supernatant sump. The sludge thickener mechanism shall be generally in MS galvanized construction, suitable for installation in a circular RCC tank and shall include the following:
    - i) Mechanism support beam spanning the diameter of the tank.
    - ii) Walkway and handrail from the edge to the center of the tank.
    - iii) Drive mechanism with internal gear type.
    - iv) Reduction gear box.
    - v) Chain and sprocket with guard.
    - vi) Central shaft with scrapper arm and picket fence.
    - vii) Skimmer Scum Baffle and Scum trough.
    - viii) Overflow weir:
    - ix) Vertical pickets.
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- x) Torque Indicating Device.
- xi) Overload Alarm protection.

**iii) Dewatering Centrifuges**

- (a) The Dewatering Machine and its peripheral equipment shall include but not necessarily be limited to the following;
  - i) Powder or liquid Coagulant storage tanks.
  - ii) Mixers and solution tanks.
  - iii) Coagulant service tanks.
  - iv) Supply line & flush line.
  - v) Chemical feeding pumps.
  - vi) Water supply pumps.
  - vii) Sludge feeding pumps.
  - viii) Dewatering Centrifuge
  - ix) Belt conveyor.
  - x) Cake hopper.
  - xi) Flow meters for feeding Sludge, and for feeding chemical solution.
  - xii) Control valves on sludge feeding line, and on Chemical feeding line.
  - xiii) Drain system
- (b) Dewatered cake shall be conveyed by a belt conveyor to cake hopper for carrying out for reuse.
- (c) To select the type of dewatering machine, Contractor shall provide technical information to show client that performance to obtain his approval in advance.

**iv) Decanter Centrifuge**

- a) The centrifuge shall comprise a conical cylindrical bowl and scroll feed horizontally mounted in bearings on a frame. The centrifuge bowl and scroll support frame shall be mounted on a fabricated steel sub-frame.
- b) The bowl and scroll shall be made from stainless steel AISI 316 material. The leading faces of the scroll shall be protected against abrasive wear by the application of a suitable hard-coated material.
- c) The whole rotating assembly shall be enclosed by a Stainless steel (AISI316) fabricated casing incorporating a Centrate discharge hopper and outlet pipe, and a rectangular solids hopper which shall discharge the dewatered sludge into the disposal system.
- d) The rotor shall consist of a solid bowl which is conical-cylindrical in shape and which rotates about a central shaft. An inner scroll shall be provided to convey separated

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sludge from the periphery of the cylindrical bowl to the beach at the conical end of the rotor.

- e) The main scroll bearings shall be arranged for lubrication by an external lubrication system. Wherever practicable greasing nipples shall be arranged together as a battery. The complete rotating assembly shall be dynamically balanced and test certificates provided.
- f) Sludge shall be fed into one end of the rotor through a centrally positioned feed tube and dispersed to the bowl through an inlet chamber.
- g) The bowl shall be provided with an adjustable 360° peripheral weir at its cylindrical end to control the depth of the Centrate in the rotor.
- h) The fixed outlet castings of the rotor shall be designed to collect the Centrate and dewatered sludge from the rotor. Baffles within the casing shall direct the separate phases to the relevant discharge points and prevent cross-contamination.
- i) The centrifuge shall be mounted on heavy-duty vibration isolators, located between the machine and the supporting steelwork or foundations, to damp vibrations and prevent vibration transmission. Two axis vibration monitors shall be provided to stop the centrifuge automatically when excessive vibration is detected.
- j) Flexible connections shall be provided on the sludge fed system and the Centrate system at the centrifuge. The dewatered sludge discharge system shall incorporate flexible chutes.
- k) Variable Speed Drive
  - i) A variable speed drive shall be provided to accelerate the rotor to operational speed and maintain that speed during the centrifuge's duty period. The bowl drive shall be electric or hydraulic and shall be coupled to the drive shaft by a multiple 'V' notch belt drive.
- l) Differential Scroll Drive
  - i) The scroll drive shall be provided with a separate drive mechanism to control its rotation in the same direction but at a different speed to the outer bowl. The differential speed shall be adjustable.
  - ii) The drive shall be linked to the main bowl drive by an epicyclic gearbox. The differential speed of the scroll shall be automatically and manually adjustable so that the moisture content of the dewatered sludge can be controlled as required.
- m) For safe operation, contractor shall provide control panel showing proper Sequence of operation with interlocking.
- n) Chutes and interconnecting piping shall be provided with flexible joint (minimum 10 mm flexible in all direction) to avoid vibration.

**v) Screw Press:**

- a) The screw press should be with a conical screw shaft and cylindrical sieve consisting of three treatment zones: inlet and drive zone, three-part thickening and dewatering zone, and press zone with pneumatic counter-pressure cone.
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- b) The screw press must be fed with flocculated sludge of sufficient stability. The first part of the screw press should be provided with large free screen surface so that the free supernatant liquor is quickly removed from the sludge.
  - c) The pressure probe should be provided in the inlet to protect the plant against excessive primary pressure and consequently excessive pollution of the filtrate liquor and excessive residual moisture in the sludge outlet.
  - d) The second part of the screen is to be designed in such a way that the volume of material between the screw flights is reduced by the conical screw and the sludge is pressed against the inner screen surface so that the sludge is dewatered, with a continuous reduction of the filter cake thickness. The screen apertures should be much smaller in this screen section.
  - e) In the third part of the screen the residual water will be pressed out of the sludge, at a minimum filter cake thickness, by the pneumatic counter pressure cone at the press discharge. Depending on the type and consistency of the sludge flocks the pressure applied on the sludge is to be varied infinitely.
  - f) The conveying screw should push the dewatered sludge past the pressure cone into the discharge chamber.
  - g) The sludge residence time in the screw press and thus the filtration time should be adjustable to individual requirements by adjusting the rotational speed of the screw shaft.
  - h) Brushes should be fitted on the flights to ensure permanent automatic sieve cleaning from inside.
  - i) Intermittent cleaning of the sieves from outside is to be accomplished by a spray bar. The spray bar should be stationary mounted whereas the screen basket is a rotating element.
  - j) For the purpose of cleaning, the feed into the screw press is to be temporarily stopped and the screw shaft should rotate in reverse. The flexibly supported screen drum should perform one complete rotation passing by the spray nozzle bar to clean the complete screen surface.
  - k) In pressing mode, sludge feeding should start again and the screw shaft should rotate forward. The screen basket should rotate until arrested by ratchets anchored in the casing. Thus the pressing process should continue.
  - l) Electrical appliances on the machine:
    - i) Drive motor of screw
    - ii) Solenoid valve in the wash water connection
    - iii) Pressure sensor on the sludge inlet housing
    - iv) Pressure switch for compressed air supply (optional)
  - m) Material of construction : Screw Press should be made of stainless steel material AISI 316 (or similar) and pickled in an acid bath
  - n) Accessories for Screw Press :
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- i). Polymer injection and mixing device -For continuous mixing of coagulants and sludge, comprising of polymer injection ring with integrated distribution channel and 4 injection nozzles. Double sealed cover provides easy access to distribution channel and nozzles.
- ii). One-piece blockage-free design, self adjusting mixing energy via lever and adjustable weight. Weight loaded mixing valve with inspection opening.

Nominal width	DN 65, DIN 2501
Fitting length	280 mm
Total length	660 mm incl. Lever and weight
Polymer connection	DN 25 socket
Housing	Cast iron, RAL 5015
Movable parts	AISI 420

o) Supercharge reactor

- i). For optimal floc formation downstream the polymer injection and mixing unit. Horizontal reactor shaped to provide defined turbulence and pressurized feeding of the screw press.

Reactor length	4000 mm
Diameter	250 mm
Height adjustment range	180 – 200 mm
Volume	approx. 160 l
Inlet flange	DN 65
Outlet flange	DN125

- ii). Material of Construction: Reactor completely made AISI 316, including height adjustable support legs.
- iii). Pressure adjusting system-To regulate the pneumatic pressure cone. The system allows a fine adjusting of the compressed air. Lack of air is electronically detected and the cone can be moved backwards by hand lever valve.
- iv). Supply should include pressure sensor and a hand lever valve wired ready for connection on a galvanised plate.

L x H: 334 x 355 mm

Air inlet (6-8 bar): 1 x 10 mm push-in fitting

Air outlet: 2 x 10 mm push-in fitting



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Electronic pressure switch with 2,5 m connector cable for voltage supply (24 V) and PNP switch output.

- v). Electrical control panel for Screw Press-Control panel suitable for wall mounting in compliance with UVV and VDE standards, complete with all components required for fully automatic plant operation, switch on/ off of individual drives via function keys on control unit, motor protection relay, overload protection, fuses, relays, lockable mains isolator, socket-power unit 24V DC. Display on control unit of operating hours, operating and fault signals, and run times.

**Control panel:**

Painted steel RAL 7032

Protection grade: IP55

To control the following units:

One (1) Screw Press incl. Power element (frequency converter)  
One (1) flocculation reactor stirrer incl. Power element (frequency converter)  
One (1) filling level probe in flocculation reactor to prevent reactor overflow  
One (1) washing system control  
One (1) release/ fault thin sludge pump  
One (1) release/ fault coagulant agent pump

- vi). Frequency convertor-Designed in compliance with CE safety and EMV standards, convertor for integration in main control panel of the electrical switchboard comprising:

Three-phase alternating voltage 3 x 380 / 460 V AC

Typical shaft power PM,N = 3.0 kW

Frequency f = 50 Hz

protection IP 20

Integral class A EMI filter

Control display

- vii). Compressed-air plant - Miniature compressor for compressed-air production and pneumatic regulation.

Type Piston compressor  
Effective delivery : Q=200l/min  
Max. Pressure : p=10bar  
Reservoir volume : V=24l  
Performance with 400 V AC: P=1.1kW  
Protection grade : IP54  
incl. Maintenance unit and pressure regulating valve

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## **2) Pumps and Mixers**

### **a) Dry Pit Pumps**

#### **i) General**

- a) The total head capacity curve shall be continuously rising towards shut off with the highest at shut off.
- b) Pumps shall be suitable for single as well as parallel efficient operation at any point in between the maximum and minimum system resistances.
- c) Pumps shall run smoothly without undue noise & vibration. Noise level shall be limited to 85 dB(A) at 1.86 M at sites. Vibration shall be limited to class II C of BS 4675/ zones A & B of ISO 10816-1The pump set shall be suitable for starting with discharge valve open or closed.
- d) The pump set shall be capable of withstanding accidental rotation in reverse direction.

#### **ii) Construction Features**

- a) Pump shall be centrifugal, back pullout, single stage type.
  - b) Pump casing shall be of robust construction. Liquid passages shall be finished smooth and designed so as to allow free passage of solids. The volute tongue shall be straight across and filed to a smooth rounded edge. Casing shall be provided with wearing ring.
  - c) Hand hole shall be provided in the casing to allow easy access to the impeller as well as to the casing throat. Casing drain connection with stainless steel collared plug shall be provided.
  - d) Impeller shall be non clog type with smooth blunt edges and large water ways so as to allow free passage of the 50 mm size solids. It shall be free from sharp corners and projections likely to catch and hold rags and stringy material.
  - e) The critical speed of the rotor shall be at least 30% above the operating speed. Complete rotor shall be balanced dynamically as per ISO 9906
  - f) Replaceable shaft sleeves shall be provided and shall be securely locked or keyed to the shaft to prevent loosening. The surface hardness of the shaft sleeve shall be minimum 400 BHN.
  - g) Bearings shall be easily accessible for inspection and maintenance. The bearings shall have a minimum working life of 40000 hours of working. Bearings shall be grease lubricated or non grease type.
  - h) Stuffing boxes shall be of such design that they can be repacked without removing any part other than gland and lantern ring. Stuffing box drain with pipe connection shall be provided at the lowest point so that no leakage accumulates in it.
  - i) Lantern ring shall be sandwiched between packing and shall be easily removable. Lantern ring shall be of axially split type. Grease shall be used for stuffing box sealing. Water will not be available for this purpose.
  - j) The pump and motor shall be coupled through a flexible coupling. The motor shall be mounted directly on pump casing.
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- k) It should be possible to lift the complete pump vertically through the opening provided in the motor floor level in the pumping station.
- l) Tapings shall be provided at suction and discharge nozzles for pressure gauge connection. Water flushing arrangement shall be provided for cleaning of sludge pipe line at its delivery side.
- m) Impeller wear ring hardness shall be min 50 BHN higher than that of Casing wear ring.
- n) The material of construction for Centrifugal Dry Pit Pump shall be as follows :

Sr. No.	Component	Material	
		Non-clog type	For clean water (for service water etc)
(i)	Impeller *	Stainless Steel : ASTM A 743 CF8M	Cast Iron to BS EN : 1561 Gr EN-GJL-200 with 1.5 to 2% Nickel, or better
(ii)	Casing *	Cast Iron to BS EN : 1561 Gr EN-GJL-200 with 1.5 to 2% Nickel	Cast Iron to BS EN : 1561 Gr EN-GJL-200 with 1.5 to 2% Nickel
(iii)	Shaft*	Stainless Steel : BS:970 Gr 431 S29	Carbon steel or better
(iv)	Shaft sleeve	Stainless Steel : ASTM A 743 CA 15 Hardness 400 BHN	Stainless Steel : ASTM A 743 CA 15 Hardness 400 BHN
(v)	Casing ring	Stainless Steel : ASTM A 743 CA 15	Stainless Steel : ASTM A 743 CA 15
(vi)	Impeller ring	Stainless Steel : ASTM A 743 CA 15	Stainless Steel : ASTM A 743 CA 15

\* Material test certificates shall be furnished by the Contractor

**b) Submersible Pumps**

**i) General**

- a) Submersible pumps shall be of the single entry design supplied complete with boltless self-aligning duck-foot assemblies giving automatic connection to the discharge pipe work.
- b) The total head capacity curve shall be continuously rising towards the shutoff with the highest at shutoff.

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- c) Pumps shall be suitable for single as well as parallel efficient operation at any point in between the maximum and minimum system resistances.
  - d) The pumps shall be designed to handle solid sizes of up to 80 mm.
  - e) Pumps shall run smooth without undue noise and vibration.
  - f) The pump set shall be suitable for starting with discharge valve open and/or closed.
  - g) The pump set shall be capable of withstanding the accidental rotation in reverse direction.

**ii) Construction Features**

- a) Pump shall be centrifugal, vertical spindle, non-clog, wear resisting, and single stage type.
  - b) Pump casing shall be of robust construction. Liquid passages shall be finished smooth and designed as to allow free passage of solids. The volute tongue shall be filed to a smooth rounded edge.
  - c) Double mechanical seal shall be provided to protect the motor from ingress of liquid along the shaft. The preliminary and secondary seals shall be oil-lubricated with tungsten carbide or silicon carbide faces and they shall be equipped with an electrical monitoring system for seal failure detection. Sensors are to be provided to detect if leakage of liquid into oil housing is above 30% concentration.
  - d) Double mechanical seals shall be provided to protect the motor from ingress of sewage along the shaft. the preliminary and secondary seals shall be oil-lubricated with tungsten carbide or silicon carbide faces and they shall be equipped with an electrical monitoring system for seal failure detection.
  - e) Impeller shall be non-clog open/semi open type for raw sewage and sludge application and enclosed type for clear water/treated sewage / filter rate pumping application with smooth blunt edges and large water ways so as to allow free passage of the large size solids. It shall be free from sharp corners and projections likely to catch and hold rags and stringy materials. The number of impeller vanes for pumps up to 1000 m<sup>3</sup>/hr shall be limited to two and shall be limited to three for the pumps higher than 1000 m<sup>3</sup>/hr.
  - f) The critical speed of the rotor shall be at least 30% above the operating speed.
  - g) Pump sets shall have double bearings. the bearing life shall be minimum 40,000 hrs of operation.
  - h) Each pump shall be complete with a CI delivery connection arrangement for fixing to the concrete floor of the suction well. All necessary SS fixtures required for guiding the pumps during lifting/lowering shall be provided. The installation shall facilitate automatic installation and removal of pump without a person entering the wet well. Each pump shall be provided with a SS-316 lifting chain with suitable provision for engaging the hook of the crane at 1 m interval.
  - i) Each pump shall be provided with an automatic coupling device for attaching the crane hook to the pump at low level, even whilst the pump is submerged, without the need for personnel to enter the wet well. This automatic coupling devise shall easily
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and automatically couple and uncouple the hoist hook and be complete with necessary accessories. All links and cables shall be multi-stranded SS.

- j) The submersible pumps shall be suitable for operation with or without submergence.
- k) The pump shall start and stop automatically based on the level in the wet well.
- l) The synchronous speed shall not exceed 1500 rpm at 50 Hz supply.
- m) The material of construction for submersible pumps shall be as follows:

Sr. No.	Component	Material
1	Impeller	SS : ASTM A 743 CF8M
2	Casing	CI, IS: 210 Gr FG 260 with 1.5 to 2 % Nickel
3	Shaft & Sleeve	SS : BS:970 AISI Gr 316
4	Bearing Bush & Wearing ring	Bronze IS 318 Gr LT B2
5	Guide Rail Pipe	SS : BS 970 AISI Gr 316
6	Fasteners and Foundation Bolts	Ss : BS:970 AISI Gr 316
7	Bearing	Ss : BS:970 AISI Gr 316

- n) The submerged cable shall be a multi-core flexible cord, Vulcanized rubber insulated with tough rubber sheath and outer PCP sheath to BS 6500.
- o) Where both thermal protection and moisture-sensitive devices are incorporated within the pump, both devices shall be brought out via separate conductor within the motor cable, although one such conductor may be common

**c) Centrifugal Pumps**

- a) Centrifugal pumps shall have head/quantity characteristics which fall continuously from the maximum pressure at closed valve conditions and which are steep in order that variation in head shall have a minimal effect on the quantity discharged.
- b) The design speed of any pump with a duty flow greater than 20 l/s shall not exceed 1500 rpm. Pump motor rating shall exceed the maximum pump power consumption over the operational range of the pump by at least 10%.
- c) Waterway through the pump shall be smooth in finish and free from recesses and obstructions. Impeller passageways shall be as large as possible. The leading edges of the impeller vanes shall be rounded and smooth.
- d) Water velocities in the pump suction side shall not exceed 1.5 m/s and on delivery branches of a pump the velocity shall not exceed 2.0 m/s when the pump is operating within its specified duty range and within this working range there shall be no discernible noise due to hydraulic turbulence or cavitations within either the pump or its associated pipe work and valves.

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- e) The NPSH requirements of the pumps, based on the 3% output drop criterion shall be at least 2 m less than the NPSH available at every working condition.
  - f) The velocity of vibration shall be within 4.5 mm/sec. Combined noise level of pump motor system shall be limited to 85 dB(A) at a distance of 1.85 m from the equipment, at manufacturer's works / free field condition at site after erection.
  - g) The pump shaft shall be of SS BS:970 Gr 410S21 compatible with the impeller which shall be of stainless steel ASTM A743 CF8M and the impellers and shaft sleeves shall be secured to the shaft by means of a key/s. The impeller retaining nut shall be fitted with a locking device. The pump casing shall be of cast iron to IS 210 Gr. FG 260, wearing rings shall be of bronze to IS: 318 Gr. LT B2 and shaft sleeve shall be of SS ASTM A 743 CA 15.
  - h) All parts exposed to wear shall be adequately protected by means of renewable sleeves, bushes, wear rings etc. which shall be arranged for easy inspection, adjustment, or replacement without removal of the pump casings, pipe work etc, or the need to disturb the drive shaft alignment.
  - i) The pump thrust shall be taken by a combined thrust and radial type bearing assembly capable of taking the weight of the moving parts and the hydraulic load under all conditions of the operation with minimum life of 100 000 hours.
  - j) Bearing cooling arrangement if used shall be designed on the closed-circuit principle; open discharge of cooling water into the pumping station drainage system is not permissible.
  - k) The pump casing and other parts of the pump subjected to pressure shall be hydraulically tested by the manufacturer to at least one and half times the maximum working pressure.
  - l) Integral inlet & discharge flanges shall be provided and integral lifting lugs shall be incorporated.
  - m) Facilities shall be provided for the removal of air during priming and for draining.
  - n) Glands may be fitted with mechanical seals or conventional soft packing. The gland arrangement shall be designed for easy adjustment and removal of the seal.
  - o) When soft packed gland are used suitable means shall be provided for collecting and preventing splashing of the gland leakage water.
  - p) Drainage and gland leakage water shall be piped into the building drainage system.
  - q) The shaft of the pumps fitted with conventional packed glands shall be fitted with removable gland sleeves.
  - r) The rotating element of the pump and the motor shall be readily removable from the pump casing without the need to disconnect the adjoining pipe work.
  - s) Rotating assemblies of the pumps of 100 mm dia. inlet and over shall be statically and dynamically balanced and shall be designed so that the first critical speed is at least 50% greater than the maximum operating speed.
  - t) Lubrication arrangements shall be so designed that there is no contamination of the pumped fluid.
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- u) On pumps of 75 mm inlet and over, tapping shall be provided at both the suction and discharge flanges of suitable size for pressure gauges.

**d) End Suction Pumps**

- a) End suction pumps shall be horizontally mounted complete with drive motor on a common base plate. The pump/Drive coupling shall be of the spacer type to facilitate removal of the pump rotating element and bearing housing without dismantling the pump casing, adjoining pipe work or drive motor. These types of pumps shall be used for filter backwash, Chlorination motive water and service water pumping applications etc.
- b) The dimensions of the pump shall be metric confirming to BS 5257 or its equivalent standard. Flanges shall conform to BS EN 1092-2/BS 4504/ IS 1538.
- c) The bedplate shall be of substantial fabricated steel construction with floor fixing bolt holes ready drilled. All holding down bolts etc. shall be supplied with the units.
- d) The velocity at the entrance to the pump impeller shall not exceed 3.5 m/s.
- e) Impellers shall be provided with means to prevent abrasive matter reaching the glands and with fully shrouded impellers, to prevent the trapping of matter between the impeller vanes and the casing.
- f) The speed of any pump shall not exceed 1500 rpm.
- g) Glands may be fitted with suitable mechanical seals or conventional soft packing. The gland arrangement shall be designed for easy of adjustment or removal of the seal or packing material. Shafts shall be sleeved around the area of the gland when soft pack gland are used.
- h) Flushing facilities shall be provided for mechanical seals or packed glands where pump fluid may be contaminated with abrasive material. Where soft packed gland are used, means shall be provided for collection of the gland leakage water, which shall be piped into the drainage system through adequately sized ports.
- i) Lubrication arrangements shall be so designed that there is no contamination of the pumped fluid.
- j) The pumps and associated pipe work shall be wherever possible, arranged so that air can be completely expelled during priming. Where this is not possible, facilities shall be provided for the removal of the trapped air. Adequate facilities shall be provided for drainage of the pumps for inspection purposes.
- k) Tapping shall be provided at both the suction and discharge flanges for pressure gauge equipment.

**e) Pump performance Guarantees**

- a) The pump performance guarantee shall relate to the flow rate, the total head and the efficiency of the pump when tested at the manufacturer's work and shall obtain approval of engineer.
  - b) The pump shall operate at its design point within acceptance tolerances for flow rate and total head laid down in BS EN ISO 9906:2000.
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- c) Each pump shall be tested at the manufacturer's work in accordance with BS EN ISO 9906:2000 or other relevant standards in conjunction with one of the contract motors.
  - d) This test shall be carried out on at least one pump set using the flexible coupling and contract drive shaft arrangement to establish that the drive arrangement with supports and couplings operates satisfactorily under all operating conditions.
  - e) Where similar drive shaft arrangement have been installed by the operator and have been proven satisfactory in service this requirement may be withdrawn subject to the approval of the engineer.
  - f) A test shall be carried out of the performance from closed valve to the maximum quantity that can be delivered under abnormally low discharge heads.
  - g) Sufficient reading shall be taken at each test to produce accurate curves of the heads, flow, pump speed and power required at pump coupling throughout the operating range of the pump.
  - h) Vibration and noise dB(A) levels shall be measured and shown to be acceptable and shall have Engineer's approval. The operator shall have engineer approval and provide acceptable test certificates, showing the NPSH requirement for the pump is at least 2m less than the NPSH available under all working conditions.
  - i) in the absence of the approved test certificates the supplier shall carry out a test on one pump of each type to verify the NPSH requirement based upon the 3% output drop criterion and shall taken approval of Engineer.
  - j) The certificates shall be submitted to the Engineer immediately following each of the test mentioned above. Performance curves shall also be incorporated in the operation and maintenance manual.
  - k) Single Pump Operation
    - i). Head / Quantity Curve
    - ii). Motor kW input/Quantity curve
    - iii). Overall efficiency/quantity curve
    - iv). NPSH required/quantity curve
    - v). Vibration and Noise dB(A) levels.
  - l) Parallel Pump Operation
    - i). Head / Quantity Curve
    - ii). Motor kW input/Quantity curve
    - iii). Overall efficiency/quantity curve
    - iv). NPSH required/quantity curve
    - v). Vibration and Noise dB(A) levels.

**f) Progressive Cavity Pumps**

- a) These pumps shall be used for handling thickened sludge transfer/feed applications.
  - b) Pumps shall be of the type in which a pumping action is generated by a helical rotating eccentrically within a resilient stator in the form of a double internal helix. The eccentric motion of the rotor shall maintain a constant seal across the stator as it travels through the pumps to give a uniform positive displacement.
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- c) Pumps shall be arranged generally with a single shaft seal at the suction end. Mechanical seals shall be used. If a flexible shaft is used to accommodate the eccentric motion, a corrosion resistant shroud shall be fitted to prevent fibre build-up on the shaft. Enlarges inspection access holes shall be fitted to the suction chambers of all pumps for periodic removal of accumulated debris.
- d) The shaft bearing shall be positively isolated from the fluid being pumped.
- e) The rotor material shall be selected and abrasion resistance for the fluid being pumped, and for prolonged service life. Hard chrome or other approved coating shall be not less than 250 micron thickness and shall be diffused in to the base material. The rotor shall generally be single stage and shall incorporate not less than 3600 of twist, but for high-end applications, it may be necessary to use more than a single stage. the stator shall be of a resilient material selected for chemical and abrasion resistance for the fluid being pumped.
- f) Pump speed shall suit the application, where variable delivery output is needed; the pump shall be provided with a variable speed drive. The size and speed range of the pump shall ensure that the highest expected duty point shall lie within the available speed range.
- g) Pumps shall normally be driven by a fixed-speed electric motor through reduction gearing and the combined drive shall be continuously rated. Pump and motor shall preferably be mounted in-line on a common base plate. Alternatively, the drive motor may be top mounted above the pump to minimize floor area, and shall be connected by external V-belts and pulleys. V-belt drive shall have full guards of the type that allow the belts observed without removal of the guard. Facilities shall be provided for ready adjustment of belt tension.
- h) Coupling guards shall be provided, which shall be rigid, securely fixed, and designed so that removal is not necessary during normal operation, routine maintenance and routine inspections. All motor enclosures shall be provided with ingress protection to IP55. Motor anti-condensation heaters shall be provided and shall be suitable for use on a 220V single phase, 50Hz supply.
- i) All bearing shall have a B10 design life not less than 40,000 running hours and shall be designed for loading 20% in excess of calculated maximum loading, pumps shall be fitted with individual dry-running protection to initiate pump trip. Dry-running protection by 'under-current' monitoring of 'pipeline-intrusive' device shall not be used
- j) Material of Construction.

Component	Material
Pump housing	CI IS 210 Gr. FG 260
Rotor	SS AISI 316 (hard chrome Plated)
Shaft	SS AISI 410 (hard chrome Plated)
Stator	Nitrite Black
Type of drive	V belt & pulleys
Base plate	MS Fabricated

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Seal Type	Gland Packing (Asbestos free)
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**g) Chemical dosing Pumps**

- a) Chemical dosing pumps shall be piston diaphragm or mechanical diaphragm type as specified. Pump may be simplex or duplex arrangements to suit the capacity or process requirements. The pump design shall incorporate positive stroke return. The maximum stroking speed shall not exceed 100 strokes per minute. Pump, motor and driving arrangement shall be mounted on a robust combined base plate.
  - b) Pump liquid ends shall be selected for compatibility with the pumped liquid. Suction and discharge valves shall be the single ball type allowing a free flow self cleaning action. Ball and seat materials shall be resistant to abrasion.
  - c) Pumps shall incorporate a variable stroke mechanism to allow the output to be varied while the pump is running. Stroke adjustment shall be manual or where specified by electrical or pneumatically controlled stroke positioner. A stroke length indicator and digital stroke counter shall be fitted, Pumps shall be driven by a flange mounted IP 55 motor, via an oil bath reduction gearbox and variable stroke mechanism giving step less adjustment between zero and maximum stroke length. where flow proportional dosing is required the variation of output shall be achieved by varying the speed of the pump motor and not the pump stroke length.
  - d) The normal operating range of dosing pump shall be not less than 6:1.
  - e) Mechanical Diaphragm: Diaphragm rigidly coupled to the drive train. Single suction pumps and discharge valves. Glandless. Accuracy: 3% of stroke.
  - f) Piston Diaphragm pumps: Diaphragm hydraulically operated by liquid displaced by a plunger and protected from excess pressure via a relief valve. Accuracy: 2% of the stroke.
  - g) Material shall be selected to suit the chemical being pumped. Liquid end shall be polypropylene, AISI 316 SS, Glass or Hastelloy C. Diaphragm material shall be butyl rubber, PTEE, or Hypalon and glands shall be PTEE or Neoprene.
  - h) Each pump shall be provided with inlet and outlet isolating valves and where necessary with pressure relief and non-return valves. dosing pumps shall be provided with back pressure loading valves and pulsation dampeners in the delivery lines depending on the downstream conditions.
  - i) A relief valve shall be incorporated in the delivery lines under conditions where the pump discharge pipe may be shut off or where pressure may rise to an excessive point. the relief valve shall be sized to handle the system pressure and to discharge maximum pump output freely, and shall be located in the discharge line between the pump and the first downstream isolating valve or in the case of dosing pumps the back pressure loading valve. Relief valves when used on the pumps handling non-hazardous chemicals shall discharge the vented liquid to waste. When used on hazardous chemicals the valve outlet shall be piped back to the suction supply tank or bounded area. The open end of the return pipe shall be located where it is visible, so that any relief valve leakage/operation can be detected.
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- j) Pump transferring/dosing chemicals to system under pressure shall incorporate a pressure gauge on the pump delivery. Air cocks shall be provided for release or air where necessary.
- k) Unless otherwise specified flushing connection shall be provided at each inlet and flushing shall be manual. when flushing, water shall be discharged either locally through a drain valve or to the point of application of the chemical. Facilities shall also be provided for flushing chemical pump suction and delivery manifolds and delivery lines to point of application.
- l) Dosing Pumps and motor shall preferably incorporate an integral reduction gearbox drive which shall be totally enclosed and oil bath lubricated. the Gear box shall incorporate the cams for the diaphragm drive and shall provided with filling and drain connections and visible oil level indicate

#### **h) Chemical Tank and Mixer**

##### **i) General**

This tank shall be used to dissolve the alum or polymer to a constant concentration and feed the solution to the outlet channel of the aeration tank or the dewatering equipment. It shall be a vertical tank and shall be composed of tank main body, mixer, manhole, electrical level gauges, direct reading level gage, ladder, air exhaust pipe etc.

##### **ii) Fabrication**

- a) The tank shall be made of corrosion resistant material.
- b) The tank shall be provided with a removable cover to prevent chemical scattering, and also with a vent pipe.
- c) The tank shall be provided with necessary mounting seats for overflow pipe, etc.
- d) The motor-driven mixer shall be vertical speed reducer, direct-coupled type of 2-stage propeller type, as a rule and shall be constructed to endure continuous operation free from vibration, etc. The mixer shall be at the center or at a position off the center according as the tank being angular or circular.
- e) The mixer shall be protected by electrical prevention of dry operation.
- f) The tank shall be constructed to seal gas and splash from below at the area where the mixer shaft drive portion passes through.
- g) Alum feed cage of stainless steel shall be provided inside the alum solution tank.

##### **iii) Material**

- (a) Main Tank body : GRP/HPDE or equivalent
- (b) Mixer frame : SS316
- (c) Mixer shaft : SS316
- (d) Blade : SS316

**iv) Accessories (per Unit)**

- (a) Foundation bolt and nut 1 set
- (b) Air vent pipe 1 set
- (c) Mixer 1 unit
- (d) Direct reading level gauge 1 unit

**i) Alum Dispersion Rapid Mixer:**

- a) The alum dispersion rapid mixer shall be in-channel submersible chemical vacuum induction unit and consist of chemical induction unit with mount bracket, guide rail assembly, floor mount base, boom hoist with manual brake winch and SS 316 cable, hose assembly, control panel and submersible power cable.
- b) The unit shall be provided instantaneous diffusion / mixing and the highest level of durability and performance required for chemical feed application.
- c) The hermetically sealed SS 316 motor shall provide the highest level of durability and performance required for chemical feed applications. All wetted materials shall be constructed from Grade 2 Titanium (unalloyed) and shall be designed for use with all common water and wastewater treatment chemicals. The mounting bracket shall be engineered for installing in open-channel applications.
- d) The material of construction of chemical induction shall be as follows:

S. No.	Component	Material
(i)	Vacuum chamber	SS
(ii)	Vacuum port	SS
(iii)	Vacuum enhancer	Non-metallic
(iv)	Propeller	SS
(v)	Propeller bolt	SS
(vi)	Shaft	SS
(vii)	Mechanical seals	Carbon /ceramic
(viii)	Hardware	SS 316

**j) Submersible Mixers**

- a) The submersible mixer shall be installed in the Anaerobic and anoxic zones, and they shall be capable of providing a velocity gradient in the range of 500 to 1000 mm/sec.
- b) The mixer shall have a self-cleaning propeller optimised for effective mixing and vibration-free running, and required power shall be at least 10Watt/ m3 of tank volume.
- c) The mixer shall be driven by a high efficiency 3 phase motors IP68 Class F. Motor shaft and rotor shall be dynamically balanced.

- d) Bearings shall be lubricated-for-life with a calculated life of more than 100,000 operating hours.
- e) The mixers shall have the flexibility to be located at different depths and thereby avoiding dead zones.
- f) The mixer shall be provided with the following :
  - i). Lifting frame with a winch which can be dismantled, free standing with adjustable boom length.
  - ii). Mounting socket for free standing hoist suitable for wall mounting.
  - iii). Guide for floor fixing components and support brackets for wall mounting.
  - iv). Stainless steel rope for raising and lowering the mixer.
  - v). Rope block for holding the stainless steel rope where the lifting frame is used in different locations.
  - vi). Support rope for reliable support and guidance of power supply cable.
  - vii). Support clamps and hooks to support the power supply cable in such a manner that it is not under strain.
- g) The propeller, propeller shaft and motor housing shall all be of SS 316.

**k) Mechanical Floating Mixer**

**i) General**

- a) Mechanical floating mixer and related equipment accessories shall consist of a motor, direct-drive impeller driven at a constant speed, an integral flotation unit, and impeller volute.
- b) Performance-Each mixer shall have a zone of complete mix and a direct pumping with a recirculation. Complete mix shall be defined as maintaining biological suspension of all mixed liquor suspended solids with design MLSS or less without the introduction of air.

**ii) Construction Features**

- a) Mixer Drive Motor-
  - i) The motor shall be rated for 415 volt, 50 hertz, three-phase service. The motor shall be standard efficiency, vertical P base design, totally enclosed fan cooled TEFC, and generally rated for severe duty. The motor shall in all cases equal or exceed standard NEMA specifications. A minimum service factor of 1.15 shall be furnished.
  - ii) The motor winding shall be non-hygroscopic, and insulation shall equal or exceed NEMA Class "F". A labyrinth seal shall be provided below the bottom bearing to prevent moisture from penetrating around the motor shaft. A condensate drain shall be located at the lowest point in the lower-end bell housing. Unit shall have a one-piece motor shaft continuous from the top motor bearing, through the lower bearing and down to and through the propeller. The shaft shall be manufactured from high quality stainless steel. Motor bearings shall be regreasable. Sealed bearings are not acceptable.
- b) Motor Mounting Base-The motor shall be securely mounted onto a solid 316 stainless steel base which is integral with the motor base extension. All submersed wetted motor mounting base components shall be constructed of 316 stainless steel.
- c) Flotation-Each unit shall be equipped with a modular float constructed of fiber reinforced polyester skin FRP or equivalent with a central float passage of a size to

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allow installation and removal of the pump impeller. The float shall be foamed full of polyurethane foam of the closed cell type, and shall be totally sealed to prevent the foam from being in contact with the external environment.

- d) Impeller -The impeller shall be designed to pump the liquid from near the surface and direct it down toward the vessel/ basin bottom. The impeller shall be a two-blade marine type precision casting of SS316 stainless steel and shall be specifically designed for the application intended. It shall be dynamically and hydraulically balanced. The propeller must be attached to the motor shaft with a hardened stainless steel pin and set screw. Impeller shall be capable of being reversed to cause back flow liquid movement without causing damage to the mixer chassis and without causing up flow liquid damage to the motor bearing and windings. No liquid spray or other liquid leakage upward onto the surface of the motor support surface or flotation chassis will be allowed.
- e) Intake Volute Assembly -The impeller shall operate in a volute made of SS316 stainless steel plate
- f) Vibration-The entire rotating assembly including the motor rotor, shaft, shaft accessories, and impeller shall be dynamically balanced within 2.0 mils peak-to-peak horizontal displacement measured at the upper and lower motor bearing. Measurements shall be taken at a frequency equivalent to the motor RPM. Measurements shall be taken with the motor in a vertical, shaft down position with the entire power section mounted on resilient pads.
- g) Cable mooring System-Each unit shall be provided with a maintenance cable mooring system complete with mooring cable, clips, and thimbles, quick disconnects, anchors, and extension springs as shown on the drawings. Mooring cable, anchors, and hardware shall be SS316 stainless steel. Field attachment of mooring points to the tank shall be the responsibility of the installing contractor
- h) Cable Mooring Electrical Service Cable-Each unit shall include conductor power cable wired into the motor conduit box and terminating at the basin wall. Electrical cable shall be supplied with kellems grips at the motor and basin wall terminations. Electrical cable floats for flotation of electrical service cable shall be provided. Attachment of cable and supply of junction box/disconnect at the basin wall shall be the responsibility of the installing contractor. 316 stainless steel adhesive anchors for attachment of mooring system components to the basin wall shall be provided.

### **3) Induction Motor**

#### **a) Scope**

The specification covers the design, material, constructional features, manufacture, inspection and testing at the VENDOR's / his SUB-VENDOR'S works, delivery to site and performance testing of Low Voltage induction motors rated up to 1000V.

#### **b) Codes And Standards**

The design, material, construction, manufacture, inspection, testing and performance of induction motors shall comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will be installed. The equipment shall also conform to the applicable standards specified in data sheet latest revision as on the date of offer. Nothing in this specification shall be construed to relieve the VENDOR of this responsibility. In case of conflict between the standards and this specification, this specification shall govern.

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SL. NO	BRIEF NAME	REFERENCE STANDARDS
1.	Energy efficient Induction motors – Three phase Squirrel Cage	IS – 12615
2.	Standard methods for determining losses and efficiency from tests	IS - 15999-(Part2/Sec 1)
3.	Permissible limits of noise level for rotating electrical machines	IS – 12065 / IEC 60034-9
4.	Mechanical vibration of rotating electrical machines	IS – 12075
5.	Guide for testing three phase Induction motors (For standard TEFC SCR motors)	IS – 4029
6.	Methods of determination of efficiency of rotating electric machines (For standard TEFC SCR motors)	IS – 4889
7.	Colours for ready mixed paints and enamels	IS – 5
8.	Thermal evaluation and classification of electrical insulation	IS – 1271
9.	Dimensions of slide rails for electric motors	IS – 2968
10.	Dimensions of vertical shaft motors for pumps	IS – 2254
11.	Values of performance characteristics for three phase induction motors	IS – 8789
12.	Guide for testing insulation resistance of rotating machines	IS – 7816
13.	Designation for type of construction and mounting arrangement of rotating electrical machines	IS – 2253
14.	Guide on effects of unbalanced voltages on the performance of three phase cage induction motors	IS – 13529
15.	Guide for selection & application of three phase induction motors for different types of driven equipment	IS – 13555
16.	Code of practice for installation and maintenance of induction motors	IS 900
17.	Dimensions of foot mounted AC Induction motor.	IS -1231
18.	Dimensions of flange mounted AC Induction motors	IS – 2223
19.	Rotating electrical machines – rating & performance	IS/IEC 60034-1
20.	Degree of protection provided by the integral design of rotating electrical machines (IP code) : classification	IS/IEC 60034-5
21.	Designation of method of cooling for rotating electrical machines / method of cooling (IC code)	IS 6362 / IEC 60034-6
22.	Terminal markings and direction of rotation for rotating electrical machines	IS/IEC 60034-8

23.	Dimension & output rating of rotating electrical machines	IEC 60072-1
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**c) Driven Equipment**

- a) When this specification forms part of the driven equipment specification, information not given in the Data Sheet will be governed by the driven equipment specification.
- b) Motors shall be capable of satisfactory operation for the application and duty as specified in the motor Data Sheet and as specified for the driven equipment.

**d) Performance And Characteristics**

- a) Motors shall be capable of giving rated output without reduction in the expected life span when operated continuously under either of the following supply conditions as specified in Data Sheet.
- b) Supply Condition
  - i). Variation in supply voltage from rated voltage:  $\pm 10\%$
  - ii). Variation in supply frequency from rated frequency:  $+5\%$
  - iii). Combined voltage and Frequency variation:  $+10\%$
- c) Motors shall be suitable for the method of starting specified in the Data Sheet.
- d) The minimum permissible voltage shall be 85% of the rated voltage during motor starting.
- e) Motors shall be capable of starting and accelerating the load with the applicable method of starting, without winding temperatures reaching injurious levels, when the supply voltage is in the range of 85% of the rated motor voltage to maximum permissible voltage specified in Data Sheet.
- f) The locked rotor current of the motor shall not exceed 600% of full load current (subject to tolerances as per the applicable standard) unless otherwise specified. The locked rotor current of VFD controlled motor shall be within the limit of IS12615 / IEC.
- g) Motors shall be capable of developing the rated full load torque even if the supply voltage drops to 70% of the rated voltage. The pull out torque of the motor shall be at least 205% of full load torque.
- h) Motors when started with the driven equipment coupled shall be capable of withstanding at least two successive starts from cold conditions & one start from hot condition without injurious heating of windings. The motors shall also be suitable for three equally spread starts per hour under the above referred supply conditions.
- i) Motors shall be of Energy Efficient type. Category of Energy efficiency shall be IE2 for VFD driven Motors & remaining shall be IE3 only.

**e) Insulation**

- a) The insulation shall be given tropical and fungicidal treatment for successful operation of the motor in hot, humid and tropical climate.
- b) Motors which are VFD controlled shall be inverter grade and shall be suitably derated to take care of reduced cooling at lower speeds.



- c) Insulation of VFD controlled Motors shall be designed to withstand a dv/dt of 0.1 micro sec rise from 10 % to 90 % of steady voltage and a maximum peak of 1600 volts as per NEMA standard MG1 Part 31.40.4.2 .
- d) The insulation shall be of double coat winding wires which having superior electric strength and thermal capability for VFD controlled motors.
- e) Winding shall be insulated as VPI (Vacuum Pressure Impregnation) of winding with suitable resin forces which eliminating voids for VFD controlled motors.

**f) Temperature Rise**

- a) The temperature rises shall not exceed the values given in IS 12802. Under extremes of supply condition (clause 4.1 above), the temperature rise shall not exceed the value indicated in IS by 10°C.
- b) For motors specified for outdoor installation heating due to direct exposure to solar radiation shall be considered

**g) CONSTRUCTIONAL FEATURES**

- a) All windings shall be of Copper. The winding insulation shall be Non-hygroscopic, oil resistant and, flame resistant.
- b) Motors weighing more than 25 kg. shall be provided with eyebolts, lugs or other means to facilitate safe lifting.
- c) Noise level and vibration limit should not exceed as specified in relevant IS / IEC.
- d) Submersed Motor (wherever applicable) shall have following specific constructional features:
  - i). Motor shall be Air Filled yet capable of Water immersion up to 20mwc for S1 duty. Motors with Oil or Water filled windings shall not be allowed. Motor's Rotor shall be of dual caged copper bar brazed type to ensure;
  - ii). Long Corrosion free Service life (in presence of high moisture inevitable in submerged motors, Aluminum corrodes much faster than Copper), Ease of Onsite Repairing & Beneficial Fly Wheel type Inertial effect (as compared to aluminum rotor, copper rotor is heavy) which reduces detrimental effects of water hammer
  - iii). Better Motor Efficiency & Cooler Operating Temperature.
  - iv). Motors rated  $\leq 110\text{kW}$  may be supplied with Aluminum Die Cast Rotors but Dual Cage Copper Bar shall be preferred.
- e) The Motor Rating should be higher of the two criteria i.e., 10% over Maximum pump shaft input at any point of the curve & / or 20% over pump shaft input @ duty point
- f) Motor Cooling -To restrict the Dead Water Level (in case of Vertical Installation) in the Sump to 1m, Medium & Large sized pumps ( $\geq 55\text{kW}$ ) should have a Cooling Jacket – i.e. motor cooling is accomplished by circulation of pumped water between the motor casing & the jacket shell.

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- g) In case the pumps are to be installed horizontally, the motor can be cooled just by water immersion i.e. no jacketing is required.
  - h) This jacket shell is fed by cold water from the pump casing & discharges its heated water back into the sump (in case of Wet Installation) or Pump casing (in case of Dry Installation) by integrally cast ducts. There should not be any pipes, hoses, etc for this circulation.
  - i) Alternatively Close Circuit cooling technology (using Glycol, etc) may also be offered.
  - j) Motor Protection-Thermal Overload Protectors (Bi Metallic Over Load Relays) should be embedded in each phase of the stator winding to detect overheating & trip the motor from the control panel in the event of the temperature exceeding the safe operating limit (above B temperature class).
  - k) To detect primary Mechanical Seal's Leakage a Moisture & Winding Sensor shall be provided in intermediately Oil Chamber (& not in the Motor casing or elsewhere) – this shall detect water mixing in oil by mode of increased leakage current from the moisture sensor.
  - l) Motors Cables: A watertight Cable Junction Box sealed from the motor shall be provided for the motor power and signalling cables.
  - m) The cable shall be brought directly out of the submerged motor without joints, and shall be of sufficient length, minimum 10 m to be terminated in an IP 67 junction box (in the scope of electrical contractor) outside adjacent to the wet well & above the HFL. They shall be sized in accordance with the electricity utility regulations and BS 7671.
  - n) It should have Power as well as Control Cables of Dual Sheathed EPRS / PVC Armoured type with Copper Core of required size. However the Cross Section of the cable be shall ample enough to ensure a Voltage Drop of not more than 2% at actual running conditions.
  - o) Stuffing Box / Oil Chamber: The pressurized entry of water into the motor (from the pump's volute casing) should be prevented by two separate mechanical seals mounted in a Tandem mode within an oil chamber.
  - p) The Primary (Inboard) seal should be of Silicon Carbide or Tungsten Carbide faces to withstand erosive wear due to any silt particles. The Secondary (Outboard) seal should be of Carbon v/s Cast Chrome Molybdenum Steel or Silicon Carbide or Tungsten Carbide – i.e., Thermally Unstable materials like Alumina/ Aluminium Oxide shall not be allowed.

**h) Bearings**

- a) Unless otherwise specified in data sheet, motor bearings shall not be subjected to any external thrust load.
  - b) Unless otherwise specified, motor bearings shall have an estimated life of at least 70,000 hrs.
  - c) The bearings shall permit running of the motor in either direction of rotation.
  - d) When forced oil lubrication or water cooling is required, prior approval from the purchaser shall be obtained.
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- e) It shall be possible to lubricate the bearings without dismantling any part of the motor.
  - f) VFD controlled Motors shall have their bearings insulated to prevent motor shaft currents from entering the bearing race.
  - g) The bearings should be Permanently Greased with Premium Quality, High Temperature, and Long Life Grease thereby obviating the need of re-lubrication for up to L10 life of the bearings.
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**i) Terminal Box**

- a) Terminal boxes shall have a degree of protection of atleast IP 55 for outdoor applicable.
- b) Unless otherwise approved, the terminal box shall be capable of being turned through 360° in steps of 90°.
- c) Terminals shall be of stud type & the terminal box shall be complete with necessary lugs, nuts, washers.
- d) When single core cables are to be used the gland plates shall be of non magnetic material.
- e) Sizes of terminal boxes and lugs shall be as given in Table-I, unless specified otherwise in data sheet.

**TABLE-I**

**415 V MOTORS - SIZES OF CABLES, STUDS, TERMINAL LUGS & TERMINAL BOXES**

**(TO BE PROVIDED ON MOTORS BY VENDOR)**

Sr. No.	Motor Rating (kW)	1100V Al Conductor, armoured PVC/XLPE Cable Cores x mm <sup>2</sup>
1.	Upto 3	3x4
2.	3.1 - 7.5	3x6
3.	7.6 - 15	3x16
4.	16 - 25	3x35
5.	26 - 40	3x70
6.	41 - 55	3x120
7.	56 - 70	3x185
8.	71 - 85	3x240
9.	86 - 110	3x400
10.	111 - 200	3Rx1Cx500

**j) Paint And Finish**

- a) All motor parts exposed directly to atmosphere shall be finished and painted to produce a neat and durable surface which would prevent rusting and corrosion. The equipment shall be thoroughly degreased, all rust, sharp edges and scale removed and treated with one coat of primer and finished with two coats of grey enamel paint

**k) Heating During Idle Periods**

- b) Motors rated above 30 kW shall have space heaters suitable for 240V, single phase, 50 Hz, AC supply. Space heaters shall have adequate capacity to maintain motor

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internal temperature above dew point to prevent moisture condensation during idle period. The space heaters shall be placed in easily accessible positions in the lowest part of the motor frame.

**l) Accessories**

- a) Two independent earthing points shall be provided on opposite sides of the motor, for bolted connection of the PURCHASER'S earthing conductors as specified in data sheet. These earthing points shall be in addition to earthing stud provided in the terminal box.
- b) Motor rated 75KW and above shall have Resistance Temperature Detectors (PT100, Simplex type) embedded in stator windings, DE/ NDE bearings (2 nos per winding & 1 no per bearing) to detect overheating & trip the motor from control panel in the event of the temperature exceeding safe operating limit.
- c) Except when otherwise specified, the motors shall be provided with a bare shaft extension having a key slot and a key at the driving end.

**m) Tests**

- a) Motor shall be subjected to all the routine tests as per applicable standard in the presence of the PURCHASER'S representative. Copies of test certificates of type and routine tests shall be furnished as specified in the distribution schedule, for the PURCHASER'S approval. The VENDOR shall ensure to use calibrated test equipment/instruments having valid calibration test certificates from standard laboratories traceable to national/international standards.
- b) If type tests have not been carried out on similar Motors, or if the type test reports submitted are not found in order, then VENDOR shall carry out these tests without any extra cost to the Purchaser.

**4) Material Handling Equipment**

Contractor shall supply, install, test, commission and maintain the material handling equipment which shall be required for normal operation and/or maintenance of the STP the selection and sizing of the equipment shall be based on the requirements of the equipment to be maintain.

**i) Electrically Operated Hoists**

- a) Electrical hoists shall be complete with hoisting motor, wire rope drum, wire rope, hook, necessary gearing, sheaves, electromagnetic brake for hoisting motion, weather & dust proof push button station, operator panel, all wiring, limit switches, etc.
  - b) Electric hoist shall confirm to IS: 3938 and shall be suitable for outdoor application. All the parts of the hoist shall be designed to withstand surrounding atmospheric conditions without any deterioration.
  - c) Rope drums shall be either cast or welded to sustain concentrated loads resulting from rope pull.
  - d) Drums shall be machined grooved right and left with grooves of a proper shape for the rope used.
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- e) Gears shall be cut from solid cast or forged steel blanks or shall be of stress-relieved welded steel construction or built-up from steel billets and welded together to form a one piece gear section.
- f) Hoist ropes shall be extra flexible, improved plough steel rope with a well lubricated hemp core and having six strands of 37 wires per strand with minimum ultimate tensile strength of  $1.6 \times 10^6$  kN/m<sup>2</sup>.
- g) Hooks shall be solid, forged, heat treated alloy or carbon steel of rugged construction of the single hook type and provided with a standard depress type safety latch.
- h) Hoisting motor shall be equipped with electrically released, spring set, friction shoe type brakes having torque capable of holding 125% of the full rated hook load. Brakes shall apply when either the motor controller or the main power switch is in "OFF" position or in the event of power failure.
- i) Drive motors shall be designed for frequent reversal, braking and acceleration and shall be as per IS: 325. Pendant control switch, controllers and resistor, controls, electrical protective devices, cable and conductors, earthing guards etc. shall be as per IS: 3938. Limit switches shall be provided for over hoisting and over lowering.
- j) The electrical hoist shall be of class II duty.
- k) 25% overload test, speed tests, limit switch tests and brake test shall be conducted for the hoist and trolley at manufacturer's works.

**ii) Hand operated Hoist and Trolleys**

- a) Manual hoist shall be complete with hand chain, trolley, pulley block, hook, hand and load chains, brake and other accessories. They shall comply with the latest applicable standards, regulations and safety codes in the locality where equipment will be installed.
- b) Each hoist shall be operated on a monorail (I-beam). The factor of safety shall not be less than 5. The load chain may be heat-treated to give ductility, toughness and as per IS 3109/BS 1663/BS 3114. The load wheel is to be made heavy duty malleable castings. the hand chain should be as per BS 6405 and hand chain wheel may be made from pressed sheet steel with roller type guarding. Gears shall be cut from solid cast or forged steel blanks or shall be stress - relieved welded steel construction. Pinions shall be of forged carbon steel of heat treated alloy steel. Strength, Quality of steel, heat treatment, face, pith of teeth and design shall be as per BS-436, BS-545 and BS 721. Spur and helical gear must comply with BS 436 and worm with BS 721. Bearing must be ball and roller type as per IS 2513 / BS 2525-32. Proper lubricating arrangements are to be provided for bearing and pinion. The brakes for the lifting gear shall be automatic and always in action.
- c) The proof testing of each chain pulley block is to be carried out as per latest applicable standards. the safe working load is to be marked in such a way that is clearly visible from the operating level.

**iii) Manually Operated Travelling Crane**

- a) The crane bridge shall consist of a single bridge girder carrying two wheels at each end of the span. steel used shall be tested quality steel confirming to IS 2062. The girder shall have enough strength to carry the test load without causing undue stress or deflection.

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- b) The long travel bridge wheels shall be rim toughened, heat treated carbon steel or low alloy steel or CI. they shall be double flanged type. The wheels shall have antifriction ball/roller bearings. The Wheels shall be machined on their treads to match the runway rail section. The bridge shall have a geared shaft and pulley connecting to opposite wheels of the span, to achieve the long travel motion of the bridge, by means of a chain. The runway rails of adequate strength and rigidity, rail clamps and other accessories for mounting the rails and suitable end stops for the bridge shall be supplied.

**iv) Trolley and chain Pulley Block**

- a) The chain pulley block shall be operated on the lower flange of the bridge girder.
- b) The load chain shall be made of alloy steel as per IS:3109. It shall be heat treated to give ductility and toughness so that it will stretch before breaking. It shall be of welded construction with a factor of safety not less than 5.
- c) The hand chain for the hoisting and traverse mechanism shall hang well clear of the hook and both the chains shall be on the same side. the hand chain wheel shall be made from pressed sheet and shall be provided with roller type guarding to prevent snagging and fouling of the chain.
- d) All the gearing shall be totally encased. Proper lubricating arrangements shall be provided for bearings and pinions. Gears shall be cut from forged steel blanks. Pinions shall be of heat treated alloy steel. Gears shall be as per BS 436/IS : 4460.
- e) The trolley track wheels shall be rim toughened, heat treated carbon steel or low alloy steel or CI and shall be single flanged and shall have antifriction ball bearings. The wheels shall be machined on their treads to match the flanges of the track joints.
- f) The travelling trolley shall be made of rolled steel as per IS : 2062. The side plates of trolley frame shall extend beyond wheel flanges, thus providing bumper protection for the wheels. the two side plates shall be connected by means of an equalizing pin.
- g) Axles and shafts shall be made of carbon steel and shall be accurately machined and properly supported.
- h) The lifting hooks shall be forged, heat treated alloy or carbon steel of rugged construction. they shall be single type provided with a standard depress type safety latch. They shall swivel and operate on antifriction bearings with hardened races. Locks to prevent hooks from swiveling shall be provided. Hook shall be as per BS: 2903/IS:3815.
- i) The break for the lifting gear shall be automatic and always in action. It shall be screw and friction disc type self actuating load pressure brake. Breaks shall offer no resistance during hoisting.
- j) Ratchet and pawl mechanism shall be provided to arrest the full load from lowering due to gravity. The ratchet and pawl shall be of steel, hardened and tempered so as to attain required wear resistance and toughness.

**v) Jib Crane**

- a) Fixed jig crane shall be provided in for lowering/removal of equipment/parts to/from the reactor tanks floor and transferring the same outside reactor area. The crane
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capacity shall be 1.25 times the maximum weight to be handled or 1.5 tons, whichever is more.

- b) The lift and reach of the crane shall be suitable for the equipment/parts to be handled. The crane shall be capable of being swiveled by 360 deg. All material used in the construction shall be corrosion resistant, MS used shall be galvanized. Rope chains and pulleys shall be of SS construction. Hardware shall be of SS 316. the jib crane shall also be provided for submersible pumps in reactor tank, thickened sludge sump.

**vi) EOT Crane**

- a) The crane shall be electrically operated, bridge type complete with all accessories including down shop conductor, crane rails and fixtures, and shall conforming to BS 2573, IS : 3177 or relevant internationally approved standards.
  - b) The crane bridge shall consist of bridge girders on which a wheeled trolley is to run. The bridge trucks and trolley frames shall be fabricated from structural steel. Access walkway with safe hand railing as required along the full span length of the bridge girder. steel shall be tested quality as per ASTM A36 except that, plates more than 20 mm thick shall conform to IS 2062, BS 4360 or relevant international standards. The All antifriction bearings for bridge and trolley track wheels, gear boxes and bottom sheaves on hook shall be lubricated manually by hand operated grease pump through respective grease nipples.
  - c) Wheel base and structural frame of the wheel mounting of the end carriages shall be designed so as to ensure that the crane remains square and prevent skewness. Bridge and trolley track wheels shall be of forged steel shall be double flanged type. The wheel dia. and rail sizes shall be suitable for the wheel loads. The crane rail shall be manufactured from wear resistant austenitic manganese steel. Mountings of the wheels shall be designed to facilitate easy removal for maintenance. Walkways shall be at least 500mm clear inside width with a 6 mm thick non-skid steel plate surface. Steel rail stops to prevent rails from creeping and trolley from running off the bridge shall be abutted against ends of rails and welded to the girders. Bridge and trolley stops to match the wheel radius shall be provided before the buffer stops.
  - d) All exposed couplings, shafts, gear, wheels, pinions and chain drives etc. shall be safety encased and guarded completely to prevent any hazard to persons working around. All bearings and gears shall have a design life of 100 000 operating hours. Electro-magnetic or hydraulic thrust breaks shall be provided for the main hoist. One electro-magnetic brake shall be provided for each of the cross travel and long travel motions.
  - e) Hook shall be solid forged, heat treated alloy or Carbon Steel suitable for the duty service. They shall have swivels and operate on ball thrust bearings with hardened races. The lifting hooks shall comply with the requirements of IS 8610 or BS: 2903 / BS:3017 or relevant internationally approved standards and shall have a safety latch to prevent rope coming off the hook. Hoist rope shall be extra flexible, improved plough galvanized steel rope with well lubricated hemp core and having six strands of 37 wires per strand with minimum ultimate tensile strength of  $1.6 \times 10^6$  kN/m<sup>2</sup> of right hand Ordinary laid construction. The ropes shall have a 6 safety factor on the specified working load, and shall conform to IS: 2266. Rope drums shall be grooved and shall be either cast iron or cast steel or welded steel as per IS: 3177, BS:466.
  - f) Gears shall be cut from solid cast or forged steel blanks or shall be stress relieved welded steel construction. Pinions shall be forged carbon or heat treated alloy steel.
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Strength quality of steel, heat treatment, face, pitch of the teeth and design shall confirm to BS: 436, IS: 4460 and BS: 721.

- g) Name plate showing the capacity, year of manufacturing and rated capacity of the crane, in figure not less than 150 mm height shall be placed on the each side of the crane girder.
  - h) The deflection test shall be done as per IS:3177
  - i) All accessory and auxiliary electrical equipment including drive motor, electrically operated brakes, controllers, resistors, conductors, insulators, current collectors, pendant, push button station, protective devices, operation devices, cables, conduits, etc, necessary for the safe and satisfactory operation of the crane shall be provided.
  - j) Power to the crane shall be provided by down shop conductors manufactured from high conductivity hard drawn copper. Conductors shall be completely shrouded such that they have no exposed current carrying surfaces. Pendant type button station shall be sheet steel enclosed and shall comprise the following push buttons and indicating lamps:
    - i) "START" and "STOP"
    - ii) Long travel -'Right' and 'left'
    - iii) Cross travel 'To' and 'Fro'
    - iv) Hook 'Hoist' and 'Lower'
    - v) Red indicating lamp for supply 'ON' indication.
  - k) Pendant type push button shall be supported independently of the electrical cable and shall be earthed separately, independent of the suspension. Automatic reset type of limit switches shall be provided to prevent over travel for each of the following:
    - i) for "UP" and "Down" motion of the hook
    - ii) Long travel motion
    - iii) Cross travel motion
  - l) Crane structures, motor frame and metal cases of all electrical equipment including metal conduit and cable guards shall be earthed. All motors, brakes, limit switches, panels, drum controllers, resistor sets shall be provided with two studs for earthing.
  - m) All motors shall be of the quick reversing type with electrical mechanical brakes suitable for the duties specified. All movements shall be electrically powered suitable for operating with the hook loaded. Facilities shall be provided for the accurate location of the hook by means of inching the cross travel and down shop travel motions.
  - n) Sufficient slings, ropes, shackles, lifting beams, etc. shall be supplied to handle all items of plant covered by the crane. they shall be labelled or marked with safe working load and the purpose for which they are intended.
  - o) The crane and all slings, ropes and other lifting equipment shall be tested by the manufacturer at their place. The test shall be carried out at 125% of safe working load and test certificate shall be supplied.
  - p) The operator shall include with the cranes all necessary contactors, control cubicles and protection equipment necessary to operate the crane and provide adequate electrical protection against overload, phase and earth fault and fail safe protection in
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the event of a power failure. All access ladders and platforms necessary to carry out maintenance and repair shall be provided and installed by the operator.

- q) All electrical equipment shall be fully tropicalized
- r) Site tests shall be carried out by the operator who shall supply the necessary materials for the test load. The test load shall be removed from site by the operator after successful tests have been carried out.

## **5) Auxiliary Equipment**

### **i) Reduction Gear Units**

- a) Reduction gear units, wherever provided shall be double reduction units without V-belts and pulley, gear shall be cut from solid cast or forged steel blanks or shall be stress relieved welded steel construction. Pinions shall be of forged carbon or heat treated alloy steel. Strength quality of steel, heat treatment, face, pitch of teeth and design shall be confirmed to BS:436 and BS:721. split gears shall not be used. Gears and pinions shall be pressed on and keyed to shafts.
- b) All pinions and gears are to be of the totally enclosed type up to the last stage of reduction in all motions and shall be carried in fabricated steel gear cases which must be dust-proof and firmly sealed to prevent oil leakages and shall be oil bath lubricated. The gear boxes shall have covers split horizontally and arranged so that top half can be removed for inspection. They shall be fitted with bolted type machined inspection covers and with cast steel cartridge housing for carrying roller bearings.
- c) Dip sticks or indicator shall be provided for indicating the oil level. Guards shall be strong enough to retain the whole gear or any part that might otherwise fall. No overhanging gears shall be used. Drain plugs shall be provided on all gear cases. Lifting lugs shall be provided for handling purposing.

### **ii) Propeller Exhaust Fan**

- a) The fan should comply with IS 2312.
- b) The blades shall be of MS and properly balanced so as to avoid noise and vibration. The blade and Blade carriers shall be securely fixed so that they do not loosen in operation. The means provided for securing the fan mounting or fan casing to the wall partition or window shall be such as to provide a secure fixing damage to the fan or wall.
- c) Suitably designed guards shall be fitted to the inlet and the outlet side to prevent accidental contact. No flammable material shall be used in the construction of fan. moulded parts, if used, shall be such material as to withstand the maximum temperature attained in the adjacent component parts.

The fan shall have protective insulation or be capable of being earthed. A fan with protective insulation may be of all insulated construction or have either double insulation or reinforced insulation. Each fan should be provided with a 10 mm<sup>2</sup> mesh bird screen. the sheet used for cowl should be 14 G.

### **iii) Air Conditioning Equipment**

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Wall mounted split type air conditioners of appropriate capacity shall be provided for the control room. Outdoor condensing unit shall be located on the roof of the building or grouted on the external side of the wall with suitable brackets.

**iv) Domestic Water Pump Sets**

The pump shall be Centrifugal type, self priming and mono-block type, suitable for pumping the clear water and treated sewage water. All the necessary piping with union, bends and tees shall be provided. Suction and discharge isolation valves and non return valves on the discharge side shall be forged steel. Piping shall be as per IS:1239 heavy class.

**v) Fire Extinguishers**

- a) Portable fire extinguishers are to be provided for all units as per the requirement of Tariff Advisory Committee (TAC) or meeting the requirement of local regulations whichever is more stringent.
- b) All the extinguishers shall be of TAC approved.

**vi) Inspection and Testing**

- a) Inspection of all the equipments shall be carried out by the manufacturer at their facility in the presence of purchaser or his representatives.
- b) Successful bidder has to intimate purchaser / his representative in writing (Inspection call), 7 working days before the scheduled date of inspection.
- c) All internal test reports (as per approved QAP/ contract Document) to be submitted along with the inspection call letter.

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**Section – 5d**

**Technical Specifications for Electrical & Instrumentation Works**

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6	Pre Commissioning Tests - Electrical, Instrumentation & Control Equipment/ Systems

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## **2. SCOPE OF WORK:**

- 1.1. The scope of services covers the design, detailed engineering, preparation of construction drawing, manufacture, acceptance testing at manufacturer's works or at any accredited agency, supply, packing, forwarding and delivery from manufacturer's works/ place of storage to erection site including transit insurance, unloading, storage at site, assembly, erection, testing, commissioning & performance demonstration and handing over along with all necessary spares of original ratings & specifications on Design, Build & Operate basis. Inland and overseas transit insurance, transport, testing at site shall be Contractor scope. Tender Bill of Quantities and Drawings are for reference purpose only which is the minimum requirements for the treatment facility as applicable; Contractor to ensure that design & equipments are as per specification requirements.
  - 1.2. The Contractor shall prepare design calculations based on parameters/ design criteria indicated in the specifications. The Contractor shall prepare detailed engineering and construction purpose drawings to make his/ her own estimate of ratings & quantities (minimum requirements as per price schedule, technical data sheets, reference drawings & other relevant details) for entire electrical & instrumentation systems including all items, systems such as equipments, cables/ cabling system, lighting, ventilation, earthing, lightning protection, main & auxiliary power distribution, instruments, civil works required for completion of Works.
  - 1.3. Contractor shall take due care of the site Seismic conditions while design of all equipments/ components used in entire electrical & instrumentation systems covered in this specification. Contractor shall furnish list of additional design parameters considered in design to fulfill above requirement.
  - 1.4. Design and detailed engineering of the materials procured by Contractor is included in scope. Contractor shall submit design drawings/ calculations of each system which is included in scope to Purchaser/ Purchaser's representative for final review/ approval. All design documents/ calculations prepared by Contractor shall be as per ISO documentation i.e., with duly signed by qualified authorities and stamped. Design documents/ calculations prepared by along with no-deviation sheet shall be submitted by the Contractor to Purchaser/ Purchaser's representative for final review/ approval.
  - 1.5. Expert or manufacturer supervision for Vendor supplied material shall be provided by Contractor and included in offer.
  - 1.6. Contractor shall be solely responsible for any shortages or damages in transit for his supply scope, handling and/ or in storage of any materials and erection of the equipment, supply of erection tools at site. Contractor shall ensure that it will not affect any activity or project schedule. Any demurrage, wharfage and other such charges claimed by the transporters, railways etc. shall be to the account of the Contractor.
  - 1.7. Contractor shall identify activities and milestones of the work forecasted for next month with optimistic and pessimistic dates of work completion. Contractor shall prepare program evaluation and review techniques to identify critical path of project and activity sequences. The project schedule shall be prepared and updated fortnightly in MS Project.
  - 1.8. Nothing in this specification shall be constructed to relieve the Contractor of his/ her responsibilities towards following best engineering practices established in the country.
  - 1.9. Obtaining necessary approval including load sanction, release of power connection & no objection certificates etc from concerned TRANSCO/ DISCOM, Electrical Inspector (CEIG),
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relevant government agencies, statutory authority, as applicable is included in Contractor's scope.

- 1.10. All necessary legal fees required for various applications to concerned TRANSCO/ DISCOM/ Electrical Inspector (CEIG), relevant government agencies, statutory authorities shall be paid by the Purchaser. The TRANSCO/ DISCOM deposit required to be paid for increase load demand/ release of electrical connection shall also be borne by the Purchaser.
  - 1.11. The Contractor's scope shall include measurement of soil resistivity at site by Wenner's four electrode method as per IS: 3043-2018 at minimum four locations at site. The earthing shall be designed for the actual mean soil resistivity value obtained.
  - 1.12. Even if all components of a system included in this specification are not explicitly identified and/ or listed herein, these shall be supplied under this contract to ensure completeness of the system and facilitate proper operation and easy maintenance of the plant. Any and all other works not indicated above but necessary/ required to complete the system in all aspects, are included in the Contractor's scope.
  - 1.13. The Contractor shall include start up spares, essential spares, recommended spares and a set of special tools necessary for operation, routine maintenance of equipment supplied for a period as specified in this contract.
  - 1.14. Whether specifically called for or not, all accessories required for normal and satisfactory operation (as deemed by the Purchaser) of the equipment shall be considered to be a part of the Contractor's basic scope of supply and/ or work and no claims whatsoever, for extra payment on these grounds, will be accepted.
  - 1.15. Contractor should visit site and get him/ her ascertained regarding the scope of work for the complete Electrical & Instrumentation works before submission of quote/ offer.
  - 1.16. Contractor's scope shall include design, engineering, manufacture, supply, testing, commissioning and handover of following electrical equipment/ systems as per tender specifications, BOQ, reference drawings and other relevant details.
    - 1.16.1. Tariff metering equipment as applicable & electric power connection including necessary liaison works (Tariff metering equipment & electric power connection shall be provided by concerned TRANSCO/ DISCOM for which necessary liaison shall be done by the Contractor)
    - 1.16.2. Switchyard Equipment- Two/ four pole structure (required to receive incoming 11/ 33 kV power supply from overhead line/ cable and to extend out required feeders), Bus bars, Isolators (GOD) with operating mechanism, Earth Switches, Lightning Arrestors, Incoming point of supply Breaker/ Ring Main Units outdoor type (required where installed capacity of transformer(s) exceeds 800 kVA/ or as per statutory requirement) & Drop Out Fuses (wherever applicable for transformer(s) being fed directly from incoming power supply) etc including necessary civil works, fence & gate etc.
    - 1.16.3. Oil type, ONAN, Dyn11, Power/ Distribution Transformer(s) with OCTC/ OLTC + RTCC, AVR, Marshalling box.
    - 1.16.4. HV Metal Enclosed Switchgears indoor type with Vacuum Circuit Breakers/ Vacuum Contactors/ Load Break Switches fully draw out including necessary control, metering & relaying devices.
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- 1.16.5. LV Metal Enclosed Switchgears including Power Control Centre (PCC) including Motor Control Centre (MCC), PDBs, Sub DBs, Lighting DBs, Utility Receptacles. Local Start/ Stop Push Button Stations shall be provided near those motors which are not controlled from a Local Console/ Starter Cubicle.
- 1.16.6. LV Capacitor Banks with control panel consisting of automatic power factor correction (APFC) relay to improve the plant power factor up to 0.99. APFC panels shall be provided on both bus sections of the LV PCC/ MCC.
- 1.16.7. Cabling system shall consists of various voltage grade, XLPE/ PVC insulated, multi-stranded Al/ Cu, GI round wire/ flat strip armoured power, control & instrumentation cables, GI ladder/ perforated type Cable Trays & associated accessories including support structures.
- 1.16.8. Provision for continuous monitoring of electrical Power & Energy parameters like Voltage, Current, Power Factor, Frequency, Kilo Watts, Kilowatt-Hours etc.
- 1.16.9. Earthing for HV/ LV equipments and lightning protection system for all buildings in the plant premises. The general design shall be on the basis of following codes and standards (their latest amendments) in line with design criteria & specification requirements.
- a) IS 3043 - 2018 : Code of practice for Safety Earthing
  - b) IS/ IEC 62305- 2013 : Code of Practice for the protection of buildings and allied structures against lightning.
  - c) CEA Regulations 2010 : Measures related to safety & electric supply.
- 1.16.10. Lighting system for all indoor & outdoor areas of plant(s). The lighting system will be controlled by lighting panels installed in respective plant/ station areas, which will be fed from the main lighting DB.
- 1.16.11. DC System:
- a) 24/ 30V or 110V DC in built DC power pack unit shall be provided wherever applicable.
  - b) 24/ 30V or 110V DC Battery & Battery Charger (with inbuilt DCDB) shall also be provided, wherever applicable.



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- 1.16.12. Contractor's scope shall also include design, engineering, manufacture, supply, testing, commissioning and handover of following Instrumentation & control equipment/ systems as per tender specifications, BOQ, reference drawings and other relevant details.
  - 1.16.13. Programmable Logic Controller (PLC) based control & monitoring system with HMI shall be implemented, covering the required functional & operational requirements of the plant involving measurement, control, alarm & interlocking functions.
  - 1.16.14. All instruments & analysers as required for monitoring/ control/ alarm/ interlocking functions involved in the process.
  - 1.16.15. All erection hardware and accessories like branch cable trays from field sensors to Junction boxes & from junction boxes to remote panel/ PLC cabinets, impulse tubes with fittings & accessories, drain/ vent valves, root valves, cable glands, structural frames/ supports, expander & reducer etc. as required for complete & proper installation of the instrumentation & control equipment/ systems.
  - 1.16.16. Instrumentation, control & any other special cables as required for entire system under Contractor's scope.
  - 1.16.17. Electronic earth pits, as per applicable standard & also meeting automation Contractor's requirement and including supply & laying of earthing cables with required accessories.
  - 1.16.18. All necessary and supplementary items & equipment required for completeness, safe & efficient operation of the system, even though these may not have been mentioned in this specification. Spares & consumables for successful commissioning, establishment of performance guarantee and five years of trouble-free & safe operation of the plant.
  - 1.17. Submission of drawings & documentation as specified under "General Technical & Particular Requirement" section for Electrical, Instrumentation & Control equipment/ systems.
  - 1.18. Contractor's scope shall also include all civil works required for electrical & instrumentation equipment/ structure such as equipment foundations, indoor & outdoor trenches, equipment support structures, two pole structures, flow meter chamber, control rooms, all excavation works including those for earthing, cabling etc, de-tanking area, soak pits, burnt oil pits, chamber etc.
  - 1.19. It is not the intent to completely specify all details of design and construction herein. Nevertheless, the Electrical, Instrumentation & Control system shall conform to high standard of engineering, design and workmanship in all respects and shall be capable of performing satisfactorily in continuous commercial operation under the specified environmental conditions.
  - 1.20. Employer reserves the right to issue addendum to the technical specification to indicate modification/ changes in the requirements, if so required at a later date.
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### 3. DESIGN CRITERIA FOR ELECTRICAL, INSTRUMENTATION & CONTROL EQUIPMENT/ SYSTEMS:

#### 3.1. GENERAL:

- 3.1.1. The design criteria, given below has to be followed by the Contractor for designing/ sizing of electrical, instrumentation & control equipments covered under Contractor's battery limits; However it is to be noted by the Contractor that, following this design criteria does not relieve the Contractor from adherence to the standards, regulatory requirements & best engineering practices.

#### 3.2. SITE/ ENVIRONMENTAL CONDITIONS:

- 3.2.1. Ambient temperature : 45°C (site specific)
- 3.2.2. Relative Humidity : 5 - 95%
- 3.2.3. Area Classification : Non Hazardous/ Hazardous
- 3.2.4. Seismic Data : As per IS 1893 (latest Issue)

#### 3.3. NOMINAL SYSTEM VOLTAGE:

- 3.3.1. Incoming AC power supply voltage to the plant premises is derived based on Load Demand as per concerned Electricity Regulatory Commission/ GERC norms as follows:

Contract Demand	Supply Voltage
Not exceeding 100 KVA	415V
Exceeding 100 KVA & up to 4000 KVA	11 kV, 22 kV and 33kV
Exceeding 4000 KVA	66 kV & above

#### 3.3.2. Plant Power/ Control Supply Distribution Voltage:

Plant Power Distribution Voltage:	6.6/ 11kV, 3 Phase, 3 Wire, 50 Hz, AC
	415V, 3 Phase, 4 Wire, 50 Hz, AC
General Lighting & Space Heating:	240V, 1 Phase, 2 Wire, 50Hz, AC
Control, Protection & Emergency Lighting:	24/ 30V or 110V, 2 Wire DC (as applicable)

- 3.3.3. Voltage Transformer Secondary: 110V, 3 Ph, 50 Hz, AC

- 3.3.4. Voltage Variation:  $\pm 10\%$ , Frequency Variation:  $\pm 5\%$  and Combined Voltage & Frequency Variation:  $\pm 10\%$

#### 3.4. SYSTEM EARTHING:

All low & medium voltage equipment shall be solidly earthed by two separate and distinct

connections with earth. In the case of high and extra high voltage the neutral points shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station or substation and the neutral may be earthed through suitable impedance in order to limit point-of-fault damage, eliminate transient over voltages, reduce the arc flash hazard, limit voltage exposure to personnel, and provide adequate tripping levels for selective ground-fault detection and coordination.

3.5. ESTIMATION OF LOAD/ MAX DEMAND: The following considerations are to be followed to arrive at the maximum electrical demand.

3.5.1. Load Factor

- |    |  |   |     |
|----|--|---|-----|
| a) | Main motors  | : | 0.9 |
| b) | Auxiliary load (Valve Actuators, Crane/ Hoist, etc.) | : | 0.4 |
| c) | Lighting load  | : | 1.0 |

3.5.2. Diversity Factor

- |    |  |   |     |
|----|--|---|-----|
| a) | Main motors  | : | 1.0 |
| b) | Auxiliary load (Valve Actuators, Crane/ Hoist, etc.) | : | 1.1 |
| c) | Lighting load  | : | 1.1 |

3.5.3. Power factor of Motors : As per the Manufacture's Data sheets

3.5.4. Efficiency of Motors : As per the Manufacturer's Data sheets

3.6. TRANSFORMER SIZING/ SELECTION:

3.6.1. Criteria 1:

- a. The capacity of the transformers will be calculated based on the total simultaneous maximum demand (calculated based on the load factors and diversity given above, PF, efficiency).
- b. Additional 10% contingency shall be considered for deriving transformer sizing.
- c. Similarly, after consideration of 10% contingency over maximum demand (MD), sizing of the selected transformer shall be such that maximum transformer loading shall not exceed 80% (of the MD + 10% Contingency) load.

3.6.2. Criteria 2:

- a. The adequacy of transformer sizing shall also be proved on the basis of % Voltage dip observed at the motor terminal. % voltage dip at motor terminal shall not exceed 15% i.e. with the use of appropriate starter & considering largest motor starting & base load (all other loads except the highest rating motor are running); the % voltage dip during starting at motor terminal shall not exceed 15%.
- b. The Voltage dip and fault level calculations needs to be calculated based on following actual data collected from nearest Substation and Grid.
  - i. The fault level of HV bus from which power supply will be taken to the plant.
  - ii. Impedance of HV Overhead Line Conductor/ HV Cable interconnecting the HV bus of Substation and HV switchboards of the Plant

- c. For the per unit calculation purpose, minimum starting current for various types of starter applications shall be considered as following:
  - i. DOL Starter – 6 times the rated current.
  - ii. Star- Delta Starter – 3 times the rated current.
  - iii. Auto Transformer Starter (ATS) – 3 times the rated current.
  - iv. Soft Starter – 3 times the rated current.

3.6.3. Wherever, HV supply (for load demand above 100 kVA/ or as per TRANSCO/ DISCOM rules prevailing at that time) is envisaged, 100% stand-by shall be provided for transformers. All the associated equipments/ accessories shall be provided for stand-by transformer as well. In normal condition, both the transformers shall feed their respective bus sections by keeping bus coupler open & in case of failure of one transformer, the other transformer shall be able to take 100% load with bus coupler in close position.

### 3.7. SWITCHGEAR SIZING/ SELECTION:

3.7.1. Switchgear shall be sized/ selected considering the following:

- a) Rating suitable for carrying full load current of the equipment.
- b) Suitability for Short Circuit Rating for 1 sec duration.
- c) Switchgear for motors shall be suitable for motor duty application.

3.7.2. Switchgear for all the motor feeders shall be as per Type-2 co-ordination.

3.7.3. Motor starter selection shall be done as follows:

- a) Direct On Line (DOL) Starter – For motors rated up to 5.5 kW
- b) Star- Delta Starter - For motors rated above 5.5 kW to 15 kW
- c) Auto Transformer Starter (ATS) - For motors rated above 15 kW & below 75 kW
- d) Soft Starter – For all low/ medium voltage motors rated for 75 kW & above.
- e) In-panel de-rating of minimum 20% or as provided in Manufacturer's catalogue, whichever is higher shall be considered.

3.7.4. Bus Bar Sizing:

- a) The Contractor shall furnish calculations after award of contract, establishing the adequacy of the bus bar sizes to meet the continuous and short time current ratings as calculated.
- b) The bus-bars shall be sized considering the following criteria:
  - i. Design ambient temperature 50°C.
  - ii. Final temperature of the bus-bars complying with requirements of IS 8623 & IEC: 60947. Reduced temperature rise limit by 5K (for indoor panels) & 10K (for

outdoor panels) to that of mentioned in IS: 8623 & IEC: 60947 shall be considered to satisfy the final temperature.

- iii. Bus bars being inside the panel; De- rating for enclosure and ventilation.
- iv. Bus bar (with insulating sleeves) suitability for carrying rated current continuously.
- v. Configuration of bus bars and Proximity effect
- vi. Bus bars shall withstand the short time rating of the panel for 1 sec duration.

3.8. POWER FACTOR IMPROVEMENT: APFC Panel shall be sized considering following design criteria:

3.8.1. Minimum 8 steps in an APFC relay shall be considered.

- a) Capacitor shall be All Poly Propylene (APP), double layer type. Each capacitor bank shall be provided with the 7% detuned filter.

3.8.2. Fixed type capacitor bank, with manual & auto switching and components as indicated in reference electrical Single Line Diagram(s) shall be provided in each mains incomer (LV) panel for transformer no load compensation.

3.8.3. For each bus section of the Main LV PCC/ MCC panel, separate APFC panel- based on above design criteria to be provided. Other requirements of APFC panel & its components shall be as per requirement provided in this specification.

3.8.4. Total capacity & capacitor bank sizes shall be as given in Table below:

Capacity	3kVAr	5 kVAr	7.5 kVAr	10 kVAr	15 kVAr	25 kVAr
* kVAr	# Nos.	# Nos.	# Nos.	# Nos.	# Nos.	# Nos.

(\*) = Contractor has to calculate the capacitor rating based on the system power factor (0.85 or actual, whichever is lesser - to be corrected for 0.99. Rating of APFC panel shall be based on 50% of running load on each bus section & not on the connected load basis. Number of stages/ steps in a particular APFC panel shall be decided by the Contractor such that minimum 8 steps & maximum 16 steps shall be provided in a particular panel. The load sensing CT changeover scheme, when, only one transformer is running to be considered.

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3.9. CABLE SIZING: The Contractor shall ensure that cable and wires associated with the power distribution and control systems, plant wiring and all other installations throughout the Works are adequately rated for their use.

3.9.1. The following main aspects shall also be considered while deciding the final size of the cables-

- a) Supply voltage and frequency
  - b) All cables shall be selected to carry the corresponding full load current under site conditions.
  - c) Route length and disposition of cables
  - d) Maximum allowable temperature rise under normal full load condition based on the material of cable insulation (XLPE/ PVC).
  - e) Maximum short circuit current duration (fault clearing time) and final temperature of cable during short circuit current flowing through the cable.
  - f) For Cables emerging from ACB outgoing, fault clearing time shall be considered as 0.16 second (for Tie feeders if any it shall be 0.5 second)
  - g) For Cables emerging from MCCB outgoing, fault clearing time shall be considered as 0.01 second
  - h) Cable from metering kiosk to PCC incomer, fault clearing time shall be 1sec
  - i) Contractor to note that, the above fault clearing times are minimum to be considered & fault clearing time shall be considered as per actual relay co-ordination study.
  - j) Appropriate de-rating factors as per cable manufacturer's catalogue and enlisted below shall be considered for sizing the cable:
    - i. Ambient Air Temperature (minimum 50°C).
    - ii. Ambient ground temperature (minimum 40°C to be considered)
    - iii. Laid in Air/ ducts/ directly in ground etc.
    - iv. Depth of cable burial (minimum 750 mm for LT and 900 mm for 11kV)
    - v. Thermal Resistivity of Soil (minimum 150°C Cm/ W to be considered)
    - vi. No. of cables in a group-touching each other or separated by a distance
    - vii. No. of cable trays in tier
    - viii. Any other de-ration factors as applicable & as per Manufacturer's catalog.
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- k) Permissible voltage dips at the time of starting the corresponding motor/ load. Contractor to ensure adherence to the Criteria mentioned above.
- l) In running condition, cumulative voltage drop (at 100% rated load) shall not exceed 5% (measured at load end) for the LV loads.
- m) LV cables shall be 1.1 kV grade, multi-stranded Al/ Copper conductor, XLPE insulated, colour coded, inner/ outer extruded PVC sheath ST2, galvanized steel round wire/ flat strip armoured cables.
- n) Cables up to & including 4.0 sq.mm shall be Cu multi-stranded conductor with galvanized steel round wire armoured & balance cables shall be Al multi-stranded conductor with galvanized steel round wire/ flat strip armoured.
- o) Single core cable shall have non magnetic material armouring.
- p) Control cables shall be Cu multi-stranded conductor with galvanized steel round wire/ flat strip armoured. For cables above 7 cores, minimum two spare cores shall be considered.

3.10. ILLUMINATION SYSTEM: Illumination for various indoor & outdoor areas shall be conforming to the requirements mentioned below:

3.10.1. The illumination levels to be considered for the design of lighting system for various areas shall be as following. These are the illumination levels achieved at Work plane. Work plane height shall be considered as 0.76 m from FGL.

Area	Illumination Level (Lux) - Average values
Office rooms	300
Switchgear rooms	250
Control rooms	300
Chemical and general stores	150
All other indoor areas	150
Outdoor platforms and walk ways	50
Outdoor plant areas	20
Switchyard & Transformer Area	
- General	10
- On Equipment	30
Roads	15

3.10.2. Critical lighting shall be designed such that at all junctions, exit passages & strategic locations the Lux level shall be maintained above 10 Lux. Installite fixtures with built in battery backup shall be considered.

3.10.3. Lighting design shall be performed using DiaLux Software Version 4.5 or its latest version/ Original Equipment Manufacturer (OEM) validated software. The Validation Report along with software and data files shall be acceptable to Purchaser/ Purchaser's representative.

3.10.4. Various design factors shall be considered as following:

a) Maintenance Factor:

- i) Outdoor area : 0.6 (0.7 for LED)
- ii) Indoor areas : 0.7 (0.8 for LED)

b) Reflectance Factors:

- i) Wall : 30%
- ii) Ceiling : 10%
- iii) Floor : 30%

c) Uniformity (Min./ Avg.) : 50% Minimum for indoor and 30% for outdoor

3.11. EARTHING & LIGHTNING PROTECTION SYSTEM:

3.11.1. The safety earthing and lightning protection system will be generally on the basis of following codes and standards (including their latest editions).

- a) IS 3043 -2018: Code of practice for Safety Earthing.
- b) IEEE 80 - 2000.
- c) IS/ IEC 62305 - 2013: Code of Practice for the protection of buildings and allied structures against lightning.
- d) CEA regulations - 2010: Measures related to safety & electric supply.

3.11.2. The fault levels considered shall be as follows:

System Voltage	Fault level in kA (*)
33 kV	26.2 kA for 1 sec
11 kV	18.4 kA for 1 sec
6.6 kV	31.5 kA for 1 sec
415 V	50 kA for 1 sec

(\*) Contractor to design on the basis of actual impedance and adequacy calculations for sufficiency of earth conductor size shall be provided. Following factors shall be considered for sizing the earthing conductor:

- a) Design Ambient Temperature : 50°C
- b) Allowable temperature rise for steel welded joints : 500°C
- c) Fault clearing time : 1 Second



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- d) Overall earthing resistance to be achieved as per IEEE std 80 - 2000 :  $\leq 1$  Ohm for transmission substation.  
 $\leq 5$  Ohm for distribution substation.
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- 3.11.3. Measurement of soil resistivity shall be done using Wenner's four (4) electrode method as described in IS 3043 -2018 including its latest amendment.
- 3.11.4. The soil resistivity of the plant area has not yet been measured; the same should be carried out during detailed engineering by successful Contractor.
- 3.11.5. After soil resistivity measurement; length of conductor, number of earth electrodes and no. of test pits shall be finalized based on these design criteria & the requirements specified in earthing requirements.
- 3.12. INSTRUMENTATION & CONTROL SYSTEMS:
- 3.12.1. Instrumentation, Control & Automation (ICA) system shall be designed, manufactured, installed and tested to ensure the high standards of operational reliability.
- 3.12.2. The instruments complete with all the necessary mounting accessories shall be designed to work at the ambient conditions of temperature, humidity, and chlorine contamination that may prevail
- 3.12.3. Instruments mounted in field and on panels shall be suitable for continuous operation of plant. Wherever required, lockable & tamperproof enclosure shall be provided for all the field mounted instruments.
- 3.12.4. All electronic components shall be adequately rated and circuits shall be designed so that change of component characteristics shall not affect plant operation.
- 3.12.5. The outdoor equipment shall be designed to withstand tropical rain. Wherever necessary, space heaters, dust and water proof cabinets shall be provided.
- 3.12.6. Unless otherwise specified, the normal working range of all indicating instruments shall be between 30% and 70% of the full scale range.
- 3.12.7. Unless otherwise stated, degree of protection for field mounted electrical and electronic instruments shall be IP-67. All instruments of submersible type shall be protected to IP-68.
- 3.12.8. Unless otherwise stated, overall accuracy of all measurement systems shall be  $\pm 1\%$  or better of the measured value.
- 3.12.9. Dual redundant SMPS shall be used for powering 24V DC Instrumentation, Control & Automation equipments.
- 3.12.10. For all the field mounted transmitters, output signal shall be 4-20 mA DC isolated with HART Protocol/ RS485 and field transmitters shall be provided with the back lit LCD/ LED display.
- 3.12.11. Electronic instruments shall be of proven design and shall utilize solid state electronic components, integrated circuits, microprocessors, etc. All digital outputs from the instruments shall be volt free.
- 3.12.12. The relay/ switch contacts shall be rated for the voltage of the circuit in which they are to be wired.
- 3.12.13. All indicating meter shall be of the digital type with no moving parts. Zero and span adjustments shall be provided for all instruments.
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- 3.12.14. After a power failure, when power supply resumes, the instruments and associated equipment shall start working automatically.
- 3.12.15. The instruments shall be designed to permit maximum inter-changeability of parts and ease of access during inspection and maintenance.
- 3.12.16. The field instruments i.e., the instruments mounted outside the control panel shall be mounted at a convenient height of approximately 1.2 meter above grade platform.
- 3.12.17. The instruments shall be given enough protection against corrosion and all the wetted parts of the instruments shall be non-corrosive.
- 3.12.18. All field instruments and cabinets/ panel mounted instruments shall have tag plates/ name plates permanently attached to them.
- 3.12.19. The performance of all instruments shall be unaffected for the  $\pm 10\%$  variation in supply voltage and  $\pm 5\%$  variation in frequency simultaneously.
- 3.12.20. Unless otherwise specified, double compression glands shall be used for glanding the cable in field instruments and instrument control panel.
- 3.12.21. Electromagnetic Flow meter sizing shall be done such that velocity of fluid inside flow tube should not be less than 0.3 m/s and not generally exceed 3.0 m/s. For underground installation, Flow Meter Chamber shall be provided.
- 3.12.22. Inlet-outlet parameter measuring instruments of plant shall be compatible to GSM/ GPRS module interface.
- 3.12.23. Online process analyzers shall be of latest technology based and shall be reagent free.
- 3.12.24. Unless otherwise specified, all instruments shall be tropicalised.
- 3.12.25. The monitoring and control system shall be designed & implemented through a Programmable Logic Controller (PLC) with HMI, covering the required functional & operational requirements of the plant involving measurement, control, alarm & interlocking functions.
- 3.12.26. PLC system selected shall be Open Platform Communications (OPC) compatible.
- 3.12.27. Input/ output philosophy for the PLC system shall be as follows:

a)	Motor	<u>Digital Input:</u> Local/ Remote Selector-1 No Run Feedback- 1 No Stop Feedback- 1 No Over Load Feedback- 1 No <u>Digital Output:</u> Start Command- 1 No Stop Command-1 No <u>Analog Input:</u> Speed Feedback (Applicable for VFD driven Pump)-1 No Vibration Sensor Feedback (Applicable for MV Motor)- 6
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		<p>Nos</p> <p><u>Analog Output:</u></p> <p>Speed Reference (Applicable for VFD driven Pump)-1 No</p> <p><u>RTD Input:</u></p> <p>Windings &amp; DE/ NDE Bearings Temperature (Applicable for motor having winding and bearing RTDs )- 8 Nos</p>
b)	Pump/ Blower	<p><u>Analog Input:</u></p> <p>Pressure Transmitter- 1 No (wherever continuous Pressure monitoring is required)</p> <p>Flow Transmitter- 1 No (wherever continuous Flow monitoring is required)</p>
c)	Motorized Valve	<p><u>Digital Input:</u></p> <p>Local/ Remote Selector-1 No</p> <p>Open Feedback- 1 No</p> <p>Close Feedback- 1 No</p> <p>Over Load Feedback- 1 No</p> <p>Torque Switch Feedback-1 No</p> <p><u>Digital Output:</u></p> <p>Open Command- 1 No</p> <p>Close Command-1 No</p> <p><u>Analog Input:</u></p> <p>Position Feedback (applicable for Modulated Control Valve)-1 No</p> <p><u>Analog Output:</u></p> <p>Position Reference (applicable for Modulated Control Valve)-1 No</p>
d)	Breaker	<p><u>Digital Input:</u></p> <p>Local/ Remote Selector -1 No</p> <p>ON Feedback- 1 No</p> <p>OFF Feedback- 1 No</p> <p>Master Trip Relay Operated- 1 No</p> <p><u>Digital Output:</u></p> <p>ON Command- 1 No</p> <p>OFF Command-1 No</p>
e)	Transformer	<p><u>Digital Input:</u></p> <p>Oil Level Low Alarm-1 No</p> <p>Oil Temperature High-1 No</p> <p>Oil Temperature Very High-1 No</p> <p>Winding Temperature High- 1 No</p> <p>Winding Temperature Very high-1 No</p> <p>Buchholz Alarm-1 No</p>

		Buchholz Trip-1 No Pressure Relief Device Trip -1 No OLTC Fault-1 No
f)	Sump/ Tank	<u>Digital Input:</u> Level High -1 No (for stopping pump at high level) Level Low-1 No (for stopping pump at low level) <u>Analog Input:</u> Level Transmitter- 1 No (wherever continuous Level monitoring is required)

- 3.12.28. PLC based control system shall be of latest industrially available configuration. PLC system shall be provided with Operator & Engineering stations along with a printer, peripherals & accessories, as required.
- 3.12.29. Unless otherwise specified, the PLC system shall be provided with hot redundant, fault-tolerant features, redundancy in processor, power supply modules, communication modules (I/O bus as well as HMI bus) and communication network, bump-less switchover from the active system to the standby system in the event of a fault.
- 3.12.30. The PLC I/O modules shall be hot swappable, i.e., card changeover, card wiring removal or communication cable change shall be possible on-line (PLC running) without causing any process interruption, bump or nuisance trip or any loss of fidelity during such action.
- 3.12.31. In case of hot swap of I/O card or card wiring removal, the interruption shall be limited to the subject card related inputs/ outputs only.
- 3.12.32. On line PLC programme modification shall be possible without stopping the processor.
- 3.12.33. The I/O modules and processors shall be of same family and series. All analog cards shall be differential type.
- 3.12.34. I/O modules shall have 3 levels of Isolation- a) Channel to Channel Isolation, b) Channel to power Isolation & c) Channel to Ground Isolation.
- 3.12.35. Channel level diagnostic features shall be available in HMI.
- 3.12.36. The engineering station forms the focal point of the control system design and acts as container of the complete control system application.
- 3.13. DRAWINGS/ DOCUMENTS FOR REFERENCE:
- 3.13.1. Typical electrical Single Line Diagram(s)/ PLC System Architecture for treatment facility form part of this specification and should be used for reference purpose only.
- 3.13.2. The equipment/ switchgear component ratings & requirements shown in the reference electrical Single Line Diagram(s) are minimum requirements & after award of contract, Contractor has to get approval for the equipment selection with the approval for sufficiency calculations.

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**4. GENERAL TECHNICAL & PARTICULAR REQUIREMENTS FOR ELECTRICAL, INSTRUMENTATION & CONTROL EQUIPMENT/ SYSTEMS:**

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Sr. No.	Description
4.1	Switchyard Equipment – 11/ 33kV Two/ Four Pole Structure arrangement inside plant premises including 11/ 33kV point of supply breaker required as per DISCOM / statutory norms or as specified in scope of supply.
4.2	HV Metal Enclosed Switchgears
4.3	Power/ Distribution Transformers
4.4	LV Metal Enclosed Switchgears
4.5	Local Push Button Stations
4.6	APFC Panel with Capacitor Bank
4.7	Cables & Cabling System
4.8	Earthing & Lightning Protection System
4.9	Lighting & Ventilation System
4.10	Instrumentation & Control Equipment
4.11	DC System
4.12	Diesel Standby Generator with AMF and Synchronizing Panel

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#### 4.1. SWITCHYARD EQUIPMENT:

- 4.1.1. The design, material, construction, manufacture and testing of substation equipment shall comply with all currently applicable standards/ statutes, regulations and safety codes in the locality where the equipment will be installed. In case of conflict between the standards and this specification, this specification shall govern. The following equipment shall be provided in the Switchyard.
- 4.1.2. Structure: Two/ four pole structures in switchyard to receive 11/ 33 kV power supply from electric supply authority shall conform to the latest applicable standards specified as under.
- a) A two/ four pole structure shall be of a rolled steel joist of minimum ISMB 150 (150mm x 75mm) for 6 meter pole/ ISMB 175 (175 mm x 90 mm) for 9/ 11meter pole with 400 mm x 400 mm x 8 mm thick base plate welded at bottom end of all the poles of structure.
  - b) Mild steel cross members of minimum ISMC 100 mm x 50 mm x 6 mm size channels of 3.5 mtr in length, 8 Nos. shall be provided with cross bracing angles of minimum ISA 50 mm x 50 mm x 6 mm size of 4.5 meter in length.
  - c) Side clamps, stay clamps, cleats etc. shall be fabricated from minimum 50 mm x 6 mm size MS flats as per actual requirements. All bolts, nuts, washers, etc. shall be of minimum 15 mm size.
  - d) All the members of two/ four pole structure should be galvanized.
  - e) Excavation of pits even in hard soil shall be done up to a depth of about 1/ 6 the length of pole and refilling the same after erection of structure and concreting work. Compacting the bottom of pits, providing cement concrete to suit at bottom and side of poles up to at-least 150 mm above FGL curing and making it hard as per requirement.
  - f) Erection of RSJ poles and fixing of all structural members as per requirement shall be in line, level and properly facing the incoming and outgoing lines. Cross members shall be firmly tightened.
  - g) All members shall be fabricated to suit mounting/ fixing of Gang Operated Disconnectors/ Isolators, Lightning Arrestors, Pin/ Post insulators, cable end termination Kit/ Box etc.
  - h) All MS parts shall be painted with two coats of red oxide and two coats of aluminum paints.
  - i) Earthing terminals shall be provided by welding 15 mm size bolts or cleats of 50 mm x 6 mm size MS flat shall be welded in each joist with a hole of 15 mm size and galvanized nuts, bolts, washers shall be provided as earthing terminals.
  - j) Necessary stay sets & hardware as required for completeness shall be supplied and erected.
  - k) All drawings/ documents such as GA drawing of two/ four pole structure showing all equipment mounted on the structure, technical particulars & Bill of Material etc shall be prepared and submitted to Purchaser/ Purchaser's representative for approval.

#### 4.1.3. Gang operated offload disconnectors (GOD) with earth switch:

- a) The double break type isolator (GOD) shall be manually operated and suitable for the specified site conditions and shall be able to-
  - i. Carry rated current without excessive temperature rise.
  - ii. Withstand the short circuit forces developed during fault.
  - iii. Carry the inrush current of the transformer.
  - iv. Interrupt small inductive and capacitive currents.
- b) The operating rod shall be extended up to the operating level and shall have a handle with 'lock and key' arrangement. The operating handle shall be at a level of 1.0 meter from finished ground level.
- c) The operating handles shall be mounted on the base of supporting structure. Guide bearings shall be provided if necessary at appropriate height above ground level. Necessary accessories viz. brackets, angles, guides, guide bearings for attaching the operating mechanism and operating handles to the structure and part of the isolator, rust proof pins, ball or roller type bearings shall be provided and installed. All bearings shall be protected by means of covers and grease retainers. Bearings pressure shall be kept low to ensure long life and ease of operation.
- d) The operating mechanism design shall be such that, as soon as the moving blades reach the sparking distance during operation of isolator, springs shall take over to give a quick snap action closing so that the isolator closing is independent of manual effort. Similarly the springs must assist during opening operation to give quick breaking feature.
- e) All copper parts shall be Silver or Tin plated. All ferrous parts shall be hot dipped galvanized to assure long protection against tropicalised weather.
- f) The contacts shall be of silver faced copper ensuring sufficient contact pressure. The male and female contacts shall be of self aligning type to ensure trouble free operation during opening and closing of isolator. Mild steel arcing horn capable of breaking the magnetizing current shall be provided. Earth mesh below GOD to be provided

#### 4.1.4. Isolator Interlock:

- a) Electrical interlock arrangement shall be provided among double break isolator (GOD) and respective HV indoor type breakers.
- b) Interlocking arrangement shall be robust, heavy-duty type and sturdy in construction.
- c) Mechanical interlock between Isolator & Earth Switch shall be provided.

#### 4.1.5. Insulators:

- a) Insulator shall be properly glazed with smooth surface without cracks etc. and dielectric property shall be properly coordinated with isolator voltage class. Porcelain used for the manufacturer of insulator shall be uniform, brown color, free from blisters,



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burns and other similar defects. Insulators of the same rating and type shall be interchangeable.

- b) Porcelain and metal parts shall be assembled in such a manner that any thermal expansion differential between the metal and porcelain parts throughout the range of the temperature variation shall not loosen the parts or create undue internal stresses which may affect the electrical or mechanical strength and rigidity. Each cap and base shall be of high grade cast steel or malleable steel casting and they shall be machine faced and smoothly galvanized. The cap and base of the insulators shall be interchangeable with each other.

#### 4.1.6. ACSR Conductor:

- a) Aluminum conductor steel reinforced shall be hard drawn from 99.5% pure electrolytic aluminum rods. The Contractor shall specify the conductivity.
- b) Chemical composition of the material shall comply with the requirements of relevant standards.
- c) The surface of conductor shall be clean and dry and free from any excess grease that may be used in its fabrication. The surface strands shall be smooth and free from burrs and other projections which may be a cause for increasing corona losses.
- d) The Contractor shall provide necessary treatment for the bus conductor to make it free from corrosion.
- e) The steel wire strand of conductor and steel conductor shall be hot dip galvanized. Zinc coating shall be evenly and uniformly for heavily coated wires.
- f) The steel core and inner layer of aluminum wires where more than one aluminum layer exist shall be protected with special grease in order to provide additional protection against corrosion due to salinity. The grease shall fill the whole space between wires within circumscribed cylinder at inner aluminum layer or at steel core if the conductor has only one aluminum layer.
- g) The grease shall be chemically neutral with respect to aluminum, zinc and steel. It shall withstand weather conditions given elsewhere and temperature of 85 degree centigrade without alternation of its properties.
- h) Bare conductor shall be covered in Alkathene pipes of suitable insulation to avoid accidental contact.

#### 4.1.7. Drop Out (DO) Fuse Unit:

- a) Drop Out Fuse shall be of approved make suitable for incoming supply voltage and shall be mounted on two or four pole structure complete with 3 fuse elements of required ampere suitable for continuous current rating and shall offer protection against fault level of incoming line.
- b) The fuse link shall consists of iron channel base to stack insulators per phase, fuse carrier Bakelite tube, heavy duty non-ferrous metal parts and spring loaded phosphor bronze contacts.
- c) The insulator shall comply with impulse voltage in accordance with relevant IS.

#### 4.1.8. Station Class Lightning Arrestors:

- a) The design, material, construction, manufacture, inspection and testing of lightning arresters shall comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will be installed.
- b) In case of conflict between the standards and this specification, this specification shall govern.
- c) The equipment covered in this specification shall conform to the latest edition of the following standards.

IS: 3070 (Part-3)

Lightning arresters for AC system – Specification  
(Metal Oxide Lightning Arrester without Gaps)

IEC: 60099-4

Metal Oxide surge arresters without gaps for AC  
system

#### d) Constructional Features:

- i. Lightning arrester shall be station class heavy duty and non- linear resistance type. The elements shall be in hollow cylindrical form, stacked together. Lightning arrestor shall be of class II, having non – linear voltage – current characteristic and having high discharge capability.
- ii. The entire arrester unit shall be housed in a porcelain insulating casing of high strength, made from brown glazed wet process porcelain, with metallic cover plates and terminal assemblies. The end castings shall be hermetically sealed and leak tested to protect the unit from moisture or breathing.
- iii. Pressure relief diaphragm, vent pipe, etc. shall be provided on the LA for the escape of gases formed. In the event of failure of L.A., the pressure relief directional aperture should be directed away from adjacent apparatus to prevent damage, due to arc transfer.
- iv. All hardware such as clamps, screws, bolts, nuts, washers etc. shall be electro galvanized.

#### e) Insulators:

- i. The porcelain insulators used shall be made from wet process, and shall be homogenous, free from lamination, cavities and other flaws, which may impair its mechanical or dielectric strength. They shall be thoroughly vitrified, tough and impervious to moisture.
- ii. The glazing of porcelain shall be uniform brown colour, free from blisters, burns, cracks and other defects. The glazing shall cover all the porcelain part of the insulators except that area which serves as support during firing or are unglazed for the purpose of assembly.
- iii. The minimum creepage distance shall be as stipulated in data sheets. The petticoats shall be spaced for natural cleaning action by wind and rain and avoid concentrated hot spots where local stress can precipitate flashover.

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- iv. All live metallic parts shall be suitably painted. All joints shall be fluid – tight and air tight. The design of insulators shall be such, as to produce uniform compression pressure joints.
  - v. All insulators of identical rating shall be interchangeable.
  - vi. Each bushing shall be provided with aluminum/ bimetallic terminal connectors suitable for inter – connection with aluminum tubular Bus bars or ACSR conductor as specified in data sheet.
- f) Accessories: Each lightning arrester shall be furnished complete with the accessories as listed below:
- i. Anti-contamination and pressure relief diaphragm complete with vent pipe.
  - ii. Two (2) grounding pads.
  - iii. Base plate suitable for mounting on GI/ steel structure or concrete structure.
  - iv. Line side terminal suitable for specified conductor.
  - v. Other standard accessories which are not specifically mentioned but are usually and provided with lightning arrester of similar type and rating for efficient and trouble free operation.
  - vi. Name plates fixed on lightning arresters giving full technical details.
  - vii. The clamps and connectors on arrestor terminals for connection to Purchaser's line conductor and the connection between incoming transmission line and LA will be in the Contractors scope.
- g) Drawings/ documents to be furnished for Purchaser's approval:
- i. Technical Particulars
  - ii. GA drawing of LA indicating weight and overall dimensions
  - iii. GA drawing of insulating base, discharge counter, terminal assembly
  - iv. Bill of Material
  - v. Mounting arrangement (base plate details) on the structure
  - vi. QAP for Lightning Arrester

#### 4.1.9. Chain Link Fencing and Gravel Filling:

- a) The work of erecting chain link fencing includes excavation, brick wall construction, erection of angle/ channel supports, providing chain link mesh on angle/ pipe frame barbed wire fencing at the top, concreting of support members, painting the complete structure and white washing the walls. All materials, hard wares, labours etc. are in the scope of Contractor.
- b) Fencing height shall be minimum 2.0 meter & shall be complying with CEA regulations/ requirements.

- c) Gate for entry in the fenced compound shall be fabricated from pipes of heavy duty class. Design of gate shall be got approved from the engineer in charge before starting the fabrication work. All necessary hard wares, fittings, stoppers, locking arrangements with brass pad locks of 100 mm size are in the scope of gate works. Gates shall be self supporting type.

- d) Gravel Filling

## 4.2. HV METAL ENCLOSED SWITCHGEARS:

### 4.2.1. Applicable Standards:

- a) The design, material, construction, manufacture, inspection and testing of Switchgear shall conform to the latest applicable standards & comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will be installed.
- b) The equipment shall also conform to the latest standards specified below. In case of conflict between the standards and this specification, this specification shall govern.

Metal Enclosed Switchgear for rated : IS: 3427/ BSEN: 60298/ IEC: 298 /  
voltage above 1kV up to and including 52 IEC 265  
kV

High Voltage AC Circuit Breakers/ : IS: 13118/ IEC: 56, 694, 62271,  
Contractors IEC: 60470, 529, 721

Current Transformers : IS: 2705/ BS: 7626

Voltage Transformers : IS: 3156/ BS: 7625 / IEC: 186

Arrangement for switchgear bus bars, main : IS: 5578, 11353  
connections and auxiliary wiring

Busbar Support Insulators : IS: 2544/ BS: 3297/ IEC: 273

Degree of Protection : IS: 13947 (Part 1)/ IEC: 947-1/ IEC:  
60529

Electrical Relays for power system : IS: 3231, 3842 / BS: 142/ IEC: 255  
protection

Electrical Indicating Instruments : IS: 1248 / BS: 89 / IEC: 51

High Voltage Fuses : IS: 9385 / BS: 2692 / IEC: 282

AC Electricity Meters : IS: 722, 8530 / BS: 5685 / IEC: 145,  
211

Specification for copper rods and bars for : IS: 613  
electrical purposes

Code of practice for phosphating iron and : IS: 6005 / BS: 3189  
steel

Low Voltage Fuses : IS: 13703 / BS: 1362 / IEC: 269

Toggle Switches : IS: 3452 / BS: 3676

Code of practice for selection, installation and maintenance of switchgear and control gear : IS: 10118

Control Switches : IS: 6875 / BSEN: 60947 / IEC: 947

HV Cable Termination : IEC: 62329

4.2.2. The switchgear shall be metal enclosed, indoor type with vacuum circuit breakers fully draw out. Circuit breakers of same ratings shall be completely inter-changeable with one another. Separate metal enclosed compartments for (a) control, metering & relaying devices, (b) circuit breaker, (c) phase bus bars, (d) Instrument transformers & (e) input/ out power cable terminations and each section shall be in conformance with Loss of Service Continuity LSC 2B.

4.2.3. The rated capacity of the breaker & switchgear configuration (no. of incomer & outgoing breakers, minimum ratings, protections, indications, annunciations, instruments etc.) shall be as per reference electrical Single Line Diagram & this specification given in table below:

Sr. No.	Description	Rating			
a)	Nominal (Rated) System Voltage	33 kV	11 kV	6.6 kV	0.415 kV
b)	Max System Voltage	36 kV	12 kV	7.2 kV	1.1 kV
c)	Lightning Impulse Withstand Voltage (1.2 / 50 microsecond)	170 kVp	75 kVp	60 kVp	-
d)	Power Frequency Withstand Voltage for 1 minute.	70 kVrms	28 kVrms	20 kVrms	3 kVrms
e)	Bus bar rating (A)	*A (As per SLD)			
f)	Short Circuit Rating (kA for 1 sec)	26.2	18.4	31.5	50
g)	Type of breakers	VCB	VCB	VCB / VCU	ACB / MCCB
h)	Bus bars material	Electrolytic Copper (Silver plated at Joints)			
i)	Degree of Protection (Indoor / Outdoor)	IP4X / IP5X (as minimum)			

4.2.4. Auxiliary relays for multiplication of contacts for following transformer protections shall be provided for oil type Transformer feeders:

a) Buchholz Protection Alarm & Trip

- b) Winding Temperature Alarm & Trip
- c) Oil Temperature Alarm & Trip
- d) Pressure Relief Device Trip
- e) Oil level gauge (MOG) Alarm
- f) Oil Surge Relay (OSR) Trip

- 4.2.5. The circuit breakers should be able to carry the rated current continuously under site conditions without exceeding the permissible temperature rise for design ambient temperature outside the switchgear cubicle as specified.
- 4.2.6. Bus bar material for switchgear panel shall be electrolytic Copper. Bus bars shall be fully insulated, supported on insulators capable of withstanding dynamic stresses due to short circuit. Maximum temperature of the main bus bars and bus bar connections, under operating conditions, when carrying rated normal current at rated frequency shall not exceed 90/ 105°C for non-silver plated/ silver plated joints as per IEC 60694. Bus bar temperature limits shall be adhered to without forced cooling method. The continuous current ratings of the droppers in each switchgear cubicle shall at least be equal to the corresponding breaker rating. However short time current rating shall be same as the short time current rating of the bus-bars.
- 4.2.7. The circuit breaker shall be fully drawn out type in horizontal with test, service and isolated positions. In test position, the circuit breaker shall be capable of being tested for operation without energizing power circuits. Additional 2 (Two) normally open (NO) contacts of test and service positions shall be available for Client's use, after meeting all the interlocks/ permissive.
- 4.2.8. Switchgear shall comprise rigid welded structural frame enclosed completely by sheet steel - minimum 2.5 mm thick (hot rolled) or 2.0 mm thick (cold rolled), smooth finished, leveled and free from flaws. Switchgear cubicles shall be provided with bottom sheet steel plates of 2.5 mm thickness. Cable compartments shall be fitted with removable plates of minimum 2.5 mm thickness for fixing cable glands. Cable gland shall be double compression type. For single core cable, removable plates of non-magnetic material shall be provided.
- 4.2.9. The switchgear panel shall be powder coated with shade RAL-7032 with minimum thickness 80 microns with structured finish and height not exceeding 2300 mm.
- 4.2.10. For vacuum circuit breakers necessary hardware for surge suppression shall be provided to take care of switching surge.
- 4.2.11. Circuit breaker shall be provided with a minimum of 6NO + 6NC contacts per pole exclusively for the Client's use. All spare contacts of the circuit breaker shall be wired up to the terminal block.
- 4.2.12. The breaker closing coils, tripping coils, indications, annunciations shall be rated for 24/ 30V or 110V DC. The spring charging motor shall be suitable for 240V AC. Space heater, power socket, panel illumination lamp shall be fed from 240V, 50 Hz, 1 phase raw power supply. All lamp test facility shall be provided with push button.
- 4.2.13. The current transformers shall be mounted in the fixed portion of the switchgear expansion panel. The CTs shall withstand momentary and short time current ratings of the associated

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switchgear. CTs & VTs shall be of the cast resin type and completely encapsulated. Adequate space shall be available for termination using heat shrinkable type cable termination in CT compartment.

- 4.2.14. The switchgear shall have complete interlocking arrangement at the fully inserted and fully drawn out position of the breaker. Withdrawal of circuit breaker shall not be possible unless it is in open position and operation of circuit breaker shall not be possible unless it is fully in service position, or is fully drawn out. Comprehensive interlocking system to prevent any dangerous or inadvertent operation shall be provided. Breaker trolley if required shall be provided with breaker.
  - 4.2.15. Automatic safety shutters shall cover live parts when the breaker is withdrawn and all other standard safety features shall be provided.
  - 4.2.16. All the High Voltage compartments i.e., Circuit Breaker, Bus Bar, and Cable Compartments shall be separated from each other by metallic partitions in line with IEC-62271-100/200. These compartments must have pressure relief flaps for exit of gas due to internal arc to ensure operators safety. All the HV design must ensure conformity to IEC-62271-100/200 and must be type tested for Internal Arc Tests.
  - 4.2.17. All non current carrying metal work of the switchgear panel shall be effectively bonded to the earth bus. Earth bus-bar shall be extended outside the switchboard at the ends. All hinged doors & bolted joints in the body of switchgear shall be earthed through flexible copper earthing braid of adequate cross section.
  - 4.2.18. Terminal blocks shall be of stud & nut type, 1100V volts grade, 10 amps rated complete with insulated barriers. Terminal blocks for CTs and VTs shall be provided with test links and isolating facilities and CT terminals with short circuiting and earthing facility. All spare contacts and terminals of cubicle mounted equipment and devices shall be wired to terminal blocks with 20% spare terminals. All terminals of different control voltages shall be separate from each other. Stud type terminals and ring type lugs shall be used for control cables.
  - 4.2.19. The sizes of wire for CT circuit shall be minimum 2.5 mm<sup>2</sup> multi-stranded copper conductor PVC insulated and for others minimum 1.5 mm<sup>2</sup> multi-stranded copper conductors PVC insulated. Ring type lugs suitable for termination of 2.5 sq mm copper wires shall be used. Colours of the secondary/ auxiliary wiring should conform to IS 375/ 1963 and latest amendments thereof.
  - 4.2.20. All wiring shall be neatly run and group of wiring shall be securely fixed with clips so that wiring can be checked without necessity of removing the clamps. Ferrules with number shall be provided on both end of the wiring, i.e. straight + cross ferruling shall be done. Printed ferrules (tubular type- cut to size after printing) white with black lettering shall be provided. Printing shall be done with the indelible ink.
  - 4.2.21. All protective relays shall be in draw out cases with built in test facilities. All auxiliary relays and timers shall be supplied in non draw out cases. Externally operated hand reset indicators shall be provided on all electro-mechanical relays and timers. Timers shall be of electromagnetic or electronic type only. All spare contacts of all relays/ timers shall be wired to terminal block. All relays shall be of self reset type, unless otherwise specified.
  - 4.2.22. Main Protection relays shall be numerical type and shall be supplied with latest version software without any extra cost. Relays and protection shall be enabled for SCADA with IEC 61850 protocol & Modbus RS-485.
  - 4.2.23. Breaker control switches shall be of pistol grip type and selector switches shall be oval or
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knob. Breaker control switches shall be 3 position spring returns to neutral.

4.2.24. Indicating lamps shall be panel mounting type of the colour specified and of multi chip/ cluster LED type only.

4.2.25. Each circuit breaker panel shall be complete with the following:

- a) T-N-C control switch, spring return to neutral position.
  - b) Key operated local/ remote selector switch stay put type.
  - c) Red, green, amber, white and blue coloured clustered type LED indicating lamps for breaker- ON, OFF, auto trip, trip circuit healthy and spring charged and breaker in Test/ Service position shall be provided.
  - d) Push Button for all lamp test facility.
  - e) 8 window (for Incomer Panel) or ICOG/ 16 window [for each Outgoing (transformer feeder) panel] annunciator with all associated accessories as per detailed in electrical SLD.
  - f) Double pole control supply switch with MCB.
  - g) Electrical anti pumping relay.
  - h) Interposing relay
  - i) Panel illumination lamp (CFL) with MCB/ switch.
  - j) Space heater with adjustable thermostat, MCB.
  - k) 5/ 15A, 1 phase receptacle with MCB.
  - l) Potential indicating multichip/ clustered type LED lamps (R, Y, and B) for incomer/ ICOG breaker.
  - m) Components as per electrical SLD.
  - n) Emergency trip push button (ETPB- Mushroom type, Red coloured latchable type)
  - o) Test Terminal Block (TTB)
  - p) Mechanical trip push button to trip the breaker when control supply is lost. The push button shall be shrouded type. Mechanical close push button provided shall be accessible only after opening of the front door.
  - q) The panel front of the circuit breaker truck shall have following devices/ indications:
    - i. Mechanical push button for breaker open.
    - ii. Mechanical indications for spring charge / discharge.
    - iii. Mechanical indications for breaker test/ service position.
    - iv. Mechanical indication for breaker ON/ OFF.
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v. Operation Counter.

vi. Device for manual charging of closing spring

- 4.2.26. All analogue indicating meters shall be 96 x 96 mm size taut band with 240° Scale. All indicating meters including Analogue Ammeter & Voltmeter shall be provided as per electrical 'Single Line Diagram'.
- 4.2.27. Multi Function Meter (MFM) shall be micro-processor based electronic meter and shall have facility for on line monitoring, reading display of each parameter and shall be provided with RS-485 communication port.
- 4.2.28. No extra charges shall be payable to Contractor in the event of any change in the contact configuration of relays i.e. from normally open (NO) to normally closed (NC) and vice versa. All wiring and necessary hardware for the completeness of the schemes shall be included in the scope of Contractor.
- 4.2.29. All operating switches shall be accessible without opening the compartment door.
- 4.2.30. All transformer outgoing feeders shall be suitable for interrupting transformer magnetizing currents. The breaker shall be electrically interlocked with downstream LV breaker such that if HV breaker trips, LV breaker shall also trip, and LV breaker cannot be closed until HV breaker is closed.
- 4.2.31. Withdrawal or engagement of circuit breakers or disconnecting switch shall not be possible unless it is in the open position.
- 4.2.32. Operation of circuit breaker or disconnecting switch shall not be possible unless it is fully in service position, or in test position or in fully drawn-out.
- 4.2.33. It shall be entirely responsibility of the Contractor to ensure that characteristics of CTs, VTs and all other devices offered by him / her are such as to be suitable for the purpose for which they are intended.
- 4.2.34. Switchgear shall be suitable for easy extension on both the sides. It shall be possible at a later stage to add cubicles on both the sides of the switchgear by extending the bus-bars.
- 4.2.35. All power and control cables entry shall be from bottom/ top to suit the site condition. The cable compartment shall house all power cable connections along with associated cable terminations.
- 4.2.36. All control cabling / wiring shall be done using 1.1kV grade, multi-stranded, Cu conductor, PVC insulated FRLS cables. Panel wiring shall be securely supported, neatly installed by lacing, and tying, readily accessible and connected to equipment terminals and terminal blocks. All the accessories such as cable troughs, cable ties, covers etc. shall be of fire retardant material.
- 4.2.37. Breaker handling trolley shall be provided if required. This shall be complete with all necessary accessories.
- 4.2.38. Earthing Switch shall be provided for bus-bar earthing for incomer panel and for cable earthing on the outgoing breaker panel with necessary interlocks. The panel earthing shall be extended up to cable alley for armour earthing.
- 4.2.39. Required suitable Cable / extension adopter boxes for power cables shall be a part of HV
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panel. The termination kit shall be heat shrinkable type only. Cable lugs for all power, control & instrumentation cables connections shall be supplied. The lugs shall be tinned copper / Aluminum depending on cable conductor and of solder less crimping type.

- 4.2.40. Padlocking facilities shall be provided for locking the shutters positively in closed position in all the panels. All door locks shall be provided with special keys to ensure opening by authorized personal only.
- 4.2.41. Caution name plate, "Caution Live Terminal" shall be provided at all the points where the terminals are likely to remain live and isolation is possible only at remote end i.e. incomer to the switchboard.
- 4.2.42. Danger notices in three languages (Hindi, English & Gujarati) and in line with the requirements of IS: 2551 shall be riveted & not pasted at appropriate locations of the switchgear.
- 4.2.43. Feeder and board name plates to be provided at front and rear of switchboard.
- 4.2.44. Panel illumination lamp shall be 9 / 11W CFL / LED with fixture & shall be provided with door limit switch.
- 4.2.45. Relays:
  - a) All relays as indicated in electrical 'Single Line Diagram' shall be mounted on the switchgear panels. The relays shall be in draw-out case, flush mounted type.
  - b) All the unit protection relays such as 50 / 50N, 51 / 51N, 51NS & 27 / 59 shall be numerical type & electro-magnetic relays shall not be used for this purpose.
  - c) In case the primary protection relays offered by Contractor do not have adequate number of contacts for protection / interlock schemes. Contractor shall supply suitable contact multiplying auxiliary relays as required. Also all necessary auxiliary relays as required to meet the Purchaser's final control/ protection/ interlock schemes shall be provided by the Contractor.
  - d) Relays shall be Numerical type. Test terminal block for testing shall be provided. Relays shall be suitable for 1/ 5A CT secondary rating as indicated in respective Single Line Diagram. Relays shall be suitable for SCADA with IEC 61850 protocol & Modbus RS-485.
  - e) Lockout relay-86 shall be having minimum 6 NO + 6 NC contacts.
  - f) All relays shall have clear identification on the associated panel by well-written inscription plates. Where indications are provided by flag relays or LEDs, these shall also be specifically identified by permanently fixed inscription adjacent to them.
  - g) The final relay ranges of each relay shall be decided at detailed engineering stage, if it is found that the offered relay range is not suitable for the intended application, the Contractor shall change the relay of appropriate range without any commercial / delivery implications whatsoever. The relay shall be subject to approval of Client's representative.
  - h) Contractor shall furnish recommended relay settings with backup calculations & approval for the same has to be obtained from Purchaser / Consultant. Entire Relay

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co-ordination shall be carried out in ETAP 12.5 version or latest available during detailed engineering. The Contractor shall obtain all interface data from all concerned.

- i) All relay / auxiliary relay coils shall operate satisfactorily between 85% to 115% of rated control voltage.
- j) It is responsibility of the Contractor to include accessories like auxiliary CTs, VTs and all other necessary devices as required for satisfactory performance of relay and protection scheme even if not indicated in drawings/ data sheets. Testing facilities like test switches / test plugs shall be provided for testing of each individual relays.
- k) Performance tests shall be conducted at site and also supervised by Contractor for all the equipment's to prove the guarantee.
- l) Prices quoted shall include the cost of all routine tests specified in relevant standard & as mentioned below. As regards type tests, copies of the earlier test certificates carried out on equipment of similar or higher ratings but not older than five (5) years shall be furnished along with the offer.

4.2.46. Current Transformers: Current Transformers shall satisfy following requirements:

- a) Current transformers for metering & protection shall be cast resin (class of insulation B or better). The CT ratios / protection class shall be as shown in 'Single Line Diagram'.
- b) Rated VA burden for metering/ protection CTs shall not be less than 15VA or 120% of total VA burden whichever is higher.
- c) The accuracy class for metering CT shall be 1.0 or better.
- d) It shall be responsibility of Contractor to ensure that CTs are suitable for correct and satisfactory operation of the instruments / relays connected across them.
- e) Short time current rating and momentary withstand rating of CTs shall be as per breaker short time current withstanding capacity.
- f) All CTs shall have secondary rating of 1A or 5A.

4.2.47. Voltage Transformers: Voltage Transformers shall satisfy following requirements:

- a) Potential transformers for metering / protection shall be suitable for operation on 33 / 11kV, 50 Hz system. The VT ratios shall be as shown in respective electrical Single Line Diagram.
- b) Rated VA burden for metering/ protection VTs shall not be less than 100VA or 120% of total VA burden whichever is higher.
- c) The accuracy class for metering VT shall be Class 1.0 / 3P as required.
- d) It shall be responsibility of Contractor to ensure that VTs are suitable for correct and satisfactory operation of the instruments connected across them.
- e) Fuses on primary side shall have rupturing capacity equal to the switchgear rating.

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- f) For VT's MCB shall be provided on secondary. MCB trip contact to be wired up for annunciation.

#### 4.2.48. Maintenance Requirements:

- a) Contractor shall supply maintenance tools including special tools (if required) for attending to the equipment supplied at no extra cost. As far as practicable, the equipment and accessories shall be so designed that no special tools are necessary for installation and maintenance of the equipment. However, if special tools are required, the Contractor shall supply one complete set for each type of equipment for the purpose.
- b) Contractor shall include supply of start-up and essential spares.
- c) Contractor shall furnish detailed inter-panel diagrams, terminal connection wiring diagram, and detailed component layout drawings to carry out maintenance work.
- d) Contractor shall ensure the use of calibrated test equipment having valid calibration test certificates from standard laboratories traceable to national standard.

#### 4.2.49. Earthing:

- a) An earthing bus shall be provided at the bottom and extend throughout the length of the switchgear. It shall be bolted / welded to the frame work of each unit and each breaker earthing bus.
- b) All non-current carrying metal work of the switchgear shall be effectively bonded to the earth bus. Hinged doors shall be earthed through flexible earthing braid of adequate size.
- c) Positive earthing of the circuit breaker frame shall be maintained both in service and test position.

#### 4.2.50. Annunciator:

- a) Microprocessor based alarm annunciator shall be provided for generating audio visual alarms for each abnormal condition. Facia annunciator, suitable for operation on 24 / 30V or 110V DC (as applicable) shall be provided.
  - b) Each alarm shall initiate the operation of both visual and audible devices equipped with 'Mute', 'Acknowledge' and 'Reset' push buttons common to annunciators on all switchgear aligned together and a 'Lamp test' push button for each annunciator on individual panels.
  - c) Annunciator shall be of facia type with translucent plastic window for each alarm point. Annunciator facia plates shall be engraved in block lettering with respective alarm inscriptions. The inscriptions shall be clearly readable and visible when the respective facia light is lighted provided with two lamps connected in parallel on each facia window with series resistors. Lamps shall be clustered LED type.
  - d) All facia annunciator points shall be suitable to accept external contacts of either 'NO' or 'NC' self or hand reset type for initiating the annunciation sequence.
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- e) Annunciators shall be suitable for accepting fleeting faults of duration as less as 15 milliseconds annunciating subsequent faults with the specified sequence immediately after acknowledging the previous fault.
- f) Facia Window shall be of minimum size of 35 mm x 50 mm.
- g) During lamp test, if a fault occurs, the corresponding lamp circuit shall be automatically disconnected from the "lamp test" circuit and shall start flashing.
- h) The sound intensity of each audible device shall be suitable for the maximum sound level of its environment.
- i) The sequence of alarm should be user selectable by dip switch. The operation or acceptance of one alarm shall not inhibit the operation of the audible device or the flashing of the appropriate alarm indicator if a future alarm condition occurs
- j) Annunciator shall be designed for an operating sequence indicated below:

Alarm Condition	Fault Contact	Audible Alarm	Visual Alarm
Normal	Open	Off	Off
Abnormal	Closed	On	Flashing
Acknowledge	Open	Off	Steady on
Reset	Open	Off	Off
Lamp Test	Open	Off	Steady on

#### 4.2.51. Cable Terminations:

- a) Necessary number of cable glands shall be supplied for terminating auxiliary power and control cables. Glands shall be of heavy duty brass castings, machine finished and complete with check nut, washers, neoprene compression ring.
- b) Cable lugs for all power and control cable connections shall be supplied. The lugs shall be tinned Copper/ Aluminium depending on cable conductor and of solder less crimping type.
- c) All necessary materials required for terminating the power cables such as tapes, fillers, binding wires, armour clamps, brass glands etc., shall be supplied.

#### 4.2.52. Tests:

- a) Routine tests and acceptance tests as per the applicable IS / IEC standards shall be carried out in the presence of Purchaser / Purchaser's representative.
- b) Type test certificates for internal arc test, SC withstand & Impulse test shall be furnished with the Bid (not older than five (5) years) from CPRI or other independent agency
- c) The test equipment, meters, instruments etc. used for testing shall be calibrated at recognized test laboratories at regular intervals and valid certificates shall be made available to the Client / Client's representative at the time of testing. The calibrating instruments used as standards shall be traceable to national/international standards.

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4.2.53. Drawings/ Documents Required: The following drawings/ documents to be furnished by the Contractor for Purchaser's approval

- a) Technical Data Sheet
- b) General Arrangement Drawing
- c) Wiring Schematic
- d) Bill of Quantities
- e) Quality Assurance Plan

4.3. POWER/ DISTRIBUTION TRANSFORMERS:

4.3.1. Applicable Standards: Transformer shall comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will be installed. The equipment shall also conform to the latest applicable standards and codes of practice specified as under. In case of conflict between the applicable reference standards and this specification, this specification shall govern.

Power transformer : IS 2026, BS 171, IEC 76, CBIP Pub No. 317

Outdoor oil immersed distribution transformer up to & including 2500 kVA, 33kV. : IS 1180 - 2014

Fittings & Accessories : IS 3639

Climate proofing : IS 3202, BS-CP-1014, IEC 354

Loading of oil immersed : IS 6600, BS-CP-1010, IEC 296

Oil : IS 335, BS-148, IEC 137

Bushing for >1000 V, AC : IS 2099, BS-223, IEC 144

Bushing for <1000 V, AC : IS 7421, BS-223, IEC 144

Degree of protection : IS 13947, IEC 76

Tests : IS 2026, BS-171, IEC 76

Tolerance on guaranteed Particulars : IS 2026

Buchhloz relay : IS 3637

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Electrical insulation classified by : IS 1271, BS 2727, IEC 85  
thermal stability

Code of practice for selection, : IS 10028  
Installation & maintenance of  
transformer

- 4.3.2. This specification is for complete design, manufacture, testing at manufacturer's works, supply, packing, forwarding and delivery from place of storage / manufacturer's works to erection site including transit insurance, storage at site, shifting from the place of storage to place of installation, installation, testing and commissioning for two winding, three phase, 50 Hz, outdoor type, distribution transformer of (\*) kVA, 33 -11/ 0.433 kV, ONAN cooled, connected in Dyn11 with OCTC/ OLTC on HV winding & other accessories as specified.
- 4.3.3. The values of Load- losses and No-load losses shall be as given in relevant IS or as per applicable standard.
- 4.3.4. The Purchaser reserves the right to reject the transformer if the same does not meet the specification requirement as follows:
- a) No load loss exceeds the guaranteed value by 20% or more.
  - b) Impedance value differs the guaranteed value by +10% or more (zero negative tolerance)
  - c) Oil or winding temperature rise exceeds the specified value by 5 deg C
  - d) Transformer fails on impulse test.
  - e) Transformer fails on power frequency voltage withstand test.
  - f) Transformer is proved to have been manufactured not in accordance with the agreed specification.
- 4.3.5. The rejected transformers shall be replaced by transformers complying with the requirements of this specification at the Contractor's cost.
- 4.3.6. If the commissioning of the project is likely to be delayed by the rejection of a transformer, the Purchaser reserves the right to accept the rejected transformer until the replacement transformer is made available. Transporting the rejected and replacement transformers as well as installation and commissioning of both the transformers shall be at the Contractor's cost
- 4.3.7. Transformer Protections: The following protections shall be provided for a distribution transformer:

Over-current protection – Instant (50 / 51)	Trip (Relay In HV Panel)
Earth fault protection – Instant (50N)	Trip (Relay In HV Panel)
Stand by Earth fault protection (51NS) with CT in transformer neutral [For transformer of 1600kVA & above]	Trip (Relay In HV Panel)

Buchholz protection relay (63) [For transformers of 500 kVA & above]	Alarm + Trip
Oil temperature indicator (OTI - 49O)	Alarm + Trip
Winding temperature indicator (WTI - 49W) [for transformer of 800 kVA & above]	Alarm + Trip
Magnetic Oil level gauge (MOG)	Alarm
Oil Surge Relay ( OSR ) [For transformers with OLTC]	Trip – For OLTC
Pressure relief device (PRD) [For transformer of 800 kVA & above]	Trip

- 4.3.8. In case of 11/ 33kV Cable feeder, an air insulated cable box with disconnecting chamber shall be provided on 11 / 33 kV side of transformer.
- 4.3.9. For the pole mounted transformers (i.e. transformers  $\leq 100$  kVA rating), suitable orientation of HV porcelain bushings shall be ensured for direct termination of ACSR conductor from 11/ 33 kV Double Pole Structure.
- 4.3.10. For transformers above 100 kVA rating, elevated foundation/ plinth of suitable height shall be provided.
- 4.3.11. All the Civil works such as, transformer foundation, Oil Soak Pit, Burnt oil pit as per CEA regulations & IS 10028 requirements shall be considered in Contractor's scope.
- 4.3.12. Ambient temperature of 50°C shall be considered for transformer design. Temperature rise shall be 40°C for oil temperature and 45°C for winding temperature. Hot spot temperature limits shall be complying with IS 2026, IS 6600 & IEC 60076-2:1993 & it shall be limited to 98°C.
- 4.3.13. The limits of hot spot temperature mentioned above will have to be satisfied by the manufacturer by carrying out the heat run test at the lowest negative tap. This test shall be carried out by feeding 1.1 times the total losses at 75°C at highest current tap.
- 4.3.14. Neutral of LV winding shall be 50% rated.
- 4.3.15. Suitable dial type instruments/ indicator with alarm and trip contacts shall be provided for monitoring of following parameters for the transformer. The settings shall be site adjustable.

Winding Temperature Indicator (WTI)	1 No local + 1 No remote on RTCC
Oil Temperature indicator (OTI)	1 No local + 1 No remote
Magnetic oil level gauge (MOG)	1 No local



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4.3.16. The bushing CT required in neutral connection for back up earth fault protection shall be provided before bifurcation of neutral.

4.3.17. Accessories listed below shall be provided for the transformer unless noted otherwise.

- a) Anti-earthquake clamping device
  - b) Marshalling Box
  - c) All interconnection cables, cable accessories for connection between the transformer marshalling box & other devices mounted on the transformer and inter-connection cables for all the associated equipments / panels including cable termination accessories such as glands, lugs etc.
  - d) Foundation bolts & hardware, mounting channel & support structures for marshalling boxes, junction boxes etc.
  - e) All MS components including steel bolts & nuts shall be hot dip galvanized.
  - f) Automatic self-resetting type pressure relief device with trip contacts wired up to marshalling box.
  - g) Additional neutral bushing.
  - h) Conservator with lifting lugs (for transformers 50 kVA and above with rated voltage up to 11kV, and all rating above 11kV with oil filling hole with cap and a drain plug) shall be complete with plug, sample and drain valve and a shut-off valve on the pipe connection between the transformer tank and conservator to permit removal of the conservator
  - i) Bushing Terminals or cable boxes complete with connectors for the Purchaser's external conductors or cable.
  - j) Neutral bushing terminal complete with connector for earth conductor.
  - k) Four plain rollers in place of fixing channels. The rollers shall be bidirectional, with suitable corrosion-free bearings, suitable for 90 degree rotation & lockable in both directions and of the detachable type.
  - l) Inspection covers (for transformers of 1000 KVA and above).
  - m) Rating and terminal marking plates
  - n) Two earthing terminals for body earthing
  - o) Drain cum sampling valve with plug or cover plate.
  - p) Dehydrating Silica Gel Breather equipped with a silica gel dehydration capsule and oil seal to eliminate constant contact with the atmosphere.
  - q) Thermometer pocket with mercury in glass bulb thermometer.
  - r) Radiator with air release plug, lifting lug, drain valve and with shut off valves.
  - s) Conservator with lifting lugs, oil filling cap & drain plug.
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- t) Prismatic oil level gauge (on conservator) with minimum level marking.
  - u) Jacking Lugs (Transformers weighing above 3000 Kg)
  - v) Filter Valves
  - w) Explosion vent with diaphragm/ pressure relief valve (for transformers 50 KVA and above). The device shall be rain-proof after operation. For transformers of 500 KVA and above an equalizer pipe connecting the pressure relief device to the conservator shall be supplied
  - x) Base channels for fixing on a platform or plinth
  - y) Lifting lugs for top cover & active part.
  - z) Lifting lugs for lifting complete transformer with oil.
  - aa) Lifting lugs for lifting core & coils.
  - bb) Pocket for O.T.I & W.T.I.
  - cc) Neutral C.T with terminal box.
  - dd) Earthing bar with insulator support.
  - ee) All indicating lamps shall be multichip LED Type.
  - ff) Dial type thermometer (150 mm Dia.) with two contacts for oil temperature 'high' and 'very high' alarms. Each contact shall be electrically independent and brought out to separate terminals, rated 220 VDC; minimum 0.5A.
  - gg) Magnetic oil level gauge (150 mm dia. 240 degree scale) with low oil level alarm contact for transformers fitted with conservator. Contact rating suitable for 220V DC, minimum 0.5A.
  - hh) Gas actuated Buchholz relay, double float type with a valve between the relay and the conservator.
  - ii) Gas sampling device at an accessible height and an air release cock for Buchholz relay.
  - jj) Winding temperature indicator, consisting of:
    - i. Temperature sensing element. Separate PT100 for digital signal shall be provided as temperature sensor
    - ii. Turret mounted CT.
    - iii. Local Winding temperature indicating instrument (150 mm Dia.) with electrically independent contact(potential free contact) brought out to separate terminals for winding temperature 'high' and 'too high' alarms. Contacts shall be suitable for 220V DC, rated minimum 0.5A.
  - kk) All digital outputs for control / remote annunciation shall be provided with at least two change-over contacts for alarm & two change-over contacts for trip conditions.

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Auxiliary relays, if required, to provide change-over contacts suitable for Purchaser's equipment are deemed to be included in the Contractor's scope.

- II) Valves: Valves shall be of Gun Metal material & of suitable diameter for their intended purpose. Following valves shall be provided for each oil immersed transformer.
- i. One (1) top filter valve with blanking plate.
  - ii. One (1) bottom filter valve with blanking plate
  - iii. One (1) bottom sampling valve with blanking plate
  - iv. Two (2) Shut-Off/ Gate Valve for OLTC Part of Conservator (on both sides of Oil Surge relay)
  - v. Two (2) Shut-Off/ Gate Valve for Main Conservator (on both sides of Buchholz relay)
  - vi. One (1) Drain valve with blanking plate for Conservator
  - vii. One (1) bottom drain valve with blanking plate for complete Transformer
  - viii. One (1) top sampling valve with blanking plate
  - ix. Radiator shut off valves with blanking plates between radiator head & tank.
  - x. Oil filling valve with blanking plate for Main & OLTC conservator.

4.3.18. General Constructional Features of Transformer: All material used shall be of best quality and of the class, most suitable for working-under the conditions specified and shall withstand the variations of temperature and atmospheric conditions, overloads, over-excitation, short-circuits as per specified standards, without distortion or deterioration or the setting up of undue stresses in any part, and also without affecting the strength and suitability of the various parts for the work which they have to perform. The transformer construction shall be suitable for Seismic Data (As per latest edition of IS 1893) or elsewhere in the specification.

a) Tanks:

- i. The exterior of tank and other steel surfaces exposed to the weather shall be thoroughly cleaned and have a priming coat of zinc chromate applied. The second coat shall be of an oil and weather-resistant nature, preferably of distinct colour from the prime and finish coats. The final coat shall be of a glossy, oil and weather resisting non-fading paint of specified shade. The interior of the tank shall be cleaned by shot blasting and painting with two coats of heat resistant and oil insoluble paint.
- ii. Steel bolts and nuts exposed to the atmosphere shall be galvanized.
- iii. Vacuum & Pressure Tests
- iv. Various Vacuum & Pressure Tests for tank, conservator, radiator, pipes etc. shall be as per mentioned in the CBIP Manual on Transformer – Publication no. 317: 2013 & latest edition thereof.

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- v. The material used for gaskets shall be cork neoprene or approved equivalent.
- b) Core:
- i. The magnetic circuit shall be constructed from high grade cold-rolled non-ageing grain oriented silicon steel laminations and shall be of 'core' type.
  - ii. The insulation structure for the core to bolts and core to clamp plates shall be such as to withstand BIL & Lightning Impulse Voltage.
  - iii. Each lamination shall be coated with insulation which is unaffected by the temperature attained by the transformer during service.
  - iv. Core laminations shall be annealed and burrs removed after cutting. Cut edges shall be insulated.
- c) Windings:
- i. Windings shall be of electrolytic grade Copper of 99.9% purity unless specifically approved by the Purchaser.
  - ii. Windings shall be of insulated Copper wire or Copper strip.
  - iii. Windings and insulation shall be so arranged that free circulation of oil is possible between coils, between windings, and between winding and core.
  - iv. Winding shall be subjected to a shrinking and seasoning process, so that no further shrinkage occurs during service.
  - v. The completed core and coil assembly shall be dried in vacuum and shall be immediately impregnated with oil after the drying process to ensure elimination of air and moisture within the insulation.
  - vi. High voltage end-windings shall be suitably braced to withstand short circuit stresses and stresses caused up by surges.
  - vii. Materials used in the insulation and assembly of the windings shall be insoluble, non- catalytic and chemically inactive in the hot transformer oil, and shall not soften or be otherwise affected under the operating conditions.
  - viii. Varnish application on coil windings may be given only for mechanical protection and not for improvement in dielectric properties. In no case varnish or other adhesive be used which will seal the coil and prevent evacuations of air and moisture and impregnation by oil.
  - ix. Permanent current carrying joints in the windings and leads shall be welded or brazed. Clamping bolts for current carrying parts inside oil shall be made of oil resistant material which shall not be affected by acidity in the oil. Steel bolts, if used, shall be suitably treated.
  - x. Terminals of all windings, and if stated also of stabilizing windings, shall be Brought out of the tank through bushings for external connections.

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- xi. Windings shall be of copper and the conductors shall be transposed at sufficient intervals in order to minimize eddy currents and equalize the distribution of currents and temperatures along the windings.
    - xii. The sequence and orientation of HV / LV side phase and neutral bushings shall be as specified in the latest edition of relevant IS.
    - xiii. Transformer shall operate without injurious heating at the rated KVA and at any voltage up to  $\pm 10\%$  of the rated voltage of any tap. Transformer shall be designed for 110 % continuous over-fluxing withstands capability.
  - d) Internal Earthing: The framework and clamping arrangement of core and coil shall be securely earthed inside the tank by Copper strap connection to the tank.
  - e) Terminations:
    - i. Transformers shall be fitted either with bushing insulators or with air insulated cable boxes / air insulated cable box with disconnecting chamber, as per requirement based on transformer HV incomer.
    - ii. The neutral of the star-connected winding shall be brought out to a separate bushing terminal. The neutral bushing shall be provided on the tank side to facilitate lead of the earth conductor down to the ground level. For transformers 1000 kVA and above, tank mounted insulators shall be provided for supporting the neutral earthing bar of specified section, along its run from the neutral bushing to ground-level.
  - f) Bushings:
    - i. Bushings shall be designed and tested to comply with the applicable standards specified in the specifications.
    - ii. Bushing rated for 400A and above shall have non-ferrous flanges and hardware.
    - iii. Fittings made of steel or malleable iron shall be galvanized.
    - iv. Bushings shall be supplied with terminal connector clamp suitable for connecting the bushing terminal to the specified conductor / cable.
  - g) Bushing Current Transformers:
    - i. Whenever applicable, bushing shall be supplied with current transformers.
    - ii. Secondary leads, including tappings, shall be brought to a weatherproof terminal box near the bushing.
    - iii. Bushing CT nameplate shall be mounted on the tank adjacent to the terminal box.
  - h) Cable Boxes and Disconnecting Chamber:
    - i. The cable boxes, wherever required as per the prescribed criteria, shall be complete with cable joint fittings or sealing ends as required, tinned copper lugs

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to suit specified cable, compound and all other accessories including compression type glands, armour earth clamps and body earth terminal.

- ii. For Cable type of terminations, disconnecting chamber shall be provided to enable the transformer to be removed without unsealing the cables or draining oil from the main tank. The disconnecting chamber shall be air insulated and complete with seal-off bushings, removable flexible connectors / links and removable covers.
- iii. Cable boxes shall be designed to accommodate all cable joint fittings or sealing ends as required, including stress / cones or other approved means for grading voltage stress on the terminal insulation of cables operating at voltages of 22 kV and above.
- iv. Phase to phase and phase to ground clearances within the chamber shall be such as to enable either the transformer or cable to be subjected separately to HV tests.

i) Marshalling Box:

- i. Whenever fittings such as OTI / WTI, temperature indicators with auxiliary contacts, Buchholz relay, bushing CTs etc. are provided the marshalling box shall be provided to marshal in it all the contacts / terminals of electrical devices mounted on the transformer.
- ii. It shall be in the Contractor's scope to provide interconnection cabling between the marshalling box and the accessory devices by either PVC insulated, FRLS wires in GI conduits and / or XLPE insulated, inner & outer extruded PVC, armoured cable and necessary compression type brass cable glands at the marshalling box for the above mentioned cables as well as for terminating the incoming cables from remote panels.
- iii. The marshalling box shall be tank mounted (at easily accessible location), outdoor type, IP-55 protected, weather-proof, sheet-steel (2.0 mm thick) enclosed, with hinged door having padlocking facility and painted as per paint shade approved by the Purchaser. All doors, covers and plates shall be fitted with Neoprene gaskets. Bottom shall be at least 600 mm from floor level and provided with gland plate and cable glands as required. Top surface shall be sloped.
- iv. The marshalling box shall be provided with glass window so as to make the WTI and the OTI dials visible from the outside without opening the door.
- v. All contacts for alarm, trip and indication circuits shall each be potential free, wired for auxiliary DC supply as specified and brought out to separate terminals at the terminal blocks in the marshalling-box. Terminals shall be rated for 10A. Wiring shall be 1.1 kV grade, with multi-stranded, copper conductors of sizes not smaller than 1.5 mm<sup>2</sup> for control and 2.5 mm<sup>2</sup> for CT circuits. CT terminals shall be provided with shorting facility and earthing.
- vi. The marshalling box shall house the winding temperature indicator (WTI, 150 mm dial), the oil temperature indicator (OTI, 150 mm dial), terminal block, 60W anti-condensation heater, 6 / 16A industrial type five pin socket and a 10W CFL with fixture, suitable for operating on 240 V AC. Contacts of Buchholz relay,

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WTI, OTI, magnetic level gauge, PRD, OSR shall be wired up to the terminal block.

- j) Noise level of transformers shall be as per latest NEMA standard.
- k) Oil - Transformers shall be supplied complete with transformer oil. Transformer oil shall be as per IS-335:1993, BS 148 or IEC 296. 10% extra oil shall be supplied with transformer in non returnable drums.

#### 4.3.19. Maintenance Requirements For Transformers & Associated Equipment:

- a) The construction of the transformer & location of the accessories like CTs, lower ends of bushings, terminals, tap-changers etc., shall be such as to afford easy access & permit replacement of auxiliaries without removing the tank cover.
- b) Instruments & wiring in the local marshalling box (cabinet) shall be completely accessible & sufficient working space shall be made available in the cabinet. Instruments, wiring & accessories in the cabinet shall be accessible from the front & the rear as well.
- c) The rating plate of the transformer shall be supplied as per latest version of IS: 2026.
- d) Transformer shall be capable of being used with any make of transformer oil complying with IS: 335.
- e) As far as practicable, transformer & accessories shall be so designed that no special tools are necessary for installation & maintenance. However, if special tools are required, the Contractor shall supply one complete set of such tools along-with transformer.

#### 4.3.20. Performance Tests:

- a) In addition to the routine tests specified in the latest edition of IS: 2026, tests listed out shall be carried out on the transformer and these shall be included in the quoted prices.
- b) The tests shall be carried out in the presence of the Purchaser / Purchaser's representative. The following tests shall be carried out on the assembled transformer during inspection at the manufacturer's works;
  - i. Measurement of resistance of windings at principal and extreme taps.
  - ii. Ratio at each tap, polarity and phase relationships
  - iii. Measurement of impedance voltage at principal and extreme taps
  - iv. Measurement of no load current and no load losses at rated frequency and at both the rated voltage and 110% rated voltage
  - v. Measurement of efficiency at  $\frac{1}{2}$ ,  $\frac{3}{4}$  and full load
  - vi. Measurement of insulation resistance
  - vii. Induced over voltage withstand test

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viii. Separate source voltage withstand test

ix. Magnetic balance test

x. Vacuum & Pressure Test for the tank.

- c) In addition to the above tests, lightning impulse withstand test shall be carried out on one limb of HV winding of the transformer if impulse test has not been already carried out on transformer of similar or higher capacity in the last five years. Similarly heat run test shall also be carried out if the same has not been already carried out on transformer of similar or higher capacity in the last five years. Type test certificate shall be submitted along with the bid. if such a test has not been already carried out then same has to be carried out & witnessed by third party (such as CPRI) at the Contractor's expense.
- d) All tests required by the specification including repeated tests and inspection that may be necessary owing to the failure to meet any tests specified, shall be carried out at the Contractor's expense.
- e) If the transformer fails to pass the tests specified, the Client shall have the option to reject the unit. Additional tests shall be conducted to locate the failure and after rectification, all tests shall be repeated to prove that the rebuilt transformer meets the specification in all respects, all at the Contractor's expense.

4.3.21. Drawings/ Documents Required: Contractor shall submit the following drawings / documents for Purchaser's approval:

- a) General arrangement drawing of the transformer, showing plan, front elevation and side elevation complete with all accessories and fittings, detailed dimensions, net weights, quantity of oil, crane lift for untanking, size of lifting lugs and eyes, clearances between HV terminals, between LV terminals, between HV and LV terminals, between HV & LV terminals and ground etc
- b) Rating, diagram and terminal marking plates, complete with polarity and vector group
- c) Foundation drawing with position of foundation bolts and depth. In case of Soak pit / Burnt oil pit requirements, the same shall also be included.
- d) General arrangement of HV cable box with air insulated disconnecting chamber.
- e) General arrangement of LV Cable Box or Bus Duct arrangement.
- f) General arrangement of marshalling box & wiring diagram.
- g) General arrangement of OLTC / RTCC & wiring diagram
- h) Guaranteed Technical Particulars for Transformer

4.3.22. Off Circuit Tap Changing Mechanism (OCTC) for Transformer <1000 KVA: OCTC shall be with  $\pm 7.5\%$  in taps in steps of 2.5% on HV winding of transformer; It shall comprise:

- a) Operating handle or wheel, accessible from ground level. Tap changer operating switch mounted on the top of the transformer tanks will not be acceptable
- b) Tap position indicator.



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- c) Pad locking arrangement without interfering with visual tap position indicator shall be provided.
  - d) The tap-changer connections and contacts shall be accessible through an excess hole having a bolted gasketed cover.

4.3.23. On load Tap Changing Mechanism (OLTC) for Transformer  $\geq 1000$  KVA: OLTC shall be with  $\pm 10\%$  taps in steps of 1.25% on HV winding of transformer; It shall have following technical features:

- a) The OLTC gear shall be designed to complete successfully tap changes for current equal to 120% of current at minimum tap position of the transformer. Also, OLTC over loading capability shall be compatible with that of transformer specified in IS / IEC specification "Guide for loading of oil immersed transformers". Devices shall be incorporated to prevent tap change when the through current is in excess of the safe current that the tap changer can handle. The OLTC gear shall withstand through fault currents without injury.
  - b) When a tap change has been commenced it shall be completed independently of the operation of the control relays and switches. Necessary safeguard shall be provided to allow for failure of auxiliary power supply or any other contingency which may result in the tap changer movement not being completed once it is commenced.
  - c) Oil in compartments which contain the making and breaking contacts of the OLTC shall not mix with the oil in other compartments of the OLTC or with transformer oil. Gases released from these compartments shall be conveyed by a pipe to a separate oil conservator or to a segregated compartment within the main transformer conservator. An oil surge relay shall be installed in the above pipe. The conservator shall be provided with a prismatic oil level gauge.
  - d) Oil, in compartments of OLTC which do not contain the make and break contacts, shall be maintained under conservator head by valved pipe connections. Any gas leaving these compartments shall pass through the oil surge relay before entering the conservator.
  - e) Oil filled compartments shall be provided with filling plug, drain valve with plug, air release vent, oil sampling device, inspection window with view glass.
  - f) OLTC driving mechanism and its associated control equipment shall be mounted in an outdoor, weather proof cabinet conforming to degree of enclosure protection IP55. The finish shall match with that of the transformer on which it is mounted. The cabinet shall include:
    - i. Driving motor (415 V, 3 phase, 50 Hz, AC squirrel cage)
    - ii. Mechanically & electrically interlocked motor starting contactors with thermal overload relay, isolating switch and MCCBs.
    - iii. Duplicate sources of power supply with automatic changeover from the running source to the standby source and vice versa will be provided in transformer marshalling box and one no. outgoing feeder extending to OLTC Driving Motor cabinet, with appropriate provision for receiving the same.
    - iv. Control switch: Raise / off / lower (spring return to normal type) or independent push buttons.
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- v. Emergency 'OFF' push button (maintained type).
  - vi. Remote/ Local selector switch (maintained contact type).
  - vii. Mechanical tap position indicator.
  - viii. Limit switches to prevent motor over-travel in either direction or final mechanical stops.
  - ix. Appropriate scheme/ device to permit only one tap change at a time on manual operation.
  - x. Emergency manual operating device (hand crank or hand wheel).
  - xi. A five digit operation counter.
  - xii. Space heaters with thermostat and MCB.
  - xiii. Control transformers with MPCB / MCBs on primary and secondary sides for each supply.
  - xiv. Interior lighting fixture with lamp, door switch / ON-OFF switch and MCB.
  - xv. Gasketed and hinged door with locking arrangement.
  - xvi. Terminal blocks, internal wiring, earthing terminals and cable glands for power and control cables.
  - xvii. Necessary relays, contactors, current transformers etc.
  - xviii. Transducers or any other appropriate device for remote tap position indication.
- g) Control Requirements for OLTC: The following electrical control features shall be provided:
- i. Positive completion of load current transfer, once a tap change has been initiated, without stopping on any intermediate position, even in case of failure of external power supply.
  - ii. Only one tap change from each taps change command even if the command is maintained.
  - iii. Cut-off of electrical control when manual operation is resorted to.
  - iv. Cut-off of a counter impulse for a reverse tap change until the mechanism comes to rest and resets the circuits for a fresh operation.
  - v. Cut-off of electrical control when it tends to operate the tap beyond its extreme position.
- h) Remote Control Equipment: The OLTC remote control equipment shall be housed in an indoor sheet steel cubicle 2.1 m high & 0.45 m deep to be located in a remote control room. It shall conform to degree of enclosure protection IP42 or better and shall comprise the following:

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- i. Control switches; Raise / Off / Lower (spring return to normal type) or independent push buttons.
  - ii. If automatic operation is specified, auto / manual selector switch (maintained contact type) and other items as listed.
  - iii. If parallel operation is specified, Master / Independent / Follower selector switch (maintained contact type) with 'out of step' annunciation.
  - iv. Tap position indicator.
  - v. Facia type alarm annunciators with "accept", "lamp test" facilities and hooter / buzzer for alarms as listed.
  - vi. Necessary auxiliary relays.
  - vii. Lamp indications for:
    - ☐ Tap change in progress
    - ☐ Lower limit reached
    - ☐ Upper limit reached
    - ☐ Transformer cooler control apparatus (if applicable)
  - viii. Cable glands for power and control cables.
  - ix. 240V rated panel space heater with thermostat.
  - x. CFL type interior lighting fixture with lamp and door switch.
  - xi. Control MCBs and Terminal blocks.
  - xii. Internal wiring.
  - xiii. Earthing terminal.
  - xiv. Hook up for the remote operation of tap lower and raise operation and contact / signal for tap position indication to Purchaser's DCS shall be incorporated in the panel.
- i) Automatic Control of OLTC: Automatic voltage regulator (AVR) for auto control of OLTC shall include:
- i. Voltage setting device, Voltage sensing and voltage regulating devices
  - ii. Line drop compensator with adjustable R and X elements.
  - iii. Timer 5-25 seconds for delaying the operation of the tap changer in the first step for every tap change operation.
  - iv. Adjustable dead band for voltage variation.

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- v. Additional features as required when parallel operation with other transformers is specified.
- j) Alarms: The following alarms shall be provided:
- i. A.C. supply failure
  - ii. Drive motor auto tripped
  - iii. Other protective purpose considered essential by the Contractor.
  - iv. Out of step operation when paralleled transformers supposed to operate on the same tap are operating at different taps.
  - v. Tap change delayed
  - vi. AVR failure (if AVR is specified)
  - vii. For the all specified above an "OLTC trouble" group alarm to be provided in DCS which is located in control room.
  - viii. Others, as specified.
- k) Tests:
- i. Routine Tests: Routine tests as per IS: 8468 shall be performed on all OLTC's & Motor drive mechanisms. Over and above, Pressure and Vacuum tests shall be conducted as per IEC: 60214.
  - ii. Type Tests: Type tests as per IS: 8468 shall be carried out on OLTC & Motor drive mechanism when called for. The bidder shall indicate in his price schedule extra price, if any, for carrying out these tests. If type tests are not called for, type test reports for tests conducted (not older than five (5) years) on a similar or higher rating OLTC & Motor drive mechanism shall be submitted for Purchaser's approval.
- l) Additional Requirements, if any: Tap position indicators and OLTC control switch shall be supplied loose if Purchaser decides to mount the same in the power transformer control panel.
- m) The finish and dimensions of the panel shall be as specified so as to match with the other panels in remote control room.

#### 4.4. 415V METAL ENCLOSED SWITCH BOARDS:

- 4.4.1. Applicable Standards: The design, manufacture and performance of equipment shall conform to the latest standards specified below. In case of conflict between standards and this specification, this specification shall govern.

Metal Enclosed Switchgear for rated : IEC: 61439/ BS: 5486  
voltage above 1kV up to and including 52  
kV - General requirements

Factory Built Assemblies of SWGR and : IEC: 61439  
control gear for Voltages up to and

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including 1000V AC & 1200VAC

Air Circuit Breakers	: IS: 60947-2/ BS: 3871/ IEC: 60947-2
Air Break Switches	: IS: 60947-3/ BSEN: 60497-33/ IEC: 60947-3
Miniature Circuit Breakers	: IEC: 60898/ IEC: 60947
Low Voltage Fuses	: IEC: 60269
Contactors	: IEC: 60947
Starters	: IEC: 60947/ IEC: 60292
Control Switches & Push buttons	: IEC: 60947
Current Transformer	: IS: 2705/ BS: 7626/ IEC: 60044
Voltage Transformer	: IS: 3156/ BS: 7625/ IEC: 60044
Indicating instruments	: IS: 1248 / BS: 89 / IEC: 60051
Marking and Identification of Conductors and Apparatus Terminals	: IS: 11353 / BS: 159
A.C. Electricity Meters	: IEC 62052/ IEC: 62053
Degree of Protection	: IEC: 60947-1/ IEC: 947(PI)
Selection installation and maintenance of switchgear and control gear	: IS: 10118/ IEC: 62091
Code of practice for phosphating iron and steel	: IS: 6005 / BS: 3169
Guide for testing under conditions of arcing due to internal fault	: IEC: 61641
Specification for copper rods and bars for electrical purposes	: IS: 613
Control transformers for switchgear and control gear voltage not exceeding 1000V AC	: IS: 12021

4.4.2. Constructional Features: The switchgear shall be metal enclosed, modular type suitable for indoor/ outdoor installation, dust & burmin proof, self standing floor / plinth mounting with a height not exceeding 2300 mm and shall have following features:

- a) Switchboard shall be complying to minimum Form-3b as per IEC 61439.

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- b) Breaker up to 1250A shall be installed in two tiers and above 1250A, it shall be mounted in single tier.
  - c) Minimum clearance between live parts shall be phase to phase 25.4 mm & phase to neutral 20 mm at any location & shall be complying with the BIL for the panel.
  - d) Switchgear shall be divided into distinct vertical sections each comprising:
    - i. A completely enclosed bus bar compartment running horizontally.
    - ii. Enclosed vertical bus bars serving all modules in vertical section.
    - iii. A separate horizontal enclosure for all auxiliary power and control buses.
    - iv. Vertical cable alley of minimum 250 mm wide covering entire height
  - e) Operating devices shall be incorporated only in the front of switchgear.
  - f) Each shipping section shall have metal sheets at both ends
  - g) Cable alley shall be provided with suitable hinged doors
  - h) All doors shall be with concealed type hinges and captive screws
  - i) Each vertical section shall be equipped with a space heater controlled by thermostat
  - j) Each switchgear cubicle shall be provided with interior lighting with 9/ 11W CFL/ LED luminaries inclusive of lamp with door limit - on/ off switch.
  - k) A power socket (240 V AC, 6/ 16 A) shall be provided in the interior of each cubicle with On-Off switch.
  - l) All identical equipment and corresponding parts be fully interchangeable without any modifications
  - m) Main and Auxiliary Buses:
    - i. Switchgear bus bars shall be of uniform cross section throughout the length and made of Electric grade Aluminium ( 91 E- 63401)
    - ii. All bus bars shall be covered with heat shrinkable black PVC sleeves. Coloured polyester tapes for phase identification shall be provided at suitable locations.
    - iii. Bus bar shall be adequately supported to withstand stresses developed due to short circuits.
    - iv. Bus bar joints shall be provided with contact grease at the joints and shall be complete with tensile steel bolts, washers and nuts
    - v. The exposed bus live parts in the cable alley shall be totally covered against accidental contact by a shroud (and not by sleeve) to protect the workmen working on the switchgear.
    - vi. Vertical bus bars shall have Short Circuit rating same as main bus bar and shall be suitable for all connected load of vertical section.

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- vii. Neutral bus bar size shall be 50% of phase bus bar.
  - viii. Termination on bus bars at ACB, MCCBs shall be as per IEC: 60947-2. For terminations on MCCBs, where phase- phase and phase to earth clearance are not possible, Cu spreaders of suitable size shall be used along with the use of separators.
  - ix. Bus bar supports shall only be SMC irrespective of bus bar size. The span between the two insulators shall be adequate. Joint positions and insulators shall be properly adjusted so that they don't interfere.
  - x. For the Main PMCC, Contractor shall ensure that incoming feeders from transformer shall be suitably designed for terminating bus duct. Contractor shall consider the necessary arrangement (dummy panel, adapter panel, rear extension etc.) if required, for terminating the bus-duct. Phase transposition, if required, will be done in the Main PMCC.
  - xi. Wherever Cu bus bars are provided, it shall be tinned copper & not bare Cu.
- n) All mounting accessories like base channels, cross angles if required, nuts, bolts etc. shall be supplied by the Contractor.
  - o) All the indoor switchgear panels shall be suitable for IP-54 degree of ingress protection for the enclosure. Outdoor panels shall be with minimum IP-55, degree of protection
  - p) All panels shall be made up of CRCA sheet steel of following thickness -
    - i. Load bearing members - 2.5 mm
    - ii. Doors and partitions - Doors - 2.0 mm, Partition - 1.6 mm.
    - iii. Mounting plate - 2.0 mm.
    - iv. Gland plate - 3.0 mm for both incomer and outgoing. For single core cable these plates shall be non magnetic.
  - q) All the panel wiring shall be done with PVC FRLS, multi-stranded copper wires
  - r) Feeder shall have hinged open-able (more than 105°) type door with panel locks. All bus-bar covers and other panel covers shall be screw fixed.
  - s) Suitable barriers of FRP material shall be provided between two terminals connected to different voltage supplies.
  - t) All doors and detachable components shall be earthed with flexible green coloured (with Yellow coloured band) PVC sheathed 2.5/ 4.0 sq.mm multi-stranded Copper cable.
  - u) The equipment shall be given tropical and fungicidal treatment.
  - v) Each compartment & component shall be provided with name plates (with white letters on Black background) at front, inside & rear side.
  - w) Equipment nameplates shall be fixed by screws / rivets and shall not be pasted.
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- x) Metallic Shrouding shall be provided for the isolation of main and vertical bus; as well as to avoid accidental contacts with live parts.
  - y) Drawing pocket shall be provided on the inside of incomer feeder door.
  - z) Provision for Top / Bottom cable entry shall be made to suit the site condition.
  - aa) Lifting hooks / eyes shall be provided in each shipping section of the equipment and shall be removable type.
  - bb) All the panels shall be provided with 20% extra power & control terminals.
  - cc) All unused contacts of the circuit breaker, protection, auxiliary, control relays shall be wired up to the terminal block.
  - dd) All terminals of different control voltages shall be separate from each other.
  - ee) Stud type terminals and ring type lugs shall be used for control cables.
  - ff) All the control / power wiring shall be dressed neatly & the wire running through troughs shall be provided with covers
  - gg) Switchgear shall be easily extensible on both sides by the addition of vertical sections after removing the end covers. It shall be provided with a metal sill frame made of structural steel channel section properly drilled for mounting the switchgear along with necessary mounting hardware. Hardware shall be zinc plated or passivated. It shall be provided with labels on the front and rear indicating the switchgear designation.
  - hh) Any operating handle of switchgear shall not be more than 1800 mm and not lower than 300 mm from base of the panel.
  - ii) For individual feeder modules arranged in multi tier formation, it is essential that the modules are integral multiples of the unit size to provide for flexibility in changes if any at site. For safety isolation of the vertical bus bars, insulating barrier with cut outs shall be provided to allow the power slab contacts to engage with vertical Bus bars. A vertical cable alley shall be sufficiently wide for motor control modules and for circuit breaker control modules.
  - jj) A horizontal separate enclosure for all auxiliary power and control buses, as required shall be located so as to enable easy identification, maintenance and segregation from the main power buses. Tap off connections from these buses shall be arranged separately for each vertical section.
  - kk) All equipment associated with a single circuit shall be housed in a separate module compartment of the vertical section.
  - ll) For draw out type modules, only the handles of control and selector switches, push buttons, knobs & cut outs for lamps and meters shall be arranged on the front doors of the respective compartments to permit operation without opening the door.
  - mm) On circuit breaker controlled circuits, protective relays shall be mounted on the front door of the compartment. All other equipment pertaining to a circuit shall be mounted on the withdrawal chassis. All cut outs shall be provided with gaskets for the purpose of dust proofing.



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- nn) Current transformers shall not be directly mounted on the buses. Current transformer on circuit breaker controlled circuits shall be mounted on the fixed portion of the compartment.
  - oo) In breaker compartments, external cable connections shall be carried out in separate cable compartments for power and control cables.
  - pp) After isolation of the power and control connections of a circuit, it shall be possible to safely carry out maintenance in a compartment with the Bus bars and adjacent circuit live.
  - qq) The withdrawals chassis shall move on suitable guides and on suitably plated steel or stainless steel rollers or balls to facilitate easy withdrawal.
  - rr) Cable alleys shall be provided with suitable hinged doors. It shall be possible to safely carryout maintenance work on cable connections to any one circuit with the Bus bars and adjustment circuits live. Adequate number of slotted cable support arms shall be provided for cleating the cables.
  - ss) Rear of single front switchgear shall be provided with removable panels. It shall be possible for one person to remove and fix the removable panel.
  - tt) All doors shall be provided with concealed type hinges and captive screws.
  - uu) The draw out contacts shall be only between copper / copper alloy / aluminum fuses, which are silver or tinplated. The contact design shall be such that there should be no arcing / deformation under the associated peak short circuit current.
  - vv) Switchgear shall be designed in such a way that all components equipment and Bus bars operate satisfactorily without exceeding their respective maximum permissible rise in temperature under ambient temperature conditions prevailing within the switchgear cubical, with reference to ambient temperature outside the switchgear cubical.
  - ww) Provision of ventilating louvers shall be provided with fine-screened brass or GI meshes to prevent entry of vermin and dust.
  - xx) The various types of modules indicating the control requirements of each type together with the list of component equipment required for each type shall be as follows: -
    - i. Incoming circuit - Draw Out type air circuit breaker for above 630A / Fixed type MCCB for 630A & below
    - ii. Outgoing feeder – ACB / MCCB / MPCB
    - iii. Auxiliary services - Starters, capacitors, Distribution Boards and other auxiliary load
  - yy) Physical size of compartment for each type of control and current rating shall be so chosen that all the basic and additional equipment can be housed in the compartment. No equipment associated with any particular circuit shall be permitted to be mounted in any other circuit module.

4.4.3. Power Distribution Board (PDB) configuration shall be two no. \*A TPN MCCB I/Cs and six

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no. \*A TPN MCCB O/G feeders. The O/G feeders shall be supplying to Sub DBs. The configuration of Sub Distribution Board (SDB) shall be \*A FP MCCB I/C and 2 nos. 63A TPN MCB & 12 nos. 20A SP MCBs as outgoing feeders. (\*A) shall be decided during detailed engineering.

4.4.4. Separate instrument's compartment for indicators of flow meter (s), energy meter, level & pressure controller (if any) shall be provided as per actual requirement of suitable size.

4.4.5. Control Voltages: Following control voltages shall be used in LV panels

- a) All ACBs tripping/ Closing shall be suitable for 110/ 240V AC or 24/ 110VDC as applicable. The trip coil and closing coils of ACBs shall operate satisfactorily under the following conditions of supply voltage:
  - i. Closing coils- 85 % to 110 % of rated voltage
  - ii. Trip coils- 70 % to 110 % of rated voltage.
- b) Indications/ Annunciator for LV Main PCC / MCC- 110/ 240V AC or 24 / 110V DC
- c) Indications for auxiliary DBs - 240V AC
- d) Space heater, 6/ 16A socket, panel illumination lamp etc- 240V AC derived from AC bus
- e) 240V AC, 110V AC and other voltages shall be segregated to avoid mix-up of voltages.
- f) Control transformers (copper wound, dry type), suitably rated of voltage ratio 415/ 230/ 110 V, on the Incomer/ Bus shall be provided. For the control transformers, fuses shall be provided on the 415V side and MCBs on the 230/ 110V side. The control transformer shall have  $\pm 5\%$  taps on its primary side.

4.4.6. Painting:

- a) First primer should be EC dip coat (RAL 7032/7035), which is free from any heavy metals, chromates and silicon thereby ensuring the RoHS compliance and Over the Primer, the final powder coating of RAL 7032/7035 paint shall be applied and the overall paint thickness should not be above 80-130 microns. The sample sheet for the finishing paint shall be approved by Client/Consultant.
- b) The final finished thickness of paint film on sheet steel enclosure shall not be less than 80 microns. Finished painted appearance of equipment shall present an aesthetically pleasing appearance, free from dents and uneven surfaces.
- c) The Panels should have compliance certificate for RoHS standards.

4.4.7. Interchangeability:

All identical equipment and corresponding parts including chassis of draw out modules of the same size shall be fully interchangeable without having to carryout modifications. For trouble free interchangeability, the draw out arrangements shall be designed such that normal dimensional variations are taken care of by self-aligning feature of the modules.

#### 4.4.8. Drawings & Documents:

Prior to fabrication of the switchgear, the Contractor shall submit following for Purchaser Representative's approval - the dimensional drawing and design calculations indicating bus bar size, short circuit rating of all the electrical component used, internal wiring, components mounting details etc. The Contractor shall submit manufacturers catalogues of the electrical components installed in the switchgear.

#### 4.4.9. Inspection:

At all reasonable times during production and prior to dispatch of the switchgear to site, the Contractor shall arrange and provide all the facilities at their plant for inspection & testing of switchgear.

#### 4.4.10. Earthing:

- a) All GI earth bus bars of adequate size shall be provided for the entire length of the panel. The framework of the enclosure shall be connected to this earth bus. Provisions shall be made for connection from this earth bus to the main earthing bus bar coming from the earth pit on both side of the switchgear.
- b) The earth continuity conductor of each incoming and outgoing feeder shall be connected to this earth bus bar. The armour of cables shall be properly connected with earthing clamp and the clamp shall be ultimately bonded with the earth bus bar.

#### 4.4.11. Labels & Name Plate:

- a) Engraved PVC labels shall be provided on all incoming and outgoing feeders. Single line circuit diagram showing the arrangements of circuit inside shall be pasted on inside of the panel door and covered with transparent laminated plastic sheet.
- b) A nameplate with the switchgear designation in bold letters shall be fixed at top of the central panel. A separate nameplate giving feeder details shall be provided for each feeder module door.
- c) Inside the feeder compartments the electrical components, equipments, accessories like switchgear shall be provided with stickers shall suitably identify control gear, lamps, relays etc.
- d) Engraved nameplates shall preferably be of 3-ply (Red-White-Red or Black-White-Black) lamicoid sheet however black engraved perplex sheet nameplates shall also be acceptable. Engraving shall be done with square grove cutters.
- e) Nameplate shall be fastened by counter sunk screws and not by adhesives.

#### 4.4.12. Danger Notice Plates:

- a) The danger notice plate shall be affixed in a permanent manner on operating side of the switchgear.
- b) The danger notice plate shall indicate danger notice in Gujarati, Hindi and English.

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- c) The danger notice plate, in general shall meet to requirements of local inspecting authorities.
  - d) Caution name plate, "Caution Live Terminal" shall be provided at all the points where the terminals are likely to remain live and isolation is possible only at remote end i.e. incomer to the switchboard.
  - e) The danger notice plate shall be made from minimum 1.6 mm thick steel sheet and after due pretreatment to the plate, the same shall be painted white with vitreous enamel paint on both front and rear surface of the plate.
  - f) The letters, figures, the conventional skull and bones shall be positioned on the plate as per recommendations of latest edition of IS 2551-1982.
  - g) The said letters, the figures and the sign skull and bones shall be painted in signal Red color as per latest edition of IS 5 - 1978.
  - h) The danger plate shall have rounded corners. Locations of fixing holes for the plate shall be decided to suit the design of the switchgear enclosure.

#### 4.4.13. Cable Entry:

- a) The panel shall have provisions of cable entry from top/ bottom. The removable cable gland plate shall be provided to make entry dust and vermin proof.
- b) The panel shall have provisions for fixing the multi-core cable glands.
- c) The cable glands support plates shall be 3 mm thick.
- d) Cable entries to the panel shall be from the bottom unless otherwise specified. Cable gland shall be double compression screwed type and made of brass.

#### 4.4.14. Mountings:

- a) All equipments in front of panel shall be of flush mounting type.
- b) All equipment shall be so mounted that the removal and replacement may be accomplished individually without interruption of services of others.
- c) All equipment inside the panel shall be so located that their terminals and adjustments are readily accessible for inspection or maintenance.
- d) The centerline of switches, push buttons and indicating lamps shall be matched to give a neat and uniform appearance. Likewise the top lines of all meters, relays and recorders etc. shall be matched.

- 4.4.15. It is important to note that when pumping station is idle and transformer is required to be kept energized under no load / part (miniscule) load condition, the necessary LV fixed capacitor bank (approx. 5% of transformer rating) shall be provided in PMCC (transformer LV incomer) panel and shall be manually / automatically switched on to maintain power factor more than 0.95 but less than 0.99 (near unity). All the components for fixed type Capacitor bank (to be mounted in Main LV PMCC) panel shall be as indicated in typical electrical Single Line Diagram attached with the specifications. This is a complete responsibility of the Contractor to maintain the power factor under idle condition of pumping station. Any power factor adjustment charges levied by power utility shall be recovered from
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the Contractor along with 5 % lump sum administrative charge by the Owner.

4.4.16. Air Circuit Breaker (ACB):

- a) All the incomers & bus coupler ACBs shall be 4P EDO type. All other ACBs shall be TPN EDO type.
- b) All the ACBs shall have  $I_{cs}=I_{cu}=I_{cw}=100\%$
- c) Up to and including 630 A, Fixed Type FP / TPN MCCB shall be considered, while above 630A FP / TPN, fully draw out type ACB shall be considered in line with the electrical Single Line Diagram requirements.
- d) All ACBs shall be provided with additional 6 NO + 6 NC contacts, exclusively for Purchaser's use.
- e) All the ACBs (except for APFC panel) shall be provided with microprocessor based O/L+ S/C + inbuilt E/F protections.
- f) ACBs / MCCBs for APFC panel shall be provided with thermal magnetic based O/L+ S/C + E/F protections.
- g) Each ACB shall be provided with – On, Off, Trip, Spring Charged, Trip Coil Healthy, Service & Test Position indication lamps.
- h) For incomer feeders R, Y & B Phase indication lamps shall be provided.
- i) Circuit breaker shall be horizontal withdrawal type, comprising three / four identical poles operated through a common shaft.
- j) It shall be suitable for switching duty of transformer and motors and other devices.
- k) It shall be possible to push in and withdraw the breaker easily and without much effort. Insulating plugs and sockets for power as well as for control circuits shall be of robust design and fully self-aligning. Plugs and sockets for power circuits shall be silver faced, insulated with PVC or other insulating material.
- l) The breaker shall have three distinct positions namely services, test and fully withdrawn positions. In test position, it shall be possible to operate the circuit breaker without energizing the power circuits. Separate limit switches each having a minimum of four (4) contacts shall be provided for both service and test position of the circuit breaker. These contactors shall be rated for 10 Amp, 240 volts AC.

4.4.17. Operating Mechanism:

- a) The EDO type ACB shall be power operated by a motor charged spring operated mechanism & MDO type shall be manual type spring operated mechanism.
- b) The operating mechanism shall have anti-pumping features under every method of closing. The operating mechanism shall normally be operated by Local / Remote electrical control, when the breaker is in service position. Shunt trip coils shall perform electrical tripping.
- c) The main poles of the breaker shall operate simultaneously. Also there shall not be any objectionable rebound of the moving contact in the fixed contacts.

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- d) The mechanism shall be such that any failure of auxiliary spring shall not prevent tripping. When the breaker is in closed position, failure of any auxiliary spring shall not cause damage to the CB or danger the operation.
  - e) A mechanical indicator shall be provided on the breaker operating mechanism to indicate open and closed position of the breaker. This shall be visible to a man standing in front of the cubical with the door closed.
  - f) It shall be possible to operate the breaker mechanically. This shall be possible only after opening the cubical door. Provision shall be made for local electrical control also when the breaker is in the test position by a control switch on the cubical doors.
  - g) All working parts of the mechanism shall be of corrosion resistance material. All split pins; bolts, nuts and other parts shall be properly pinned and locked to prevent loosening with repeated operation of the breakers.
  - h) Auxiliary switch containing 6 NO +6 NC potential free contacts rated for 10 Amp 240 V AC (Inductive breaking).

#### 4.4.18. Spring Charged Mechanism:

- a) Spring operated mechanism shall be complete with motor, opening spring, closing spring with limit switch for automatic charging and all necessary accessories to make the mechanism a complete operating unit.
- b) The breaker operation shall be independent of the motor, which shall be used only for tensioning / compressing of the spring.
- c) The closing operation shall automatically charge the tripping spring. The closing, opening shall get charged immediately after a closing operation is performed.
- d) Motor used shall be preferably universal type operated on AC supply. The Motor shall operate satisfactory at all values "between" 85% to 110% of rated voltage.

#### 4.4.19. Mechanical / Electrical Interlocking:

- a) Mechanical interlock arrangement shall be provided between two incomer breakers. Interlocking arrangement shall be robust, heavy-duty type and sturdy in construction.
- b) Interlocking between two-incomer breakers shall be provided in such a way that in normal condition bus coupler shall be in " OFF " position so that both the transformer can be kept charged and the total load can be divided equally between two circuits.
- c) During fault, maintenance or any other abnormal condition while one of the transformer is not in working mode, the bus coupler shall be in " ON " position so that total load can be supplied by the remaining transformer circuit.
- d) Interlock shall be Mechanical and Electrical type. In case if one of the interlock fails the other way can be used for interlocking purpose.

#### 4.4.20. Moulded Case Circuit Breakers (MCCB):

- a) The MCCBs shall conform to IEC 947 & the latest applicable standards.

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- b) All MCCBs shall be of fixed type unless otherwise specified in the specifications elsewhere.
  - c) MCCBs shall be of four pole/ triple pole with neutral construction arranged for simultaneous four/ three-pole manual closing and opening and for automatic instantaneous tripping on short circuit.
  - d) All the incomer & bus coupler MCCBs for Main LT PMCC panels shall be FP type with microprocessor based O/L +S/C + inbuilt E/F release & all outgoings MCCBs shall be TPN with thermal magnetic/ microprocessor based O/L +S/C + E/F releases.
  - e) For achieving the Earth Fault protection in thermal magnetic (TM) based MCCBs, external CBCT, Earth Fault relay & shunt trip provision shall be considered as part of complete TM based MCCB.
  - f) The ON, OFF and TRIP positions of the MCCB shall be clearly indicated by using LED indications.
  - g) MCCBs shall be with  $I_{cs} = I_{cu} = 100\%$
  - h) MCCB shall be capable of withstanding the thermal stresses caused by overloads and locked rotor currents of values associated with protective relay settings of the motor starting equipment and the mechanical stresses caused by the peak short circuit current of value associated with the switch gear rating.
  - i) All the MCCBs shall be of current limiting type and shall provide a cut off in 4-8 milli seconds for prospective currents during faults.
  - j) All the MCCBs shall be provided with rotary operating handle with door interlock.
  - k) MCCB terminals shall be shrouded and designed to receive cable lugs for cable sizes relevant to circuit ratings.
  - l) All MCCBs shall be provided with additional 2 NO + 2 NC contacts, exclusively for Purchaser's use.
  - m) All the switchgear selection for motor feeders shall be Type-2 co-ordinated.

4.4.21. Entire LV system shall be fuse less type & fuses shall be used only for VT / Control Transformer primary side. MCBs shall be provided on secondary of VT / Control transformer

4.4.22. Miniature Circuit Breaker (MCB):

- a) MCB shall be hand operated, air break, quick make, quick break type.
- b) Operating mechanisms shall be mechanically trip-free from the operating knob to prevent the contacts being held closed under overload or short-circuit conditions.
- c) Each pole shall be fitted with a bi-metallic element for overload protection and a magnetic element for short-circuit protection. Multiple pole MCBs 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 characteristics of the connected load. Where this is not specified, it shall be Type C.

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- d) The short circuit rating shall be not less than that of the system to which they are connected.

4.4.23. Direct-On-Line Starters: Direct on line motor starter shall have following components / features:

- a) Direct-on-line starters shall be suitable for Class AC-3 utilization category as per IS: 13947 (Part 4), unless otherwise mentioned in tender.
- b) DOL starter shall have MCCB / MPCB, Overload Relay with SPP, Contactor etc.
- c) Type 2 Co-ordination shall be ensured.

4.4.24. Automatic Star-Delta Starters: Automatic star-delta motor starters shall have following components/ features:

- a) Three sets of contactors one for the line, one for the star point and one for the delta, and a timer to automatically change the connections from star to delta.
- b) Star Delta Starters shall consist of MCCB/ MPCB, Overload Relay with SPP, Contactors, electronic timer etc.
- c) Star-delta contactors shall be electrically interlocked to permit starting of the motor in the proper sequence, namely star contactor closing, line contactor closing, timer energized after time delay, timer contact de-energizing the star contactor, and delta contactor closing.
- d) Star-delta starters shall be suitable for AC-3 utilization category as per IS: 13947 (Part 4), unless otherwise mentioned in tender.
- e) Type 2 Co-ordination shall be ensured.

4.4.25. Reversing Starters: Motor Reversing starter shall have following components/ features:

- a) Forward and reverse contactors, electrically interlocked with each other.
- b) Reversing starters shall be suitable for Class AC-4 duty as specified in applicable standards, unless otherwise mentioned in tender.

4.4.26. Auto Transformer Starter (ATS): Auto Transformer starter shall have following components/ features:

- a) Auto transformer shall be air cooled type having three (3) tapplings of 50%, 65% and 80%. The same should be wound with Copper wire. The size of the wire should be determined to suit the associated motor rating. The tapping requirement indicated is minimum required & Contractor to ensure proper tapping selection based on motor starting requirement.
- b) Stamping of reputed make and winding wire with 'B' class insulation should be used. This should also be suitable for minimum 6 starts per hour. Core shall be of CRGO material.
- c) Maximum temperature rise should not be more than 115°C. Kordnoffer circuit (Closed Transition type) should be adopted in ATS panel. There shall be an acrylic/ Hylam



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sheet over & below the transformer. Also to absorb humming rubber sheet shall be provided below auto transformer.

- d) Auto transformer shall be vacuum impregnated.
- e) Testing of transformers should withstand full load starting current for six starts per hour, each kick of 15 seconds duration as per relevant IS.
- f) ATS shall be provided with thermal overload protector in each coil of transformer from overheating. Thermal overload protector rating shall be 900°C with 10% tolerance.
- g) ATS shall consist of MCCB/ MPCB, Overload Relay, and Contactors etc.

4.4.27. Soft Starters: Fully automatic microprocessor based soft starters with built-in bypass terminals for pump control application shall be considered for the motors of 75 kW & above. The features/ requirements of the starters shall be as per following but not limited to:

- a) The soft starter shall be designed, built and tested according to the latest editions of applicable IEC standards/ IEC 947-4-UL, CE.
- b) Input Voltage – 3Ph, 415V,  $\pm 10\%$
- c) Input Frequency – 50 Hz,  $\pm 5\%$
- d) Control Voltage – 100 - 240 V AC
- e) Ambient Conditions:
  - i. Temperature- 50°C. (Operating range -5 to 70°C)
  - ii. Relative Humidity of 5 to 95%
- f) Control Method - Torque Control/ Reduced Voltage/ Ramp
- g) Motor Protection - Thermal overload protection
- h) Starter Protection - S/C, Phase imbalance, Phase failure, Phase reversal, O/ V, U/ V, Locked rotor, excessive starts per hour for application, Phase loss input/ output, Motor output loss.
- i) EMC standard – IEC 61000-4-2 level-3, IEC 61000-4-3 level-3
- j) Built-in communication port for RS 485.
- k) Type 2 Co-ordination shall be ensured.
- l) The soft starter shall be complete with the following acceleration and deceleration settings & display requirements as a minimum-
  - i. Starting Torque: Initial torque shall be adjustable from 0-100% of maximum locked rotor torque.
  - ii. Ramp Time: The time between starting torque and maximum torque shall be adjustable between 1 to 60 seconds. The time between maximum torque & stop shall be adjustable between 2 to 120 seconds

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- iii. The current limit feature shall have the following characteristics:
    - ☐ The maximum allowed current during start shall be adjustable from 150% to 500% of soft-starter maximum current rating.
    - ☐ Starting torque shall be fixed at 40% when utilizing the current limit function.
  - iv. Voltage Ramp start & Full voltage DOL start shall be possible.
  - v. For stop function – Linear torque control, Quadratic Torque Control, Voltage ramp control, soft break etc. functions shall be provided.
  - vi. The soft-starter shall be provided with a functional ground to remove and / or minimize electrical noise injected on the soft starter control board.
  - vii. Normally open output relays shall be provided for faults and status indications.
  - viii. Normally closed contacts for fault relays shall be provided as an option.
  - ix. The soft-starter shall be provided with a 2-position dip switch to select between the normal in-line connection (3-lead motor) and inside the delta (6-lead or 12-lead delta wound motors).
  - x. The soft-starter shall be controlled completely through solid state design algorithms. No moving electromechanical contacts shall be allowed.
  - xi. All adjustments shall be made from the front of the soft starter through keyboard (soft keys)
  - xii. The Soft starter shall have in-built/ remote display with following display parameters.
    - ☐ Three Phase Currents
    - ☐ Three Phase Voltages
    - ☐ Shaft Power in kW / HP (selectable)
    - ☐ Motor thermal capacity
    - ☐ Motor Energy consumption (kWh)
    - ☐ Power factor
    - ☐ Run time in hours
  - xiii. The Soft starter shall have following fault indications
    - ☐ Line failure, Phase imbalance, Over temperature – Motor
    - ☐ Over temperature – Soft Starter, Shorted Thyristor, Open Thyristor
    - ☐ Locked Rotor, Motor output loss, Overload - Shaft Torque

- ☐ Under load - Shaft Torque, Over voltage, Under voltage
- ☐ Excessive Starts, Phase reversal
- xiv. Shaft Power measurement without the use of external electro mechanical sensors.
- xv. Shaft overload and under load protection shall be available through the controller, even in a by-pass configuration.
- xvi. When fault conditions are detected, the controller shall inhibit starting or shut down SCR pulse firing.
- xvii. The standard feature pump control shall be implemented to provide closed loop control of a motor to match the specific torque requirements of centrifugal pumps for both starting and stopping. This shall aid in eliminating the phenomenon commonly referred to as "water hammer".
- xviii. The soft-starter shall be designed for three-phase control with two anti parallel SCRs in each phase. SCR-Diode combination shall not be acceptable.
  - ☐ The PCB shall provide digital microprocessor control and supervision of all controller operation, including SCR pulse firing control.
  - ☐ The PCB power supply shall be self-tuning to accept control power input from 100 to 240 or 380 to 500 V AC, 50 / 60 Hz.
  - ☐ The SCR firing circuitry shall incorporate an RC snubber network to prevent false SCR firing.
  - ☐ When fault conditions are detected, the controller shall inhibit starting or shut down SCR pulse firing.
- xix. SCRs shall have the following minimum repetitive peak inverse voltage ratings:
  - ☐ 200 to 525V: 1600 V
  - ☐ 200 to 690V: 1800V

#### 4.4.28. Variable Speed AC/DC Drives

##### a) Scope

- i. This specification covers the technical requirements/features for the design, manufacture, testing and supply of semiconductor (Thyristors, Transistors, Diodes, ) controlled variable speed DC/AC drives in industry for different application such as rolling mills, coilers, pumps, fans, cranes, conveyors, crushers, blowers, compressors, etc.

##### b) Codes and Standards

- i. The design, material, construction, manufacture, inspection, testing and performance of AC/DC Drives shall comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will

be installed. Nothing in this specification shall be construed to relieve the VENDOR of this responsibility.

- ii. Unless otherwise specified, the equipment / system shall conform to the latest applicable standards as mentioned in enclosed Data Sheet.

c) Design Basis and Power Semiconductors

- i. Power semiconductors of reputed make either in stud mounting form or disc/flat pack type can be offered based on the duty requirements specified in Data Sheet A1 and to meet the technical and functional requirements.
- ii. The peak reverse voltage rating of each power semiconductor shall be as follows:

Power Semiconductors Protected by RC Snubber

The following factors of safety shall be observed:

- (a) For converters operating in : 2.0 times peak of  
the No rectifying mode only load source voltage.
- (b) For converters operating : 2.5 times peak of  
the no both in rectifying and load source voltage  
inverting modes

Power Semiconductors Protected by Avalanche Diodes

- i. The BIDDER shall choose and recommend the factor of safety which however, shall not be less than 1.5.
- ii. The current rating of the power semiconductor shall be estimated for the specified duty class in Data Sheet A. In sizing the power semiconductor both the forward voltage drop and the forward resistance shall be considered.
- iii. A derating of approximately 20% shall be made to take into account series operation of devices.
- iv. The class of overload shall be one of the following:

Duty Class	Rated current values for converter (in percent of rated direct current)
I	100 %/ Continuous
II	100 % Continuous 150 % overload for 1 minute once in period of 24 hours
III	100% continuous 150 % overload for 2 minute once in period of 24 hours

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200 % overload for 10 seconds once in period of 24 hours

However, for mill duty drive the overload percentage shall be as per following:

115% /150% Continuous based on type of application in mill.

200% for 6 seconds in every 60 seconds based on type of application in mill

250/300% for 3 seconds in every 60 seconds based on type of application in mill (mainly applicable for shear motor/tail break pinch rolls)

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The above overload percentage criteria may vary based on process requirement.

For the cases where the power semiconductor chosen is of inadequate current or voltage capacity the BIDDER shall conform to the following guidelines:

Inadequate Current Capacity

- i. If the power semiconductor is of stud mounting type, then current sharing reactors shall be provided to prevent current missharing between the power semiconductors connected in parallel.
- ii. If the power semiconductors in parallel are of capsule type, then, one of the following options may be exercised:
  - Power semiconductors with adequate derating and the layout configured so that current mis sharing between various power semiconductors in parallel is minimised.
  - Selection of power semiconductors so that their forward voltages are within a tolerance band of 100 mV to 250 mV.

Inadequate Voltage Capacity

- i. In this case the power semiconductors shall be connected in series with adequate protection to prevent irregular voltage grading across each power semiconductor during turn-on.
- ii. The converter shall be provided with adequate surge suppression circuitry at the AC input, DC output and across the devices to limit the main voltage surges, transformer switching surges, reverse recovery transients to less than twice the peak value of line working voltage.

d) Quadrants of Operation

i. The drive should be according to the no. of Quadrants specified in Data Sheet. The Quadrant Operation of the Drive will be according to the following criteria.

- (a) One Quadrant Operation - (I): First Quadrant of operation means only Motoring is required & the drive should operate in the 1st Quadrant. The motor is rotating clockwise as the torque in the same direction as the speed. The drive is accelerating.
- (b) Two Quadrant Operation - (II):- Second Quadrant Operation means the drive should be able to control the motoring & Braking of the motor. The motor still rotating clockwise but the torque in opposite direction so the drive is decelerating.

It can be of two types.

- Voltage Positive & Current can change Polarity i.e. operating in first & second quadrant.
- Current Positive & Voltage can change Polarity i.e. operating in first & fourth quadrant.

- (c) Third & Four Quad Operation - (III & IV) :- The drive should be able to operate in third & four Quadrant i.e. the motor requires forward motoring, forward braking, Reverse motoring & Reverse braking depending upon the torque direction.

e) Control for DC Motors

ii. Armature Voltage Control Converter

- (a) This converter shall consist of, unless otherwise stated in Data Sheet-A, a three phase full wave bridge circuit.
- (b) Each arm of the bridge can have a number of power semiconductors both in series and/or in parallel. The design basis for such cases shall be in conformity with this specification.
- (c) If the drive operates in the first quadrant only, a free wheeling diode may be provided for the purpose of allowing decay of energy during the condition of braking of the drive. This diode may be housed within the same cubicle as the bridge converter.
- (d) Redundancy shall be provided as follows:
  - ☐ For power semiconductors in parallel one additional parallel three phase full wave bridge arm shall be provided as redundant element.
  - ☐ For power semiconductors in series, at least 2% of the total thyristors in series for each parallel arm shall be provided.
- The factors of safety to be observed in such designs shall be in conformity to of this specification.

iii. Field Excitation Control Converter

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- ☐ Unless otherwise stated in Data Sheet, this converter shall be powered from a single phase line-to-line source tapped at the three-phase incomer to the armature voltage control converter with adequate isolation.
  - ☐ Unless otherwise stated in Data Sheet, this converter shall be a bridge of diodes of adequate capacity.

#### iv. Transducers

##### Armature Circuit

- ☐ For drives where accuracy of speed control is better than 0.5%, the actual speed of the drive shall be measured by a digital type pulse encoder of suitable rating..
- ☐ For drives where accuracy of speed control required can exceed 2% or more, measuring the current by a current transformer on the AC side of the converter can be accepted.
- ☐ For drives whose accuracy of speed should not exceed 2% it is necessary that a suitable DC shunt of 75 mV and adequate current capacity shall be provided.

##### Field Circuit

- ☐ For Drives where there is a possibility of field circuit failing, then in such cases transducers should be provided.

#### f) Technical Requirements of AC Drives for Squirrel Cage Induction Motors

- i. The voltage source DC link frequency converters shall be provided for applications where speed of AC motors is required to be adjusted sleeplessly from approximately zero to maximum speed.
- ii. The unit shall be pulse width modulation (PWM) type with either open loop frequency control to keep the ratio of voltage and frequency (v/f) constant throughout speed range to maintain constant motor torque or vector control for closed loop speed control with or without pulse encoder feedback where high speed accuracies and good dynamic performance of the motor desired.
- iii. The unit shall comprise incoming load-break isolator, line semiconductor fuses, moulded case circuit breaker (MCCB), main contactor as required, reactor, three phase rectifier as the line converter and three phase inverter as load converter interconnected through DC link reactor and capacitor unit.
- iv. The PWM inverter shall have fully digital microprocessor based regulation and control system with suitable interfaces for communication with plant automation system. The microprocessor based control shall carry out all the functions required from the unit including triggering, protections, self diagnostics and operator interface. Display of faults, alarms as well as diagnostic messages will be available in plain text on the operator panel mounted in the drive cubicle. All metering feature viz voltage, current, frequency for incoming and outgoing side shall be included in the panel.

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- v. Wherever system called for electrical braking viz dynamic braking resistor unit shall be provided.
  - vi. By-pass arrangement of VVFD shall be considered as per requirement.
  - vii. AC Drives should be considered with built in DC choke for longer life of DC link capacitors, minimize voltage drop at motor terminal & harmonic reduction at the drive input.
  - viii. Regenerative AC drives shall be provided as per process application requirement.
  - ix. Drive shall be capable to start running load without fail (flying restart facility). The drive shall have capability to decelerate the load as per process requirement without over voltage tripping.
  - x. Inverter shall be fully microprocessor based, in design having 3 phase controlled rectification and IGBT based inverter with pulse width modulation (PWM) power section, suitable for constant torque application. It shall be complete with programming unit.
  - xi. Communication - Drive shall have following minimum features:
    - RS 232 / RS 485 Modbus / Ethernet / Profibus / Device net / Control net / Profinet
  - xii. Control supply and power components shall be so arranged that they do not cause any heating to the controller and allied section of the inverter.
  - xiii. Acceleration and de-acceleration time with adjustable setting shall be provided which will be independently programmable.
  - xiv. Adjustable current limit setting shall be provided.
  - xv. In case of power failure, drive shall be able to store and memorize set parameters and software blocks.
  - xvi. All the MCCB inside the drive unit should be with positive isolation feature.
  - xvii. All live terminals shall be properly protected from unintentional human contact.
  - xviii. Shielded/ Armoured power & control cables from drives to motor terminals shall be provided by the purchaser until and unless special cables are recommended by the drive manufacturer. Also, drive manufacturer shall indicate the maximum distance limitations from drives to motors to avoid output choke.
  - xix. 24 pulse, 18 pulse, 12 pulse or 6 pulse rectifier & inverter units shall be considered as required based on process requirement.
  - xx. Duty of AC drives (heavy duty or light duty) shall be provided based on process requirement as per applicable IEC standards.
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xxi. Drive window tool with all necessary hardware & software shall be provided for parameterization, diagnosis, monitoring & programming by laptop/desktop from different location without disturbing the drives panel.

xxii. Drives shall be selected based on rating & application of motors, duty class, current, torque values, GD<sup>2</sup> value, speed range, etc. Drives shall be suitably de-rated for ambient temperature & altitude.

g) Frequency Converters for Squirrel Cage Induction Motors

i. Configuration

Frequency converters shall have one of the two configurations given below:

(a) Current source inverter

(b) Voltage source inverter

ii. DC Link

Current Source Inverter

- ☐ The smoothing reactor shall be sized to avoid conditions of discontinuous current operation of the frequency converter at its lowest frequency of operation, which shall not be less than 5 Hz.
- ☐ The smoothing reactor shall be uniformly insulated and shall be protected for voltage surges occurring during sudden load throw-off.
- ☐ The smoothing reactor shall be made from electrolytic grade copper/ aluminium and shall be epoxy encapsulated with suitable class of resin decided from techno-economic considerations and performance requirements in conformity with relevant IEC standards.

iii. Voltage Source Inverter

- ☐ The smoothing reactor shall conform to requirements specified in this tender.
- ☐ The DC capacitor shall be shunt connected at the input to the inverter.
- ☐ It shall be sized so that the reactive power requirements of the motor during its total range of operation are met. Further, the following aspects shall be observed:
  - ☐ As per standards, the nominal value of capacitance referred to the temperature of 250C shall be within tolerance range of 10%. At the design ambient temperature, the value of capacitance and the tolerance range shall be such as to meet the normal operation/performance requirements of the frequency converter.
  - ☐ As per standards, the dissipation factor of each unit of the capacitor shall be less than 1% at 250C. However, the design ambient shall be

such as to meet the normal operational/performance requirements of the frequency converter. (iii) The impregnant used for the capacitor shall be non-inflammable, non PCB dielectric liquid.

- ☐ The voltage rating of each capacitor shall be selected based on considerations of life expectancy, overvoltage during regeneration of energy, design ambient temperature, ripple voltage etc.

#### iv. Inverter

- ☐ The inverter system suitable for three phase output shall consist of the following subsystems:
- ☐ The basic inverter circuit consisting of the switching device IGBT connected so as to supply three phase power.
- ☐ The logic network to enable rapid transition of the main inverter switching devices from on-state to off-state.
- ☐ Suitable feedback system to allow balance of reactive power flow during load power factor fluctuation as well as regeneration.
- ☐ The filter system of the inverter output to suppress 5th, 7th, 11th, 13th harmonics at the output of the inverter to less than 5% of the fundamental amplitude for voltage THD. However, individual frequency voltage distortion shall not exceed 3% as per IEEE standard.
- ☐ The ripple control system to limit current ripple to 4% at the input terminals of the inverter caused by distorted current output.
- ☐ The output frequency of inverter shall be controlled to within the limits specified in Data Sheet.

#### v. Inverter for AC drive

##### Current Source Inverter

##### (a) Constant Torque Operation

- ☐ The current output by the DC link shall be accurately monitored so that the ratio of the terminal voltage of the motor and the corresponding frequency remains constant and the duty cycle requirements indicated in Data Sheet A are met. Necessary protective features for tripping the frequency converter, alarm/annunciation and fault diagnostics shall be provided.

##### (b) Constant Horsepower Operation

- ☐ In this type of operation, the motor's internal voltage shall be maintained within  $\pm 1\%$  while the frequency of the inverter is varied to meet the duty cycle requirements indicated in Data Sheet A. Necessary protective features for tripping the frequency converter, alarm/annunciation and fault diagnostics shall be provided.

##### Voltage source Inverter

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(a)Constant Torque Operation

- ☐ The DC voltage input to the inverter shall be accurately monitored to maintain the ratio the terminal voltage of the motor to frequency at the rated/design value so that the duty cycle requirements indicated in Data Sheet A are met. The DC voltage input shall be maintained within  $\pm 1\%$  of the required value. Should this fall for any reason, necessary action for tripping the frequency converter, and initiation of annunciation/alarm and fault diagnostic shall be provided.

(b)Constant Horsepower Operation

- ☐ In this type of operation, the voltage at the terminals of the motor shall be maintained within  $+1\%$  of the rated value while the frequency of the inverter is varied to meet the duty cycle requirements indicated in Data Sheet A. Necessary protective features for tripping the frequency converter, initiation of alarm/annunciation and fault diagnostic shall be provided.

Output overcurrent limit

- ☐ Unless otherwise stated, the inverter shall be capable of being temporarily overloaded to 150% of its full load ampere capacity for sixty (60) seconds beyond which a current limit action shall be initiated and an alarm contact initiated for annunciation.
- ☐ AC drives should meet the relevant IEC standard for EMC & operate reliably at their full rated capacity.
- ☐ Additional output filters as required shall be provided based on cable distance between drive panels to motor terminal. Manufacturer shall also recommend the type of cables from VVFD to motor

h) Control requirements

- i. Short time voltage dips upto 80% of nominal (e.g. in case of large motor start- up connected to same bus) shall not cause the control system to stop functioning and shall not trip the drive system.
- ii. The drive motor shall be speed regulated corresponding to 4-20mA or 0-10V reference input signal. Upon complete loss of users speed reference signal, the drive shall automatically run at constant speed as determined by the last speed reference available prior to loss of the signal.
- iii. The required provision for interfacing with PLC/DCS, including details of communication module and data transfer facility, I/O details shall be furnished by the Bidder.
- iv. The required provision of RTD and BTD inputs for motor winding and bearing temperature shall be furnished by bidder.
- v. The required provision of interface module for pulse encoder shall

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be furnished by bidder.

- vi. Local/Remote selection provision should be available in offered drive panel.
- vii. The required inputs to interface thermistors of motor shall be considered.
- i) Drives with wobulation control
  - i. Drives used in application like synthetic fibre projects should have the main feature of Wobulation control as specified in the data sheet.
  - ii. The Wobulation control should consist of a generation of a modulated frequency, in converters feeding traversing drives. The drive should produce a triangular voltage of variable frequency and amplitude, which is
- j) Protection
  - i. Protection of power semiconductor
    - ☐ Each power semiconductor shall be protected against short circuit. The fuse shall be sized so that its I<sup>2</sup>t does not exceed the I<sup>2</sup>t characteristic of the power semiconductor itself. The voltage and current rating of the fuse shall match the duty on the power semiconductor. The arc voltage, due to melting of the fuse shall not exceed the repetitive peak reverse voltage of the power semiconductor.
    - ☐ All fuses shall have a trip indicator to operate a suitable micro switch with at least 1 NO + 1 NC potential free contacts for annunciation and/or tripping.
    - ☐ A fast tripping feeder circuit breaker shall be used in case fuses for short circuit protection of thyristors are not used.
  - ii. Protection of converter system for dc drive

#### Armature Circuit

The basic protections to be provided are as follows:

- (a) Earth fault relay
- (b) Thermal overload relay

Other optional protections that are required shall be considered in scope of supply as listed in Data Sheet A.

#### Field Circuit

The basic protections to be provided are as follows:

- (a) Minimum excitation limit relay
- (b) Thermal overload relay
- (c) Earth Fault Relay

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Other optional protections that are required shall be considered in scope of supply as listed in Data Sheet.

iii. Protective systems for ac inverter drive

- ☐ Fuses for all power semiconductors and/or other devices like commutation chokes, capacitors etc. which are not adequately protected against flow of abnormal currents.
- ☐ Under voltage and over voltage protection on the input side. Loss of input voltage to inverter shall entail tripping of the inverter.
- ☐ Protection for all control cards, power supply stabilisers, filter circuits etc. Protection shall be provided such that failure of a part does not cause damage elsewhere in the system.
- ☐ Polarising relay to prevent reversal of polarity on the input side of the inverter.
- ☐ Protection of inverter thyristor, commutating circuits and other inverter elements during regenerative operation of the inverter and also during sudden load throw-off.
- ☐ Besides the above, the following protective systems shall be supplied if called for in Data Sheet.
  - i) Current limit fuses at the output of the inverter.
  - ii) Commutation circuit under voltage
  - iii) Inverter over frequency
  - iv) Programmable overcurrent
  - v) Phase sequence/loss of phase protection
  - vi) Earth fault protection
  - vii) DC link overvoltage protection
  - viii) Specific motor protection
  - ix) Incoming line surge protection
  - x) Ventilation Loss
  - xi) Over temperature
  - xii) Phase loss protection

All controls, indication, Metering, Annunciation on the Drive Panel, will be as specified in Data Sheet.

Common Technical feature of AC Auxiliary Drive:

(i) Control Method: DTC (direct torque control) Control, PWM technique with harmonic compensation.

(ii) Rated Output frequency: 5-300 Hz.

(iii) Inverter: The inverter of each drive shall be IGBT based.

(iv) Over Torque Capacity: As per requirement.

(v) Braking Torque: As per project requirement.

(vi) Provision of Control I/Os: Digital Inputs  
Analogue Inputs  
Digital Output (Relay) Analogue Output  
RTD/BTD inputs as required.  
(All PLC Compatible)

(vii) Line choke: To be provided

(viii) Output choke/Reactor: To be provided, If required.

(ix) Acc / Dec Time: 0-3600sec.(programmable independently).

(x) Response time of torque loop: Less than 5 msec

(xi) Provision of remote or on-board programming console / operating control.

(xii) Protections: Drive overload protection, phase loss, instantaneous over current, power loss ride through, ground fault, fin overheat, o/p short circuit protection, stall prevention, I/P & O/P open circuit protection, torque limit etc.

(xiii) Provision for EMC Filters: To be provided.  
Harmonics to be limited to as defined by relevant IEEE standard.

iv. Selection of inverters and line supply units:

The sizing of the inverters shall be considered as continuous load of 125% of the installed motor load including margin under stall condition

v. Selection of inverters and line supply units:

The sizing of the inverters shall be considered as continuous load of 125% of the installed motor load including margin under stall condition

vi. Ac inverters

Main circuit to DC converter along with Semi conductor fuses. It shall include following protection:

- 
- Overload protection
  - Stall Protection
  - Instantaneous over current protection
  - Over speed protection
  - Loss of speed feedback

#### Operating and Indicating Equipment

- Each inverter is to be provided with prevention of unexpected start up
- Each inverter shall be provided with drive monitoring display units.  
Such as status for ready, run and fault on the front door
- Each line shall have drive control panel where setting of parameter and reading can be done

#### Interlocking

Fool proof interlocking should be provided in complete system:

- (a) Potential free contacts of drive fault, ready to start, normal stop, emergency stop, Zero speed should be terminated for using in other equipment and PLC inputs.
- (b) Wires from start, normal stop, and emergency stop circuits should be terminated so that potential free contact and PLC outputs can be connected in the same.

#### PLC Interfacing:

All drives should be suitable to accept the following from PLC as a minimum requirement:

- (a) Start-command
- (b) Normal stop
- (c) Emergency stop
- (d) Master speed reference
- (e) Additional speed reference
- (f) Current limit reference
- (g) Jog speed reference.

All drives should be able to send following to PLC as a minimum requirement:

- (a) Normal stop
  - (b) Emergency stop
  - (c) Fault and event
  - (d) Zero speed
  - (e) Actual speed
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(f) Motor mounted field device feedback from drive to PLC.

k) Cooling of power converters

- i. Power semiconductors shall be mounted on heatsink which can be individual or common to a number of devices. Adequate provision for clamping and mounting the power semiconductors shall be available.
- ii. Cooling of power semiconductors can either be natural air cooled or forced air cooled. The BIDDER shall recommend the type of cooling. However, for power converters which exceed capacities of 2 kA continuous load, alternative cooling methods as oil or water cooling shall be considered. The power semiconductors shall preferably be double side cooled.
- iii. Auxiliary power supply for the forced cooling system shall be drawn from the alternatives specified in Section-B. All equipment required for safe and correct operation as drive motor, blower/pump, cooling water/oil header, water/oil distribution piping, deionizer system, flow monitors etc. as applicable shall be considered in the BIDDER's scope of supply.
- iv. The drive should have enough free space for the components to ensure sufficient cooling. Minimum clearance should be maintained for each components inside the drive panels.
- v. The air inlets and outlets must be equipped with fine wire mesh/ gratings to ensure the following:
  - Guide the air flow
  - Protect against contact
  - Prevent water splashes from entering the cabinet and prevent entry of insects
- vi. The thick filter mats are used to prevent water splashes from entering the cabinet so that higher IP as required can be achieved. Hot air exhaust fans may also be required to achieve the higher IP.

l) Switching devices

- i. Switching devices as circuit breakers, isolators, contactors; switch-fuse units/MCCB etc. shall be considered in the scope of supply as specified in Section-C of this specification and Data Sheet A-3.
  - ii. The switching devices shall be enclosed in a separate enclosure forming the set of panels for the power converters. They shall have adequate clearance both with adjacent devices and metalwork at earth potential. Connection between devices shall
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be by adequate size of electrolytic grade of copper/aluminium strips. These connections shall be adequately braced and insulated.

m) Constructional features

The controller should have modular construction to facilitate maintenance.

i. Busbars

- Power connections shall be of the bolted type and mating surfaces shall be tinned.
- The bus bars running to various converters shall be suitably designed to ensure equal sharing between the parallel strings and prevent mechanical stress on the fuse.
- All bus bars shall be adequately insulated for full circuit voltage by insulating tapes and similar insulating material.
- In case aluminium bus bars are specified, care shall be taken to ensure that bimetallic connections are provided wherever necessary.
- All cubicles shall have copper earth buses of adequate size running the entire cubicle height along the sides.

ii. Cubicle

- Cubicles housing the power semiconductors and drive level control system shall conform to IP 42 degree of protection to enclosures.
- All doors, removable covers and panels shall be gasketed all round with neoprene gaskets. Ventilating louvers shall have screens and filters. The screens shall be made of either brass or GI wire mesh.
- Design, material selection and workmanship shall be such as to result in a neat appearance inside and outside with no welds, rivets or bolt heads apparent from outside, with all exterior surfaces true and smooth.
- Panels shall be free standing, floor mounting type, dust and vermin proof and shall comprise rigid welded structural frames enclosed completely with cold rolled sheet steel of thickness no less than 2.5 mm for front and rear portions and 2.0 mm for sides, top and bottom portions. There shall be sufficient re-inforcement to provide level surfaces, resistance to vibrations and rigidity during transportation and installation.

iii. Painting

- All sheet steel work shall be phosphated in accordance with the following procedure and in accordance with relevant IS standard.

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- Oil, grease, dirt and swarf shall be thoroughly removed by emulsion cleaning.
  - Rust and scale shall be removed by pickling with dilute acid followed by washing with running water, rinsing with slightly alkaline hot water and drying.
  - After phosphating, thorough rinsing shall be carried out with clean water followed by final rinsing with dilute dichromate solution and oven drying.
  - The phosphate coating shall be followed by the application of two coats of ready mixed stoving type zinc chromate primer. The first coat may be "flash dried" while the second coat shall be stoved.
  - After application of the two coats of primer finishing synthetic enamel paint shall be applied, each coat followed by stoving. The second finishing coat shall be applied after completion of tests.
  - The final finished thickness of paint film on steel shall not be less than 100 microns and shall not be more than 150 microns.
  - Finished painted surface of panels shall present an aesthetically pleasing appearance free from dents and uneven surface.
  - A small quantity of finishing paint shall be supplied for minor touching up required at site after the installation of the panels.

iv. Bins and printed circuit cards

- Individual bins shall be mounted on a swingable frame so that the connections at the rear are also accessible.
  - Self retaining thumb head screws shall be needed for holding the bins in position.
  - Adequate number of card/bin extenders for testing of PCBs shall be provided, each with flexible cables at least two metres long. These extenders shall be of a universal type suitable for use with any card / bin as the case may be.
  - All adjustments which are to be made while changing a card shall be outside in a separate module preferably plugged into the regulator bin.
  - Locking of individual cards in a bin shall preferably be through self retaining thumb-head screws.
  - Control modules shall be in the form of plug in packages, plugged into a module bin. Each plug in unit shall consist of a strong frame on which a printed circuit board would be permanently screwed. The plug connections shall only be of the pin type.
  - The printed circuit board (P.C.B.) shall be made of glass fibre filled with epoxy laminates. The plug in unit shall be screwed to the basic
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socket in the module bin with long through bolts and knurled heads.

- The front plates of the plug in unit shall have the switches, the potentiometers, miniature monitoring meters, test points etc. Each plug in unit shall have its own identification legend.
- All plug in units shall be polarised to prevent incorrect insertions into the module bin.
- The gap between two plug in units inside a bin shall be sufficient to permit adequate ventilation.
- The copper side of the printed circuit board shall be lacquered to prevent oxidation.
- Each side of the printed circuit board shall have a shield cover to prevent inter circuit and external interference.
- The P.C.B. shall be mounted on P.C.B. guides fixed on standard racks and the shield properly grounded.
- Control circuit test points shall be easily accessible for monitoring and maintenance.

v.      Annunciation

- The annunciator shall work on DC power supply as specified in Data Sheet.
  - Each annunciator window shall have two lamps connected in parallel which operate at not more than 75% of their rated voltage.
  - Window shall be arranged in a logical group.
  - The annunciator shall have a module construction with glass epoxy plug in cards.
  - Alarm bell/siren shall be continuously rated and shall have a series resistance.
  - The annunciator shall have the following facilities.
    - (a)    First in sequence, memory reset.
    - (b)    Fleeting faults shall be memorised.
    - (c)    Test Feature.
  - There shall be a three tier system of protection and annunciation:
    - (a)    Alarm both audible and visual.
    - (b)    Warning with delayed shut down –time delay through a timer of range 0-60 sec.
    - (c)    Disturbance associated with failures of systems elsewhere.
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vi. Meters

- Individual meters shall be provided for speed reference, speed feedback, current reference, current feedback, pulse output, and regulated power supply voltages.
- All meters shall be identical and fed through individual buffer I.C. amplifiers.
- All meters shall be the circular scale type having a full scale deflection of 270 deg.
- All meters shall conform to at least accuracy class 1.0
- All meters with their individual buffer amplifier cards shall be housed in separate bin. It is recommended that the buffer amplifiers all be housed on a single/two card/s and this card/s be itself/themselves housed in the regulator bin.
- Sensitive signal leads in that case will not have to traverse from one bin to another, only noise insensitive buffer amplifier output leads will need to go to the meter bin.
- Selector switches if used with any meters shall have pistol grip handles.

vii. Wiring

- Stranded, flexible copper cable of 2.5 sq.mm shall be used for C.T. circuits and 1.5 sq.mm for other control circuits. However for PCB terminals 0.75 sq.mm may be accepted.
- Ultra flexible cables shall be used for all connections from a fixed part to a movable member. In addition, a hanging loop of sufficient length shall be provided to avoid any cable stressing.
- All terminal boards for outgoing connections shall be at a height of at least 250 mm from the cubicle floor, and preferably tilted at an angle of 45° to the horizontal for ease of connections. Similarly, connection of the incoming power cables to the bus bars shall be done at a height of at least 250 mm from the cubicle floor.
- Item designation and location marking shall be in line with IEC recommendations.
- Device labeling shall be on its fixed mounting and not on the device itself such that labeling remains even when the device is replaced. Metallic labels/paper labels or sticker shall be accepted.

n) Testing

- All routine tests shall be carried out on various devices / assemblies in line with codes & standards indicated in data sheet-A4. Type Tests shall be carried out wherever indicated in Data sheet-A1 to A3 and / or in Section 'C'
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o) Tests on power semiconductors

- All power semiconductors selected shall be subject to quality assurance tests to check on the characteristics submitted by the successful BIDDER on samples. The BIDDER and/or his sub-vendor shall allow PURCHASER'S authorised representative to witness the tests. Details of the test are to be agreed between the PURCHASER and the BIDDER. The broad outlines of the tests to be conducted are as follows:

- (a) Off state voltage and reverse voltage
- (b) Critical rate of rise of off state voltage
- (c) On state voltage
- (d) Thermal resistance
- (e) Surge on-state current
- (f) Triggering data
- (g) Recovery charge and recovery time
- (h) Critical rate of rise of on-state current
- (i) Switching losses
- (j) Environmental Tests

p) Tests on converters

- Converter with its enclosure and cooling system shall be connected to a dummy load. A variable voltage source on the source side shall be adjusted so that the specified current rating of the converter at no-delay of the firing angle (in case thyristors) shall be passed. At the end of stipulated period of test a timer shall cut-off the source. The load side and source side current shall be measured/recorded during the testing phase. The temperature of the case and the heat sink and wound components like chokes shall be suitably recorded. The temperature decay measurement/recording shall continue for the off-duty cycle at agreed intervals. During the course of test the cooling system shall be operative.
  - The following tests shall be conducted: as per relevant (IEC standard).
- (a) Checking of the setting of the protection devices and their functioning.
  - (b) Checking of the auxiliary devices and their functioning.
  - (c) Speed regulation of the drive shall be observed at different output voltage and frequency settings (for AC drives).
  - (d) Determination of the power losses at specified loads (By Calculation). (Type Test)
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- (e) Load test or rated current test for large converters (above 1 MW).
- (f) Insulation test
- (g) Temperature rise (Type Test). (h) Light load & Functional Test.
- (i) Observation of various wave forms i.e. current and voltage.
- q) Other composite test at no load
  - Environmental tests on printed circuit boards, pulse transformers etc. (b) Other tests as may be agreed on various converter subsystems.
- r) Acceptance test
  - These shall be conducted at the works of the VENDOR'S and/or his sub- vendor to ascertain that performance stipulated in this specification has been honoured (e.g. overcurrent capability, measurement of ripple voltage & current, P.F. measurement, Audible noise, etc). Dummy loads as required for the purpose of simulating the operation conditions at the VENDOR's works shall be considered in scope of this specification. However, should this not be possible, testing at site with the actual load shall be conducted to prove the performance of the power converters.
  - All the meter, instruments, devices used for the testing purpose shall be properly calibrated by standard authorised agencies which shall be traceable to National Standards. For each such instrument proper validity of calibration shall be documented by Vendor.
- s) Harmonics limitations
  - When specified in Data Sheet A, the harmonics generated on source (Input) side (Both AC/DC drive) and output side (For AC drive only) shall be restricted to the following limits: (relevant IEEE for source side and IEC- for load side)

(a)	Voltage Harmonics	Source side Maximum 5%	Load side Maximum 5%(THD)
(b)	Current Harmonics	Source side	
	5 <sup>th</sup>	Maximum 30%	
	7 <sup>th</sup>	Maximum 20%	
	11 <sup>th</sup>	Maximum 10%	

Bidder shall indicate clearly the method of achieving above requirement.

4.4.29. Contactors: The power contactors used in switchboard shall have following features:

- a) The contactors shall confirm to IS 13947 & the latest applicable standards

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- b) The power contactors shall be of, air break, single throw, triple pole, electromagnetic type.
  - c) The insulation class of contactor's coil should be B or higher.
  - d) Operating coils of all contactors shall be suitable for operation on 110 / 240 V, single phase, 50 Hz, AC supply.
  - e) Contactors shall be provided with at least two pairs of NO and NC auxiliary contacts.
  - f) Contactors shall not drop out at voltages down to 70 % of coil rated voltage.
  - g) Motor starters components shall be type 2 coordinated, complete with auxiliary relays, timers and necessary indications.

#### 4.4.30. Relays:

- a) Main protective relays shall be Numerical type. They shall be suitable for semi-flush mounting with only flanges projecting on the front with connections from the rear.
- b) All relays shall be enclosed in rectangular shaped, dustproof cases and shall be suitable for flush mounting.
- c) All protective relays shall be in draw out cases with built in test facilities.
- d) Auxiliary relays and timers shall be rated to operate satisfactorily between 70 % and 110 % of the rated voltage
- e) Test block and switches shall be located just below each relay for testing unless otherwise specified. All auxiliary relay and timers shall be supplied in non-draw out cases.
- f) All protective relays shall be provided with at least two pair of potential free output contacts, exclusively for Purchaser's use.
- g) Relay cases shall have adequate number of terminals for making potential free connections, to the relay coils and spare contacts. Paralleling of contacts if any shall be done at the terminals on the casing of the relay.
- h) Each relay shall have provision for easy isolation of trip circuit for the purpose of testing and maintenance.
- i) All relays shall with stand out a test voltage of 2 kV, 50 Hz RMS voltages for one minute.
- j) Auxiliary seal in units provided on the protective relay shall be shunt reinforcement type.
- k) 300 kW & above rated motors shall be breaker controlled with motor protection relay from approved make list.

#### 4.4.31. Thermal Overload Relays:

- a) Starters shall be complete with a three element, positive acting, ambient temperature compensated, time lagged thermal overload relay with adjustable settings. The setting range shall be properly selected in accordance with the rating of the motor.
- b) Thermal overload relays shall be hand reset type
- c) 'Stop' push button of the starter and hand-reset device shall be separate from each other.
- d) Overload relay hand reset push button shall be brought out on the front of the compartment door. Overload relay shall be provided with at least 1 'NO' and 1 'NC' or one changeover contact.

#### 4.4.32. Timers:

Thermal/ Electronics timer for change over in star-delta and ATS panel should be provided.

#### 4.4.33. Switch And Contactor Ratings:

Switch and contactor rating for various motor starter modules shall be selected by the Contractor, based on the specifications. Contractor shall also select appropriate ratings & ranges for thermal overload relays. These details shall be subject to the Purchaser's approval.

#### 4.4.34. Single Phasing Preventers:

- a) Single phasing preventer relay shall be provided to protect motors against single phasing.
- b) It should operate satisfactory from 320/ 480V. Timing range of delay start 0 - 45 seconds.
- c) Toggle switch for Auto SPP by pass should be provided on front of unit.
- d) The relay shall not operate for supply voltage unbalance of  $\pm 5\%$ . After sensing single phasing, the relay shall operate with a time delay of 2 to 3 secs.
- e) The relay shall not operate for a 3- phase power supply failure. The relay shall be of the hand-reset type with a hand-reset push button. Resetting shall be instantaneous and independent of the adjusted time delay in the tripping of the unit. Visual indication for the operation of the relay shall be provided.
- f) The relay shall be suitable for application to protect reversible and non reversible motors.
- g) The relay operation shall be independent of the motor kW rating, the loading conditions prior to the occurrence of the single phasing and RPM of the motor.
- h) The relay shall be of the fail-safe type and shall operate to trip the motor when the relay internal wiring is accidentally open circuited.



#### 4.4.35. Power & Control Wiring Connections:

- a) Terminals for both incoming and outgoing cable connections shall be suitable for 1.1kV grade Al / Cu conductor XLPE armoured cable and shall be suitable for connections of solder less sockets for the cable size.
- b) Main PMCC incomer feeder shall be suitable for bus duct connections using Aluminum Bus bars
- c) Both control and power wiring shall be suitable for Bus Duct/ Cable termination as per guidelines mentioned in transformer specifications.
- d) Both control and power terminals shall be properly shrouded. Power terminals shall be of stud type.
- e) 20% spare terminals shall be provided on each terminal block. Sufficient terminals shall be provided on each terminal block so that not more than one out going wire is connected to per terminal.
- f) Suitable barriers of enclosures shall preferably separate terminals strips for power and control from each other.
- g) Wiring inside the modules for power, control, protection and instruments etc shall be done with use of 1.1 kV grades, multistranded Cu, PVC FRLS wiring.
- h) Power wiring inside the starter module shall be rated for full current rating of respective contactor but not less than 4.0 Sq. mm. 2.5 Sq. mm copper wire shall be used for current transformer circuits.
- i) Other control wiring shall be done with 1.5 Sq. mm copper conductor wires.
- j) Wires for connection to the door shall be flexible. All conductors shall be crimped with solder less sockets at the ends before connections are made to the terminals.
- k) There shall be control transformer for control power supply (110 / 240V AC) and separate control bus.
- l) Particular care shall be taken to ensure that the layout of wirings is neat and orderly. Identification ferrules shall be filled to all the wirings terminations for ease of identification and to facilitate checking and testing.
- m) Washers shall be used for all Copper and Aluminum connections.
- n) Final wiring diagram of power and control circuit with ferrules nos. shall be submitted along with the panel as one of the documents against the contract.

#### 4.4.36. Terminals:

- a) The outgoing terminals and neutral shall be brought to a cable alley suitably located and accessible from the panel front.
- b) The current transformer for instruments metering shall be mounted on the disconnecting type terminal blocks. No direct connection of incoming or outgoing cables to internal components of the distribution board is permitted; only one conductor may be connected in one terminal.

#### 4.4.37. Wire Ways:

- a) The horizontal PVC wire way with screwed covers shall be provided at the top to take interconnecting control wiring between different vertical sections.

#### 4.4.38. Indicating Instruments:

- a) All analogue indicating meters shall be 96 x 96 mm size taut band with 240° Scale. All indicating meters shall be provided as per enclosed electrical Single Line Diagram.
- b) Ammeters for motor feeders shall have suppressed scale up to 6 times beyond full load.
- c) Dials shall be parallax free and white with black numbers and letterings & pointer shall be of knife-edge type. Such instruments shall be provided with zero adjustor accessible from the front.
- d) Instruments shall have an accuracy class 1.0 or better.
- e) Instrument dials shall be white with black numbers and lettering.
- f) Ammeter and current coils of wattmeter's and ammeters shall continuously withstand 120 % of rated current and 10 times the rated current for 0.5 second without loss of accuracy.
- g) Voltmeters and potential coils of voltmeters shall withstand 120% rated voltage continuously and twice the rated voltage for 0.5 seconds without loss of accuracy.

#### 4.4.39. Metering Instruments:

- a) Multifunction meters shall be provided for incomers, main pump motor feeders and outgoing feeders of 250A & above. Size of the MFM shall be 96 x 96 sq. mm & provided with following metering features:
  - i. Current, Voltage, Energy (kWh), MD (kW, kVA), PF & Hz etc.
  - ii. MFM shall be with accuracy class 1.0 or better & having RS 485 communication port.
- b) Multifunction meters shall be suitable for operation from the secondary of CTs and VTs. They shall be provided with a separate 3 phases, 4 wires type test terminal blocks for testing of meters without disturbing CT and VT secondary connections.
- c) Current coils of meters shall have a continuous overload capacity of 120 % for both accuracy as well as thermal limits. Also the coil shall withstand at least 10 times rated current for 0.5 second without loss of accuracy.

#### 4.4.40. Current Transformers:

- a) Current transformers shall be of cast resin type. Insulation Class shall be Class 'E' or better.
- b) Current transformer shall have a short time withstand rating equal to the short time withstand rating of the associated switchgear for one second for breaker feeders.

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- c) Unless otherwise specified, the minimum performance requirement of current transformers is as follows:
    - i. Measuring CTs - 15 VA, accuracy class 1.0 or better.
    - ii. Protective CTs - 15 VA, accuracy class 5P20.
  - d) The above mentioned burdens are minimum required & it will be Contractor's responsibility to coordinate the current transformer burden with the requirements of relays, instruments and leads associated with that particular current transformer. Contractor has to provide sufficiency calculations for the same.
  - e) Current transformer (CT) shall have polarity markings indelibly marked on each transformer and at the lead terminations at the associated terminal block
  - f) CT shall be able to withstand the thermal and mechanical stresses resulting from the maximum short circuit current
  - g) Test links shall be provided in both secondary leads of the CTs to easily carry out current and phase angle measurement tests.
  - h) Identification labels giving type, ratio, output and serial numbers shall be provided.

#### 4.4.41. Voltage Transformers:

- a) Voltage transformers shall be of cast resin type. Insulation Class shall be Class 'E' or better.
- b) Unless otherwise specified, the minimum performance requirements of Voltage transformers are as follows:
  - i. Measuring VTs - 50 VA per phase and accuracy class 1.0
  - ii. Protective VTs - 50 VA per phase and accuracy class 3P.
  - iii. Dual purpose VTs - 100 VA and dual accuracy class 1.0 / 3P for metering and protection respectively. VA is per phase.
  - iv. The above mentioned burdens are minimum required & Contractor has to provide sufficiency calculations for the same.
- c) All secondary windings of voltage transformers including open delta windings shall be rated for  $110\text{ V} / \sqrt{3}$ , 110V/ 3 per phase.
- d) Voltage transformer shall have a continuous over voltage factor of 1.2 and short time over voltage factor as follows:
  - i. 1.5 for 30 seconds in case of effectively earthed system.
  - ii. 1.9 for 8 hours in case of non-effectively earthed system.
- e) Voltage transformers shall be complete with suitable rated primary, fuses. Primary fuses shall have a rupturing capacity equal to the rupturing capacity rating of the associated switchgear. All the secondary circuits of the VT shall be protected by MCBs.

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- f) It shall be possible to replace voltage transformers without having to de-energize the main bus bars.
  - g) The terminals of VT secondary and tertiary windings, which are required to be connected to earth, shall be earthed by an isolating link without a fuse.
  - h) Identification labels giving type, ratio, output and serial numbers shall be provided.

4.4.42. Push Buttons:

- a) Push buttons shall have two normally open and two normally closed contacts unless otherwise specified. The contacts shall be able to make and carry 5A at 110V DC and shall be capable of breaking 1A inductive load at 110V DC. They shall be provided with inscription plates engraved with their functions.
- b) Emergency stop' push buttons shall be of Mushroom type, lockable in the pushed position and shall be shrouded to prevent accidental operation. Key shall not be required for the operation of the push button.
- c) The Internal wiring and terminal blocks shall meet the relevant requirements.

4.4.43. Auxiliary Transformers:

Any auxiliary voltage required for any of the component inside the switchgear shall be derived from the main supply by providing adequately rated auxiliary transformer mounted inside.

4.4.44. Indicating Lamps: Indicating lamps shall be:

- a) Clustered LED type and of low watt consumption.
- b) Provided with series resistors.
- c) Provided with translucent lamp covers of colors 'Red', 'Green' and Amber' etc. as required.
- d) Indicating lamp shall be of the double contact, bayonet cap type rated for operation at either 110V AC or at the specified AC / DC system voltage as applicable.

4.4.45. Control & Selector Switches: Control and selector switches shall be:

- a) Rotary type with enclosed contacts.
- b) Adequately rated for the purpose intended (Minimum acceptable rating is 10A continuous at 230V AC and 1A (inductive break) 220V DC.
- c) Provided with escutcheon plates clearly marked to show the positions.
- d) Control switches shall be spring return to normal type & provided with pistol grip type handles.
- e) Selector switches shall be maintained contact stay put type. Switches in ammeter circuits shall be of break type contact. Selector switches shall be provided with oval handles.

#### 4.4.46. Space Heaters:

- a) Adequately rated anti-condensation space heaters shall be provided, one for each control panel, for each switchboard and for each marshalling kiosk.
- b) Space heater shall be of the industrial strip continuous duty type, rated for operation on a 240V, 1 phase, 50 Hz, AC system.
- c) Each space heater shall be provided with a single pole MCB with overload and short circuit release, a neutral link and a control thermostat to cut off the heaters at 35°C.
- d) Space heater indicated in the breaker modules represents the space heater for each vertical section of the switchboard. Where breakers are mounted in two-tier formation, then only one space heater with associated MCB and thermostat is adequate for the vertical section

#### 4.4.47. Cubicle Lighting/ Receptacle:

- a) Each control cabinet, marshalling box, etc. shall be provided with interior lighting by means of 11W CFL/ LED luminaries with door operated On/ Off switch.
- b) A 240 V, 1 phase, AC receptacle (socket) plug point shall be provided in the interior of each panel with a MCB.

#### 4.4.48. Routine and Acceptance Tests to be conducted by the manufacturer at their own risk and cost in presence of Purchaser/ Purchaser's representative during inspection & testing at manufacturer's works:

- a) Following Routine tests as per IS: 13947 and IEC: 60947 standards & other specified relevant IS standards shall be performed by the manufacturer and witnessed by Purchaser / Purchaser's representative on LV Switchgear panel complete with the accessories.
  - i. Dielectric test on main circuit.
  - ii. Test on auxiliary and control circuit.
  - iii. Measurement of insulation resistance of the main circuit.
  - iv. Tightness of main circuit.
  - v. Design and visual check.
  - vi. Dimensional check and BOM verification.
  - vii. High Voltage test on power & control circuit.
  - viii. Functional & mechanical operation test of all components.
  - ix. Measurement of thickness of sheet steel & paint.
  - x. Verification of wiring as per approved schematic.
- b) Following Type Tests reports as per IS: 13947 and IEC: 60947 to be submitted for the same rating & type of LV Switchgear panel conducted in past for review of Purchaser

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at the time of inspection & testing of equipment. Type test reports should be valid and not be older than the 5 years.

- i. Dielectric test on main and auxiliary circuit.
  - ii. Temperature rise test.
  - iii. Making and Breaking test of switching elements.
  - iv. Degree of protection test.
  - v. Short circuit withstand test.
  - vi. Electromagnetic compatibility test.
- c) Certified copies of all type and routine test certificates and Calibration Certificates of measurement instruments which are used during inspection shall be submitted for the Purchaser's review / approval before dispatch of the switchgear.

#### 4.4.49. Test Certificates:

- a) Testing of switchgear shall be carried out at factory or at site as per standard in presence of Purchaser / Purchaser's representative.
- b) The test results shall be recorded on prescribed forms. The certificates for the test carried out at factory or at site shall be submitted in duplicate to the Purchaser / Purchaser's Representative for approval. Components and equipment that are not fully interchangeable are liable for rejection. Contractor shall replace all such non interchangeable equipment at his cost.

#### 4.4.50. Drawings/ Documents: After award of contract, Contactor has to submit drawings / documents for Purchaser's approval as mentioned below but not limited to:

- a) General arrangement diagram showing dimensions of enclosure, length, widths and depth of enclosure and bill of quantity indicating the rating, make of each components and quantity.
- b) Complete assembly drawings of the switchboard/ distribution board/ MCC showing plan, elevation and typical sectional views and location of cable boxes and control cable terminal blocks for external wiring connections, etc.
- c) Foundation plan showing the location of channel sills, foundation, anchor bolts and anchors, floor plans and openings.
- d) Schematic power and control wiring diagrams with bus bar rating with material, instrument & control transformers, switchgear rating, control interlocks, relays, instruments, space heaters details etc.

#### 4.5. LOCAL PUSH BUTTON STATIONS:

##### 4.5.1. Constructional Features: The constructional features of the local push button stations shall be as follows:

- a) Metal enclosed, weatherproof, suitable for mounting on wall or steel structures. The enclosure shall be die cast aluminum or sheet metal of 2.0 mm thickness.

- b) Dust and vermin proof.
- c) Provide a degree of protection of not less than IP-55.
- d) Metal parts shall be given tropicalising treatment as per standards and painted with one coat of epoxy primer and two coats of light gray epoxy paint.
- e) Provided with inscription plates of rear engraved Perspex with white letters on black background. The letter size shall be 6 mm.
- f) Provided with two earthing terminals suitable for earthing wire/ strip.
- g) Provided with removable undrilled gland plate and cable glands for two nos. 5C x 1.5/ 2.5 mm<sup>2</sup> Copper conductor, XLPE insulated, armoured cable. The cable entry shall be from the bottom.
- h) Earthing shall be provided by 8 SWG GI wire and connected to earthing system.

#### 4.6. APFC PANEL WITH CAPACITOR BANKS:

4.6.1. Scope of this specification covers design, manufacture, testing at manufacturer's works, supply, packing, forwarding and delivery from place of storage/ manufacturer's works to erection site including transit insurance, unloading, storage at site, assembly, erection, testing, installation, commissioning and performance demonstration of the following equipment with associated accessories.

#### 4.6.2. Capacitor Banks:

- b) The type of capacitors shall be All Polypropylene type double layer conforming to IS: 13585 – 2012 & having following specifications:

Supply	3 Phase, 3 Wire
Rated voltage	440 - 480V
Rated frequency	50Hz.
Permissible over voltage	1.1V <sub>n</sub>
Permissible over current:	1.5 I <sub>n</sub>
Temperature category:	50°C

- c) The capacitor shall be vacuum impregnated with liquid dielectric having high thermal stability.
- d) The capacitors shall have Low Dielectric Loss of  $\leq 0.5 \text{ W / kVAr}$ .
- e) Each capacitor bank shall be provided with the 7% detuned filter.
- f) \* kVAr is net reactive compensation required to maintain 0.99 PF at 415 V Bus, i.e. excluding compensation required for detuned filters.
- g) Bushing should have high mechanical strength & method of fixing should be proper so that no leakage occurs.

- h) Auto/ Manual switch shall be provided in the APFC panel. For manual switching, every capacitor bank feeder shall be provided with ON & OFF push buttons along with the ON & OFF indications.
- i) Minimum current rating under site conditions, of circuit breakers, contactors and cables shall be at least 150% of rated capacitor current, to take care of harmonics.
- j) Contactor for switching of capacitor banks shall have AC-6b utilization category according to IEC 60947-4-1 & sized accordingly.
- k) All the components shall be suitable for capacitor duty application.
- l) The capacitor banks shall be complete with all parts that are necessary or essential for efficient operation. Such parts shall be deemed to be within the scope of supply whether specifically mentioned or not. Capacitor shall be designed to improve the power factor to 0.99 lagging
- m) It shall be complete with the required capacitors along with the supporting post insulators, steel rack assembly, Al/ Cu bus bars, Al/ Cu connecting strips, foundation channels, fuses, fuse clips, etc. The steel rack assembly shall be hot dip galvanized.
- n) The capacitor bank may comprise of suitable number of single phase units in series parallel combination. However, the number of parallel units in each of the series racks shall be such that failure of one unit shall not create an over voltage on the units in parallel with it, which will result in the failure of the parallel units. The assembly of the banks shall be such that it provides sufficient ventilation for each unit.
- o) Each capacitor case and the cubicle shall be earthed to a separate earth bus.
- p) The units shall be capable of continuously withstanding satisfactorily any overvoltage up to a maximum of 10% above the rated voltage, excluding transients.
- q) Each capacitor unit / bank shall be fitted with directly connected continuously rated, low loss discharge device to discharge the capacitors to reduce the voltage to 50 volts within one minute upon disconnection, in accordance with the provisions of the latest edition of IS: 13585 – 2012.

#### 4.6.3. Control Cubicles:

- a) Capacitor and capacitor control shall be housed in a metal enclosed cubicle conforming to IS 16636-2017 with latest amendment. Capacitor shall be housed in the lower compartment and capacitor control unit at the top compartment, the two compartments being segregated. Control cabinets shall be free standing floor mounted type and shall meet the requirements of Metering, Protection & related provisions for APFC panel as tabulated below:

Panel Name	Breaker Type	Protection	Metering	Indications	Other
APFC Panel					
Incomer	ACB (TPN, MDO/ EDO) OR	TM based O/L, S/C release ,	Analogu e A, V	R Y B, On, Off, Trip	ETPB, A/M SS, Annunciator



	MCCB (TPN, Fixed Type)	APFC Relay, E/F Relay with CBCT & Shunt Trip			
Outgoing	MCCB (TP, Fixed Type)	TM based O/L, S/C release	A, AS	On, Off, Trip	Start, Stop Push Buttons

- b) APFC panel shall have Al/ Cu bus bars sized for appropriate SC rating for 1 sec & to carry continuous rated current.
- c) All CTs/ VTs shall be cast resin type.
- d) All the MCCB's shall be current limiting type. Necessary auxiliary contact block required is included in Contractor scope.
- e) One contact of power factor correction relay shall be provided for annunciation "POWER FACTOR LOW". The relay shall switch-on/ off capacitor banks for loads from 5% to 100%. The annunciation window shall be with test, accept and reset push button & hooter.
- f) Capacitor switching and automatic power factor correction panel shall be designed in such a way that power factor of 0.99 lagging shall always be maintained. Timings to cut in capacitors shall be provided in such a manner to facilitate capacitor discharging before next switching and shall also avoid hunting due to temporary fluctuations of load. The timer shall be provided in both auto and manual mode.
- g) The Automatic power factor correction panel and capacitor panel are integral type, prewired including power connections. Due consideration shall be given for adding/removal of capacitor or other components and maintenance considerations. Contractor shall submit General Arrangement drawings of capacitor and capacitor control panel, with description of power factor control panel with its components.
- h) For control circuit 415/ 230/ 110V AC control transformer (with  $\pm 5\%$  tapping on primary side) shall be considered. VA burden to be decided by the Contractor.
- i) Minimum clearance between live parts shall be phase to phase 25.4 mm & phase to neutral 20 mm.
- j) Bus bars shall be sleeved with coloured heat shrinkable sleeves. All the Bus bar supports shall be SMC type only.
- k) Degree of protection shall be IP-42 for the enclosure, epoxy painted, powder coated with colour shade RAL-7032 for exterior & interior with minimum thickness 80 micron.
- l) All necessary auxiliary contactors are included in scope.
- m) Contractor shall note that verification of double layer construction shall be done on any one of the capacitor bank during inspection by opening the capacitor bank at no extra cost.
- n) The cubicle shall be fabricated out of 2.0 mm thick cold rolled sheet steel & shall comprise of :

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- i. Isolating ACB/ MCCB
  - ii. Contactors with overload element
  - iii. Sequencing devices, timers and auxiliary relays for automatic sequential switching of capacitor units in and out of circuit.
  - iv. Auto-manual selector switch
  - v. Microprocessor based Automatic Power Factor Correction (APFC) Relay – minimum 10 stage relays.
  - vi. Push button for opening and closing the power circuit
  - vii. Red and Green lamps for capacitors ON/ OFF indication
  - viii. Protective relays to protect the healthy capacitor units when one unit fails in a series connection
  - ix. Space heater and cubicle lighting & receptacles.

4.6.4. Principle of Operation: On deviations from set power factor, the power factor controller shall release command signals to switch on / switch off capacitor bank stages and maintain the set power factor.

4.6.5. APFC Relay: APFC relay shall have following standard features:

- a) The Automatic Power Factor Correction relay shall be of microprocessor based type and shall automatically switch ON/ OFF the capacitor banks to attain the value of “pf” close to the set value.
  - b) Switching shall follow first in first out (FIFO) method to ensure uniform use of all capacitor banks. At least eight steps shall be provided for switching.
  - c) To measure/ monitor power factor and VAR continuously. Status of switching step shall be displayed through LED.
  - d) Following adjustment shall be available in APFC Relay.
    - i. Power factor
    - ii. Dead band capacitive region with respect to set power factor (PF).
    - iii. Inductive region with respect to set PF
    - iv. Operating time for programmable switching steps.
    - v. Auto/ manual selector switch.
    - vi. Manual step control.
  - e) All control knobs, LEDs for display and selector switches shall be mounted on the front face of relay casing / panel.
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- f) It should be fully programmable. There should be a choice for customer to select operating sequence up to 4 to 5 which will have maximum number of steps of capacitors equal to fourteen (14). The sequence shall be arithmetic 1, 2, 3.....13, 14.
  - g) Operating time selection of time interval designation between switching stages shall be possible using time selector switches. The device shall take care that any stage which has just been switched out will only be reconnected by the pulse counter, after 60 sec. has elapsed so that it has safely discharged. This is a requirement for 415 V capacitors
  - h) Loss of voltage element- This would prevent abnormal switching surges on loss of supply. Also it would control the switching On / Off surges.
  - i) Dead band features- Relay response sensitivity adjustable using dead band so that hunting is prevented.
  - j) Auto/ Manual control- This would help testing and commissioning at site as well as ease in operation when either mode fails during service time.

#### 4.6.6. Performance Tests:

- a) Contractor shall carry out all routine tests as specified in relevant IS / IEC standards on all major components and furnish copies of test reports for Purchaser's approval. Wherever required, Contractor shall conduct the necessary type tests in the presence of Purchaser / Purchaser's representative.
- b) Contractor shall also carry out all routine and functional tests as specified in the relevant IS on the assembled switchgear panels in the presence of the Purchaser's representative at works before dispatch and furnish copies of test reports for approval. If required stage inspection will be carried out by the Purchaser.
- c) During inspection, Contractor shall furnish copies of routine test report for all bought out items for Purchaser's approval.
- d) Primary Injection Test for various currents & time settings shall be provided in routine test.
- e) All the components shall be tested for their entire operating range & certification for the same shall be provided at the time of inspection.

#### 4.6.7. Maintenance Requirements:

- a) As far as possible the switchgear shall be so designed that no special tools are necessary for installation and maintenance. However, if special tools are required, the Contractor shall supply one complete set of such tools along-with the equipment.
- b) Contractor shall furnish detailed inter panel wiring diagrams, internal wiring diagrams, detailed component layout drawings to carry out maintenance work.

#### 4.6.8. Drawings/ Documents Required:

- a) Dimensioned general arrangement drawings of capacitor and capacitor control panel.
- b) Justification for number of steps for switching.

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- c) Fully dimensioned general arrangement drawings of capacitor and capacitor control panel with elevation side view, sectional view and foundation details.
  - d) Complete schematic and wiring diagrams for capacitor control panel.

#### 4.7. CABLES & CABLING SYSTEM:

4.7.1. The scope shall be inclusive of supply, installation, testing & commissioning of power, control and instrumentation cables, cable terminations, cable accessories, stripping of cable insulation, supplying and fixing of Aluminium lugs for aluminium cables & tinned plated copper lugs for copper cables and crimping the same to the conductor, supply and fixing of double compression cable glands including all labour supply and consumable material required for jointing/ termination. The rate shall also include the laying of cable in ground/ in cable trays/ cleating to structure etc.

4.7.2. Applicable Standards: The cables shall confirm to the latest applicable standards specified below. In case of conflict between standards and this specification, this specification shall govern.

PVC insulated cables (for voltage up to 1100V)	: IS: 694
HRPVC & PVC insulated cables - heavy duty	: IS: 1554
Cross linked polyethylene insulated PVC sheathed cables	: IS: 7098
Low frequency cables and wires with PVC insulation and sheath	: IEC: 189-1 & IEC-189-2
PVC insulation and sheath of electric cables	: IS: 5831
Polyethylene insulation and sheath for electric cables	: IS: 6474
Conductors for insulated electric cables	: IS: 8130
Methods of test for cables	: IS: 10810
Specification for drums of electric cables	: IS: 10418
Specification for PVC insulated cables for electricity supply	: BS: 6346
Specification for PVC insulation and sheath of electric cables	: BS: 6746

#### 4.7.3. Constructional Features:

- a) HV power cables shall conform to 11kV (E) grade, three core, stranded, Aluminium conductor, screened by extruded semi-conducting compound, cross-linked poly ethylene (XLPE) insulated, cores screened with non-magnetic metallic tape laid up with inner and outer extruded PVC sheath compound Type-ST2 and galvanized steel

strip armouring. The cables shall generally conform to IS: 7098-1985 with relevant parts thereof.

- b) LV Power cables shall be 1.1kV grade, 4/ 3.5/ 3/ 2 Core, multi-stranded, Al/ Cu conductor, XLPE insulated, extruded inner PVC & outer PVC FRLS sheath compound type ST2 and galvanized wire (up to 6 sq mm)/ steel strip (>6 sq mm) armoured cables. All single phase, Lighting cables, UPS cables shall have 100% Neutral. The cables shall generally conform to IS: 7098-1985 with relevant parts thereof.
- c) All the control cables shall be 1.1kV grade, no. of cores (as per requirement/ application) multi-stranded, Copper conductor, XLPE insulated, extruded inner PVC & outer PVC FRLS sheath compound type ST2 and galvanized steel round wire armoured. The cables shall generally conform to IS: 7098-1985 with relevant parts thereof.
- d) All control cables shall be with following specific requirements:
  - i. Copper conductor stranded class 2.
  - ii. XLPE Insulated
  - iii. Provided with inner extruded PVC and outer PVC FRLS sheath of extruded black PVC compound.
  - iv. Galvanized steel armouring in the form of GI round wire.
  - v. Core identification shall be by printed numerals.
  - vi. The insulation over the individual conductor core will be colour coded.
  - vii. Minimum two (2) spare cores for above 7C.
- e) The DC power supply cable shall be two core, multistranded copper conductor, armoured cables with inner extruded PVC & outer PVC FRLS sheath. All control wiring shall be PVC FRLS insulated.
- f) All the power, control & instrumentation cables used in the Hazardous area shall be flame proof type suitable for the intended application.
- g) Earthing Cable shall be Single core multi-stranded Cu, 1.1 kV grade, XLPE insulated, un-armoured green coloured outer sheath with yellow strips/ band cable to be laid in trays, underground, trenches etc. as applicable.
- h) Submersible Cables: Multi core flexible Cu conductor XLPE insulated & PVC sheathed heavy duty cable suitable for submersible application (in case of submerged pumps) shall be manufactured as per governing standards. High purity electrolytic grade, annealed Cu conductor shall be used. Cables shall be extruded inner & outer PVC sheathed. PVC compound shall be dielectric grade & shall be impervious to water, oils & grease etc. Similarly double PVC sheathing shall also be done as per IS: 5831/ 1984. Flexible inner sheath & high abrasion resistant flexible outer sheath is required for these cables. Double PVC sheathing shall be done so as to withstand abrasion & prevent ingress of water along the interstices of the cable. Core identification shall be by printed numerals. Conductors shall be as per IS 8130. Cable shall be constructed as per relevant IS/ IEC standards.

#### 4.7.4. Cable Colours:

- a) All cable cores shall be colour coded throughout their length and shall be so connected between switchboard, distribution board, plant and accessories, that the correct sequence or phase colours are preserved throughout the system.
- b) The colour coding should be as follows:
  - i. 3 phase Red, Yellow and Blue
  - ii. single phase or dc supply Red and Black
  - iii. earth Green/ Green with Yellow coloured band
  - iv. control Gray (DC)

#### 4.7.5. Cable Conductors;

- a) Cables up to 4.0 sq.mm shall be Cu multi-stranded conductor with galvanized steel round wire armoured & balance cables shall be Al multistranded conductor with galvanized steel round wire/ flat strip armoured.
- b) Single core cable shall have non magnetic material armouring.
- c) Lighting final distribution circuits shall be of a minimum cross-section of 1.5 mm<sup>2</sup>.
- d) Small control cables shall be of a minimum cross-section of 1.5 mm<sup>2</sup>.
- e) Internal wiring of control panels shall be of a minimum cross-section of 1.5 mm<sup>2</sup> flexible and multistranded.
- f) Instrumentation and control cabling shall be of a minimum cross-section 1.5 mm<sup>2</sup> for external use and 1.0 mm<sup>2</sup> for internal use.
- g) Cable Sizing shall be done as per design criteria specified in specifications.

#### 4.7.6. Cable Numbering: All cables shall be allocated a unique number which shall be fixed to each end of the cable using a corrosion resistant label. Necessary loop at both ends shall be provided for future use and cables of different categories shall be tagged with the following subscripts and three digit number.

HV power	HV-P_ _ _
LV power	P_ _ _
Control	C_ _ _
Instrumentation	I_ _ _
Protection	PR_ _ _
Telecommunication	T_ _ _

#### 4.7.7. Cable Terminations:

- a) Cable Lugs
  - i. Cable lugs shall be of tinned copper, solder less crimping type for Cu cables &

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AL lugs for the AL cables.

- ii. The current rating of the lugs shall be same as that of the respective cable conductors.
- iii. Bi-metal strip/ Bi-metallic lug shall be used whenever two different metals are to be connected together.
- iv. Double holes extended neck (long barrel neck) type lugs shall be used in case of cables above 185 sq. mm.
- v. Anticorrosion/ anti-oxidation compounds shall be used for crimping lugs. This shall especially be ensured for Al cable terminations & bimetallic terminations shall be used wherever required.
- vi. If termination is done with crimping tool employing crimping die then forming dies shall be used to make the sector shaped conductor into a round conductor before crimping the lugs on the conductor. The lug must not be crimped directly on the sector conductor. Before crimping the lug, the conductor shall be thoroughly cleaned and special jelly applied over it to prevent further oxidation.

b) Cable Glands

- i. Glands shall generally be of the double compression hexagonal type brass glands. Earth continuity of brass glands shall be assured.
- ii. Double compression type cable glands shall be used. Cable glands shall be brass casting, machine finished and Nickel-plated to avoid corrosion and oxidation. Rubber components used in cable gland shall be of neoprene.
- iii. For single core cables, gland shall be with brass ring.
- iv. Glands for single core cables shall be constructed from non-magnetic materials.
- v. Cable glands shall be with metric threads.
- vi. Where holes for cable entries are not provided it shall be the responsibility of the Contractor to mark out and drill such holes. Burrs and swarf shall be removed, care being taken to ensure that swarf and filings, etc do not enter the equipment.
- vii. For non-hazardous areas cable glands in situations where moisture may be present shall be double seal weatherproof type, gland shrouds shall be used and entry shall be sealed.
- viii. For dry indoor situations, standard industrial glands with shrouds are acceptable.
- ix. For hazardous areas, glands conforming to EEE standard shall be used with double seal and shroud.

c) Trefoil Clamps for Single Core Cables:

- i. All the single core cables shall be laid in trefoil formation only.

- ii. The grouping & sequencing of three single core cables arranged in trefoil formation shall be done in such a way to ensure balanced current distribution.
  - iii. Trefoil clamp of suitable size & having non magnetic material shall be used.
  - iv. The Trefoil groups shall be held in trefoil clamps at an interval not exceeding 3.0 meters.
  - v. In addition to trefoil clamps as mentioned above, the tre-foil groups of cables shall be additionally tied by means of 3.0 mm dia. nylon cord clamp at an interval not exceeding 750 mm.
- d) Wherever applicable, supply & installation provision of bimetallic strip for connection between Al to Cu strip & GI to Cu strip shall be provided.

#### 4.7.8. Instrumentation Cables:

- a) This specification covers the requirements for instrument signal cables, thermocouple extension cables, RTD cables and power/ control cables.
- i. Single pair shielded signal/ alarm cables shall be used between field instruments/ switches and junction boxes/ local control panels.
  - ii. Single pair shielded thermocouple extension cables shall be used between thermocouple head and junction boxes/ transmitters/ local control panel mounted instruments.
  - iii. Single triad shielded signal cables shall be used between RTD head and junction boxes/ transmitters/ local control panel mounted instruments.
  - iv. For field bus compatible instrument single pair shielded cable shall be used between instrument to junction box/ local panel and to control room.
  - v. Foundation Field bus shall be Type-A cable. Construction of same shall be as per IEC 61158-2. Trunk cable shall be used of 1 Pair, 5 Pair, and 12 Pair.
  - vi. Separate Multipair/ multitriad cables shall be used between junction boxes/ local control panel and control room as per following applications.
    - ☐ 4-20 mA signals (for conventional HART Transmitters)
    - ☐ Foundation Field signals
    - ☐ Thermocouple signals
    - ☐ Resistance Temperature Detectors (RTD) signals
    - ☐ Switch contacts/ Proximity switch contacts
    - ☐ Gas detectors
  - vii. Instrument power cables shall be used between power supply distribution boards and power consumers such as control panels, DCS/ PLC cabinets, any instruments requiring power supply, etc.



- viii. Instrument control cables shall be used for valves, feedback of feeders etc.
- ix. Thermocouple cables design shall comply with ANSI MC 96.1.
- x. The insulation grade shall be 1100 V AC for all cables.
- xi. The primary insulation shall be PVC with temperature rating 70°C conforming to BS: 5308/ IS: 1554.
- xii. Inner and outer sheath/ jacket shall be made of extruded fire retardant, low smoke/ low halogen, low toxic, polymeric compound having physical properties as per IS:5831, Type ST1.
- xiii. All cables shall be armoured and suitable for operation when installed as follows:
  - ☐ Directly buried in the ground.
  - ☐ Fastened to cable ladder rack or tray in the open air.
  - ☐ In underground ducts.
  - ☐ In overhead closed cable ducts.
- xiv. Running length of the cable shall be printed at least at every five (5) metre interval.
- xv. For Multipair/ multitriad cables, pair identification shall be provided with numbers at interval of not more than 250 mm as per Contractor's standard.
- xvi. Contractor shall ensure a minimum of 20% of quantity of each type of cables supplied as spare including any special cable and in each Multipair cable 20% pairs shall be kept as spare.
- xvii. A pair of communication wire shall be provided for Multipair/ multitriad cables.
- xviii. Each wire shall be 0.5 mm<sup>2</sup> of plain annealed single or multi-strand copper conductor with 0.4 mm thick 70°C PVC insulation.
- xix. All cables shall be fire retardant and low smoke.

b) Design and Testing Standards:

- i. Instrument signal, RTD and thermocouple cables

Sr. No.	Description	Particulars
1	Conductors	BS: 6360/ IS: 8130 for instrument signal and RTD cables and ANSI MC 96.1/ IEC-60584-3 for thermocouple cables.
2	Insulation: PVC	Insulation shall be PVC as per BS: 5308/ IS: 1554.

Sr. No.	Description	Particulars
3	Armour	Round wire armour galvanized steel as per IS: 1554 Part 1
4	Inner & Outer Sheath-PVC	<p>Extruded Fire Retardant, Low Smoke/ Low Halogen, Low Toxic, PVC having physical properties as per IS 5831-Type ST1. Flammability and chemical properties shall be as follows:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Oxygen Index: 30 (minimum) at room Temp as per ASTM-D-2863-77</li> <li><input type="checkbox"/> Temperature Index: 250 Deg C (minimum) at Oxygen Index of 21 as per ASTM-D-2863.</li> <li><input type="checkbox"/> Light Transmission: 70% (minimum) as per IEC1034.</li> <li><input type="checkbox"/> Flammability test: As per IEC 332 Part-1 &amp; Part-3 Cat. A</li> <li><input type="checkbox"/> Corrosivity of combustion gases: pH-index &gt;4.3, Electrolytic conductivity &lt;100 micro S/cm as per IEC 754-2</li> <li><input type="checkbox"/> Toxicity index: Maximum 05 Gases to be extracted – HCl, HBr, HF, CO, CO<sub>2</sub>, NO, SO<sub>2</sub>, HCN as per NES-713. HCl shall be first gas to be extracted.</li> </ul> <p>Inner Sheath and outer sheath thickness: Minimum Inner sheath thickness and outer sheath thickness shall be as per IS: 1554(Part-1)1988 (should not be less than 0.5 mm).</p> <p>Outer Sheath Colour: Blue Inner Sheath Colour: Black</p>
5	Testing of the instrument Signal and RTD cables.	BS: 5308
6	Testing/ Calibration of Thermocouple cables.	ANSI MC96.1/ IEC:60584-2
7	Dimensions	BS: 5308

ii. Instrument power and control cables:

Sr. No.	Description	Particulars
1	Conductors	IS: 8130/ BS: 6360
2	Insulation: XLPE	Insulation shall be Polyvinyl Chloride (PVC) as per BS 5308/ IS 1554.
3	Armour	Round wire armour galvanized steel as per IS 1554 Part 1

Sr. No.	Description	Particulars
4	Inner & Outer Sheath-PVC	<p>Extruded Fire Retardant, Low Smoke/ Low Halogen, Low Toxic, PVC having physical properties as per IS 5831, Type ST1. Flammability and chemical properties shall be as follows:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Oxygen Index: 30 (minimum) at room Temp as per ASTM-D-2863-77</li> <li><input type="checkbox"/> Temperature Index: 250°C (minimum) at Oxygen Index of 21 as per ASTM-D-2863.</li> <li><input type="checkbox"/> Light Transmission: 70% (minimum) as per IEC 1034.</li> <li><input type="checkbox"/> Flammability test: As per IEC 332 Part-1 &amp; Part-3 Cat. A</li> <li><input type="checkbox"/> Corrosivity of combustion gases: pH-index &gt;4.3, Electrolytic conductivity &lt;100 micro S/cm as per IEC 754-2</li> <li><input type="checkbox"/> Toxicity index: Maximum 05 Gases to be extracted – HCl, HBr, HF, CO, CO<sub>2</sub>, NO, SO<sub>2</sub>, HCN as per NES-713. HCL shall be first gas to be extracted.</li> </ul> <p>Inner Sheath and outer sheath thickness: Minmum Inner Sheath thickness and outer sheath thickness shall be as per IS: 1554(Part-1)1988, should not be less than 0.5 mm.</p> <p>Power Cables: Black</p> <p>Control Cables: Blue with black bands (4 bands at 90 apart)</p>
5	Testing of the power and control cables.	IS : 1554 Part I, BS 6469/ BS 6346

- c) Cable Construction: The various mechanical/ electrical parameters indicated here are indicative and the Contractor shall be responsible to select/ design the cables as per applicable standards.

- i. Instrument Signal Cables (4 – 20 mA or Switch Contacts):

Sr. No.	Description	Particulars
1 i)	Conductor Single/ Multi Pair	7 stranded/ 0.53 mm dia (1.5 mm <sup>2</sup> ) stranded annealed tinned copper conductors of electrolytic grade copper.
2	Insulation	Polyvinyl Chloride (PVC) as per BS: 5308/ IS: 1554.
3	Inner & outer sheath	PVC, fire retardant, low smoke/ low halogen, low toxic, polymeric compound.

Sr. No.	Description	Particulars
4	Pairs	Two insulated conductors shall be uniformly twisted together to form a pair at least 10 twists per metre.
5	Maximum DC resistance	Shall not exceed 12.3 ohms/ km at 20°C for cables with 1.5 mm conductor.
6	Mutual capacitance	BS: 5308 Part 1
7	L/ R ratio of adjacent cores/ pairs	BS: 5308 Part 1
8	Shield	Shield shall be aluminium backed mylar/ polyester tape bonded together with the metallic side down helically applied with either side having 25% overlap and 100% coverage. The minimum shield thickness shall be 0.05 mm in case of single pair and 0.075 mm in case of multi pair cable.
9	Drain wire	Drain wire shall be provided for individual pair and overall shield with 0.5 mm <sup>2</sup> ) multistranded bare tinned annealed copper conductor continuously in contact with aluminium side of shield. The drain wire resistance including shield shall not exceed 30 ohm/km. Electrostatic noise rejection ratio shall be over 76 dB.
10	Colour coding	Individual pair core insulation: Blue & Black Inner jacket : Black Outer jacket: Blue for intrinsically safe application and blue with black bands (4 bands at 90° apart) for non IS applications.

ii. RTD cables:

Sr. No.	Description	Particulars
1	Conductor Single/ Multi Triad	7 stranded/ 0.53 mm dia (1.5 mm <sup>2</sup> ) annealed tinned copper conductors of electrolytic grade copper.
2	Insulation	Polyvinyl Chloride (PVC) as per BS: 5308/ IS: 1554.
3	Inner & outer sheath	PVC, fire retardant, low smoke/ low halogen, low toxic, polymeric compound.
4	Triads	Three insulated conductors shall be uniformly twisted together to form a Triad at least 10 twists per metre.

Sr. No.	Description	Particulars
5	Maximum DC resistance	Shall not exceed 12.3 ohms/ km at 20°C for cables with 1.5 mm <sup>2</sup> conductor
6	Mutual capacitance	BS 5308 Part 1
7	L/R ratio of adjacent triads	BS 5308 Part 1
8	Shield	Shield shall be aluminium backed mylar/ polyester tape bonded together with the metallic side down helically applied with either side having 25% overlap and 100% coverage. The minimum shield thickness shall be 0.05 mm in case of single triad and 0.075 mm in case of multitriad cable
9	Drain wire	Drain wire shall be provided for individual pair and overall shield With 0.5 mm <sup>2</sup> multistranded bare tinned annealed copper conductor continuously in contact with aluminium side of shield. The drain wire resistance including shield shall not exceed 30 ohm/ km. Electrostatic noise rejection ratio shall be over 76 dB.
10	Colour coding	Core insulation: Red, Yellow and Blue Inner jacket : Black Outer jacket: Blue for intrinsically safe application and blue with black bands (4 bands at 90° apart).

iii. Thermocouple cables:

Sr. No.	Description	Particulars
1	Conductor Single pair cable	16 AWG or 1.5 mm <sup>2</sup> solid conductors Conductor material should be as follows: K type T/C – Nickel/ Chromium; Nickel/ Aluminium (KX), Class 1.0
2	Insulation	Polyvinyl Chloride (PVC) as per BS: 5308/ IS: 1554. Colour code: Nickel/ Chromium: Green Nickel/ Aluminium: White
3	Pairs	Two insulated conductors shall be uniformly twisted together to form a pair at least 10 twists per metre. The lay length of adjacent pairs/ Triads in case of Multipair cables shall not be equal, to reduce cross-talk.

Sr. No.	Description	Particulars
4	Mutual capacitance	BS 5308 Part 1
5	L/R ratio of adjacent triads	BS 5308 Part 1
6	Core inductance	Shall not exceed 4 mH/ km. However, for J-type thermocouple inductance could be 8 mH/ km.
7	Shield	Shield shall be aluminium backed mylar/ polyester tape bonded together with the metallic side down helically applied with either side having 25% overlap and 100% coverage. The minimum shield thickness shall be 0.05 mm in case of single pair and 0.075 mm in case of multi pair cable
8	Drain wire	Drain wire shall be provided for individual pair and overall shield with 0.5 m m <sup>2</sup> multistranded bare tinned annealed copper conductor continuously in contact with aluminium side of shield. The drain wire resistance including shield shall not exceed 30 ohm/ km. Electrostatic noise rejection ratio shall be over 76 dB.
9	Colour coding	Outer sheath colour - Green Inner sheath colour - Black

All thermocouple extension cable shall be matched and calibrated in accordance with IEC-60584-2/ ANSI MC 96.1

iv. Instrument power/ control cables:

Sr. No.	Description	Particulars
1	Conductor 2 Core/ Multi-core type	7 stranded/ 0.53 mm dia (1.5 mm <sup>2</sup> ) annealed tinned copper conductors of electrolytic grade copper. The size of the conductor specified here is minimum, however; the exact size of the conductor shall be selected based on the length of cable and power consumption.
2	Insulation	Polyvinyl Chloride (PVC) as per BS 5308/ IS 1554.
3	Inner & outer sheath	PVC, fire retardant, low smoke/ low halogen, low toxic, polymeric compound.
4	Maximum DC resistance	Shall not exceed 12.3 ohms/ km at 20°C for cables with 1.5 mm <sup>2</sup> conductor
5	Core Identification	IS : 1554/ BS 6746

v. Ethernet Cables:

Sr. No.	Description	Particulars
1	Conductor	EIA/ TIA 568 A Category 5, 4 pair 0.5 mm <sup>2</sup> (24 AWG) solid conductors, with plastic foil wrapping.
2	Shield	Overall screen to consist of aluminium bonded polyester tape and tinned copper wire.
3	Colour Coding	Overall sheath shall be light grey PVC.

vi. Fibre Optic Cables:

Sr. No.	Description	Particulars
1	Conductor	62.5/ 125 micron multimode, graded index, glass silica fibre core, mechanical protection provided by round galvanized steel armour with polyester laminated tape layered over inner sheath.
2	Colour Coding	Outer sheath shall be orange HDPE conduit shall be orange colour.

- d) Any other special cables such as co-axial cable or cables with glass insulation, required for instruments shall also be supplied as per requirements.
- e) Contractor shall ensure that these cables are armoured type and shall meet all other requirements specified above, as applicable.

4.7.9. Cable Drums:

- a) Cables shall be supplied in non-returnable wooden drums. The wood used for construction of the drum shall be properly seasoned and free from defects and wood preservative shall be applied to the entire drum. All ferrous parts shall be treated with a suitable rust preventive coating to avoid rusting during transit or storage.
- b) Before winding the cables on drums, Contractor shall obtain Purchaser's approval for the drum lengths. Cable ends shall be sealed by non-hygroscopic sealing caps.
- c) Contractor has to ensure reference of an arrow and suitable accompanying wording which shall be stenciled on the sides of the drums indicating which way it should be rolled. The number on each drum shall be either branded at the end of the drum or stamped on the metal attached to an end of the drum. The cable shall be placed on

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the drum in such a manner that it will be protected from injury during transit. Each end of the cable shall be firmly and properly secured to the drum. The drum shall be securely blocked in position so that the cable will not be displaced during transit. Cable ends shall be sealed by non-hygroscopic sealing caps.

- d) It shall be the Contractor's responsibility to prepare the drum cutting schedule so that cable wastage is minimum while cutting.
- e) Contractor shall obtain Purchaser's approval for the drum lengths.
- f) The following information shall be given on the drums as a minimum:
  - i. Drum identification number
  - ii. Voltage grade
  - iii. Type of cable.
  - iv. Number of cores and cross-sectional area
  - v. Cable quantity
  - vi. Purchaser's order number and item number
  - vii. Total weight of cable and drum

4.7.10. Tests Before and After Laying of Cables at Site: Following routine & acceptance tests on each drums as per IS: 10810, IS 7098 standard & other specified relevant standards shall be performed by the manufacturer and witnessed by Purchaser/ Purchaser's Representative.

- a) For 1.1 kV Power & Control cables:
    - i. Dimensional & visual check
    - ii. Conductor resistance test
    - iii. Insulation Resistance Test
    - iv. High voltage test
  - b) For 11/ 33 kV power cables:
    - i. Design and visual check
    - ii. Conductor resistance test
    - iii. Very low frequency AC HV test (instead of DC test)
    - iv. Insulation resistance including P.I. at rated voltage
    - v. Capacitance and tan delta
    - vi. AC leakage current
-



vii. Partial discharge measurement

- c) All HV cables shall be subjected to DC or AC (preferably DC) high voltage test after terminating but before commissioning as per Table 6.0 in IS: 1255 (Code of practice for Installation & Maintenance of Power Cables up to and including 33kV).
- d) Cables shall be checked for insulation resistance before and after jointing. The voltage rating of the Megger for cables of different voltage grades shall be as indicated below.

Voltage Grade	Megger rating
1.1kV	500V
11kV	1000V
33kV	2500V

- e) Following tests in the presence of Purchaser/ Purchaser's representative shall be carried out at site before commissioning of cables.
- Insulation Resistance test between phases and phase to Neutral and phase to earth.
  - Continuity test of all the phases, neutral and earth continuity conductor.
  - Sheathing continuity test.
  - Earth resistance test of all the phases and neutral.
- f) Instrument Cable Testing: Contractor shall submit routine and Acceptance test certificates, in original at the time of delivery of cables.
- Type Test: Certificate from independent test house for the following tests shall be furnished by the Contractor for the FRLS low halogen sheathed cable.
    - ☐ Flammability Test as per IEC 60332, Part-III, Cat A.
    - ☐ Electrostatic noise Rejection test.
    - ☐ Oxygen Index, Temperature rating, light transmission, pH Index, electrical conductivity and toxicity index for the cable
  - Routine Test and Acceptance test: Each of the following tests to be carried out by Contractor during various stages of manufacturing. Purchaser shall review the related documentations. In addition, the following test shall be carried out for checking properties of low halogen FRLS sheathing material.
    - ☐ Light Emission test as per IEC-1034. Acceptance norms shall be minimum 70%
    - ☐ Determination of the degree of acidity of gases evolved during combustion as per IEC 754-2 (pH value to be minimum 4.3 and conductivity to be maximum 100 micro Siemens/cms)

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- ☐ Toxicity Index as per NES-713. Value shall not exceed 5
  - ☐ Tear Resistance as per BS 7655 Section 6.1
  - ☐ Abrasion test method as per BS 6724 Annexure E
  - iii. All above tests shall be carried in presence of Purchaser or his authorized representatives. Immediately after completion of the electrical test the ends of the cable shall be sealed to prevent ingress of moisture with suitable rubber/ PVC caps.
  - iv. Identification Marks on Instrument Signal Cables: Outer Embossing: Following embossing should be in bold fonts at outer sheath at every five (5) meter interval.
    - ☐ Type of Cable i.e., Signal Cable
    - ☐ No of Pairs i.e. 1, 2, 4, 6, 12 etc.
    - ☐ Core Size i.e. 1.0/ 1.5 sq mm etc.
    - ☐ Sequential meter marking shall be embossed at every one (1) meter interval
    - ☐ Individual pairs Embossing and identification: Core no shall be printed on each core for identification at regular interval of 250 mm or so.
    - ☐ The pair numbers shall be available on individual pair by method of polyester number tape also.
  - v. Identification marks on Instrument Control Cables: Following embossing should be in bold fonts at outer sheath at every 5 meter interval.
    - ☐ Type of Cable i.e., Control Cable
    - ☐ No of Cores i.e., 2, 5, 7, 10, 12, 24 etc.
    - ☐ Core Size i.e., 1.0/ 1.5 sq mm
    - ☐ Sequential meter marking shall be embossed at every one (1) meter interval
  - vi. Identification marks on Instrument Thermocouple Cables: Outer Embossing: Following embossing should be in bold fonts at outer sheath at every five (5) meter interval.
    - ☐ Type of Cable i.e., T/C Cable
    - ☐ No of Pairs
    - ☐ Core Size i.e., 16 AWG
    - ☐ Temperature Range
-

- ☐ Sequential meter marking shall be embossed at every 1.0 meter interval
- ☐ Individual pairs Embossing and identification: Each core of pair shall be numbered for identification at regular interval of 250 mm or so.

g) Cable Gland:

- i. Cable glands required for glanding all cables at both ends shall be supplied by Contractor.
- ii. A minimum of 20% of cable glands shall be supplied as spare.
- iii. Cable glands shall be of SS 316 and double compression type suitable for armoured cables.
- iv. All cable glands shall be weatherproof to IP-66. Flameproof glands wherever required shall be supplied with Ex (d) certification suitable for Gas Groups IIA/ IIB/ IIC.
- v. All cable glands shall be with LSF shrouds.
- vi. For all field items and junction box end, NPT threaded cable glands shall be used and for control room/ control panel end, cable glands shall be ET threaded types.

h) Junction Boxes:

- i. In order to make the most economic use of cable tray and trench capacity, multicore/ multipair cabling shall be utilised in order to connect instrumentation groups by using suitably located junction boxes.
- ii. The junction boxes shall have weather protection suitable for the area in which they are to be installed and for the type of circuit.
- iii. They shall be readily accessible for maintenance and clearly labelled.
- iv. Junction box shall be constructed of die cast aluminium/ CRCA and provide degree of protection IP 65.
- v. Wires and terminals for the digital and analog signals shall be segregated within junction boxes. For instrument auxiliary power supply, separate junctions boxes shall be provided.

4.7.11. Drawings/ Documents Required:

- a) As a part of the Bid, Contractor shall furnish the following :
  - i. General information
  - ii. Principal technical data
- b) After award of contract it shall be the responsibility of Contractor to work out a detailed layout for the complete plant cabling system. The layout drawing shall be furnished for the approval of Purchase/ Purchaser's representative before commencement of installation including cable trays, cable racks/ trenches, accessories, tray supports, conduits etc.
- c) Contractor to submit following drawings/ details after award of contract

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- i. Cable Sizing calculations
  - ii. Details of Installation of cables in trenches, on cable trays, directly buried etc at all locations inside the plant.
  - iii. Cable routing lay out inside and outside the plant with route marker provided at 30 meter interval.
  - iv. Bill of quantities of cables, lugs and glands.
  - v. HV Cable termination and mounting Kit Layout drawing.
- d) Following Type Tests reports as per relevant standard to be submitted for the same rating & type of Cables conducted in past for review of Purchaser/ Purchaser's Representative by the Contractor at the time of inspection & testing of equipment. Type test reports should be valid and not be older than the 5 years.
- i. Annealing test
  - ii. Tensile test
  - iii. Wrapping test
  - iv. Test for thickness of insulation & sheath
  - v. Physical test for insulation & sheath
  - vi. Tensile strength and elongation at break of insulation and sheath
  - vii. Loss of mass test
  - viii. Ageing in air oven
  - ix. Shrinkage test
  - x. Heat shock test
  - xi. Insulation resistance test
  - xii. High voltage test
  - xiii. Flammability test

#### 4.7.12. Cable Trays & Accessories:

- a) Cable trays shall be of Galvanized Steel/ Fiber Reinforced Plastic and of ladder/ perforated/ solid type, complete with all necessary coupler plates, elbows, tees, bends, reducers, stiffeners and other accessories and hardware as detailed in the relevant drawings. All hardware (i.e. bolts, nuts, screws, washers, etc) shall be hot dip galvanized.
- b) Cable trays of ladder and perforated types and the associated accessories such as coupler plates, tees, elbows etc., shall be fabricated from 14 gauge (2.0 mm thick) mild steel sheets. Cable tray covers shall be fabricated from 16 gauge perforated (1.60 mm thick) M.S. sheets.

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- c) The cable trays shall be supplied in standard lengths of 2500 mm and clear inside widths of trays shall be as follows:
    - i. Perforated type trays: 100, 150, 300, 450 and 600 mm.
    - ii. Ladder type trays: 150, 300, 450, 600 and 750 mm
  - d) Cable trays, accessories and covers shall be painted with one shop coat of red oxide zinc chromate primer and two site coats of aluminium alkyd paint for indoor use.
  - e) For outdoor use, cable trays, accessories and covers shall be either galvanized or made of aluminium as specifically mentioned in the layout drawings.
  - f) For use in corrosive atmospheres both indoors and outdoors, the cable trays, accessories and covers shall be as per serial no. (e) above.
  - g) The spacing of rungs for ladder type of trays shall be 250 mm unless otherwise noted.
  - h) All finished cable trays and accessories shall be free from sharp edges, corners, burrs and unevenness.

#### 4.8. EARTHING & LIGHTNING PROTECTION SYSTEM:

##### 4.8.1. Scope:

- a) The scope includes collection of data, design of the system as per relevant National/International Standards preparation of layout drawing supply of earthing conductors, earth electrode, earthing strips installation and approval to the satisfaction of electrical inspector under this tender specification.
- b) Earthing system shall be provided to ensure equipment safety, personnel safety and facilitate designed operation of protective switching during earth fault conditions in the associated system.

##### 4.8.2. Applicable Standards: The earthing and lightning protection system shall conform to the CEA regulations and the latest applicable standards indicated below:

- a) Code of Practice for Earthing : IS: 3043
- b) Code of Practice for the Protection of : IEC: 62305
- c) Building and allied structure against
- d) Lightning.
- e) Hot dip galvanizing : IS: 2629, 2633, 4759
- f) Structural steel : IS: 2062 & 808
- g) Welding : IS: 816

##### 4.8.3. Earthing & Lightning system:

- a) The design basis for designing earthing conductor is indicated under design criteria for electrical system. Earthing system shall be provided for complete plant i.e.

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pumping stations, switchyard and all electrical equipments as per the latest edition including all official amendments and revisions of IS-3043 and CEA regulations.

- b) All materials and fittings used in the earthing installation shall conform to the relevant Indian Standards or shall be approved by the Engineer's representative & CEIG.
- c) Contractor has to carry out soil resistivity test at, at least 4 locations for which locations shall be provided by Purchaser's representative. Testing to be done at each site.
- d) Soil resistivity shall be carried out by Wenner's four electrode method as described in IS: 3043. Contractor has to carry out the test in presence of Purchaser's representative & test shall be carried out keeping electrode spacing as 1, 2, 4, 6, 8, 10, 15, 25 M (each, along all 8 directions) as per normal practice and report has to be submitted. Polar curves shall be used for measurement of mean soil resistivity, which shall be used in finding earthing resistance at a particular location. Mean soil resistivity values shall be approved by Purchaser's representative.
- e) The Contractor shall base his earthing calculations on actual measurement carried out by him in the presence of Purchaser/ Purchaser's Representative.
- f) Galvanized Iron flat/ wire shall be used as earthing conductor.
- g) The conductor sizes & types shall be as per specified in the Technical schedules in Volume- II, Section A3. Contractor to note that, the sizes indicated are minimum required & earthing conductor sizes shall be approved by the Purchaser/ Purchaser's representative on the basis of adequacy calculations submitted by Contractor.
- h) The underground joints in the system shall be properly welded or brazed and the bolted type connection shall be made with structures/ equipments. Petroleum jelly shall be applied to contact surface of the bolted joints, which will be covered with bituminous compounded and tapes.
- i) Earthing conductor shall be protected against mechanical damages considering the installation conditions.
- j) The earthing system shall comprise one or more earth electrodes, earthing grid or a combination of these in order to obtain the required earth electrode resistance of less than one (1) Ohms/ or as per IEEE Std 80 -2000.
- k) For equipment earthing, two earthing leads will be used if rated voltage of the equipment is 250 volts & above and one earthing lead will be provided for equipment rated below 250 volts.
- l) The earthing conductors in outdoor areas shall be installed at a minimum depth of 600 mm below FGL.
- m) For each 11 kV DP/ FP Structure, minimum 2 nos. of CI plate type earthing electrodes shall be provided. The earth plate shall be buried in specifically prepared earth pit- 3 mtr. below ground with alternate layers of charcoal and salt, 40 NB GI pipe with funnel with a wire mesh for watering and bricks masonry block and CI Cover complete as per IS: 3043 with necessary length of double GI earth flat 25x6 mm bolted with lug to the plate complete connected to the required point of DP with end socket as per direction and duly tested by earth tester conforming to IS as per drawing and specifications complete with 600 x 600 x 6.0 mm CI earth plate.

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- n) For each transformer neutral, minimum two (2) nos. of Cu plate type earthing electrodes shall be provided. The earth plate shall be buried in specifically prepared earth pit 3 mtr. below ground with alternate layers of charcoal and salt, 40 NB GI pipe with funnel with a wire mesh for watering and bricks masonry block CI Cover complete as per IS: 3043 with necessary length of double Copper earth flat 25x6 mm bolted with lug to the plate complete connected to the transformer neutral with end socket as per direction and duly tested by earth tester conforming to IS as per drawing and specifications complete with 600 x 600 x 3.15 mm Copper earth plate.
- o) For other equipment & area, Earth electrodes shall be of heavy duty galvanized mild steel of not less than 40 mm NB and minimum 3000 mm long. Where multiple rods are used they shall be separated by a distance of not less than the driven length.
- p) Each earth electrode pipe shall be welded at the top to a mild steel plate to which the earthing strips shall be connected. These connections shall each be housed in individual inspection chamber set which shall project 100 mm above the finished ground level and shall allow disconnection for testing of individual electrodes. The chamber shall be permanently marked 'Electrical Earth'.
- q) All materials used for the earth electrode installation shall be purpose made for the application and site conditions and shall be approved by the Purchaser's Representative.
- r) All civil works, such as excavation, boring, provision of charcoal & salt in adequate quantity, backfilling for the installation of the earth electrodes and the earth pit/ inspection pit shall be in the scope of Contractor.
- s) After the earth installation has been completed the Contractor shall demonstrate to the Purchaser/ Purchaser's Representative that the resistance of the electrodes to earth and the continuity of the earth network are within the limits specified. Any additional earth electrodes and test instruments required for the tests shall be provided by the Contractor.
- t) Main Equipotential Bonding Conductor: Main equipotential bonding conductors shall be provided to connect the earth electrode system to conductive parts forming the Works.
- u) Circuit Protective Conductors: An independent circuit protective conductor shall be provided for each circuit and may comprise one or any of the following as appropriate:
- i. a separate core within a multicore cable
  - ii. A separate conductor installed within a conduit or trunking. Steel conduit or trunking shall not be used as a circuit protective conductor.
  - iii. The metal sheath of an armoured cable. The sheath shall be bonded to the metal work of the apparatus and to the apparatus earth bar, if any.
  - iv. the copper sheath of a mineral insulated copper sheathed cable
  - v. An independent earthing conductor MS or GS run adjacent to the circuit it protects.
  - vi. The size of the circuit protective conductor shall be calculated in such a manner as not to take into consideration the contribution of any other parallel or
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fortuitous earth paths.

- vii. The armouring of the supply cable shall not form the sole means of earthing a switchboard or large electrical load.

v) Instrumentation Earth:

- i. An instrumentation earth bus shall be provided in each control panel. This shall comprise a GI flat of cross section not less than 25 x 6 mm and length to suit the number of connections. It shall be mounted on at least two insulated supports and be provided with a single earth connection to the control panel electrical power earth.
- ii. If due to the physical size of a control panel more than one instrument earth bar is required the additional bar shall be connected again with a single earth connection to the same point as before on the control panel electrical earth bar. In this fashion all instrument earths shall be connected radial from the same earth point.
- iii. All signal cable screens (analogue and digital) shall be terminated on to the instrument earth bar. Signal cable screens shall be earthed at the control panel end only. Screens at the field end shall be tied back and insulated.
- iv. Surge Protector Devices (SPDs) associated with the control and instrumentation system shall be earthed to the instrument earth in accordance with the SPD manufacturer's recommendations.
- v. Separate electronic earthing system with dedicated earth pit shall be provided by the bidder for I&C equipment.

4.8.4. Important Instructions for Earthing:

- a) Each pole of lightning arrestors shall be earthed with separate earth pit.
- b) Two-earth conductor shall connect outdoor CT secondary winding to earth grid.
- c) The switchyard fencing shall be earthed at every alternate block and the switchyard gate shall be earthed with flexible GI wire.
- d) All the earthing material with laying etc. shall be included in the scope.
- e) The entire plant will have an earth grid laid in trenches/ trays/ buried in the ground outside. The main earthing grid shall be embedded at a minimum depth of 600 mm below FGL which shall be connected to earth electrodes.
- f) All interconnections of the earthing grid conductors will have welded type joints except at electrodes with disconnecting facility and at equipment with bolted connections. All indoor earthing grids will be suitably interconnected to the external earthing grid.
- g) Each steel/ RCC column of the building will be interconnected to the floor-earthing grid. Steel columns, steel strips/ conduits, cable trays etc. will not be used as earth continuity conductors.



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- h) Disconnecting type facility shall be provided between Earthing grid & each earth electrode.
  - i) All connection between the conductors shall be welded/ brazed type. Metallic pipe, conduit, structures shall be bonded to lightning protection conductors to prevent the side flashover. But no metallic pipe, conduit, structure shall be used as air termination conductor or down conductor.
  - j) The down conductors shall be fixed with embedded brass posts (on concrete columns) with nuts & bolts used for fixing the saddle/ clamp (direct drilling of down comer and fixing with screw shall not be acceptable).
  - k) Cleats for 'earthing and lightning protection systems' shall be of GI.
  - l) The lightning protective conductor shall not be connected with the earthing above ground however both the systems shall be interconnected below ground.
  - m) The earth pits may require boring & drilling in the soil & the same shall be considered in Contractor's scope.
  - n) Earth electrode with disconnecting facility shall be provided so that the resistance of the independent earth electrode may be measured.
  - o) Internal earth Bus of each panel shall be connected to both ends to the earthing system by means of earthing conductor.
  - p) Metallic frames of all current carrying equipment, structures supporting and adjacent to current carrying conductors, lightning protection system conductors, metallic structures, metallic stairs, hand rails, fences shall be connected to a single earthing system. Neutral points of various systems shall be connected to the dedicated treated earth pits and these earth pits shall be interconnected to each other below ground.
  - q) All connections in the equipment earth conductors buried in ground (or otherwise) shall be cad welded/ brazed, whereas connection at equipment end shall be of bolted type. All connections shall be of low resistance. All bimetallic connection shall be treated with suitable compound to prevent moisture ingress. For Bimetallic bolted connection, bimetallic washers shall be used. All bolted joints shall have minimum two bolts to ensure proper surface contact. Termination of stranded conductors at earth inserts shall be with ring type/ lugs.
  - r) Galvanized conductors shall be touched up with zinc-rich paint where holes are drilled at site for bolting to equipment/structure.
  - s) Suitable earth risers approved by the Engineer shall be provided above finished floor/ ground level, if the equipment is not available at the time of laying of the main earth conductor. The minimum length of such risers inside the building shall be 200 mm and outdoor shall be 500 mm above ground level.
  - t) Metallic conduits and pipes shall be connected to the earthing system unless specified otherwise.
  - u) All cable trays will be earthed at minimum two places by suitable sized GI flats to main earthing system earth conductor. The cable trays shall also be earthed at a regular interval of not more than 10 meters by 25 x 3 mm GS flat

v) Earthing Pits:

- i. Adequate number of earthing pits shall be provided in conjunction with earthing grid for the earthing system. The minimum spacing between two adjacent earthing pits shall not be less than length of the electrode (minimum 3 m) and shall be kept 1500 mm away from footings of the structure.
- ii. Earthing pits shall be located in ground, which has a reasonable chance of remaining moist. Arrangement comprising of GI pipe with top funnel with wire mesh shall be made to facilitate pouring of water to keep earthing pit wet.
- iii. A galvanized iron strip of adequate size (as per calculations) shall be provided from plate electrode to about ground level to facilitate jointing with earth conductors. Each earth electrode ending at the pit shall be connected to suitable linking strips to connect and disconnect the earthing suitably.
- iv. Earthing chamber shall be of RCC/ brick chamber of 600 mm x 600 mm, with removable 6 mm thick MS chequered plates. The covers shall have holes for handling. Earthing pits (chambers) shall be painted Green and the earth-pit number shall be marked on it.
- v. Earthing cables crossing other metallic structures such as conduits pipelines etc shall be minimum 300 mm away from such structures.
- vi. Earthing conductors shall be protected against mechanical damage.
- vii. All earth lead connections shall be as short and direct as possible and shall be without kink.
- viii. The main earth loop in plant area shall be generally routed along cables. When equipments are located away from main earth loops, suitable sub-loops shall be run up to them for deriving connections for individual equipment. The entire earthing system shall fully comply with the CEA regulations and requirements.
- ix. The Contractor shall have to carry out any changes as desired by the Electrical inspector or the Engineer in charge, in order to make installation conforming to the CEA regulations 2010.

4.8.5. Lightning Protection:

- a) The lightning protection system need will be established by calculating the risk factor value of each building, structure etc. as per procedure given in IEC 62305 and if found necessary the same shall be provided by the Contractor.
- b) For Lightning protection of Civil Structures including RCC Buildings, fixing of 25x6 mm GI earth strip to roof as per IS/ IEC std, saddle clamp, down comer connector etc. as required with all hardware shall be in Contractor's scope. Structural Columns (which are used as down comers for lightning protection system) bottom shall be connected to the earth pit with 25x6 mm bare GI strip.
- c) Air termination ESE type ( ISO: 9001 Certified, Tested in CPRI) shall also be acceptable. The air terminal shall be made of non corrosive material. It shall be equipped with a central rod made of copper alloy or stainless steel.

#### 4.8.6. Galvanizing:

- a) Wherever galvanizing has been specified, the hot dip process shall be used. The galvanized coating shall be of uniform thickness. Weight of Zinc coatings for various applications shall not be less than those indicated below

<b><u>Fabricated Steel</u></b>	
i. Thickness less than 2 mm, but not less than 1.2 mm	340 gm/ sq.m
ii. Thickness less than 5 mm, but not less than 2 mm	460 gm/ sq.m
iii. Thickness 5 mm and over	610 gm/ sq.m
<b><u>Fasteners</u></b>	
i. Up to nominal size M10	270 gm/ sq.m
ii. Over M10	300 gm/ sq.m

- b) Burrs shall be removed before galvanizing. Any site modification of galvanized parts should be covered well by zinc rich primer and aluminium paint.
- c) Contractor shall ensure to use calibrated test equipment having valid calibration test certificates from standard laboratories traceable to National Standards.

#### 4.8.7. Drawings/ Documents Required:

The Contractor should prepare layout drawings, after award of contract and before commencement of work for Purchaser's approval, showing the location of earthing grid, electrodes, interconnection grids and earthing leads to various equipment, down comers, isolating links etc. should be accompanied by design calculations.

#### 4.9. LIGHTING & VENTILATION SYSTEM:

##### 4.9.1. Scope

- a) The scope of the Contractor shall include design, supply and installation of all equipment necessary for a complete lighting and receptacle system. The lighting system includes Lighting fixtures (indoor/ outdoor), lamps, lighting panels (LP), switchboards, Receptacles, JB's, cables/ wires for lighting/ receptacles, conduits etc. The supply of street light/ flood light poles as per IS 2713 or IS 3713 is also included in the Contractor's scope.
- b) The various types of lighting fixtures as per specified in this specifications shall be assembled, installed, tested & commissioned by the Contractor. LED luminaires shall be used for internal & outdoor lighting. Luminaires shall be installed to permit ease of maintenance. The Contractor shall provide all equipment necessary to carry out maintenance on the lighting installation and demonstrate its operation to the satisfaction of the Engineer.
- c) It shall be the responsibility of the Contractor to work out complete detailed requirement of lighting and receptacle system for the whole plant and staff quarters including area lighting as per specification and accordingly procure and install them.

##### 4.9.2. General Requirements: The Lighting system includes following items.

- a) Lighting fixtures complete with Lamps and accessories

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- b) Lighting system equipment
  - c) Light control switches, receptacle units with control switch units, lighting wires, conduits, earth wires and other similar items necessary to complete lighting system.
  - d) Lighting fixture supports, street lighting poles and flood light towers/ poles.
  - e) Lighting main distribution board, lighting panels
  - f) Multi core cables for street, boundary and flood lighting

4.9.3. Lighting Layout:

- a) It shall be the responsibility of the Contractor to work out a detailed layout for the complete plant in order to provide the levels of illumination as indicated in the relevant standards
  - b) The types of fixtures to be used in various areas are also indicated in the above mentioned drawing. The Contractor shall be responsible for measuring the levels of illumination and uniformity after installation and establish compliance with the specification.
  - c) The lighting system will comprise the following:
    - i. Normal A.C Lighting: Normal lighting in all indoor and outdoor areas will be operated on 230V, 1Phase, 50 HZ A.C supply
    - ii. Emergency Lighting: Emergency Lighting shall be designed such that at all junctions, exit passages & strategic locations, lux level shall be maintained above 10 Lux. Emergency light fitting shall be 240 V self contained 2 x 9/ 11 W LED with built in Ni-Cd battery having charging facility and six hours back-up time. The emergency light fittings shall be provided at strategic locations of each area including pump house, electrical switchgear rooms & control room etc. Emergency fixtures shall come in service when AC supply fails.
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4.9.4. Applicable Standards: The design, manufacture and performance of equipment shall conform to the latest standards specified below. In case of conflict between the standards and this specification, this specification shall govern.

a) Lighting Fixtures & Accessories

Electrical lighting fittings general and safety requirements : IS: 1913/ BS: 4533

Code of practice for industrial lighting : IS: 6665

Code of Practice for Interior Illumination : IS 3646

Code of Practice for Lighting of Public Thoroughfares : IS 1944

Calculation of co-efficient of utilization : IS: 3646 (Part - III)

Industrial lighting fittings with metal Reflectors : IS: 1777

Decorative lighting fittings : IS: 5077

Dust proof electric lighting fittings : IS: 4012

Dust tight electric lighting fittings : IS: 4013

Flood lights : IS: 10322/ BS: 4533

Luminaries for street lighting : IS: 10322 Part 5

Water tight electric lighting fittings : IS: 3553/ BS: 4533, 5225(I)

General lighting LED and LED Modules : IS 16101, IS 16103 (Part-1 &2)

Self ballast LED lamps for general lighting services : IS 16102 (Part-1 & 2)

Safety of lamp control gear : IS 15885 (Part-2/ sec-13)

DC or AC supplied electronic control gear for LED modules : IS 16104

Ballast for use in fluorescent lighting fittings : IS: 1534 (Part 1)

Method of measurement of lumen maintenance of solid state light (LED) sources : IS 16105

Method of electrical and photometric measurements of solid state light (LED) products : IS 16106

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Luminaries performance : IS 16107 (Part 1 &2)

Photo biological safety of lamps and lamp system : IS 16108

Emergency lighting units : IS: 9583

Ignition proof enclosures, dust-tight for elect. equipment : IS: 11005

Luminaries : IS: 10322 (Part I to V)

b) Lighting System Equipment: :

Arrangement for busbars, main connections and auxiliary wiring and marking : IS: 5578/ 11353/ BS: 159

Enclosed distribution fuse boards and cutouts for voltages not exceeding : IS: 2675/ BSEN 60439

General requirements for switchgear and control gear for voltages not exceeding 1000 V : IS: 13947

Code of practice - installation and maintenance of switchgear : IS: 10118/ BS: 6423, BS 6626, BS 6867

Factory built assemblies of switchgear and control gear for voltages up to and including 1000 V AC and 1200 V DC : IS: 8623/ BS-5486/ IEC: 439

Miniature air break circuit breakers for AC circuits : IS: 8828/ BSEN 60898

HRC cartridge fuse links up to 650 V : IS: 9224/ BS: 88/ IEC: 269

Electric ceiling type fans & regulator : IS 374

Current transformers : IS: 2705/ BS: 7626/ IEC: 185

Voltage transformers : IS: 3156/ BS: 7625/ IEC: 186

Direct acting electrical indicating Instruments : IS: 1248/ BS: 89/ IEC: 51

A.C. electricity meters : IS: 722/ BS 5685

Electrical relays for power system protection : IS: 3231/ BS: 142/ IEC: 255

Switches for domestic and similar purposes : IS: 3854/ BS: 3676

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Code of practice for electrical wiring installation (system voltage not exceeding 650 Volts)	: IS 732
Three pin plugs and socket outlets	: IS: 1293/ BS: 546
Boxes for enc Switches for domestic and similar purposes.	: IS: 3854/ BS: 3676
Enclosure of electrical accessories	: IS: 5133(1)
Rigid steel conduits for electrical wiring	: IS: 9537/ BS: 31
Accessories for rigid steel conduits for electrical wiring	: IS: 3837/ BS-31
Fittings for rigid steel conduits for electrical wiring	: IS: 2667
Flexible steel conduits for electrical wiring	: IS: 3480
Rigid non-metallic conduits for electrical installations	: IS: 9537/ BS: 4607(2)
Fittings for rigid non-metallic conduits	: IS: 3419/ BS: 4607(2)
PVC insulated cables for working voltages up to and including 1100 V	: IS: 694
Tubular steel poles	: IS: 2713
Specification for copper rods and bars for electrical purposes	: IS: 613
Code of practice for phosphate iron and steel	: IS: 6005/ BS: 3189
National Building Code of India (NBC)	: NBC 2005

#### 4.9.5. Other Design considerations for Lighting:

- a) Lighting panels shall be provided in various areas and circuit wiring to the lighting fixtures shall be made from lighting panels. Lighting panel shall comprise of Four pole MCB + RCCB (100 mA) for incomer and SP MCB's for each outgoing single phase circuits.
- b) The wiring for lighting circuits in indoor areas will be done by wires run in GI conduits. For outdoor lighting, wiring will be done by using armoured cables.
- c) Lighting cable from Main lighting DB (MLDB) to Lighting panels for indoor/ outdoor area lighting shall be Al/ Cu conductor, 1.1kV grade XLPE/ PVC insulated, laid in cable trays/ directly buried in ground/ cleated along the wall/ column/ beam.

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- d) For lighting fixtures (Pump room) 1.1 kV grade, 4C x 2.5 sq. mm. 1.1kV grade XLPE/ PVC insulated, multistranded copper conductor armoured/ unarmoured cables shall be used.
  - e) For lighting fixtures (for office, electrical room, toilets etc. areas) 1.1 kV grade, PVC insulated, multi-stranded Copper conductor wires of size not less than 1.5 sq mm laid in minimum 20 mm dia GI conduit (above false ceiling) shall be used.
  - f) For 6/ 16A decorative sockets (for office, toilets etc. areas) 1.1 kV grade PVC insulated, multi-stranded copper conductor wires of size not less than 2.5/ 4.0 sq. mm. Cu laid in minimum 20 mm dia. GI conduit shall be used.
  - g) Wiring shall be concealed in wall below false ceiling with concealed switch board. Minor civil work like chasing wall, cut outs for conduit, switch board, Lighting Panel in wall, entries for tray, conduits etc. is included in the scope.
  - h) The point wiring for lighting/ receptacle/ exhaust fan/ wall mounted fan/ ceiling fan shall include conduits, conduit accessories, FRLS PVC insulated multistranded Copper conductor wires and earthing wires, pull boxes, ceiling rose, clamps, cleats, hardware, accessories, anchor fasteners etc. It shall include wiring from lighting panel to switchboard and receptacles & switchboard to lighting fixtures. Sheet metal switchboard embedded in wall shall be considered for receptacles and lighting switchboards on wall shall be considered for lighting.
  - i) For power sockets in wall/ furniture, PVC switch box of approved make with switch plate & accessories and 16 Amp piano modular switches and 6/ 16A sockets etc. as applicable shall be considered. For all types of point wiring the receptacles with switches shall be included in the point wiring rate.
  - j) Lighting switchboard consisting of (\*) no. of 6A piano switch without indicator, 1 no. 6A piano switch with indicator, 1 no. white coloured cover plate for (\*) module ( 4/ 6/ 8/ 12 module), 1no. 2/ 3 pin shuttered socket of 6/ 16A and metal flush box.
  - k) Decorative socket switchboard consisting of (\*) no. of 16A piano switch with indicator, (\*) no. 2/ 3 pin shuttered socket of 6/ 16A and metal flush box, 1 no. white coloured cover plate for (\*) module ( 4/ 6/ 8/ 12 module).
  - l) Lighting fixtures and fans will be grouped on the circuit wherever required. However, separate circuits shall be used for receptacles wiring.
  - m) Lighting Control Philosophy as per mentioned below shall be observed. From each switch –
    - i. Max. 2 (3 in case unavoidable) compact fluorescent/ LED luminaries (2x36W)
    - ii. Max. 4 (5 in case unavoidable) down lighters luminaries (2x18W)
  - n) All high, medium & low bay including street light fixtures shall be controlled directly from respective Lighting Panels, through MCB.
  - o) Each lighting panel/ Receptacle DB shall have minimum 2 spare circuits of 10/ 16A SPN outgoing feeders. A circuit consists of R, Y and B Phase each.



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- p) Lighting for staircase shall be controlled with flushed modular switch. The conduit for main staircase shall be concealed. Lighting for all staircases shall be with 2 way switch
- q) Contractor shall note that any chasing in walls or cutouts or openings such as fixing of LPs, DBs, switchboards, concealing conduit in wall etc. in walls required shall be made before plastering of brickwork wherever applicable and installation rates quoted shall be inclusive of chasing, cutting & making the plaster as per standard practice.
- r) Lighting for street light fixtures/ flood light fixtures and metal halide fixtures shall be carried out with cables. The supply of cables, junction boxes, street light poles & structural steel required for mounting fixtures/ LPs etc. are in the scope of Contractor. The cable wiring shall include supply & installation of cable required from LP to the junction box mounted on street lighting pole/ near indoor fixture and also between junction box mounted inside pole/ near indoor fixture to control gear box and same for flood lighting, supply and installation of all termination accessories such as lugs, cable glands etc. Contractor's scope shall also include excavation, preparation of soil bedding, supply and installation of protection cover, back-filling, supply and installation of cable route markers etc.
- s) Point Wiring for lighting/ raw power receptacle/ emergency lighting:
- i. Point wiring covers the wiring between a circuit of the lighting panel to switchboard and then from switchboard to lighting fixtures connected to that circuit of the lighting panel.
  - ii. For receptacle circuits point wiring shall cover wiring between circuits of the lighting panel to receptacles connected to that circuit of the lighting panel.
  - iii. The scope of the Contractor shall include the supply, erection, testing and commissioning of the above LPs/ DB boards for supply of power to the various sockets required for computers, raw power points etc. The point wiring rate from these DBs shall include supply of wires, conduits, cleats/ clamps etc. as may be required and shall be in the scope of electrical Contractor.
  - iv. The conduit point wiring rate for exhaust fan shall include conduits/ casing capping, conduit/ casing capping accessories, Switch boards, PVC insulated wires and earthing wires, pull boxes, ceiling rose, clamps, cleats, hardware, sheet metal switchboards fabricated out of 16 SWG. sheet steel housing 5 Amp piano switches. It shall include wiring from EXHAUST FAN DB/ RDB to switchboard & switchboard to exhaust fan as applicable. Neutral for individual circuit shall be run separate from DB to individual receptacles.
  - v. All mounting accessories like base channels, cross angles if required, nuts, bolts etc. shall be supplied by the Contractor under the scope of this contract.
  - vi. Required no. of 1-Ph & 3-Ph, industrial receptacles with respective 2P/ 4P ELCB (30mA) & 3/ 5 pin plug shall be provided for maintenance purpose.
  - vii. Receptacle & its ELCB shall be mounted in prefabricated CRCA box of 16 SWG, epoxy painted with shade 631 of IS-5. Earthing studs shall be provided for connecting external earthing with receptacle box.
  - viii. The Configuration of Industrial receptacle units shall be as per following – Combination
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- 240V, 1-Ph, 50Hz, 3 pin, 16A Industrial receptacles with RCBO (30mA).
- 415V, 3-Ph, 50Hz, 32/ 63A Industrial receptacles with respective RCBO (30mA).

t) Lighting Fixtures and Accessories:

i. General

Normal supply voltage, phase and frequency		240 V, 1 ph, 2 wire, 50 Hz,
Variation in supply		
Voltage (AC & DC)		±10
Frequency		±5
Combined voltage & frequency		±10
Design ambient air temperature		50°C

- ii. The Luminaries shall be designed so as to facilitate easy maintenance, including cleaning, replacement of lamps/ starters etc.
- iii. Connections between different components shall be made in such a way that they will not work loose by small vibration.
- iv. For each type of Luminaries the Contractor shall furnish the utilization factor tables to indicate the proportion of the light emitted by the bare lamps which falls on the working plane.
- v. All Luminaries shall be supplied complete with lamps suitable for operation on a supply voltage and the variation in supply voltage, frequency and combined voltage and frequency of ±10%, ±5% and ±10% respectively.
- vi. The Luminaries and accessories shall be designed to have low temperature rise. The temperature rise above the ambient temperature shall be as indicated in the relevant Standards.
- vii. Contractor to provide comprehensive technical details of the luminaries and the lamps being offered. The details must be sufficient to take in to consideration maximizing of energy efficiency and minimizing overall shop power consumption.
- viii. In Crane bays, lighting fixtures shall be mounted with the minimum 500 mm clearances above overhead crane clearance level as asked by Crane Manufacturer.
- ix. All the outdoor purpose luminaries including Street light luminaries shall be with ingress protection of IP 65 minimum.
- x. In case of Hazardous areas, if any- Flame proof luminaries (complete with suitable lamp & accessories) in line with the requirements of IS 5572 shall be provided by the Contractor.

- xi. Each luminaries shall have a terminal block suitable for loop-in, loop-out and T-off connection by 230/ 415V, 1 core, FRLS PVC insulated copper conductor wires up to 4 sq. mm in size. In outdoor areas the termination at the luminaries shall be suitable for 1100V, PVC insulated, Cu/ Al conductor, armoured cables of sizes up to 6/ 16 sq. mm conductor. Terminals shall be of stud or clamp type. The internal wiring should be completed by means of stranded Copper wire of minimum 1 sq. mm size and terminated on the terminal block. Terminal blocks shall be mounted with minimum two fixing screws.
- xii. Mounting facility and conduit knock-outs for the luminaries shall be provided.

u) Earthing

- i. Each luminary shall be provided with an earthing terminal suitable for connection to the earthing conductor of 12 SWG GI wire.
- ii. Where separate control gear box is provided for housing the accessories the same shall be provided with an earthing terminal suitable for connecting earthing conductor of 12 SWG GI wire.
- iii. All metal or metal enclosed parts of the luminaries/ control gear box shall be bonded and connected to the earthing terminal so as to ensure satisfactory earthing continuity.

v) Painting/ Finish:

- i. All surfaces of the luminaries/ control gear box housing accessories shall be thoroughly cleaned and degreased. It shall be free from scale, rust, sharp edges and burrs.
- ii. When enamel finish is specified, it shall have a minimum thickness of 2 mils for outside surface and 1.5 mils for inside surface. The finish shall be non-porous and free from blemishes, blisters and fading.
- iii. The luminaire housing shall be stove-enameled/ epoxy stove-enameled-vitreous enameled or anodized as indicated under various types of fittings.
- iv. The surface shall be scratch resistant and shall show no sign of cracking or flaking when bent through 90° over 1/2" dia. mandrel.
- v. The finish of the luminaries shall be such that no bright spots are produced either by direct light source or by reflection.
- vi. External control gear box provided for housing accessories shall be painted or galvanized.

4.9.6. Surface Mounted Luminaries:

- a) The luminaries shall be provided with CRCA sheet steel mounting rail with reflector of minimum 20 SWG thicknesses and complete with all control accessories mounted on it. The finish shall be vitreous enameled.
- b) Luminaries mounted recessed in false ceiling shall be with reflector housing and spring loaded fixing arrangement for the diffuser/ louver frame. It shall be possible to have access to the lamp and other accessories from below.

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- c) Luminaries shall be suitable for the number of lamps of specified wattage, direct mounting on ceiling/ wall/ column/ pendent mounting.
  - d) The distribution of light shall be such that at least 80% of the total luminous flux from the luminaries shall be in the lower hemisphere.
  - e) The luminous output of the luminaries with reflector shall not be less than 75% irrespective of type of reflector used.

4.9.7. High, Medium and Low Bay Luminaries:

- a) Luminaries selection on the basis of height shall be generally selected considering following height criteria-
  - i. High Bay for mounting heights above 9 meter
  - ii. Medium Bay for mounting heights from 6 m to 9m
  - iii. Low Bay for mounting heights below 6 meter
- b) High and medium bay luminaries shall be with cast aluminium/ stove enameled housing, anodized aluminium mirror polished reflector, canopy with eye bolt for suspension, cooling fins. Glass cover shall be provided. The luminaries shall be suitable for required wattage as per design criteria. The control gear accessories shall be mounted integral with the luminaries.
- c) Low bay luminaries may be with sheet steel/ cast aluminium enclosure, wide angle distribution type polished reflector, acrylic cover and wire guard complete with neoprene gaskets, mounting bracket etc. The luminaries shall be suitable for required wattage as per design criteria. The control gear accessories shall be mounted integral with the luminaries.

4.9.8. Well glass luminaries:

Well glass luminaries shall be robust construction, cast aluminium/ vitreous enameled housing, clear heat and shock resistant glass cover fixed with neoprene gaskets for sealing. For mechanical protection to the glass cover, round steel wire – guard with vitreous enameled finish shall be provided. Additional heavy gauge vitreous enamel reflector shall be provided. The luminaries of required wattage as per design basis shall be suitable for suspension mounting by conduit pipe.

Luminaries shall be with degree of protection IP- 54 generally used indoor.

4.9.9. Flood Light Luminaries: General purpose flood light luminaries:

- a) Flood light luminaries shall be of weather proof construction with cast aluminium housing, anodised aluminium mirror polished reflector, heat resistant, toughened glass cover and necessary neoprene gaskets to prevent ingress of dust.
- b) The housing shall be supported on a cast iron base and capable of being swiveled in both horizontal and vertical directions and locked in any desired position.
- c) For focusing purposes, knobs, shall be provided along with sector plate indicating the angle in degrees between 0 and 90° in vertical direction.

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- d) The Luminaries shall be suitable for 150/ 250/ 300 watts etc. as required. The same shall be mounted in a separate sheet metal enclosed/ cast aluminium weather proof control gear box.
  - e) The luminaries shall be provided with cable gland on the canopy in down ward direction for cable connection.
  - f) It shall be possible to adjust the lamp position to achieve wide beam, medium beam or narrow beam.

#### 4.9.10. Outdoor/ Street Lighting Luminaries:

- a) Street Light Luminaries: LED
  - (i) The luminaires shall have a sturdy and corrosion resistant high pressure Die cast Aluminium housing with weatherproof gasket for lamp and control gear accessories. The Housing shall be Epoxy coated, without any cracks or thorough holes, made in a single piece of die-cast LM6 aluminium alloy. The luminaries shall be totally enclosed, dust tight and water proof.
  - (ii) Heat sink used should be aluminium extrusion having high conductivity. The dimensions of luminaries shall be optimum and adequate to permit sufficient heat dissipation, through the body itself, so as to prevent abnormal temperature rise inside the lantern and consequential damage to the cover and gasket materials, LEDs, lenses and electronic drivers. Heat sink must be thermally connected to MCPCB/ LED light source. Chip on Board (COB) LEDs are not accepted as there is extremely high per square inch heat generation and the heat sink is too small to take this heat out.
  - (iii) The luminaire housing shall be suitable for termination of Cable with Double Compression Cable Glands
  - (iv) The optical system shall consists of individual PC lenses on high power LEDs designed & tested to achieve typical street lighting distribution from the LED lantern. These lenses provided for individual LEDs are to be fixed on lens plate in order to have consistent light distribution from luminaires. Luminaires should conform to the photometric Distribution/ requirements of Cut-Off/ Semi Cut – off light distribution and optics as classified in IS 1944.
  - (v) The luminaires shall be provided with high tensile heat resistant toughened glass of minimum 0.8mm thickness or UV resistant polycarbonate cover fixed with stainless steel screws.
  - (vi) An extruded silicon loop gasket shall be provided in the lantern body to ensure a weather proof seal between the cover and the metal housing to exclude the entry of dust, water, insects, etc. Luminaire should conform to degree of protection of IP 65 or above. Full glass luminaire is not accepted as toggles/ clamps are used which will compromise the IP of the luminaire.
  - (vii) Year of Manufacture, Batch No., Serial Number or Identification No., Luminaire Manufacturer's Name/ Logo, Wattage and Frequency should be embossed on the housing.

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- (viii) The luminaires, should conform to the various National/ International standards for safety & performance. Manufacturer should provide test reports as per LM 79 & LM80. Lumen maintenance report as per LM 80 guidelines shall be submitted for the LEDs used. In case of luminaires are imported, the BIDDER shall conform to test parameters as per UL or equivalent standards.
  - (ix) The electrical component of the LED and LED driver must be suitably enclosed in sealed unit to function in environment conditions mentioned earlier. It shall not be acceptable where single luminaire is split into two parts and driven by double drivers.
  - (x) All the connecting wires inside the Luminaire shall be low smoke halogen free, fire retardant cable.
  - (xi) Adequate protection against Overloading, Short Circuit, Over Voltage, Over temperature, Under Voltage, String Open shall be provided within the luminaire.
  - (xii) Design of the thermal management shall be done in such a way that it shall not affect the properties of the diffuser.
  - (xiii) The equipment should be compliant to IEC 60598-1, IEC 62031 and IEC/ PAS 62612 depending on the type of luminary.
  - (xiv) All the material used in the luminaries shall not contain any toxic material/ metal like mercury; shall be halogen free and fire retardant confirming to relevant standards.
  - (xv) The Manufacturer shall have all the relevant testing facilities certified by an accredited laboratory and shall be offered for inspection to the PURCHASER for verification of the required parameters and tests. BIDDER shall confirm the same in the BID.
  - (xvi) The control gear shall comply with the provisions of IEC 61347-2-13, IEC 62031 and IEC 62384 as appropriate.

b) Post Top Lantern: LED

- i. Post top lantern luminaries shall be generally outdoor weather proof type for illumination of walkways, gate posts, gardens etc.
- ii. The luminaries shall have cast aluminium spigot finished with corrosion proof paint for mounting, opal acrylic or high density polyethylene (HDP) diffuser bowl, complete with integral mounted control gear, neoprene gaskets, earthing terminal etc.
- iii. The luminaire shall be suitable for 15/ 18W.

c) Bollard Luminaries: LED

- i. Bollard luminaries shall be outdoor, weather proof type for illumination of lawns, gardens, pathways etc.
  - ii. The luminaries shall be of FRP housing, clear acrylic cover, louvers for directing light downwards and bottom cable entry.
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iii. The luminaries shall be suitable for 6/ 9W

4.9.11. Technical Particulars – LED Luminaire complete with all accessories.

Sr. No.	Description	Particulars
1.	Type	LED Luminaries
2.	Rated Voltage	230 V
3.	Expected Frequency	50 Hz +/- 3%
4.	Operating Voltage Range	150 V to 270 V
5.	Power Factor	> 0.95
6.	Operating Temperature Range	0 Deg C to 50 Deg C
7.	Working Humidity	10% - 90% RH
8.	Driver Type	Constant Current based Electronic Driver
9.	Driver Efficiency	> 92%
10.	Driver Life	>20000 hrs.
11.	Protection required in Driver module	
a.	Short Circuit	Yes
b.	Over Voltage	Yes
c.	Over Temperature	Yes
d.	Under Voltage	Yes
e.	String Open Protection	Yes
12.	Luminaire IP Protection	Minimum IP 65 for Outdoor Fixtures
13.	Minimum Surge Protection	>4 KV
14.	THD	≤10%
15.	Rated Minimum LED Life (L70)	50000 Burning Hours
16.	Rated Minimum Driver Life	20000 Burning Hours
17.	CRI	>75
18.	Junction temperature rise	< 85 Deg C
19.	Solder point temperature	< 70 Deg C
20.	Maximum temperature rise for Driver	<30 Deg C at 45 Deg C ambient
21.	Make of LED	Cree/ Nichia/ Philips/ Osram/ Equivalent make as approved by Purchaser
22.	Make of Driver	Cree/ Nichia/ Philips/ Osram/ Equivalent make as approved by Purchaser
23.	Operating Hours	Dusk to Dawn (max 12 Hrs.)

24.	Efficacy of Luminaries	>110 lm/W
25.	Colour Temperature	5500K - 6500K
26.	Illumination Regulation	<5%
27.	Material used for following	
a.	Housing	Die cast aluminium/ extruded Aluminium body with powder coated finish
b.	Heat Sink	Aluminium extrusion
c.	Clip/ Fastners	Stainless steel.
d.	Diffuser	Toughened glass (0.8mm thick)/ UV stabilized Poly carbonate material
28.	Maximum temperature of Heat sink	<70 Deg C
29.	IK protection of Optic Cover	>IK05
30.	Wires used Inside Luminaries	Cu conductor, low smoke halogen free, fire retardant e-beam cable
31.	Cable gland IP protection	IP 65
32.	Scotopic to Photopic Ratio	>2.15

#### 4.9.12. High Mast Flood Light/ Flood Light Towers (where applicable):

- a) High mast shall be outdoor weather proof type for illumination of main roads and area lighting, wherever found necessary.
- b) The high mast shall be continually tapered, polygon cross section, telescopically jointed steel fabricated construction. The mast shall be hot dip galvanized internally and externally. Weather proof door shall be provided near the base to permit access to winch, cables, plug, socket etc. The mast shall be designed for wind speeds depending upon wind pressure and direction as per relevant Indian Standards. Foundation bolts shall be included in the scope of supply.
- c) The moving platform shall be of steel construction hot dip galvanized and designed to hold the number of flood light luminaires specified. The control gear boxes shall be cast aluminium weather proof type mounted on the moving platform. The moving platform shall be raised or lowered with the help of winch, pulley system and stainless steel wire ropes. The winch shall be suitable for hand operation or alternate by electric power.
- d) The mast shall be suitable for mounting numbers of luminaires as required. The standard mast heights are generally from 16 to 30 meters.

#### 4.9.13. Galvanized Octagonal Poles

- a) All the Poles shall be designed to withstand the maximum wind speed as per IS 875. The top loading .i.e. area and the weight of fixtures are to be considered to calculate maximum deflection of the pole and the same shall meet the requirement of BSEN 40-3:2000, pr EN- 40-3-3.



- b) All pole shafts shall be provided with the rigid flange plate of suitable thickness with provision for fixing foundation bolts. This base plate shall be fillet welded to the pole shaft at two locations i.e., from inside and outside.
- c) The pole shall be adequately strengthened at the location of the door to compensate for the loss in section.
- d) Aesthetic appearance - All the grooves and carvings of the pole unit shall be free from any kind of distortion for a pleasing aesthetic appearance.
- e) The poles and bracket shall be hot dip galvanized as per IS: 2629/ IS: 2633/ IS: 4759 standard with average coating thickness of 75 micron. The galvanizing shall be done in single dipping.
- f) Top Mountings -The galvanized mounting bracket shall be supplied along with the Poles for Installation of the luminaries.
- g) The pole manufacturing & galvanizing unit shall be ISO 9001: 2000 & ISO 14001 certified to ensure consistent quality & environmental protection.
- h) Electrical connections - Four way connectors shall be provided along with Slide lock suitable for connecting 1.1 kV grade, 4 core Al cable. It shall also in house 1 no. 6 amps DP MCB, 2.5 mm<sup>2</sup> connectors for looping with 2.5 mm<sup>2</sup> Copper wires for connecting to the luminaire through 1.1 kV grade, 3 core x 2.5 mm<sup>2</sup> PVC insulated copper conductor flexible un-armoured cable from the terminal block to the fixture within the pole. All the cables laid through the pipe shall be without any joint.
- i) Two nos. Earth Boss shall be provided at the bottom of the pole (diagonally opposite) suitable for connecting 25 x 6 mm GI earth strip or 6SWG GI wire for earthing of the poles.
- j) Two nos. 50 mm NB HDPE Sleeves of suitable length shall be provided through the foundation up to the Junction Box for entry of power cable.

#### 4.9.14. Emergency Light Luminaries:

- a) Emergency light fitting shall be 240 V self contained 2 x 9/ 11 W compact fluorescent tube/ LED with built in Ni-Cd battery having charging facility and six hours back-up time. The emergency light fittings shall be provided at strategic locations of each house/ area.
- b) Emergency fixtures shall come in service when AC supply fails.
- c) Pump room, electrical switchgear & control room shall be considered for emergency lighting.
- d) In addition to above emergency fixtures, every pump station shall be provided with two nos. of portable emergency luminary, which shall be with CRCA sheet steel enclosure, complete with metalized mirror reflector, leak proof re-chargeable battery rated for two hour discharge, battery charger, charger-on lamp, push button switches, automatic changeover switch/ relay, two meter length cord with plug, mounting pads and other accessories required for satisfactory operation of the luminaries.
- e) The luminaries shall be suitable for connection to 240V, 50 Hz single phase supply with 9/ 11 W CFL/ LED. On failure of normal AC supply the luminary shall start

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automatically and on restoration of AC supply the luminary shall switch off automatically.

#### 4.9.15. Accessories for Luminaries:

##### a) Reflectors

- i. The reflectors shall be made of CRCA sheet steel/ aluminium/ silvered glass/ chromium plated sheet copper as indicated for above mentioned luminaries.
- ii. The thickness of steel/ aluminium shall comply with relevant standards. Reflectors made of steel shall have vitreous enameled finish. Aluminum used for reflectors shall be anodized/ epoxy stove enameled/ mirror polished. The finish for the reflector shall be as indicated for above mentioned fittings.
- iii. Reflectors shall be free from scratches or blisters and shall have a smooth and glossy surface having an optimum light reflecting coefficient so as to ensure the overall light output specified by the Contractor.
- iv. Reflectors shall be readily removable from the housing for cleaning and maintenance without disturbing the lamps and without the use of tools. They shall be securely fixed to the housing by means of positive fastening device of captive type.

##### b) Lamp/ Starter Holders:

- i. Lamp holders shall have low contact resistance, shall be resistant to wear and shall be suitable for operation at the specified temperature without deterioration in insulation value. They shall hold the lamps in position under normal condition of shock and vibration met with under normal installation and use.
- ii. Lamp holders for the fluorescent lamps shall be of the spring loaded bi-pin rotor type. Live parts of the lamps holder shall not be exposed during insertion or removal of lamp or after the lamp has been taken out. The lamp holder contacts shall provide adequate pressure on the lamp cap pins when the lamp is in working position.
- iii. The starter holders shall be so designed that they are mechanically robust and free from any operational difficulties. They shall be capable of withstanding the shocks met within normal transit, installation and use.

##### c) Ballasts:

- i. The ballasts shall be designed to have a long service life and low power loss. The ballasts shall be of the inductive, heavy duty type copper wire wound, filled with thermosetting, insulating, moisture repellent polyester compound filled under pressure or vacuum. Ballasts shall be provided with taps to set the voltage within the range of variation in supply voltage of  $\pm 10\%$  of 240 V. End connections and taps shall be brought out to a suitable terminal block rigidly fixed to the ballast enclosure. Ballasts shall be free from hum and such of those which produce hum shall be replaced by Contractor free of cost.
- ii. Ballasts shall be mounted using self locking, anti-vibration fixings and shall be easy to remove without demounting the fittings. They shall be in dust tight, non combustible enclosures.

#### 4.9.16. Lighting System Equipment:

##### a) Main Distribution Boards and Lighting Panels:

- i. Main Lighting distribution board (MLDB) shall have MCCB as incomer & outgoing feeder with thermal magnetic release for O/L+S/C+E/F protections.
- ii. This MLDB shall feed to different Lighting Panels/ Lighting DBs for further distribution.
- iii. Where ever MLDB is not applicable, lighting feeder of appropriate rating shall be derived from the local distribution board. This feeder will feed to local LP catering to lighting requirements of that particular area.

##### b) Constructional Features:

- i. Boards and panels shall be sheet steel enclosed and shall be fully dust and vermin proof, providing a degree of protection of IP-54 for indoor. Outdoor panels shall in addition be completely weather-proof with a sloping canopy for protection against rain and providing a degree of protection of IP-55. The sheet steel used for frame, frame enclosures, doors, covers and partitions shall be cold rolled 2.0 mm thick.
- ii. The lighting panel for outdoor lighting shall have a programmable timer for automatic control of lighting along-with contactor, MCB, auto/ manual selector switch.
- iii. All boards and panels shall be provided with hinged doors for access to equipment. Doors shall be gasketed all round with neoprene gaskets.
- iv. A slotted metallic sheet shall be provided inside. Only the MCBs operating knobs shall project out of the metallic sheet slots for safe operation and neat appearance. Incomer to lighting panels shall be provided with Four pole MCB + RCCB
- v. All accessible live connections/metals shall be shrouded and it shall be possible to change individual MCBs from the front of the boards/ panels without danger of contact with live metal.
- vi. For floor mounting type distribution boards, adequately sized mounting channels shall be supplied and for wall/ column/structure mounting type panels suitable mounting straps shall be provided.
- vii. Adequate interior cabling space and suitable removable cable entry plates shall be provided for top/ bottom entry of cables through glands and or conduits as required. Necessary number of glands to suit the specified cable sizes shall be provided. Cable glands shall be screwed on type and made of brass.
- viii. Two earthing terminals shall be provided to suit the earthing conductor.
- ix. All sheet steel parts shall undergo rust-proofing process which should include 7 tank processing. The steel works shall then be painted with two coats of Zinc - chromate primer and two coats of final epoxy based finish paint of colour 63I as per IS 5.

c) Busbars:

- i. Busbars shall be of copper conductor of hard drawn (HD) and high conductivity.
- ii. Busbars shall be provided with at least the minimum clearances in air as per applicable standards.
- iii. Busbars shall be adequately sized for the continuous current rating such that the maximum temperature of the bus bars, bus bar risers/droppers and contacts does not exceed 85° C under site reference temperature.
- iv. The bus bars, bus bar connections and bus bar supports shall have sufficient strength to withstand thermal and electro-mechanical stresses of the MCB's let through/cut-off current associated with the specified short-circuit level of the system.
- v. Busbar supports shall be SMC type. Separate supports shall be provided for each phase of the bus bars.
- vi. The neutral bus of the main 3 phase, 4 wire distribution board shall be 100% of the phase busbars.

d) Panels/ Boards' Component & Lighting Accessories:

i. MCB/ ELCB :

- ☐ MCBs shall be C curve type for lighting panels.
- ☐ For all the lighting panels RCCBs shall be with 100 mA sensitivity & for all receptacles RCBO sensitivity shall be 30 mA.

ii. MCCB :

- ☐ MCCB requirements shall be as per specified in the LV switchgear requirements & as specified above.

iii. Indicating Instruments and Meters:

- ☐ Whenever required, instruments and meters shall be of the flush mounting type. They shall be suitably mounted so as to provide for easy access to CTs and small wiring.
- ☐ Instruments shall be of minimum 96 mm square size, shall have provision for zero adjustment outside the cover and black numerals on white dial.
- ☐ Ammeter/ Voltmeter selector switches having 3 positions and off, with stay-put contacts rated 10A shall be provided when specified.
- ☐ Potential fuses shall be provided at the tap-off point from the bus bars for the voltmeters.

iv. Instrument Transformers:

- ☐ Current and voltage transformers shall be of cast resin type, with insulation class B, & accuracy class 1.0 unless otherwise specified, it shall be the

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responsibility of the Contractor to ensure that the VA burden of the instrument transformer is adequate for the meters connected to it.

- ☐ Test links shall be provided in both secondary leads of the CTs to easily carry out current and phase angle measurement tests. Facilities shall be provided for short-circuiting and grounding the CTs at the terminal blocks.
- ☐ Voltage transformers shall be provided with suitably rated primary and secondary fuses.

v. Indicating Lamps:

- ☐ Indicating lamps shall be of the clustered LED type, low watt consumption.

vi. Internal Wiring

- ☐ Panels/ boards shall be supplied completely wired, ready for the external connections at the terminal blocks. Wiring shall be carried out with 1.1 kV grade, FRLS PVC insulated, multistranded Copper conductors. Conductors of adequate sizes shall be used to suit the rated circuit current.
- ☐ Cross Ferruling i.e., engraved identification ferrules, marked to correspond with the wiring diagram shall be fitted at both ends of each wire.
- ☐ All wiring shall be terminated on terminal blocks. Terminal blocks shall be one piece moulded rated 500V, of reputed make of approved list, preferably stud type for higher current ratings such that wires are connected by cable-lugs and complete with nuts and washers. Terminals shall be adequately rated for the circuit current, the minimum rating shall be 20 A.
- ☐ Terminals for circuits with voltage exceeding 125V shall be shrouded.
- ☐ Terminals shall be numbered and provided with identification strip for identification of the circuit.
- ☐ Terminal blocks for CT secondary lead wires shall be provided with shorting and disconnecting/ earthing facilities.

vii. Labels & Diagram Plate:

- ☐ All door mounted equipment as well as equipment mounted inside the switchboard/ panels shall be provided with individual labels with equipment designation/ rating. Also the boards/panels shall be provided on the front with a label engraved with the designation of the board/ panel.
- ☐ Labels shall be made of non-rusting metal, 3-ply lamincoid or engraved acrylic
- ☐ Inside the door of the 1 phase ways lighting panels a circuit diagram/ description shall be fixed for reference and identification.

viii. Conduits:

- ☐ Rigid steel/ non-metallic conduits and their associated fittings as required shall conform to applicable standards. The minimum size of conduit shall be 20 mm for surface installation and 25 mm for concealed installation.
- ☐ Steel conduits shall be seamed by welding and hot dip galvanized. They shall be supplied in standard lengths of 5 metre.
- ☐ Supply of conduits shall include all associated fittings like couplers, bends and tees as required for lighting system installation work.

ix. Junction Boxes:

- ☐ Junction boxes with terminals shall be supplied for branching and terminating lighting cables when required for outdoor areas, three (3) phase receptacles etc.
- ☐ The junction boxes shall be dust and vermin proof and shall be fabricated from 14 SWG sheet steel and shall be complete with removable cover plate with gaskets, two earthing terminals each with nut, bolt and washer. Boxes shall be additionally weather proof.
- ☐ The boxes shall have provision for wall, column, pole or structure mounting and shall be provided with cable/ conduit entry knock outs, terminal blocks, and HRC fuses as required.
- ☐ The terminal blocks, with specified number of terminals, shall be mounted securely on brackets welded to the back sheet of the box. The terminals shall be 600V, grade, one piece construction complete with terminals, insulation barriers, galvanized nuts, bolts and washers and provided with identification strips of PVC. The terminals shall be made of Copper alloy and shall be of box clamp type.
- ☐ The boxes shall be painted with one shop coat of red oxide zinc chromate primer followed by a finishing coat of paint.

x. Lighting Poles and Flood Light Pole Mounting:

- ☐ Lighting poles for street lights and flood lights shall be of stepped tubular steel poles construction as per applicable standard. These poles shall be coated with bituminous preservative paint on the inside as well as embedded outside surface. Exposed outside surface shall be painted with one coat of red lead oxide primer. After completion of installation two coats of aluminium paint shall be applied.
- ☐ Poles for mounting flood lights shall be supplied whenever required and as per typical attached drawing. Unless otherwise specified, poles shall be painted with red lead oxide primer and two coats of aluminium paint. One steel ladder shall be provided separately. The length of each step of the ladder shall be at least 300 mm and spacing between two adjacent steps not more than 300 mm.
- ☐ The supply of poles shall be complete with fixing bracket/ necessary pipe reducer for fixing the fitting and also include the necessary associated pole mounted junction boxes.

- ☐ The required sizes of poles and the junction box shall be as indicated in the attached drawings.
- ☐ Cable entry for street lighting junction boxes shall be from bottom. Pole junction box shall be minimum IP55 protected.
- ☐ Rain water canopy shall be provided at the top for the outdoor JB's. Terminal strip shall be provided for looping loop out of cables.
- ☐ Street lighting JB shall consist of terminal strip (3 ways) for looping in & loop out of cables. The JB shall be provided with 6A MCB (C- Curve type) for isolation of lighting fixture, as well as sufficient arrangement (earthing studs) for termination of 2 nos. earthing connections.

xi. Ceiling Fans/ Wall Mounted Fans:

- ☐ Ceiling/ Wall mounted fans shall be suitable for operation on 240V, 1 phase, 50 Hz supply and shall be complete with standard mounting accessories such as suspension rods, top and bottom caps etc for ceiling fans and easy accessibility for wall mounted fans. The fans shall be supplied with appropriate speed regulators.
- ☐ Exhaust fans, where ever required shall also be provided. The exhaust fan with all parts shall be according to IS: 2312- 1967 & its latest amendment with IP-55 specification. The exhaust fan shall have epoxy powder coating with specially pretreated components for better resistance to corrosion and acid alkali flumes. The exhaust fan shall have totally enclosed highly efficient heavy duty motor with pressure die cast aluminum rotor mounted on two ball bearings.
- ☐ The fans shall generally conform to the applicable standards indicated in Tender. Details regarding blade sweep and suspension requirements shall be as per Project layout drawing/price schedule.

4.9.17. Testing of Luminaire

- (a) The Routine test on each of the offered luminaire shall be carried out by manufacturer before dispatch. Following tests shall be carried out as Routine tests for the offered luminaires;
  - (i) Visual and Dimensional check
  - (ii) Checking of documents of purchase of LED
  - (iii) Insulation resistance test
  - (iv) HV test
  - (v) Reverse polarity
- (b) The Acceptance test shall be carried out by manufacturer and witness by PURCHASER or PURCHASER's Representative on a sample of the lot offered for Acceptance. The lot shall be different from the lot from which the type test samples have been drawn. Following tests shall be carried out as Acceptance tests for the offered luminaires;

- 
- (i) Visual and Dimensional check
  - (ii) Checking of documents of purchase of LED
  - (iii) Insulation resistance test
  - (iv) HV test
  - (v) Over voltage protection
  - (vi) Surge protection
  - (vii) Reverse polarity
  - (viii) Lux measurement
  - (ix) Test for IP 65 protection
- (c) Following Type tests reports not older than 5 years shall be provided by the BIDDER for the offered Luminaires.
- (i) Resistance to humidity
  - (ii) Insulation resistance test
  - (iii) HV test
  - (iv) Over voltage protection
  - (v) Surge protection
  - (vi) Reverse polarity
  - (vii) Temperature rise Test
  - (viii) Ra (Colour Rendering Index) measurement test
  - (ix) Lux measurement
  - (x) Fire retardant Test
  - (xi) Test for IP 65 protection
  - (xii) Endurance Test,
  - (xiii) Life Test
  - (xiv) Photometric Measurements Test Report (IES LM 79)
  - (xv) LED Lumen Maintenance Test Report (IES LM 80)
  - (xvi) Vibration test as per ANSI
  - (xvii) Drop Test

4.9.18. Drawings/ Documents Required:

- e) As part of proposal, the Contractor shall furnish relevant descriptive and illustrative literature & drawings/ data for the respective lighting fixtures & accessories with manufacturer's catalogue numbers.



- f) It shall be the responsibility of the Contractor that, on award of contract to work out a detailed lighting layout for the complete plant in order to provide the levels of illumination as indicated under Design Criteria and shall be furnished for the approval of the Purchaser's representative before commencement of installation.
- g) Detailed Room wise Lighting Layout with Type of fixture details, mounting detail arrangement and Circuit diagram showing phase wise load distribution and interconnection between switches, fixtures, Lighting panel, receptacles etc.
- h) Conduit layout showing room wise routing of wires from lighting panel to lighting fixtures covering primary & secondary point wiring, receptacles etc.
- i) Internal road Lighting and Area lighting layout with type of mounting details and fixture details.
- j) Street Light pole details with Foundation details
- k) General arrangement of lighting panel & lighting distribution board showing plan, elevation and typical section views.

#### 4.10. INSTRUMENTATION & CONTROL EQUIPMENT (AS REQUIRED):

4.10.1. **List of Measurements and Control:** The plant shall be provided with required instrumentation equipment for real time monitoring & control functions, indicated below as a minimum, but not limited to the following:

- a) Flow measurement at inlet and outlet of treatment plant
- b) Flow measurement at common header of pump(s) and blower(s)
- c) Pressure measurement at discharge of each pump(s), blower(s) & common header
- d) Level measurement of each sump & tank
- e) Differential Level measurement across the screen
- f) pH measurement at inlet and outlet of treatment plant
- g) Dissolved oxygen measurement at Aeration tank/ Biological reactor
- h) Residual chlorine at outlet of CCT
- i) Total suspended solids (TSS), Biochemical Oxygen Demand (BOD) & Chemical Oxygen Demand (COD), Ammonia at inlet & outlet of treatment plant
- j) Bidder may propose additional instruments & control equipments for safe, reliable & efficient operation of treatment process proposed by him.
- k) Necessary alarms, status signals along with the measurements of process parameters etc. shall be displayed in HMI.
- l) SCADA generated report for all Process Parameters including Power and Energy Parameters and Equipment Duty Hour Report shall be attached by contractor along with monthly bill of O&M.

4.10.2. **Fields Instruments/ Process Analyzers required:** Field instruments/ process analyzers shall be provided as per the process requirement for proper functioning of the plant as per approved P&ID & following technical specifications:

**a) Full bore Electromagnetic flow meter:**

- i. Full bore type Electromagnetic flow meter shall be provided as per approved P&IDs. The flow meter shall consist of flow sensor (i.e., flow tube), flow transmitter/ flow computing unit and remote flow indicator cum integrator.
  - ii. The electromagnetic flow meter shall be manufactured as per BS EN ISO 6817 standard- measurement of conductive liquid flow in closed conduits, method using electromagnetic flow meters.
  - iii. The flow tube flanges and transmitter housing shall be properly earthed.
  - iv. Flow tube shall have waterproof construction (IP 68) and shall be suitable for installation on underground pipe lines buried directly in the soil and also suitable for above ground pipelines.
  - v. The transmitter of the flow meter shall be SMART type microprocessor based using digital technology having facilities for configuration of engineering units, flow range and features of memory and self diagnosis.
  - vi. The transmitter shall be mounted separate from the flow tube, connected by a cable.
  - vii. The flow transmitter and flow computation/ evaluation unit shall be mounted in a field mounted metallic field enclosure / cabinet.
  - viii. The electromagnetic flow meter shall have bi-directional measurement feature and with accuracy better or equal to + 0.5% of measured value inclusive of linearity, repeatability, pressure effect etc.
  - ix. Flow transmitter/ flow computing unit should be microprocessor based having digital display with flow-rate indications and integrated flow values with the configuration facility from the front face.
  - x. Material of construction of the wetted parts of flow meters shall be suitable for functioning on treated / raw and chlorinated water applications.
  - xi. Flow tube shall be rugged in construction and shall be suitable for continuous operation.
  - xii. Flow meters shall be suitable for the water turbidity at site during various seasons.
  - xiii. The flow meter shall be installed in such a way that it always remains filled with water.
  - xiv. To avoid the effects of disturbances in the velocity profile, a straight and uninterrupted run, upstream as well as downstream from the location of the flow meter shall be provided, as required by the flow meter manufacturer.
  - xv. The flow tube shall be installed at a location free from flow turbulence. In order
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to achieve the same, the flow tubes shall be installed in the pipe section such that straight lengths of pipe without bends or tee connection shall be minimum 5 diameters on upstream and 2 diameters on downstream side.

- xvi. The Contractor shall finalize the exact location of flow transducers in consultation with Employer/ Engineer In-Charge.
- xvii. The flow meter output signals shall contain the data for flow-rate and integrated flow readings.
- xviii. The output signal of the flow meter will be connected to panel mounted Flow Indicator & integrator and PLC.
- xix. Technical Particulars- Full Bore Electromagnetic Flow Transmitter:

Sr. No.	Description	Particulars
1	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Full Bore Electromagnetic Flow Meter
1.3	Service	Common Header of Pump Discharge
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous
2	<b>Flow Sensor</b>	
2.1	Type	DC pulsed
2.2	Electrode / Sensor MOC	Hast alloy C
2.3	Flow Tube MOC	SS304
2.4	Coil Housing MOC	Non corrosive (SS 304) or Die cast aluminium with anti-corrosive grade paint suitable for application
2.5	Grounding Ring MOC	SS 304
2.6	Liner MOC	PTFE
2.7	Process Connection	Flanged
2.8	Flange MOC	CS
2.9	Housing Protection	IP 68
2.10	Pressure Rating	16 Kg/cm <sup>2</sup>
2.11	Temperature	50°C Ambient
2.12	Size(mm)	To suit mains flow parameters, with pipe reducer / expander provided as necessary
3	<b>Flow Indicator and Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Power Supply	230 VAC ( UPS )

Sr. No.	Description	Particulars
3.3	Accuracy	± 0.5 % of measured value
3.4	Repeatability	± 0.1%
3.5	Transmitter Protection	IP67
3.6	Transmitter MOC	Dia-cast Aluminium with PU finish / Polycarbonate
3.7	Output	One Current – 4 to 20 mA ( isolated) proposanal to flow rate HART / RS 485 One Scalable Pulse One Status Output
3.8	Communication	Modbus RS485
3.9	Display	2 Line Backlit LCD, Programmable
3.10	Maximum Digit Display	8 Digit
3.11	Indication on Display	<input type="checkbox"/> Actual Flow Rate/ Instantaneous Flow Rate <input type="checkbox"/> Cumulative Forward Flow <input type="checkbox"/> Cumulative Reverse Flow <input type="checkbox"/> Cumulative Flow/ Sum/ Totalizers <input type="checkbox"/> Alarm
3.12	Zero and Span adjustment	Factory set Password protection of all parameters and hardware protection of calibration and revenue parameters
3.13	Facility for on line diagnosis	Continuous self test shall include <input type="checkbox"/> Error message Coil Error <input type="checkbox"/> Error message Signal input circuit Break <input type="checkbox"/> Error message for Electrode impedance <input type="checkbox"/> Empty Pipe Detection
3.14	Cable Gland	Required
3.15	Cable Length (sensor to transmitter)	10 Meter minimum or suit to site
3.16	Data Protection:	All data shall be stored in an EEPROM.
3.17	Power Supply in case of Raw power is not available ( Remote Area)	Battery power/ Solar power operated

**b) Technical Particulars- Open Channel Flow Transmitter:**

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Open Channel Flow Meter
1.3	Service	Open Channel ( inlet/ outlet of plant)

Sr. No.	Description	Particulars
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Flow Sensor</b>	
2.1	Type	Ultrasonic
2.2	Sensor MOC	PP / PVDF
2.3	Seal MOC	EPDM
2.4	Sensor Housing MOC	Diacast Aluminium with PU finish / Polycarbonate
2.5	Process Connection	Flanged
2.6	Flange MOC	PP / CS
2.7	Housing Protection	IP 68
2.8	Temperature compensation	Required
2.9	Swirling arm arrangement for mounting of sensor	Required for access during maintenance
2.10	Size(mm)	To suit Open Channel flow parameters
2.11	Pressure Rating (Kg/cm2)	Atmospheric
2.12	Temperature	50 °C Ambient
<b>3</b>	<b>Flow Indicator and Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Power Supply	24 VDC/ 230 VAC
3.3	Accuracy	± 1 % of measured value
3.4	Repeatability	± 0.1%
3.5	Transmitter Protection	≥ IP65
3.6	Transmitter MOC	Dia-cast Aluminium with PU finish / Polycarbonate
3.7	Output	One Current – 4 to 20 mA ( isolated) proposanal to flow rate HART / RS 485 One Status Output
3.8	Communication	Modbus RS485
3.9	Display	2 Line Backlit LCD, Programmable
3.10	Maximum Digit Display	8 Digit
3.11	Indication on Display	<input type="checkbox"/> Actual Flow Rate / Instantaneous Flow Rate <input type="checkbox"/> Totalized Flow <input type="checkbox"/> Alarm

Sr. No.	Description	Particulars
3.12	Zero and Span adjustment	Factory set Password protection of all parameters and hardware protection of calibration and revenue parameters.
3.13	Facility for on line diagnosis	Continuous self test shall include - Error message Signal input circuit Break
3.14	Cable Gland	Required
3.15	Cable Length ( sensor to transmitter)	10 Meter minimum or suit to site
3.16	Data Protection:	All data shall be stored in an EEPROM.
3.17	Power Supply in case of Raw power is not available	Battery power/ Solar power operated

c) **Pressure Gauge:**

- i. Pressure Gauges shall be bourdon tube with diaphragm seal type with dial size of minimum 150 mm in diameter and calibrated for the required range. The colour of dial shall be white. The pointer shall be adjustable & micrometer type. The indicator shall be incorporating with damper and shall have external zero setting mechanism and safety blow out mechanism. The glass shall be shatter proof. The over range protection shall be 25% above maximum pressure. All wetted parts material shall be SS 316. The pressure gauges shall have an accuracy of  $\pm 1\%$  full scale and weather protection class minimum IP 65.
- ii. The gauge shall be supplied complete with sensing diaphragm unit, sealing liquid, a pressure indicator and an armored capillary connecting the diaphragm to the pressure indicator.
- iii. The pressure indicator shall be supported on a rigid support and the capillary shall be well supported to prevent physical damage.
- iv. Pressure gauges shall comply with IS 3624. Where the gauge is subject to pressure pulsations and/or vibration, it shall be provided with snubber or glycerine filled dial.
- v. Unless and otherwise specified the measuring range shall be from 0 to 20 kg/cm<sup>2</sup> with accuracy of  $\pm 1\%$  of maximum scale confirming to the IS 3624. The vendor shall submit test calibration certificate along with the pressure indicators.
- vi. Pressure gauges shall be provided on discharge of each pump and common header of pump discharge.

vii. **Technical Particulars- Pressure Gauge:**

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list

Sr. No.	Description	Particulars
1.2	Item	Pressure Gauge
1.3	Service	Pump/Blower individual Discharge and Common Header
1.4	Fluid	Sewage Water, Air
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Pressure Gauge</b>	
2.1	Type	Bourdon
2.2	Sensor and other wetted parts M.O.C	SS 316
2.3	Process connection	½" NPT (M)
2.4	Dial size	150 mm
2.5	Material of dial	Aluminium with white back ground and black numerals
2.6	Glass	Shatterproof
2.7	Housing material	Die cast aluminium with epoxy coating
2.8	Accuracy	±1% of full scale or better
2.9	Over range protection	125% of maximum pressure
2.10	Gauge Protection	≥ IP65
2.11	Temperature	50°C Ambient
2.12	Range	As per pump design (Range to be finalised during detailed engineering without any cost implication)
2.13	Accessories	<input type="checkbox"/> Snubber <input type="checkbox"/> 3 way isolation valve <input type="checkbox"/> Impulse tubing, fittings <input type="checkbox"/> All other installation hardware
2.14	Diaphragm Seal M.O.C	SS316
2.15	3 Way Isolation Valve M.O.C	SS316
2.16	Impulse Tube Fitting M.O.C	SS316

**d) Pressure Transmitter**

- i. Pressure Transmitter shall consist of a pressure sensor/transducer/ transmitter and panel mounted digital pressure indicator and any other items required for completing the measuring system. Where the transmitter is subject to pressure pulsations and/or vibration, it shall be provided with snubber.
- ii. The pressure transmitters shall be designed for operation over 130% of full range.

iii. Technical Particulars- Pressure Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Pressure Transmitter
1.3	Service	Pump/ Blower Discharge Common Header
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Pressure Sensor</b>	
2.1	Type	Diaphragm / piezoelectric
2.2	Sensor and other wetted parts M.O.C	SS 316
2.3	Process connection	½" NPT (F)
2.4	Sensor Fill Fluid	Silicon Oil
2.5	Temperature	50°C Ambient
2.6	Range	As per pump design (Range to be finalised during detailed engineering without any cost implication)
<b>3</b>	<b>Pressure Transmitter</b>	
3.1	Type	SMART Type / Microprocessor Based, Head Mounted
3.2	Power Supply	24 VDC
3.3	Accuracy	± 0.1 % of measured value
3.4	Response Time	100 ms
3.5	Transmitter Protection	≥IP65
3.6	Transmitter MOC	SS316 /Diacast Aluminium with PU finish
3.7	Output	One Current – 4 to 20 mA ( isolated) proposanal to pressure HART/ RS 485
3.8	Display	Alphanumeric LCD Type, Programmable
3.9	Over range protection	125% of maximum pressure
3.10	Zero and span adjustment	Required
3.11	Cable Gland	Required
3.12	Accessories	<input type="checkbox"/> Snubber <input type="checkbox"/> 3 way isolation valve <input type="checkbox"/> Impulse tubing, fittings <input type="checkbox"/> Mounting Bracket <input type="checkbox"/> Tag Plate <input type="checkbox"/> All other installation hardware



Sr. No.	Description	Particulars
3.13	Diaphragm Seal M.O.C	SS316
3.14	3 Way Isolation Valve M.O.C	SS316
3.15	Impulse Tube Fitting M.O.C	SS316

**e) Technical Particulars- Pressure Switches: (wherever required)**

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Pressure Switch
1.3	Fluid	Sewage Water
1.4	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Pressure Sensor</b>	
2.1	Type	Diaphragm / piezoelectric
2.2	Sensor and other wetted parts M.O.C	SS 316
2.3	Process connection	½" NPT (F)
2.4	Temperature	50 °C Ambient
2.5	Range	As per pump design (Range to be finalised during detailed engineering without any cost implication)
2.6	Accuracy	± 1% of full scale or better
2.7	Range	As per pump design, Adjustable setting over full span and as per P&ID.
2.8	Over range Protection	125% of range
2.9	Body Material of casing	Die Cast Aluminium / non-corrosive
2.10	Set point adjusting scale	Required
2.11	Accessories	<input type="checkbox"/> Snubber <input type="checkbox"/> 3 way isolation valve <input type="checkbox"/> Impulse tubing, fittings <input type="checkbox"/> All other installation hardware
2.12	Diaphragm Seal M.O.C	SS316
2.13	3 Way Isolation Valve M.O.C	SS316
2.14	Impulse Tube Fitting M.O.C	SS316

f) **Ultrasonic Level Transmitter**

- i. Ultrasonic Level Transmitter shall consist of a level sensor, level transmitter cum computing unit, sensor cable(as applicable) connecting the sensor and transmitter, panel mounted digital level indicator etc. and any other item required for completing the level measurement system.
- ii. The level sensor shall be suitable for flange or bracket mounting as required and have a minimum protection conforming to IP 65. It shall have ambient temperature compensation and adjustable datum setting facilities.
- iii. The level transmitter cum computing unit shall be provided in an enclosure conforming to minimum IP 65. It shall be programmable with an integral programming keyboard, LCD display, relays for alarm, control and system fault and shall provide an isolated 4 to 20mA DC output signal proportional to the level.
- iv. The design and application of ultrasonic level meters shall take into account the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size etc.
- v. The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation. For applications where spurious reflections are unavoidable the control unit shall be provided with facilities for spurious reflection rejection.
- vi. If turbulence exists, shielding, stilling tubes or other measures shall be provided to avoid effects on the measurement.
- vii. Technical Particulars- Ultrasonic type Level Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Level Transmitter (Integral/ Remote Type)
1.3	Service	Sump / Tank/ Screen
1.4	Fluid	Sewage Water, Chemical Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Level Sensor</b>	
2.1	Type	Ultrasonic
2.2	Sensor MOC	PP / PVDF
2.3	Seal MOC	EPDM
2.4	Sensor Housing MOC	Diacast Aluminium with PU finish / Polycarbonate
2.5	Process Connection	Flanged
2.6	Flange MOC	PP / CS
2.7	Housing Protection	≥IP 65

Sr. No.	Description	Particulars
2.8	Temperature compensation	Required
2.9	Swirling arm arrangement for mounting of sensor	Required for access during maintenance
2.10	Size(mm)	To suit Sump / Tank Height
2.11	Pressure Rating (Kg/cm2)	Atmospheric
2.12	Temperature	50 °C Ambient
<b>3</b>	<b>Level Transmitter</b> (Integral/ Remote Type)	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Power Supply	24 VDC/ 230 VAC
3.3	Accuracy as minimum	± 0.3 % of measured value
3.4	Transmitter Protection	≥ IP65
3.5	Transmitter MOC	Diacast Aluminium with PU finish / Polycarbonate
3.6	Output	One Current – 4 to 20 mA ( isolated) proposanal to Level HART/ RS 485
3.7	Display	Backlit LCD, Programmable
3.8	Maximum Digit Display	Minimum 5 Digit
3.9	Indication on Display	Actual Sump / Tank Level Alarm
3.10	Zero and Span adjustment	Factory set Password protection of all parameters and hardware protection of calibration and revenue parameters.
3.11	Cable Gland	Required
3.12	Cable Length ( sensor to transmitter)	10 Meter minimum or suit to site (as applicable)

**g) Hydrostatic Level Measuring System**

- i. Hydrostatic level measuring system shall consist of a level sensor, level transmitter cum computing unit, sensor cable (as applicable) connecting the sensor and transmitter, panel mounted digital level indicator and any other item required for completing the level measurement system.
- ii. The level sensor shall be suitable for flange or bracket mounting as required and have a minimum protection conforming to IP 68. It shall have ambient temperature compensation and adjustable datum setting facilities.
- iii. The level transmitter cum computing unit shall be provided in an enclosure conforming to minimum IP 65. It shall be programmable with an integral programming keyboard, LCD display, relays for alarm, control and system fault and shall provide an isolated 4 to 20mA DC output signal proportional to the level.

- iv. The design and application of level instrument shall take into account the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size etc.
- v. The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation. For applications where spurious reflections are unavoidable the control unit shall be provided with facilities for spurious reflection rejection.
- vi. If turbulence exists, shielding, stilling tubes or other measures shall be provided to avoid effects on the measurement.
- vii. Technical Particulars- Hydrostatic Type Level Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Level Transmitter
1.3	Service	Aeration Tank
1.4	Fluid	Sewage Water, Chemical Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Level Sensor</b>	
2.1	Type	Hydrostatic
2.2	Sensor MOC	SS316
2.3	Process Connection	Flanged/ bracket mounting
2.4	Flange MOC	PP / CS
2.5	Housing Protection	IP 68
2.6	Temperature compensation	Required
2.7	Swirling arm arrangement for mounting of sensor	Required for access during maintenance
2.8	Size(mm)	To suit Sump / Tank Height
2.9	Pressure Rating (Kg/cm <sup>2</sup> )	Atmospheric
2.10	Temperature	50°C Ambient
<b>3</b>	<b>Level Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Power Supply	24 VDC
3.3	Accuracy as minimum	± 0.3 % of measured value
3.4	Transmitter Protection	≥IP65

Sr. No.	Description	Particulars
3.5	Transmitter MOC	Diacast Aluminium with PU finish / Polycarbonate
3.6	Output	One Current – 4 to 20 mA ( isolated) proposanal to Level HART/ RS 485
3.7	Display	Backlit LCD, Programmable
3.8	Maximum Digit Display	Minimum 5 Digit
3.9	Indication on Display	Actual Sump / Tank Level Alarm
3.10	Zero and Span adjustment	Factory set Password protection of all parameters and hardware protection of calibration and revenue parameters.
3.11	Cable Gland	Required
3.12	Cable Length ( sensor to transmitter)	10 Meter minimum or suit to site (as applicable)

**h) Displacer/ Float Type Level Switch (wherever required)**

- i. Level switch shall be displacer/ float type with flexible rope, non corrosive displacer/ float, 2 set point micro switch, flange connection and spring housing (as applicable) and shall have external cage.
- ii. Level switch shall be supplied complete with mounting bracket and associated accessories.
- iii. Perforated still well is required for tanks with excessive turbulent liquids.
- iv. The micro switch contacts being rated for 5A at 230 VAC can be directly wired to control devices through instrument cable.
- v. Level switch range shall be suitable to sump and tank height.
- vi. Technical Particulars- Level Switch:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Level Switch- Displacer/ Float Type
1.3	Service	Tank / Sump
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous
<b>2</b>	<b>Level Switch</b>	
2.1	Type	Displacer / Float

Sr. No.	Description	Particulars
2.2	Flexible Rope MOC	PP / SS316
2.3	Displacer/ Float MOC	PP / SS316
2.4	Spring Housing (As Applicable)	PP / SS316
2.5	Process connection	Flanged
2.6	Process connection MOC	PP
2.7	Switching Type	Micro switch
2.8	Switching Contacts	2 SPDT, 5A
2.9	Housing material	Die cast aluminium with epoxy coating
2.10	Protection Class	IP65
2.11	Perforated Still well	PP
2.12	Ambient Temperature	50 °C
2.13	Range	As per Sump / Tank design (Range to be finalised during detailed engineering without any cost implication)

i) **Technical Particulars- Float & Board Type Level Indicator:**

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Level Indicator
1.3	Service	Sump / Tank
1.4	Fluid	Sewage Water, Chemical Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Level Indicator</b>	
2.1	Type	Float and Board
2.2	Construction	Guided
2.3	Measuring Range	To Suit Sump / Tank Height
2.4	Travel	Full Range
2.5	Float	SS316
2.6	Float / Guide wire Rope	SS316
2.7	Calibrated Gauge Board	6" wide x aluminium powder coating with black graduations and numerical
2.8	Pointer	Red, powder coated steel with measuring rope holder

Sr. No.	Description	Particulars
2.9	Protection Conduit	Vertical and Horizontal limb in galvanized steel
2.10	Elbow pulley	Cadmium plated steel or PP pulley with PTFE bush and SS shaft housed in weather proof aluminium or PP enclosure
2.11	Tensioner	Cadmium plated steel spring housed in CS or PP enclosure
2.12	Anchor	SS316 plate (25mm x 6mm thick plate to be welded at bottom of sump / tank at site)
2.13	Rope Fastener	SS316
2.14	Gauge Brackets	Powder Coated Steel
2.15	Counter weight for rope type probe to keep it straight	Required
2.16	Spacers between the probes to avoid entangling with each other	Required

j) **pH Measurement**

- i. Online pH sensor based on Potentiometric measurement using glass sensor.
- ii. The sensor shall have analog / digital communication to transmitter.
- iii. The transmitter / sensor shall have inbuilt memory to store calibration data, and other additional diagnostic information.
- iv. The offered transmitter shall be 4 wire digital with possibility of connecting multiple sensor inputs for additional parameters – referred as multichannel / multi parameter type
- v. The transmitter shall be suitable for outdoor installation with minimum IP65 rating
- vi. Technical Particulars- pH sensor and Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	pH Sensor & Transmitter
1.3	Service	Raw Sewage at Inlet & Treated Sewage at Outlet of STP
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous

Sr. No.	Description	Particulars
<b>2</b>	<b>pH Sensor</b>	
2.1	Type	Electrode
2.2	Principle	Potentiometric measurement
2.3	Range	0 to 14 pH
2.4	Material	Glass
2.5	Max Process temperature	50°C
2.6	Max Process pressure	6bar
2.7	temperature sensor	Pt100
2.8	Connection	Analog / digital connection with Transmitter
2.9	Ingres protection	IP68
2.10	Resolution	0.01pH, Temp 0.1°C
2.11	Calibration data	Inbuilt calibration & application data storage in sensor / Transmitter
2.12	Sensor capability	The sensor connection should be able to withstand corrosion , moisture , and can be also connected under water
2.13	Data safety	The sensor / transmitter should store on-board calibration data , diagnostics information
<b>3</b>	<b>pH Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Output	4-20 mA/ RS 485
3.3	Supply voltage	230 V AC, 50Hz
3.4	Material	Field Housing : ABS PC
3.5	Display	LC display with backlight with status indicators
3.6	Electromagnetic compatibility	interference emission and interference immunity acc. to EN 61326-1:2006
3.7	Protection class of field housing	≥ IP 65
3.8	Ambient temperature	–20 ... +60 °C
3.9	Self-Diagnostic feature	Required
3.10	Transmitter channels	Single (optionally, one multichannel transmitter catering more than one parameters/ sensors with a provision of minimum one channel as spare shall be acceptable )

**k) Residual Chlorine Measurement**

- i. Online chlorine analyser based on Amperometric/membrane based



measurement of active chlorine converted to free chlorine by means of pH compensation.

- ii. The sensor shall have analog/ digital communication with Transmitter.
- iii. Bidder shall provide complete measuring system including chlorine sensor, pH sensor with suitable flow assembly for mounting these sensors along with transmitter.
- iv. The offered transmitter must be minimum IP65 or better protection class, Interference emission & immunity as per EN 61326-1:2006.
- v. Technical Particulars- Chlorine sensor and Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Residual Chlorine Sensor & Transmitter
1.3	Service	Chlorine Contact Tank
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Residual Chlorine Sensor</b>	
2.1	Type	Free Chlorine
2.2	Principle	Amperometric measurement of free chlorine.
2.3	Measurement range	0.01 – 5 ppm free chlorine
2.4	pH Compensation	Required , add on pH sensor for compensation
2.5	Material	Sensor shaft : PVC
		Membrane : PTFE
		Membrane cap :PBT (GF30); PVDF
2.6	Process temperature	2°C - 45°C
2.7	Max Process pressure	1 bar
2.8	temperature sensor	Pt100
2.9	Connection	Analog / digital connection with Transmitter
2.10	Ingres protection	IP68
2.11	Resolution	0.01mg/l
2.12	Accuracy	± 1% of measured value
2.13	Sensor capability	The sensor connection should be able to withstand corrosion , moisture without loss of any data

Sr. No.	Description	Particulars
<b>3</b>	<b>Residual Chlorine Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Output	4-20 mA/ RS 485
3.3	Supply voltage	230 V AC 50Hz
3.4	Material	Field Housing : ABS PC
3.5	Display	LC display with backlight with status indicators
3.6	Electromagnetic compatibility	interference emission and interference immunity acc. to EN 61326-1:2006
3.7	Protection class of field housing	≥ IP 65
3.8	Ambient temperature	-20 ... +60 °C
3.9	Self-Diagnostic feature	Required
3.10	Transmitter channels	Two channel ( Chlorine +pH) minimum (optionally, one multichannel transmitter catering more than one parameters/ sensors with a provision of minimum one channel as spare shall be acceptable )

**I) Dissolved Oxygen Measurement**

- i. Online Dissolved Oxygen measuring system based on Optical / Luminescent / Fluorescence technology.
- ii. The sensor shall have analog / digital communication with Transmitter.
- iii. Bidder shall provide ccomplete measuring system including D.O sensor, Mounting arrangement and clamp along with transmitter.
- iv. The offered transmitter must be IP67, Interference emission & immunity as per EN 61326-1:2006.
- v. Technical Particulars- Dissolved Oxygen sensor and Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	DO Sensor & Transmitter
1.3	Service	Aeration Tank
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Dissolved Oxygen Sensor</b>	
2.1	Principle	Optical/ Luminescent/ Fluorescence

Sr. No.	Description	Particulars
		technology
2.2	Measurement range	0 – 20 mg/L(ppm)
2.3	Material	
	Wetted Parts	Silicone and SS316 TI
	Sensor	POM Polyoxymethylene or equiv ,
2.4	Max Process temperature	50°C
2.5	Max Process pressure	10bar
2.6	Connection	Fixed cable connection
2.7	Ingres protection	IP68
2.8	Additional Certifications	Calibration certification
2.9	Resolution	0.01 mg/l
2.10	Accuracy	< 5 % of the measured value or 1 % of full scale
<b>3</b>	<b>Dissolved Oxygen Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Output	4-20 mA/ RS 485
3.3	Supply voltage	230 V AC, 50Hz
3.4	Material	Field Housing : ABS PC
3.5	Display	LC display with backlight with status indicators
3.6	Electromagnetic compatibility	interference emission and interference immunity acc. to EN 61326-1:2006
3.7	Protection class of field housing	≥ IP 65
3.8	Ambient temperature	–20 ... +60 °C
3.9	Self-Diagnostic feature	Required
3.10	Transmitter channels	Minimum two channel for single parameter. Optionally, one multichannel transmitter for more than one parameters with a provision of minimum one channel as a spare may be provided

**m) TSS Measurement**

- i. Online TSS measuring system based on Light scattering at 90deg &135deg four beam pulsed method with wavelength at 860nm+/- 30nm or technologies as suggested in CPCB guidelines
- ii. The sensor should have two light sources and four light receivers for improved measurement of suspended solids.

- iii. The sensor must be easy plug and play with digital communication based on inductive energy transfer with IP68 rating suitable for measuring range 0 to 4g/l
- iv. The sensor shall store on-board all the calibration data and other diagnostic information
- v. The offered transmitter shall be 4 wire digital with possibility of connecting multiple sensor inputs for additional parameters – referred as multichannel / multi parameter type
- vi. The transmitter shall be suitable for outdoor installation with IP66/67 rating
- vii. Technical Particulars- TSS sensor and Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	Suspended Sensor & Transmitter
1.3	Service	Raw Sewage at Inlet & Treated Sewage at Outlet of STP
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>Suspended Solid Sensor</b>	
2.1	Principle	Light scattering at 90deg & 135deg four beam pulsed method with wavelength at 860nm+/- 30nm or technologies as suggested in CPCB guidelines
2.2	Measurement range	0 to 4g/L
2.3	Material	Sensor shaft : Stainless steel 1.4404 (AISI 316 L) Optical window : sapphire O-rings : EPDM
2.4	Max Process temperature	50°C
2.5	Max Process pressure	10bar
2.6	Connection	Fixed cable connection
2.7	Ingres protection	IP68
2.8	Accuracy	< 5 % of the measured value or 1 % of full scale
<b>3</b>	<b>Suspended Solid Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Output	4-20 mA / RS 485
3.3	Supply voltage	230 V AC, 50Hz
3.4	Material	Field Housing : ABS PC

Sr. No.	Description	Particulars
3.5	Display	LC display with backlight with status indicators
3.6	Electromagnetic compatibility	interference emission and interference immunity acc. to EN 61326-1:2006
3.7	Protection class of field housing	≥ IP 65
3.8	Ambient temperature	-20 ... +60 °C
3.9	Self-Diagnostic feature	Required
3.10	Transmitter channels	Single (optionally, one multichannel transmitter catering more than one parameters/ sensors with a provision of minimum one channel as spare shall be acceptable )

**n) COD / BOD / TOC Measurement**

- i. Online sensor based on organic substance measurement on absorbance measurement at wavelength at UV254nm, using potassium hydrogen phthalate as organic reference or technologies as suggested in CPCB guidelines.
- ii. Sensor output will be in digital format for reliable and long distance transmission without loss of signal due to moisture or water
- iii. The offered transmitter shall be 4 wire digital with possibility of connecting multiple sensor inputs for additional parameters – referred as multichannel / multi parameter type
- iv. The transmitter shall be suitable for outdoor installation with IP66/67 rating
- v. Technical Particulars- COD/ BOD/ TOC sensor and Transmitter:

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved vendor list
1.2	Item	COD / BOD/ TOC Sensor & Transmitter
1.3	Service	Raw Sewage at Inlet & Treated Sewage at Outlet of STP
1.4	Fluid	Sewage Water
1.5	Area Classification	Non Hazardous / Hazardous
<b>2</b>	<b>TOC / COD / BOD Sensor</b>	
2.1	Measuring principle	UV photometric or technologies as suggested in CPCB guidelines
2.2	Process temperature	50°C
2.3	Process pressure	10 bar
2.4	Sensor Ingress Protection rating	IP 68
2.5	Maximum measured error	2 % of upper end of measuring range

Sr. No.	Description	Particulars
2.6	Measuring range	COD/BOD: 0 to 75mg/L, 370 mg/L, 1000 mg/L TOC: 0 to 30mg/L, 150mg/L, max up to 410mg/L
<b>3</b>	<b>TOC/ COD/ BOD Transmitter</b>	
3.1	Type	Microprocessor Based, Remote Mounted
3.2	Output	4-20 mA/ RS 485
3.3	Supply voltage	230 V AC, 50Hz
3.4	Material	Field Housing : ABS PC / Polycarbonate
3.5	Display	LC display with backlight, two lines, with status indicators
3.6	Electromagnetic compatibility	Interference emission & immunity as per EN 61326-1:2006, class A
3.7	Protection class of field housing	≥ IP 65
3.8	Ambient temperature	-20 ... +60 °C
3.9	Self-Diagnostic feature	Required
3.10	Transmitter channels	Minimum two channel for single parameter. Optionally, one multichannel transmitter for more than one parameters with a provision of minimum one channel as a spare may be provided

**o) Technical Particulars- Digital Process Indicator/ Totalizers (Panel Mounted):**

Sr. No.	Description	Particulars
<b>1</b>	<b>General</b>	
1.1	Make	As per approved Contractor list
1.2	Item	Process Indicator
1.3	Service	Panel Mounted
1.4	Area Classification	Non Hazardous
<b>2</b>	<b>Process Indicator</b>	
2.1	Type	Microprocessor based
2.2	Display	Digital LED display
2.3	Digit Height	14 mm or higher
2.4	No. of Digits	3 ½
2.5	Input	4-20 mA
2.6	Zero & Span Adjustment	Required
2.7	Engineering Units for	Required (User Defined)

Sr. No.	Description	Particulars
	display	
2.8	Accuracy	±0.1 % of span
2.9	Enclosure Material	Non corrosive Polycarbonate or better
2.10	Retransmission output	Isolated 4-20 mA DC-2 nos
2.11	Power supply	230VAC/ 24 V DC
2.12	Alarm outputs	1NO+1NC for high and Low alarms (adjustable)
3	<b>Process Indicator/ Totalizer</b>	
3.1	Type	Electronic, Microprocessor based, single unit for flow indicator and integrator.
3.2	Display	Digital, LED display
3.3	Digit Height	14 mm or Higher
3.4	No. of Digits a) Flow indicator b) Flow integrator	4 Digits 8 Digits
3.5	Input	4-20 mA DC (Isolated)
3.6	Zero and span adjustment/ Manual Reset Facility for flow integrator	Required/ Required (shall be protected)
3.7	Engineering Units for Flow rate indicator	m <sup>3</sup> /hr
3.8	Accuracy	±0.1 % of span
3.9	Enclosure Material	Non corrosive Polycarbonate or better
3.10	Retransmission output	Isolated 4-20 mA DC-2 nos
3.11	Power supply	230VAC/ 24 V DC
3.12	Alarm outputs	1NO+1NC for high and Low alarms (adjustable)
3.13	Battery backup for flow integrator	Required

Note: Bidder has to supply, any other Analytical Instrument required as per P&ID or Process requirements without extra cost to Employer.

#### 4.10.3. **Laboratory Instruments:**

- a) The treatment plant shall be provided an administrative building that will house the laboratory.

- b) The laboratory shall be equipped with instruments, equipment, chemicals and other infrastructure that is necessary to perform the routine analysis for the parameters as detailed in table below.
- c) Contractor shall submit the complete list of lab equipments required for full analysis of parameters to the employer's representative for approval.
- d) Contractor shall include in his offer supply of chemicals required for analysis along with proposed lab instruments and associated equipment, including for the O&M period as specified elsewhere in the bid document.
- e) Typical Laboratory equipments to be provided are detailed as below:

Sr. No.	Description	Unit	Quantity
1	Comparator test set for residual chlorine or chloroscope	No.	1
2	Multi parameter (pH & Conductivity Meter)	No.	1
3	Mains operated pH meter completed with one calomel electrode and glass electrode	No.	1
4	Photoelectric calorimeter / Spectrophotometer	No.	1
5	Water bath with 6 to 8 concentric holes and discs, electrically heated	No.	1
6	Hot plates	No.	25
7	Distilled water plant	No.	1
8	Demineraliser	No.	1
9	Refrigerator (280 litres capacity) double door	No.	1
10	Muffle furnace	No.	1
11	Electric oven	No.	1
12	Magnetic' stirrer	No.	1
13	Analytical balance with weight box	No.	1
14	Jar-Test apparatus (Phipps & Bird)	No.	1
15	Centrifuge	No.	1
16	Gas cylinder if gas supply is not available	No.	1
17	Fume cupboard	No.	2
18	Depth Sampler	No.	2
19	Total Organic Analyser	No.	1
20	Sieve shaker with standard sieves and two pan balance weighing up to 200gm samples	No.	1
	Equipment Needed For Bacteriological Examination		
21	Hot Air Oven	No.	1
22	Autoclave	No.	1



Sr. No.	Description	Unit	Quantity
23	Incubator 37°C or 44°C (Water/Air-Jacketed)	No.	1
24	Binocular microscope	No.	1
25	pH Meter	No.	1
26	Pipette Box (Stainless Steel)	No.	10
27	Wooden Racks/Aluminium Racks	No.	5
28	Wire Baskets	No.	10
29	Cotton/ Aluminium Foils	No.	10
30	Burners (Bunsen) With Pilot Lamp	No.	3
31	Suction Flask (1 Litre Cap)	No.	2
32	Suction Pump	No.	1
33	Sampling Bottles	No.	10
34	Measuring Cylinders (1000 MI, 500 MI, 200 MI, 100 MI, 50 MI, 25 MI)	Set	3
35	Vacuum pump	No.	1
36	Soxhlet extraction unit	No.	1
37	Kjeldhal digestion unit	No.	1
38	Weighing Balance (max 10kg)	No.	1
39	Laminar Air Flow chamber	No.	1
40	Bacteriological Media	No.	1
41	M. Endo Broth (dehydrated)	No.	1
42	Lactose or Lauryl Tryptose broth	No.	1
43	Mac Conkey broth	No.	1
44	Brilliant Green Bile Lactose Broth	No.	1
45	Total Plate Count Agar	No.	1
46	Peptone/Tryptone Water	No.	1

- f) The equipment shall be supplied with all the accessories that are necessary to make the equipment functional for analyzing parameters.
- g) Contractor shall provide additional Equipment if necessary for the performance of the plant without extra cost to the Employer.
- h) Work Tables and Benches**
- i. Minimum of 1set of work table and chair per staff shall be provided for the laboratory and office staff.
  - ii. The furniture and chairs shall be of ergonomic design so that staff can work

most efficiently and safely.

- iii. The work tables shall be along the wall and shall be provided with adequate storage capacity and open glass shelves on the top to provide additional space for storage of chemicals and stock solutions.
- iv. A fume cupboard with ventilation hood shall be provided to prevent spreading of toxic and irritant fumes and odours into other parts of the laboratory.
- v. Forced ventilation with exhaust fans shall be provided. The wall space and offsets shall be convenient to locate cabinet, benches, hoods, incubators alongside without any loss of floor space.

4.10.4. **Instrument Indicator cum Alarm Annunciation Panel (where applicable):**

- i) An Instrument indicator cum alarm annunciation panel shall be provided at sewage treatment plant for the operation and monitoring of the plant process parameters.
- j) Panel shall be fabricated from CRCA sheet steel, stand alone cubical design, non-compartmentalized, floor mounted, free standing type suitable for Indoor installation with IP 52 protection and shall have built in locking facility.
- k) The panel shall be properly earthed. The panel shall have bottom cable opening.
- l) Voltage level for control schemes and power supply for instruments in the panels shall be limited to 230 VAC.
- m) Any other necessary voltage shall be derived by the Contractor using necessary inverters, converters, transformers, rectifiers etc. which shall be in his scope of supply.
- n) Strip type space heaters of adequate capacity shall be provided inside control panels to prevent moisture condensation on the wiring and panel mounted equipment when the panel is not in operation.
- o) The heaters shall operate on 230 VAC. Heaters inside the panels shall not be mounted close to the wiring or any panel mounted equipment.
- p) The operation of heaters shall be controlled by thermostats.
- q) The panel shall be provided with either a fluorescent lighting fixture rated for 230 VAC supply for the interior illumination of the panel during maintenance.
- r) The illumination lamp shall be operated by door switch. Additionally, the panel shall be provided with 230 VAC combined 5 amps and 15 amps, 3 pin receptacle with a switch and neon indicating.
- s) The receptacle with switch shall be mounted inside the panel at a convenient location.
- t) All the equipment mounted on the front facia of control panel as well as equipment mounted inside the panels shall be provided with individual labels with equipment designation engraved.

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- u) The labels shall be mounted directly below the respective equipment. Also the panel shall be provided at the top with a label engraved with panel designation.
  - v) Each control panel shall be provided with necessary arrangement for receiving, distributing, isolating and protecting of DC and AC supplies for various control, signaling, lighting and space heater circuits.
  - w) The incoming and sub-circuits shall be separately provided with Miniature Circuit Breakers (MCBs).
  - x) Potential circuits for relaying and metering also shall be protected by MCBs.
  - y) Connections within a panel, between panel mounted devices and terminal blocks or between two panels mounted devices shall be made PVC insulated stranded copper conductor.
  - z) The wires shall be shielded for all analogue signals.
  - aa) Panels shall be supplied completely wired internally, with a colour coding scheme to be finalised during detailed engineering, to equipment and terminal blocks and ready for external cable connections at the terminal blocks.
  - bb) Wires within the panel shall be continuous i.e. without splicing and shall comprise stranded copper conductors.
  - cc) Wire termination shall be made with solder less crimping type of tinned copper lugs which firmly grip the conductor and insulation.
  - dd) Insulated sleeves shall be provided at all the wire terminations.
  - ee) Engraved core identification plastic ferrules, marked to correspond with panel wiring diagram shall be fitted at both ends of each wire.
  - ff) Ferrules shall fit tightly on the wires and shall not fall off when the wire is disconnected from terminal blocks.
  - gg) All wires directly connected to trip circuit of breaker or device shall be distinguished by the addition of a red colored unlettered ferrule.
  - hh) Terminal blocks shall be one-piece moulded, complete with stud type terminals, washers, nuts and lock nuts and identification markings.
  - ii) Terminal block design shall include a white fiber marking strip with clear plastic, hinged terminal covers.
  - jj) Markings on the terminal strips shall correspond to wire numbers on the wiring diagrams.
  - kk) All spare contacts and terminals of the panel mounted equipment and devices shall be wired to terminal blocks.
  - ll) There shall be a minimum clearance of 250 mm between the first row of terminal blocks and the associated cable gland plate. Also the clearance between two rows of terminal blocks shall be a minimum 250 mm.

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mm) Panel internal wiring shall not be looped directly from instrument to instrument. The same shall be looped through the panel terminal block only.

nn) If accidental short circuiting of certain wires is likely to result in malfunction of equipment, such as closing or tripping of a breaker or positive and negative wires, these wires shall not be terminated on adjacent terminal blocks.

#### 4.10.5. Cabinets for Field Instruments

- a) A cabinet shall be provided for enclosing instruments and associated accessories which are mounted outside the control panel such as transmitters, SPDs, terminal blocks etc. at all measurement locations.
- b) The cabinets for electronic indicating instruments like transmitters, flow computing units etc. mounted outdoors shall be provided with proper sunshade.
- c) The cabinets shall be fabricated from cold rolled sheet steel of 2 mm thickness with powder coating and shall be suitable for wall mounting or pedestal mounting as required.
- d) The cabinet shall be properly painted from inside and from outside by paint shade RAL 7035.
- e) The cabinet shall conform to IP 65 weather protection and shall have built in locking facility.
- f) The cabinet shall be earthed properly. A steel plate/ pipe, as per the requirement, shall be provided in the cabinet for mounting the instrument and accessories.

#### 4.10.6. **PLC based control panel with SCADA (Supervisory Control & Data Acquisition) system:**

- a) PLC based control panel with SCADA system shall be provided in central control room of treatment plant for monitoring, control, recording, and logging etc.
- b) All the Treatment Units including SBR/ Cyclic Activated Sludge Process etc. shall be designed for manual & automatic operation through PLC and SCADA system.
- c) Provision shall be made to operate each process unit manually, if required. All the essential drives shall be provided with standby arrangements.
- d) The control system shall be selectable to either "Local (Manual)" or "Remote (Auto)" or "Remote (Manual)" modes.
- e) Annunciation shall be provided on the HMI.
- f) All electrically actuated Valves shall be operated from HMI through PLC/SCADA system.
- g) Operation & control philosophy of entire treatment plant shall be suggested by vendor/technology provider and same shall be submitted to Engineer In-charge for their approval.
- h) The PLC based control panel with SCADA system shall consist of minimum following devices:

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- i. PLC with integral alarm annunciation & all required hardware and software, PC based SCADA system with all required hardware, software and peripherals.
  - ii. Redundant Power Supply Module, Surge Protection units, Indicators for level, pressure, flow and process parameters.
  - iii. Selector switches for selection of normal mode, flush mode, scour mode and various other modes as per process design requirements.
  - iv. Push buttons (Accept, Reset & Emergency Stop)
  - v. MCBs: All MCB shall be mounted inside the panel which can be operated after the door opening.
  - vi. Earthing: Protective Copper Earth Bus- 25 x 6 mm are provided and projected on both sides through GI Earth Stud for connection to Electrical Earth Conductor. Electronic Copper Earth Bus - 25 x 6 mm are provided and connected to the electronic earth pits using flexible PVC insulated 1 core X 25 Sq.mm copper cable through flexible GI conduit.
  - vii. Accessible live parts shall be shrouded with Hylem/ Acrylic Transparent Sheet.
  - viii. Panel internal wiring shall run through PVC channel with cover.
  - ix. 11W CFL Illumination Lamp(s) protected by MCB with Door Switch interlock shall be provided.
  - x. Necessary cooling Fans & Louvers shall be provided.
  - xi. Doors are provided with 4 point hinges and open outwards, hinges shall be concealed type. The Swing of the door shall be 130°.
  - xii. PLC Panel hardware shall be assembled on Front side of Panel while termination of field cabling shall be done at rear side of panel.
  - xiii. Any other item required for proper functioning of the system.

**i) PLC shall comply with the following codes and standards :**

- i. International Society of Automation (ISA)
- ii. National Electricity Manufacturers Association (NEMA)
- iii. International Electro-technical Committee (IEC)
- iv. American National Standards Institute (ANSI)
- v. The Institution of Electrical and Electronic Engineers (IEEE)
- vi. The complete paint process including solvent will be RoHS compliance

**j) Design and Construction Requirements:**

- i. PLC shall be provided as a standalone controller to perform combinational and sequential logic functions, status monitoring and reporting

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functions with counter and timer facilities.

- ii. PLC shall comprise of necessary processors, input/output (I/O) modules, communication interface modules, power supply modules, prefab cables etc.
- iii. PLC shall have the following attributes as a standalone controller:
  - ☐ PLC shall be microprocessor based with state of the art technology.
  - ☐ It shall carry out sequential operation of sewage treatment plant based on process requirements.
  - ☐ It shall carry out sequential start/stop logic implementation for operation of the pumps and motorised valves.
  - ☐ It shall accept downloaded program from a programmer.
  - ☐ It shall have different functional modules to perform the desired functions
  - ☐ It shall scan the inputs in time cycles and update the status of inputs/outputs
  - ☐ It shall have relays, counter/timer functions, internal registers/ flags, watch dog timer, set/reset facilities, up-down counter etc.
  - ☐ It shall have a provision for spare input and output modules.
  - ☐ The PLC system shall be expandable and shall be modular in construction so as to carry out the future expansion.
  - ☐ System components shall be carefully chosen so that the reliability of the PLC shall be high.
  - ☐ PLC shall use standard bus protocols and structures for communication within and outside the system.
  - ☐ In case of system failure or power supply failure all the outputs shall attain pre-determined fail safe condition.
  - ☐ Spurious signals shall not cause equipment operation.

**k) Central Processing Units**

- i. The Central Processing Unit (CPU) shall be high performance processors with modular configuration suitable for real time process application.
- ii. High inherent reliability, self checking, error-recovery and trouble-shooting features shall be source of the features of CPU.
- iii. Automatic restart of the system on resumption of power shall be provided.

**l) Memory Unit**

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- i. Memory unit shall comprise of highly reliable memory chips which are industry standard, proven design with fast random access and suitable for operation in process environments.
  - ii. Main memory shall be modular and facility shall be provided for up-gradation and expansion of memory to meet future demands.
  - iii. Sufficient program memory and data memory space shall be provided.
  - iv. System initialization and application software shall be stored in EEPROM with necessary hardware.
  - v. Running data shall be stored in a RAM with internal battery back-up.
  - vi. The battery back-up provided shall last for at least one month with life of battery a minimum of 3 years.
  - vii. Appropriate programs for application software modification shall be provided.
  - viii. At least 20% extra memory space shall be provided over the actual requirements.

**m) Input/ Output Modules**

- i. Standard rack mounted I/O modules with plug-in cards shall be provided.
- ii. Field wiring shall be terminated in screwed terminal and interconnected to the processor I/O system with pre-fabricated cables with plug-in type connectors.
- iii. 20% extra points of installed capacity for each type of input shall be provided as spares and shall be wired to the terminal block of the control panel.
- iv. Provision shall be made for future expansion of extra I/O modules.
- v. Some of the common features of the I/O modules shall be as follows :
  - ☐ All inputs shall be terminated with input protective network and necessary isolating barriers.
  - ☐ Filters for noise rejection.
  - ☐ Provision for isolation of faulty channels.
  - ☐ Test points and fault indication LEDs shall be provided to carry out module testing.
  - ☐ Surge withstands facility as per IEEE standards.
  - ☐ All the modules shall be of addressable type.
  - ☐ Protection for continuous overload up to 200% of all input ranges.
  - ☐ Fuse protection and fuse failure detection.

- ☐ Internal battery backup.

**n) Software**

- i. The online real time operating system supplied shall be proven for similar application and shall be able to support all the equipment/ peripherals.
- ii. Software shall support various mode of operation of the sewage treatment plant automatic/ manual & various modes as per process requirements & shall be upgradable at any time during O&M period.
- iii. Software (HMI, SCADA & other required softwares) licenses shall have lifetime validity.
- iv. All graphics for sewage treatment plant operation and controls.

**o) PLC Programming**

- i. The PLC programming software shall be Windows based user friendly package.
- ii. The software shall be supplied along with its documentation (hard copy as well as soft copy).
- iii. The software shall have facilities for:
  - ☐ carrying out program revision and management of these revisions
  - ☐ insertion of comprehensive program subroutine and rung comments
  - ☐ search and find and search and replace 'contacts' and 'coils'
  - ☐ simulation functions and testing of the program by changing the status of contacts and monitoring the outputs
  - ☐ preparation of coil and contact list and their locations and memory maps
  - ☐ make system backup copies while the system is online
  - ☐ upload and down load programs to the PLC online
  - ☐ carry out line maintenance and fault finding on the PLC
  - ☐ The PLC programming shall be prepared using the PLC manufacturer's programming software package only.
  - ☐ The PLC code shall be structured in the manner of the best industry standard and have comprehensive subroutine and rung annotation.
  - ☐ The PLC shall be commissioned using RAM memory storage modules which shall be replaced with an EEPROM when testing is complete.

**p) Technical Particulars (PLC System)**

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Sr. No.	Description	Particulars
<b>1.</b>	<b>General</b>	
1.1.	Make	As per approved vendor list
1.2.	Item	PLC System
1.3.	Service	Sewage Treatment Plant
1.4.	Area Classification	Hazardous / Non Hazardous
<b>2.</b>	<b>PLC System</b>	
2.1.	Type of Control system	Programmable Logic Controller (PLC)
2.2.	Offered PLC System configuration and PLC system hardware	Latest system available / being supplied in the international market by the manufacturer with proven performance record for the similar type of application
2.3.	Operating System windows based	Windows 10 or latest.
2.4.	Hierarchical protection for operator & engineer functions	Multi-level security required
2.5.	Response time (Maximum) for	
a.	Analog input	250 m sec
b.	RTD/ Thermocouple	1 sec
c.	Digital Input / output	25 - 50 m sec
2.6.	Loop cycle time inclusive of controller processing time	250 m sec (Analog); 100 m sec (Digital)
2.7.	Auto switchover time to backup/ redundant component at	Instantaneous and bump-less (Bidder to indicate the time)
a.	Processor level	
b.	Communication level	
c.	Power supply level	
2.8.	Card changeover, card wiring removal or communication cable change shall be possible on-line (PLC running) without causing any process interruption	PLC Card removal shall be hot swappable.
2.9.	Display Call up time in HMI monitor	1 sec or better
2.10.	Dynamic update time of parameters in the HMI monitor for measurement and control	1 sec. or better

Sr. No.	Description	Particulars
2.11.	Spare capacity required in the control processor considering spare I/O channels and future I/O modules to be located in the spare I/o slots	Minimum 20 %
2.12.	Output status on controller failure	Configurable in engineering station
2.13.	Output status on power supply failure	Configurable for switching to fail safe mode
2.14.	Status indication for each channel in DI / DO card	LED indication required
2.15.	Power supply healthiness status in all modules	LED indication required
2.16.	Optical Isolation with IPR for DI / DO	Required
2.17.	Galvanic isolation for AI / AO	Required
2.18.	Fuse Protection for AI / DI modules	Required
2.19.	Fused terminals with LED indications for each DO and also for Power supply to PLC	Required
2.20.	All I/O module status monitoring (Channel & Module level) in PLC system HMI & shall be from same processor family.	Required
2.21.	Self-diagnostics for all PLC modules	Required
2.22.	Control processor with floating point arithmetic capability	64 bit processor
2.23.	Capacity of RAM	2 MB minimum
2.24.	Spare capacity in RAM	Minimum 50 % including spare I/Os
2.25.	Processor Redundancy	Required. Dual redundant hot stand-by, Physical cable connectivity between primary and secondary controllers, loading of programs in primary controller alone.
2.26.	Power supply source redundancy with Auto changeover scheme.	Required. Shall be implemented at each PLC side.
2.27.	Power supply module redundancy in the PLC panel	Required
2.28.	Communication module redundancy	Required
2.29.	Failure of communication module/ data bus/	Required

Sr. No.	Description	Particulars
	communication bus/Power supply module shall not lead to change over of Processor/ CPU	
2.30.	Network & Network module redundancy	Required
2.31.	Hot redundant connectivity between processor to I/O rack	Required
2.32.	Primary and secondary indication on controllers	LED indication & also in MMI required
2.33.	Memory expandability	150% of offered capacity
2.34.	RAM with Battery back up	Minimum 72 hr without power.
2.35.	Supply of Flash RAM for memory /Program retention	Required
2.36.	Closed loop control	Required as per process requirement
2.37.	Open loop control (Logic , protection & interlock)	Required as per process requirement
2.38.	Maximum number of channels in I/O modules -	
a.	Analog I/O modules	8 Channels (Differential type)
b.	RTD, Thermocouple	16 Channels
c.	Digital I/O modules	16/ 32 Channels
2.39.	Power supply to the field transmitters	Analog input module shall drive the connected field transmitter on 2 wire loop
2.40.	Interrogation voltage for Digital signals	24 V DC
2.41.	Concept of I/O grouping	a) No two identical / similar equipment shall be grouped in the same I/O module b) I/Os related to equipment and I/Os related to its associated auxiliaries shall be connected to different modules. c) Inputs and outputs shall not be combined in a single module.
2.42.	Operator Work Station (OWS)	One no. Industrial grade/ Work Station grade OWS shall be considered. - Intel I5/ I7, Minimum 3.6 GHz processor or latest - 22" LED Monitor - 8 GB RAM min or better - 1 TB HDD - ASCII keyboard - DVD R/W Drive - Workstation model - Original OS & antivirus
2.43.	Engineering Work Station	One no. industrial grade/ Work Station

Sr. No.	Description	Particulars
	cum OWS	grade EWS cum OWS shall be considered. - Intel I5 / I7, Minimum 3.6 GHz processor or latest - 22" LED Monitor - 8 GB RAM min or better - 1TB HDD - DVD R/W Drive - QWERTY Keyboard - Workstation model - Original OS & antivirus
2.44.	USB ports on Operator station	4 nos.
2.45.	DVD R/W drives on Operator Station	One(1)
2.46.	Displays on HMI monitor	Process mimic displays, trend displays, system status, alarm displays, logs / reports etc. HMI software shall have minimum 100 pages or minimum (2,000) tags.
2.47.	Minimum no of plant mimics configurable	100
2.48.	Time activated logs	Periodic logs, shift report, daily report, status change log, Control system fault log
2.49.	Annunciation System	Integral to the PLC/ SCADA System
2.50.	Printers	One A4 size colour laser jet printer (min. 600 DPI resolution)
2.51.	Hot Spare I/O modules	20 % (wired up & mounted) hot spare modules for each type of I/O module shall be provided in the panel
2.52.	Spare Channels in each I/O Module used	20 % (wired up) spare channels over the entire population of each type of module.
2.53.	Spare slots in the I/O rack (wired with connector)	20% additional slots/base in each rack shall be provided which shall be wired with connectors for future provision. This is in addition to the required 20 % (wired & mounted) hot spare modules.
2.54.	Fuse with led indication for I/O channels	- Individual for analog signals - Group of max 8 for digital channels
2.55.	PLC hardware conformity to Environmental conditions	G2 rated
2.56.	Sequence of event recording (SER)	Required
2.57.	Interposing Relays	24V DC with freewheeling diode across the coil – Relay contact rating 5A at 230 V AC (To be provided at associated MCC end)
3.	Panels/ Cabinets/ Consoles	

Sr. No.	Description	Particulars
3.1	Type & Constructional Features	a) Indoor, Self Standing type with maximum height of 2200mm b) Enclosure MOC shall be CRCA Sheet Steel with following thickness. <input type="checkbox"/> Frame/ Load bearing Member- 2.0 mm <input type="checkbox"/> Doors- 2.0 mm <input type="checkbox"/> Side/ Top Covers- 1.5 mm (minimum) <input type="checkbox"/> Mounting Plate- 2.5 mm (minimum) <input type="checkbox"/> Undrilled Removable Gland plate- 3.0 mm <input type="checkbox"/> Panel Base/ Plinth- ISMC 75 or as per manufacturer's Std. c) Paint- Siemens Grey RAL 7032/ 7035 or equivalent as per IS 5. d) Enclosure protection Class- minimum IP 52 e) Anti-vibration pad of minimum 15mm thickness. f) Doors are provided with hinges and open outwards. The Swing of the door shall be 130°.
3.2	Accessories	a) Panel door switch b) Fans and louvers c) Automated panel Illumination by door switch d) Space Heater with thermostat etc. e) Plug Socket f) Accept, Reset, Emergency Push Button g) 3 point Door Lock h) Power On Indication Lamp
3.3	Earthing	Safety earth for enclosure and Electronic earth for PLC system.
4.	Quality Assurance	As per quality plan to be approved by the Employer / Engineer
5.	Inspection Requirements	Factory Acceptance Test & Site Acceptance Test as per procedure approved by the Employer / Engineer.
6.	Communication	The communication shall be redundant between the control processors and HMI as well as across processors and transmission rate shall be minimum 100 MBPS/ 1GBPS through multi- port switch having FO ports, ensuring adequate number of spare ports. Also communication between control processors and I/O shall be redundant. PLC shall be provided with required number of Modbus ports. PLC shall have time synchronisation facility with master clock directly connected to PLC cards.

Sr. No.	Description	Particulars
7.	Undertaking for Spares & support	OEM's undertaking shall be furnished for Spares & service support for minimum 10 years.
8.	Consoles & Chairs	Consoles for OWS, EOWS & Printers. Two (2) nos. operator chairs (revolving type)
9.	Software:	
a.	PLC Development License Software	Required
b.	SCADA Development License Software	Required
c.	SCADA Run Time License Software	Required
d.	Work Station Operating System License Software	Required
10.	Air Conditioner:	
a.	Inverter based energy efficient Air Conditioner minimum 2 Ton, minimum 3 Star Rating with Copper Tubing, Fittings & Accessories.	Required, (Minimum 2 Nos AC, in 1 working + 1 stand by configuration)

**q) Uninterruptible Power Supply (UPS)**

- i. The industrial grade Uninterrupted Power Supply (UPS) True On-line, double conversion modules having 415V, 50 Hz, 3 phase, 4 wire supply at input and 230V, 50 Hz, 1 phase, 2 wire supply at output shall be adequately sized to cater Instrumentation, Control & Automation loads of the facility. The UPS with 60 minute battery back up on full load (0.9 pf) using Ni-Cd batteries to provide continuous, regulated AC power under normal and abnormal conditions, including loss of the utility AC power.
- ii. The UPS shall have sealed maintenance free NI- Cd batteries with 10 years life and AC distribution board. UPS shall also have 2x100% parallel redundant 6-Pulse SCR Based Rectifier cum DCDB (having 5 nos MCB controlled outgoings- 24/ 30V or 110V DC) in matching height of UPS system, wherever required.
- iii. The batteries shall be sized such that the maximum recharge time does not exceed 8 hours.
- iv. Contractor shall furnish UPS sizing calculations for review and approval.
- v. Technical Particulars (UPS System)

Sr. No.	Description	Particulars
1	<b>General</b>	

Sr. No.	Description	Particulars
1.1	Make	As per approved vendor list
1.2	Item	Industrial grade UPS
1.3	Service	Instrumentation & Automation System
1.4	Area Classification	Non Hazardous
<b>2</b>	<b>UPS</b>	
2.1	Input	415V, 3P, 4 Wire AC
2.2	Output	230V AC, 50 Hz
2.3	UPS Capacity	*KVA (* KVA rating shall be finalized during detailed engineering)
2.4	UPS Battery back-up time	Minimum 60 min.(SMF NI-CD)
2.5	No of UPS feeders (outgoing)	As per system requirement.
2.6	UPS Type	Online, Double Conversion, Industrial
2.7	Rectifier Charger Type	SCR / IGBT Based
2.8	Static Inverter Type	SCR / IGBT Based
2.9	Static Transfer Switch Type	SCR-SCR Based
2.10	Bypass	Solid State Static Bypass with Isolation in matching cubical
2.11	Manual Bypass Switch Type	Change over
2.12	Battery Type	NI-CD with 10 years life
2.13	Isolation Transformer	Required, Built in within UPS- Input Side & Output Side
2.14	Degree of Protection	IP40 or better
2.15	Cable Entry	Back Side Bottom
2.16	Communication - SNMP Card or MODBUS	Required for following feedbacks - Rectifier Trip - Inverter Trip - Load on Battery - Battery low Pre-alarm Load on Static Bypass
2.18	Drawings / Documents	SLD, GA, Power & Control Wiring Diagram & Foundation Details, Type Test Certificate, FAT/SAT Procedure
2.19	Reference standard	IEC 62040-3 or equivalent
<b>3.</b>	<b>Rectifier cum DCDB (Wherever applicable)- 2 x 100% Parallel Redundant 6-Pulse SCR Based Rectifier cum DCDB in matching height of UPS system.</b>	
3.1	DC Rectifier Rating	Minimum 0.5KW for 24/ 30V or 110V DC

Sr. No.	Description	Particulars
3.2	DCDB Feeders	Incomer:- DP MCB  Outgoing Feeders :6A DP MCB – 5nos.

**r) Surge Protection Devices:**

- i. Surge Protection Devices (SPDs) shall be provided for each signal and power loop for field instruments located outdoor.
- ii. One SPD shall be provided in the field near transmitter and the other SPD of the loop shall be mounted in the control panel.
- iii. SPDs shall be suitable for withstanding the surge arising out of high energy static discharge / lightning discharges and protect the instrument to which it is connected against damage.
- iv. SPDs shall provide protection through the use of quick acting semiconductors like Tranzorb, zener diodes, varistors and an automatic disconnect and reset circuit.
- v. SPDs shall be passive and shall require negligible power for operation.
- vi. During the occurrence of a surge it shall clamp on the allowable voltage and pass the excess voltage to the ground.
- vii. The SPDs shall be self resetting to minimise the down time of the measurement loop. SPDs shall have minimum surge rating of 10 KA.
- viii. SPDs shall have a weather proof casing and shall be suitable for field / back of panel mounting as applicable.
- ix. There should be total isolation between input, output and ground terminals.
- x. Surge protection devices (SPDs) shall be provided at the control panel end of all instrumentation cables for the instruments located outside the building, in addition to the SPD at the instrument end. The SPDs shall be grouped in a specific area within instrument panel.

**s) Junction Box:**

- i. Junction Box Enclosure shall comply with minimum IP65 protection.
- ii. Enclosure shall meet global certifications- DIN standard EN 62 208 or EN 60529/09.2000 compliance with NEMA 4 and UL approved.
- iii. Enclosure material of construction shall be Cold Rolled close annealed (CRCA) steel sheets.
- iv. Enclosure Surface shall be anti-corrosive type. Enclosure and door shall be electro-phoric dipcoat primed, powder coated in textured RAL 7032/ 7035 and Mounting Plate shall be Zink Plated.



- v. Enclosure of all-round solid construction, single sheet construction, single door, 1 gland plate in the enclosure base, right hand door hinge, may be swapped to opposite side with lockable arrangement.
- vi. In case of single sheet construction thickness will be 1.2 -1.38mm however if it is welded, thickness will not be less than 2.5mm.
- vii. The JB shall have Z- bend design for superior mechanical strength.
- viii. The gasketing will be PU foam and complete paint process will be Restriction of Hazardous Substances (ROHS) compliant (including solvent) with EC dipcoat. Alternatively, galvanised sheet with direct powder coating is also acceptable.
- ix. Technical Particulars (Junction Box)

Sr. No	Content	Technical Specification
1	Make	As per approved vendor list
2	Item	Junction Box
3	Type	Single Sheet, Solid Construction
4	Protection Class	IP 65
5	MOC of Junction Box and Mounting Plate	CRCA
6	Color	Paint- Siemens Grey RAL 7032/ 7035 or equivalent as per IS 5.
7	Gasket	PU Foam
8	Locking facility	Required
9	Certification	EN 62 208 – Fabrication Standard EN 60529/09.2000 – Fabrication Standard, NEMA 4, UL

#### 4.10.7. Quality Assurance, Inspection and Testing:

- a) The Instrumentation, Control & Automation system shall be designed, selected & supplied ensuring proper quality & performance. Contractor's procedures for Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT) shall be submitted at least 60 days prior to the scheduled conduction of these tests for review/acceptance.
- b) The proposed FAT & SAT procedures of Contractor shall be reviewed and modified as required to generate mutually agreed & finalized procedures, based on which these acceptance tests will be performed and supervised by authorized agency of Employer.
- c) All system hardware & software used for testing shall be complete as specified and shall use actual equipment to be shipped to the site as per scope.
- d) The test equipment, meters, instruments etc. used for testing shall be calibrated at recognized test laboratory at regular intervals and valid certificates shall be made available to the Employer at the time of testing. The calibrating instruments used as standards shall be traceable to international standards. Calibration certificates for test instruments shall be produced from a recognized laboratory for the Employer's

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consent in advance of testing and if necessary the instruments shall be recalibrated or substituted before the commencement of the test.

- e) Flow meter/ Pressure transmitter/ Level Transmitter / Level Switch / Pressure gauge/ Temperature scanner shall be designed, selected & supplied ensuring proper quality & performance. Contractor's procedure for Quality assurance shall be submitted at least 60 days prior to the scheduled Factory Test for review / acceptance.
  - f) For Flow meter testing at Factory, following test shall be conduct as minimum. Hydro test, Calibration Test, Dimension Test, Megger test, Internal Inspection Report and material Test certificate review Test.
  - g) Factory Acceptance Tests (FAT):
    - i. The factory acceptance test shall be held at Contractor's works. Prior to the FAT, all the equipment shall be fully assembled, wired and properly connected & tested to establish all the specified features & functional requirements of the systems.
    - ii. During FAT, functional integrity of the system hardware and software shall be tested & demonstrated. All the necessary simulation kits as may be required for testing of software shall be arranged.
    - iii. Contractor shall perform functionality tests of complete system and satisfy himself of the results before giving notice regarding readiness of the system and its availability for FAT. Such notice shall be given minimum 15 days before the scheduled start of the FAT.
    - iv. The factory acceptance tests shall include visual and mechanical testing to establish correctness, completeness, good workmanship and functional testing.
    - v. The tests shall systematically, fully & functionally establish performance of all the hardware & software in presence of authorized representatives. All the sub-systems shall be interconnected to simulate, as close as possible, the total integrated system. Each test carried out shall be documented. Simulators shall be used for simulating field inputs. Any deficiency or problem faced shall be clearly brought-out and corrected.
    - vi. Before start of the FAT, the complete integrated system shall be kept powered on for 72 Hrs.
    - vii. All assemblies shall be aligned & adjusted and all test results shall be documented.
    - viii. The automation system shall be shipped to site only after successful completion of FAT and receipt of dispatch clearance from Employer.
  - h) Site Acceptance Test (SAT):
    - i. At site, the system shall be properly installed taking care of manufacturer's recommendation, after which Site Acceptance Tests (SAT) shall be carried out taking into the actual field instruments/ equipment in the loops.
    - ii. The Site Acceptance Test shall be held at site after the system has been installed as per the finalized SAT procedures. The tests shall be witnessed by
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Employer.

- iii. The minimum tests to be carried out shall be as indicated in table below.
  - iv. A log of all failed/ mal-operating components /modules in a sub-system shall be maintained by Contractor, with description of the affected components /modules, cause of failure, effect of failure on the sub-system and number of hours of operation before it failed. This will start from the date of powering on of the system for cold commissioning.
- i) Test & Acceptance Criteria:
- i. Following tests shall be performed as a minimum for automation system, during both FAT & SAT, in presence of authorized representatives and documented test results shall be compiled:

Sr. No.	Test Description	FAT	SAT
1.	Check of supply completeness	√	√
2.	Visual & dimensional check	√	√
3.	Check of complete system configuration loading	√	-
5.	Check of system diagnostic features. These shall include failure of any sub-system, module, power supply, interface unit, failure of transfer to redundant module on main module failure etc.	√	√
5.	Power-off and power-on of any single unit	√	√
6.	Test of alarm system	√	√
7.	Check of correct functionality of keyboards	√	√
8.	Testing of proper working of the printers	√	√
9.	Simulation of power failure and restart. Self-booting up of system configuration & program after power restoration.	√	√
10.	Analog / digital input / output check	√	√
11.	Check of scan time for PLC	√	√
12.	Check of scan time, screen update time and loop cycle time.	√	√
13.	Check of loop configuration for correct entry of ranges, limits etc.	√	S
15.	Check of HMI displays (all kind of displays)	√	S

15.	Checking of HMI screen refresh rate, data base update and display call-up time.	√	S
16.	Check of system internal loading (processor, communication system etc.)	√	-
17.	Check of various log formats, shutdown reports etc.	√	S
18.	Demonstration of all PLC system builder functions including addition/deletion of an input/output, addition/deletion of a rung or an element in a rung generation of dynamic graphics and other views, report generation etc.	√	√
19.	100% checking of logic configured in the PLC by connecting switch/lamp at input/output.	√	-
20.	Checking of output status on processor failure for PLC & checking of first-out alarm generation.	√	√

FAT= Factory Acceptance Test; to be performed at Contractor's workshop. SAT= Site Acceptance Test; to be performed at site. √= Complete test; 100% of devices/ functionality will be tested. S = Sample test All the necessary simulation kits as may be required for testing of software shall be arranged. Acceptance of any equipment or the exemption of inspection shall in no way absolve the Contractor of the responsibility for delivering the equipment meeting the entire requirement specified in this specification and also as may be required for satisfactory operation of the process.

- ii. Acceptance Criteria: Automation system shall be suitable to meet the below minimum acceptance criteria, which are to be demonstrated by the successful tenderer during testing of the system.

Sr. No.	Description	Criteria
1	Availability of Automation System	99.8% [calculated over a period of seven (7) working days]
2	HMI screen refresh time	1 sec
3	I/O scan time/data upgradation time	250 milisec for analog signals 100 milisec for digital signals  Priority processing shall be provided for the data requiring faster scan rate.
5	Network bandwidth utilization (Average of 5 minutes) (To be measured over continuous period of 8 hours)	< 10%

5	Spare (free) memory capacity available (for system, server & PCs, PLC controller)	50% (after commissioning)
6	Spare I/O capacity of each type at each location, spare ports of networking switches	20% (after commissioning)
7	CPU loading (5 minutes average)	50% (after commissioning)

#### 4.10.8. Spares & Consumables:

##### a) Commissioning Spares:

- i. Bidder shall submit a list of spares & consumables required for start-up and commissioning of the plant, equipment, systems etc. which will be supplied as part of scope.
- ii. The list shall broadly include spares & consumables for the field instrumentation items, as per manufacturer's recommendation and one no. of each type of I/O module of the PLC based automation system, with respective description & quantities.
- iii. In addition, any other spare & consumable, required during these activities, shall also be supplied by bidder under his scope.

##### b) O&M Spares:

- i. As specified in the Scope of Work, bidder shall keep with himself necessary spares during entire period of Operation & Maintenance for repair, replacement, maintenance etc. of ICA equipment.
- ii. The list of recommended spare parts shall be provided by the bidder but shall not consider in price bid. Mandatory spare parts shall be inclusive of quoted price.

##### c) Tools and Tackles:

- i. Bidder shall include in his offer and provide all the special tools and tackles for erection, testing & maintenance of the instrumentation & automation system, as required for proper functioning and maintenance system

#### 4.10.9. Applicable Standards:

- a) All equipment shall comply with all applicable national and local laws regulations and Standards, in addition to those listed below:

1	ISO 9000 and 9004	Quality Systems
2	ISO 6817	Measurement of conductive liquid flow in closed conduit- Methods using Electromagnetic Flow meter
3	ISO 4185	Measurement of liquid flow in closed conduits --

		Weighing method
4	ISO 9104	Method of evaluating the performance of electro-magnetic flow meters for liquids
5	BS EN 50081	Electromagnetic Compatibility
6	ISO 12242:2012	Measurement of fluid flow in closed conduits-Ultrasonic transit time flow meters.
7	ISO 7066-2	Assessment of uncertainty in the calibration & use of flow measurement device.
8	IEEE 587	Power Supply Surge Protection
9	IEC 61158-2	Communication Protocols
10	ISO 9075 (BS 6964)	Structured Query Language (SQL)
11	BS 5515	Documentation of Computer Based
12	BS 7165	Recommendation for Achievement of quality in Software
13	ISO 3511	Process measurement & control functions-Instrumentation symbolic
14	ISO-OSI	7 Layer Communication Model
15	IEEE 472-1974	Surge protection.
16	EEMUA	Alarm rationalization and management
17	DNP	Distributed Network Protocol
18	UHF Radio/ GPRS standards	
19	Network standards	SNMP/ SMTP Statement of Compliance

- b) The Contractor shall provide a list of the reference standards used and shall provide a compliance/non-compliance statement during drawing / documents evaluation and the bid submission.

#### 4.10.10. Drawings/ Documents Required:Not Applicable during Bidding Stage

- a) To be submitted along with the Bid (as minimum, but not limited to following):
- i. P&IDs for the complete process indicating all the local & remote /panel mounted measurements & controls, alarm & interlocking functions, using ISA symbols.
  - ii. Consolidated instrument list (Instrument Index) indicating description, application, location, type, quantity, accuracy, process parameters, measuring

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ranges, etc.

- iii. Tentative instrumentation power (UPS & Non UPS) & air requirements, as applicable.
- iv. Instrumentation, Control & Automation system configuration diagram along with a write up explaining the system functions, redundancy features, interfacing with other systems, etc.
- v. Broad bill of materials for the Instrumentation, Control & Automation equipment & peripherals.
- vi. Tentative I/O list.
- vii. Control Room layout indicating disposition of various panels, cabinets, consoles, etc. with dimensional details (approx). Heat load in the control room shall be furnished.
- viii. List of spares and consumables with details and quantities.

b) To be submitted after the award of Contract (as minimum, but not limited to following):

Drawings:

- i. Power supply distribution single line and schematics diagrams for each control panel;
- ii. Internal and external general arrangement for each control panel (dimensional);
- iii. Control panel wiring diagram, relay logic diagram along with terminal block details;
- iv. System configuration and layout diagram along with bill of material, program listings, block logic diagram and control logic write up for PLC;
- v. UPS and battery sizing calculations;
- vi. Control and instrumentation loop drawings (control and instrumentation loop drawings shall show on a single drawing the complete circuit associated with an instrument or device including details and location of power supplies, cabling and terminations)
- vii. Instrument installation detail drawing (Hook-up drawings shall detail how an instrument or device is installed)
- viii. Cable block diagrams
- ix. Cable routing/ installation drawings
- x. Foundation and fixing details and trenches drawings
- xi. Mimic general arrangement (full colour copies shall be provided)

Schedules:

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- i. Cable schedule
  - ii. Cable interconnection schedule
  - iii. Control and instrumentation load schedule for each control panel
  - iv. I/O schedule
  - v. Junction box schedule
  - vi. Instrument schedule with tag nos
  - vii. Instrumentation, process control set point schedule
  - viii. Instrument data sheets

Documents:

- i. Functional Design Specification (FDS)
- ii. Factory Acceptance Test procedure (FAT)
- iii. Site Acceptance Test procedure (SAT)

**4.11. DC SYSTEM :**

**4.11.1. Scope:** DC system (where applicable) shall include the following:

- a) One set of 24/ 30V or 110 V DC, maintenance free rechargeable sealed lead acid batteries of adequate AH capacity shall be provided for control of electrical switchgears in the Plant.
- b) Batteries shall be provided with battery charger cum DC distribution board. Battery charger shall include a float & float cum boost charger, indicating lamps and annunciations.

**4.11.2. Sealed Maintenance Free Lead Acid Battery:**

- a) Applicable Standards: The sealed maintenance free lead acid battery shall conform to the latest applicable standards specified below. In case of conflict between standards and this specification this specification shall govern.

Sealed lead acid: IS: 1651, 1652 BS: 6290

- b) The sealed batteries shall be a starved electrolyte type with electrolyte immobilized in a micro-porous material to allow recombining of generated oxygen internally. The battery shall be completely explosion resistant, shall tolerate freezing and shall not allow gases to escape during normal charging conditions. The battery shall not require any watering and be maintenance free.
- c) Positive Plates: Positive plates shall be either of cast solid in pure lead in one piece with plate formation and shall have adequate mechanical strength or of tubular plate which shall consist of a suitable bar with spines cast of suitably alloyed lead to give adequate mechanical strength or of pasted positive plates consisting of either pure lead, low anti-monial lead alloy or lead calcium positive grids; having double



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separation with a glass wool retainer mat or any other suitable material placed against the surface of the positive plates for good service life.

- d) **Negative Plates:** The negative plates shall normally be of the box type. End negative plates, if of box type may be of the half pasted type. Pasted plates shall have adequate mechanical strength and shall be so designed that the active material is maintained in intimate contact with the grid under normal working conditions.
- e) **Containers:** The containers shall be made of plastics, or fiber reinforced plastics (FRP). The container shall be spill proof, leak proof, explosion resistant and increased safety type enclosure.
- f) **Vent Plug:** The vent plug shall be for safety pressure vent and of self resealing type.
- g) **Separators:** The plate separator shall consist of a micro-porous matrix which shall serve as the mobiliser for the electrolyte. The battery separator shall maintain the electrical insulation between the plates and shall allow the electrolyte to permeate freely.
- h) **Connectors and Terminal Posts:** Inter-cell and inter-tier connectors and terminal posts shall be of Copper. Terminal posts shall be designed to accommodate external bolted connection conveniently and positively. Each terminal post shall have two bolt holes of the same diameter, preferably at right angles to each other. The bottom hole shall be used to terminate the inter-cell connection. The top hole shall be left for terminal connections. All the metal parts of the terminals shall be lead coated. The junction between terminal posts and cover and between cover and container shall be so sealed as to prevent any seepage of electrolyte.
- i) **Electrolyte:** The electrolyte shall be battery grade sulphuric acid conforming to latest editions of relevant standards. The sealed battery shall be transported with the electrolyte immobilized, sealed and fully charged.
- j) **Accessories:** The battery shall be complete with accessories and devices, including but not limited to the following:
  - i. Battery racks
  - ii. Set of inter cell, inter-tier and interbank connectors as required for the complete installation.
  - iii. One Voltmeter with suitable range and leads for measuring cell voltage
  - iv. Insulated wrencher.
- k) One set of terminals and cable boxes with glands for connecting cable as required.
- l) **Battery Racks:** Battery racks shall be constructed from good quality teak wood and painted with two coats of approve alkali resisting paint. The construction of the racks shall be suitable for fixing to a flat concrete floor. The racks shall be rigid, free standing type and free from warp and twist. The completed racks shall be suitable for being bolted end to end to form a continuous row. Insulators shall be provided below the legs of the stands.
- m) **Capacity:** The standard ampere-hour capacity at ten hour rate of discharge of the battery has been based on the requirements of loads as applicable and the minimum

ambient temperature specified. Contractor shall guarantee that the capacity of the battery offered by him is adequate for the duty specified (all loads being coincident from the instant of supply failure even at the minimum ambient temperature as specified) assuming that the battery is fully charged to

- i. 2.15 V at the start of the cycle
  - ii. 1.75 V/ cell at the end of the cycle.
- n) The Battery sizing basis shall be IEEE 485 & the Contractor to note that the Battery sizing shall be done considering design ambient temperature of 50°C & following factors.
- i. Design Factor- Min. 1.1
  - ii. Aging Factor- Min. 1.25
  - iii. Temperature Correction Factor- Min. 1.1
- o) Cell Identification: Each cell shall be marked in a permanent manner to indicate the following information:
- i. Cell number
  - ii. Type of positive plate
  - iii. Ah capacity at 10 hour rate
  - iv. Type of container
  - v. Manufacturer's name
  - vi. Month and year of manufacture.
- p) Drawings/ Document: The complete battery layout drawing shall be furnished as part of the tender and also after award of contract for Employer's approval

#### 4.11.3. Battery Chargers:

- a) The battery charger and DC Distribution board shall conform to the latest applicable standards specified below. In case of conflict between the standards and this Specification, this Specification shall govern.

Basic climatic and mechanical durability tests for components for electronic and electrical equipment	IS:9000
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Environmental tests for electronic and electrical equipment	IS:9000
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Metal clad base material for printed circuits for use in electronic and telecommunication equipment	IS:5921
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Transformers and inductors (power, audio, pulse and switching) for electronic equipment	IS:6297
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Printed wiring boards	IS:7405
Environmental requirements for semi-conductor devices and integrated circuits	IS 6553
Terminals for electronic equipment	IS:4007
Factory built assemblies of switchgear and control gear for voltages up to and including 1000 V AC and 1200 V DC	IS:8623/BS: 5486 / IEC:439
Air break switches	IS : 13947 (Part –3)BSEN 60947-3
Miniature circuit breakers	IS 8828/BSEN:60898
HRC cartridge fuses	IS:9224/BS:88
Contactors	IS:13947 (Part – 3) /BS:775/ IEC:158-1
Control switches/push buttons	IS:6875
Degree of Protection	IS:13947- (Part 1) /IEC:947-1
Climate-proofing of electrical equipment	BSCP:1014
Code of practice for phosphating iron and Steel	IS:6005/BS:3189
Semi-conductor converters	IEC:146
Semi-conductor rectifier equipment safety code	IS:6619
Specification for copper rods and bars for electrical purposes	IS : 613

- b) Requirements: The Battery Charger shall be microprocessor based & shall have two chargers mainly- i) Float Charger ii) Float cum Boost Charger.
- c) The float & float-cum-boost type battery charger shall comprise silicon controlled rectifiers (SCRs) connected in a full wave bridge circuit. Each battery charger shall be suitable for float charging the battery under normal conditions and boost charging the battery when it has discharged during service conditions. The changeover from float to boost mode and vice versa shall be automatic. Microprocessor shall be MU 1000C or Equivalent makes from the approved makes.
- d) The rectifier transformer shall be dry type and double wound with required number of taps. The DC output voltage during float charging shall be stabilized within  $\pm 1\%$  of the set DC bus voltage for AC input voltage variation of  $\pm 10\%$ , frequency variation of  $\pm 5\%$  and DC load variation from 0 - 100%. The voltage regulation shall be achieved by a constant voltage regulator having fast response SCR control. The ripple content shall be within  $\pm 1\%$  of DC output nominal voltage with battery disconnected and shall be designed to have voltage regulation of  $\pm 1\%$ . Also in any mode of operation, the maximum harmonics in the charger output shall not exceed 5%.The setting of the output DC bus voltage shall be adjustable between  $\pm 10\%$  of nominal rated voltage. There shall be provision for manual control if auto mode fails. Line surge suppressers shall be provided.
- e) If the spare float charger supplying DC load fails, the load shall be fed from the point of connection at the tapping of the battery via adequately rated blocking diodes. Two blocking diodes in series shall be provided to take care of short circuit of any one diode
- f) For boost charging the discharged battery after a mains failure, the rectifier shall charge the battery at high rate limited to the maximum boost charging voltage. The

boost charging shall come on only when selected for boost mode manually. In auto control, the DC output current shall be stabilized within  $\pm 2\%$  for AC input voltage and frequency variation of  $\pm 10\%$  and  $\pm 5\%$  respectively. There shall be provision for manual control if auto-mode fails. The boost charge voltage and current settings shall be adjustable between 70 to 100% of maximum boost charge voltage and between 30 to 100% of maximum boost charging current.

- g) Boost charging time for charging the battery to full capacity from fully discharged condition shall not exceed 8 hours.
- h) In the float charging mode, the charger shall be designed for supplying:
  - i. The DC loads of control, indication and annunciation circuits that remain energized during normal operation and the momentary closing and trip coil loads of circuit breakers, vacuum contactors; and
  - ii. The float charging current of the battery.
  - iii. 25% margin over the above load.
- i) Battery charging equipment complete with all accessories shall be housed in a free standing sheet steel cubicle having degree of protection of IP 42. Sheet steel used for construction shall be 2 mm thick. The units shall be wired using 1100 V grade, FRLS PVC insulated, multi-stranded Copper conductor cables.
- j) During boost charging the DC bus load shall be connected via two diodes in series connected to the tap cell of the battery. This is to take care in case of failure of standby charger supplying DC load.
- k) All printed circuit cards shall be plug-in type, interlocked to prevent insertion in a wrong slot. Each card shall have LED indication on its front plate to indicate normal condition and readily marked test pins.
- l) All components shall be accessible to the maintenance technician for easy disassembly and replacement. Access to parts of equipment shall be with minimum danger from all hazards.
- m) All components and modules shall be clearly and unambiguously marked and all wiring colour coded and tagged
- n) Each battery charger shall be provided with accessories that include, but not limited to the following:
  - i. Electronic controller comprising of power supply card, soft start cum current limit card, auto trickle mode card with facility for setting trickle charge current and monitoring battery current, error amplifier cards and pulse generating cards for achieving the DC output voltage stabilization of  $\pm 1\%$  and also for achieving current limiting feature. The electronic controller shall have protection features with indications for under-voltage, over-voltage, earth fault, set output voltage and phase failure or voltage unbalance. The controller shall also be suitable for boost charging the battery in case of float-cum-boost charger.
  - ii. Boost charge current limiter with potentiometer to adjust the setting
  - iii. Silicon controlled rectifiers connected in full wave bridge circuit with ripple

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control devices and transient suppression network.

- iv. 240 V AC compact fluorescent lamp fixture for internal lighting with MCB
- v. Automatic voltage regulator unit with Manual/ Auto control switch
- vi. Double wound, dry type, three phase suitably rated mains transformer with fuse protection and with one set of power factor correction capacitors to maintain a power factor of 0.85 (lag).
- vii. Electronic controller comprising of power supply card, soft start cum current limit card, auto trickle mode card with facility for setting trickle charge current and monitoring battery current, error amplifier cards and pulse generating cards for achieving the DC output voltage stabilization of  $\pm 1\%$  and also for achieving current limiting feature. The electronic controller shall have protection features with indications for under-voltage, over-voltage, earth fault, set output voltage and phase failure or voltage unbalance.
- viii. Adequately sized necessary built-in accessories shall be provided such that on failure of the controller in auto mode the voltage can be effectively controlled manually.
- ix. Filter circuit comprising of smoothing choke and condensers complete with HRC fuse with trip indication for filter condenser circuit
- x. Coarse and fine control potentiometers for manual control
- xi. Selector switch for mode of charging i.e. float charging / boost charging
- xii. Off-load tap changing switch for changing the taps of the transformer
- xiii. DC voltmeter with fuses and a three position selector switch
- xiv. DC ammeter with shunt
- xv. AC ammeter with selector switch for incoming AC power
- xvi. AC voltmeter with selector switch for incoming AC power
- xvii. MCB for incoming AC supply along with surge suppressers
- xviii. MCB on DC output side with kick fuses and alarm contacts
- xix. Voltage dropping diodes in load circuit during boost charging mode
- xx. DC under voltage relay and earth fault relay
- xxi. AC/ DC switching relays for alarm and indication circuits including buzzer
- xxii. Cubicle space heater suitable for 230 V AC, 1 ph, 50 Hz supply, with MCB and thermostat
- xxiii. Each battery charger shall be provided with the following alarms / indications:
  - ☐ AC and DC supply 'ON'

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- ☐ AC and DC supply fail
  - ☐ Modes of charging
  - ☐ Over voltage
  - ☐ Under voltage on DC side
  - ☐ Earth fault on DC side
  - ☐ AC/ DC MCB trip
- o) The DC circuit switching shall be through DC MCBs only.
- p) Power Electronic Components:
- i. Diode and thyristors shall be of mono-crystalline type silicon, capable of providing continuous output at specified voltages. It shall have high power efficiency.
  - ii. If many diode or thyristor assemblies are connected in parallel, care shall be taken to ensure that each rectifier or thyristor operates within its rating and shares the load uniformly.
  - iii. Each diode or thyristor built in a multi-built assembly shall be provided with a short circuit protection to avoid complete shut-down of the equipment because of a fault on single unit. Suitable fuses shall be provided for such protection.
  - iv. Necessary spare capacity shall be built in the equipment to continuously supply full load even with one unit out of circuit.
  - v. The diodes or thyristors shall be protected against overvoltage due to chopping surges with the aid of snubbers (i.e resistor-capacitor combination and Metal oxide variator

#### 4.11.4. DC Distribution Board:

- a) The distribution board shall be of floor mounting design. Entry for incoming and outgoing cables shall be from the bottom. Bus bars shall be of Copper. Incomers, bus coupler and outgoing circuits shall be controlled by suitably rated double pole MCBs suitable for DC application.
- b) Constructional features, pre-treatment, painting and other aspects shall comply with the specifications for LV switchboard.
- c) An earth busbar of 25x3 mm copper flat shall be provided along the length of the DB at the bottom. Two nos. earthing terminals shall be provided on the external face of the board for connection to the earthing grid.

#### 4.11.5. Tests:

- a) The batteries, chargers and distribution boards and their components shall be subjected to routine/ acceptance tests as per the applicable standards. For battery & battery charger, following tests are also to be carried out:
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- i. Visual checks for dimensions and general arrangement.
  - ii. Wiring checks.
  - iii. Functional checks.
  - iv. IR Test.
  - v. Capacity test.
  - vi. Test for voltage charging and discharging.
  - vii. Ampere-hour and watt-hour efficiency test.
  - viii. Hipot test, excluding electronic controller, at 2 kV AC for one minute.
- b) Certificates of type tests carried out on similar equipment not older than 5 years shall be furnished by Contractor.

#### 4.11.6. Drawings/ Documents Required:

After award of contract Contractor has to submit the below mentioned drawings/ documents for Employer's approval :

- a) Dimensioned general arrangement drawings
- b) Fully dimensioned general arrangement drawings of battery and battery charger with elevation, side view, sectional view and foundation details
- c) Complete schematic and wiring diagrams.
- d) Detailed BOM for the complete panel, with details of switchgear, controller, components etc.

#### 4.12. DIESEL STANDBY GENERATOR:

- 4.12.1. Applicable Standards : The Diesel Standby Generator and its components shall conform to the latest applicable standards specified below:

Diesel Engines for General Purposes	:	BS 5514 / ISO 3046
The Electrical Performance of Rotating Electrical Machinery	:	BS 5000
Rotating Electrical Machines	:	IS 4722
Circuit breakers	:	IS-13118, BS-5311, IEC-56 & 694, BSEN-60942 (P-2)
Air break switches air break disconnectors, air break switch disconnectors and fuse combination units for voltage not exceeding 1000 V AC or 1200 V DC	:	IS-13947 (P-3), BS-EN60947, IEC-60947-3
Current transformer	:	IS-2705/BS-7626, IEC-60185
Voltage transformer	:	IS-3156/BS-7625/IEC 60186

Electrical Relays	:	IS-3231, 3842/BS-142/IEC-60255
Contactors for voltage not exceeding 1000 V ac or 1200 VDC	:	IS-13947 Part-IV/ BSEN-60947-4-1/ IEC-60947-4-1
Control switches/ push buttons	:	IS-6875/BSEN-60947 / IEC-60947-4-1
High Voltage Fuse		IS-9385/BS-2692/ IEC-60282
Low Voltage Fuse	:	IS-13703/BS-1362 IEC-269-1
Electrical direct acting indicating instruments	:	IS-1248/BS-89/IEC-6005
A.C. electricity metres of induction type voltage greater than 1000 volts	:	IS722, 8530/BS-5685 / IEC-60145, 60211
Resistance wire, tapes and stripes for heating elements	:	IS-3725
Wrought aluminium and aluminium alloy bars, rods, tubes and sections for electrical purposes	:	IS-5082
Specification for copper rods and bars for electrical purposes	:	IS-613
Toggle switches	:	IS-3452/BS-3676
Noise and Emission Limit	:	As per latest notification of ministry of Environment and Forests

#### 4.12.2. General Requirements:

The diesel engine and generator shall be skid mounted and shall be located in a room near Treatment plant substation building. The diesel engine shall draw cooling air directly from outside the room through a weatherproof, acoustically treated duct. The exhaust system shall be insulated to minimize the amount of heat entering the room and to prevent injury to personnel. The silencer shall be of the 'residential' type and be located externally.

The generation voltage shall be 415V for DG capacity less than 2MVA and generation voltage shall be 11kV for D.G capacity more than 2MVA. In case more than one D.G set is required for achieving the required capacity they shall be operated in parallel with necessary synchronizing arrangement. At no point DG sets will be operating parallel with grid.

The diesel engine fuel shall be stored in an above ground bulk storage steel tank to be located adjacent to the generator room at a site accessible for filling to local road tankers. The storage tank shall be sized to store fuel for one (1) day running of the engine at full load. The tank shall be provided with fittings to permit the visual observation of fuel level and filling by local tanker operators. A level meter shall also be mounted in the tank so that remaining fuel volume can be monitored at the generator / substation PLC and the operator stations in the SCADA room.

The fuel storage tank shall be located in a bund capable of holding not less than 125 % of the maximum storage tank contents. Fuel transfer pumps shall be provided to automatically



transfer fuel from the bulk storage tank to a high level 990 litres day tank located in the generator room or generator skid mounted day fuel tank. A semi-rotary hand pump shall be provided to permit transfer of fuel in the event of a failure of the transfer pump. Any leakage from the pumps shall be routed to the bund.

A system shall be provided within the generator room to detect fire, to raise a local audible alarm (manually silenced locally) and if a high level day tank is used, to automatically dump the day fuel back to the bulk storage tank.

The system shall be constructed such that leakage of water, fuel or oil within the generator room shall be routed to a local sump where a detector shall be provided to raise an alarm.

The system shall be constructed such that the leakage of fuel or the accumulation of water within the fuel storage bund shall be detected and shall raise an alarm.

All alarms shall be conveyed to the central HMI through the PLC.

#### 4.12.3. Diesel Generating Set Automatic Control

AMF Diesel Generator Set capable of automatic starting and picking the load within 30 seconds shall be provided to cater for emergency loads and lighting during mains power failure. Diesel generating set for use in auto mains failure mode shall have a three position automatic / off / manual selection and shall operate as follows:

(i) Automatic mode :

On occurrence of mains failure the following sequence shall be followed.

Mains to Generator changeover

- mains failure detected
- delay of 10 seconds
- generator is started and run up to speed
- time delay of 50 seconds
- mains supply is switched off
- generator supply is switched on

Generator to Mains changeover

- mains healthy detected
- manual changeover signal received,
- generator supply is switched off
- mains supply is switched on
- generator runs for 2 minutes and stops

All timer settings shall be adjustable.

If mains power is restored during the initial one minute delay then the power shall be monitored for a further one minute and if it is still healthy, mains power shall be restored. The generator shall be stopped after a further 2 minutes of running on no load. If the generator fails to start after an initial period of cranking, two further attempts shall be made with an appropriate interval between each attempt. If the engine fails to start after three attempts the system shall shut down and a local and remote alarm shall be annunciated.

(ii) Manual mode:

The generator shall run to the dictates of manual controls on the generator. No automatic changeover of mains to generator supply or vice versa shall take place. The generator shall be loaded by manual switching if required.

#### 4.12.4. Alternator for Diesel Generating Set:

The generation voltage shall be 415V for capacity less than 2MVA and generation voltage shall be 11kV for capacity more than 2MVA.

Alternator shall be 4 pole, 3 phase, 50 Hz, 0.8 P.F, salient pole, revolving field, brushless type, self-regulating continuously rated and manufactured in accordance with IS 4722, BS 5000 : Part 99 or IEC 60034-1. They shall be totally enclosed, screen protected, fan ventilated and vertical drip-proof conforming to IP 23. The Alternator shall be complete with excitation system, AVR and all necessary auxiliaries. The alternator shall be driven by diesel engine detailed below and shall match the same in all respects. The terminal box shall be dustproof with IP 54 degree of protection. The terminal box shall be suitably sized to terminate the size and number of cables involved. Alternators shall be capable of withstanding a 10% overload for 1 hour in any 12 hour Period under the specified conditions of temperature, humidity and atmospheric pressure.

Alternator windings shall be of Class H insulation with Class F temperature rise and tropicalised. The alternator shall have pre-packed grease lubricated ball or roller bearings and provided with facilities for regreasing whilst in service.

The alternator shall be foot mounted on a common bed frame with the prime mover close coupled to the engine flywheel housing. The direction of alternator rotation when viewed from the driven end shall be clockwise and phase voltage sequence UVW. The alternator vibration level shall not exceed the values defined in IS 12075.

The alternator shall be capable of maintaining a short circuit current of three times full load current for a period of 10 seconds. The alternator shall be fitted with an anti-condensation heater. No individual harmonic shall exceed 1% and the total harmonic shall not exceed 3%. The alternator, its neutral and control panel shall be earthed as per relevant standards.

The alternator rotor assembly shall comprise exciter rotor, full wave silicon bridge rectifier surge protection device and salient pole rotating field system. The rotor shall be fitted with interconnected pole face damping windings. Voltage regulation shall be maintained to within  $\pm 2.5\%$  for a power factor of 0.8 to unity, including hot to cold variations. The steady state frequency droop between no load and full load shall not exceed 5%. Transient voltage deviation following a step load of 60% of rated at a power factor of between 0.4 and zero shall not exceed 15% with a voltage recovery time to 97% rated voltage not exceeding 0.5 second. The set shall be capable of continuous operation with a phase current imbalance of 33% of rated current whilst maintaining the output voltage within  $\pm 5\%$  of rated.

#### 4.12.5. Diesel Engine for Generating Set:

Engine shall be four stroke, direct injection, turbocharged industrial machines. They shall be fitted with renewable wet cylinder liners if water cooled and shall be direct coupled to the alternator and mounted on a common rigid steel bedplate.

Engines shall be rated for continuous duty at site ambient conditions with an inherent O/ L Capacity of 10% for 1 hour in any 12 hours. The engine shall be capable of running at full load for not less than 180 hours without maintenance adjustments and 10000 hours between major overhauls. The maximum operating speed shall be 1500 rpm. The range of manual adjustment shall not be less than  $\pm 5\%$  of rated speed. The performance of engine governors under load conditions shall be to Class A2 in accordance with BS 5514: Part 4. Engine governors shall be suitable for remote control load sharing between identical engine units. In addition to any electrical over speed trips, there shall be a mechanical device which shall operate at 120% of the rated speed. Re-setting of the over speed trip shall be

possible by hand only. The steady state output speed drop between no load and full load shall not exceed 5%. The transient output speed deviation shall not exceed 10% for a step of 60%. Engines shall be designed to run on fuel oil complying with IS 1460 or BS 2869, Class A2. Engines shall be cooled by means of a water jacket, heavy duty air blast radiator with integral radiator header tank, circulating pump and engine driven pusher type fan. The fan shall draw air in from the vicinity of the engine block and discharge it through the radiator core. The radiator shall be mounted on the same bedplate as the engine and alternator on suitable vibration isolators and be arranged so that it is located directly behind automatic louvers set into the external wall of the engine room. A thermostatically operated by-pass valve shall be fitted in the cooling system to maintain an optimum operating temperature during starting and running conditions. Drain cocks shall be provided so that all the water can be drained from the system. A separate oil cooler shall be used for cooling the engine oil. A thermostatic by-pass valve shall be incorporated. Engine lubrication shall be by a closed circuit wet sump, forced feed system supplied by an engine driven pump fitted with pressure regulating and relief valves, sump suction filter and changeover renewable micro-felt full flow line filters. A hand operated semi-rotary oil pump shall be installed to carry out initial priming or to fill or empty the sump as required. The sump shall be fitted with an easily accessible drain point. The oil shall be of the grade recommended by the engine manufacturer. The starting system shall comprise 12 or 24 V heavy duty lead acid batteries (positioned on a floor mounted stand adjacent to the engine) connected by heavy duty flexible butyl rubber cables. Batteries shall be sized to give six consecutive starts of the engine at 0°C. An engine driven alternator and charging system shall be provided. An automatic mains energised battery charger shall be provided, with sufficient capacity to maintain the battery in a condition to fulfil the starting requirements. Barring (hand turning) equipment shall be provided so that the engine can be manually rotated for maintenance purposes. It shall be arranged so that normal starting of the engine is inhibited whilst the hand turning equipment is connected. Twin heavy duty air intake filters in accordance with IS 3169 or BS 7226 suitable for operating in dust laden atmospheres shall be fitted. The filters shall be of the paper element with pre-cleaner type. Turbocharger filters shall be fitted. Breathers shall be fitted with washable filters which are easily accessible for maintenance.

Instrumentation shall be provided to monitor speed, oil pressure, oil temperature (sets larger than 250 kVA), water temperature and battery charge current. The bedplate shall be of heavy gauge steel construction, stress relieved and free from distortion.

Machined surfaces shall be incorporated for mountings and for levelling. Anti-vibration mountings shall be fitted between the bedplate and the floor to prevent vibrations being transmitted to the building. The mountings shall be adjustable for leveling purposes and shall be designed to resist horizontal movement of the diesel set.

The fuel System shall comprise an engine driven feed pump with duplex filters, 990 litres day tank with supporting structure or generator skid mounted day fuel tank, with all interconnecting pipe work, flexible engine connection pipe etc.

4.12.6. Diesel Generator Control Panel: The control panel shall be separately mounted on anti vibration mountings and shall comprise the following:

- ☐ Breaker incorporating short circuit and overload trip
- ☐ Earth fault protection for the Alternator
- ☐ Alternator Over & Under Voltage Protection
- ☐ Voltage Controlled Over Current Relay
- ☐ voltmeter and seven position selector switch
- ☐ ammeter and 4 Position selector switch
- ☐ frequency meter
- ☐ Power Factor Meter

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- ☐ Kwh Meter
  - ☐ engine temperature and oil pressure gauge
  - ☐ service hours run indicator
  - ☐ key switch start and stop control
  - ☐ operational status indicator
  - ☐ anti-condensation heater and thermostat
  - ☐ alternator anti-condensation heater controls
  - ☐ mains fed battery charger
  - ☐ Auto start on mains power supply failure facility
  - ☐ Fails to Start (Alarm )
  - ☐ Over / Under Voltage Alarm
  - ☐ Battery Charger Fault (Alarm)
  - ☐ Low fuel Oil Level (Alarm)
  - ☐ Over Load (Alarm)
  - ☐ Low Lube Oil Pressure (Trip)
  - ☐ High Water Temperature(Trip)
  - ☐ High Lube Oil Temperature (Trip)
  - ☐ Electrical Protection Relays (Trip).

A reset button shall be provided to cancel the alarm /shut-down condition prior to re-starting. Simple operating instructions shall be detailed on the fascia of the control panel.

#### 4.12.7. Synchronizing Panel

Whenever two sets are required to operate together, necessary synchronizing panel complete with circuit breaker, synchroscope, relays, meters etc shall be provided. The Panel shall be floor standing, CRCA Sheet steel enclosed.

#### 4.12.8. Acoustic Enclosure

- a) The DG Set shall be provided with acoustic enclosure, fully integrated, weather proof with superior finish for long and durable life.
- b) The acoustic enclosure shall be CRCA sheet steel enclosed with necessary panels and doors, inside lining of fire retardant foam /glass wool as acoustic material.
- c) The sound level shall be restricted to 75 dB at a distance of 1 meter, under full load, free field conditions as per relevant standards.
- d) The acoustic enclosure shall be certified to meet the emission norms.

#### 4.12.9. Bulk Fuel Storage Tanks

Tanks and fittings, etc shall conform to IS 803 or BS 799: Part 5. The tank shall be constructed in mild steel and the fittings in materials other than:

- Yellow brass, including low grade alloys of copper and zinc.
- Lead and zinc.
- Galvanized metals.
- Natural rubber.

An ullage volume above maximum contents level of the tank shall not be less than 5% of the maximum volume of the fuel. The maximum fuel surface level below the point of entry of the vent shall not be less than 100 mm. The internal surface shall be cleaned and treated with temporary preservative, soluble in fuel oil, before shipment. The following fittings shall be included:

- (a) 600 mm diameter manhole complete with portable cover situated in the top of the tank complete with ladder to the interior.
  - (b) Dipstick, calibrated in litres with guide tube and striker plate.
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- (c) Local indication of fuel level to be given at a position where it can be easily read during fuel delivery.
  - (d) Filling pipe work and fittings complete with isolation valve and captive end cap. The filling point to be at the top of tank to prevent siphoning.
  - (e) Outlet pipe situated at the raised end of the tank not less than 150 mm above tank bottom, complete with check valve, isolating valve and end cap.
  - (f) Drain pipe situated at lowest point in tank complete with isolating valve and captive end cap.
  - (g) Inlet fittings for overflow pipe from daily service tank or tanks (where specified).
  - (h) Vent pipe situated at high level in the tank. The pipe shall rise continuously from the tank and terminate with an inverted 'U' bend and vermin screen.
  - (i) External ladder for horizontal tanks more than 2 m diameter.

#### 4.12.10. Drawings / Documents Required:

All Drawings, data, technical particulars, calculations, detailed literature, catalogues Test certificates etc shall be submitted along with the bid/ after award of contract.

#### **4. SAFETY EQUIPMENTS/ REQUIREMENTS AND MISCELLANEOUS ITEMS:**

- 4.1. Following safety procedure and practice should be provided by Contractor in switchgear room/ sub-station as per latest edition of I.S. 5216.
    - 4.1.1. 900 mm wide antiskid insulating mat as per IS 15652 and of reputed make to be spread in front of the 11kV, 415V switch gear panels & power DBs, DCDB etc.
    - 4.1.2. First aid box with all the standard contents.
    - 4.1.3. First aid chart made of cloth for electrical shock treatment printed in English, Hindi and Gujarati duly framed with front glasses.
    - 4.1.4. Charts/ drawings duly framed with front glass.
    - 4.1.5. HV and LV power supply single line diagrams in adequate sizes approved by Employer/ Employer's representative & in line with the local electrical inspector.
    - 4.1.6. Routine maintenance schedule for High Voltage Switchgear, Distribution Transformers, Low voltage Switchgears, APFC panels, Fire Alarm System, UPS system etc.
    - 4.1.7. Provision of portable type Class A, B, C, and D type fire extinguishers at various locations in line with the statutory requirements.
  - 4.2. FIRE SAFETY:
    - 4.2.1. The requirement of hand appliance in switchgear room, electrical equipment room shall be provided as per Clause 4.0 of Fire Protection Manual by Regional Tariff Committee, 10th edition 1988.
    - 4.2.2. Water Sealing & Fire Barriers at appropriate locations as specified in this specifications & good engineering practices.
  - 4.3. DEGREE OF PROTECTION:
    - 4.3.1. The enclosures of the control cabinets, junction boxes and Marshalling boxes, panels etc. to be installed shall provide minimum degree of protection as detailed here under
      - i. Installed outdoor – IP 55
      - ii. Installed indoor – IP 54
    - 4.3.2. The degree of protection shall be in accordance with IS 13947 (Part I)/ IEC 947 (Part I)/ IS 2063/ IEC 529
  - 4.4. ELECTRICAL EQUIPMENT FOR HAZARDOUS AREAS: The electrical equipments for hazardous areas shall be selected as per IS 5572. Following factors shall be considered for proper selection of electrical equipments for use in Hazardous Area.
    - 4.4.1. Area Classification (Zone)
    - 4.4.2. Gas Classification (Group) – The characteristics of the gas or vapour involved in relation to the ignition or energy and safe gap data
    - 4.4.3. Temperature Classification- The ignition temperature of the gas or vapour involved or
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lowest value of the ignition temperature, if more than one combustible material is present.

- 4.4.4. Environmental conditions – In which apparatus is to be installed. The selected electrical apparatus shall be adequately protected against corrosive and solvent agencies water ingress, thermal and mechanical stresses as determined by the environmental condition.

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5. **INSTALLATION, TESTING & COMMISSIONING – ELECTRICAL & INSTRUMENTATION EQUIPMENT**

5.1. GENERAL:

- 5.1.1. In accordance with the specific installation instructions, as shown in Contractor's drawings or as directed by the Engineer In Charge the Contractor shall unload, erect, install, wire, test and place into commercial use of all electrical & instrumentation equipment included in the contract. Equipment shall be installed in a neat manner so that it is level, plumb, and properly aligned and oriented.
- 5.1.2. The Contractor shall furnish all supervision, labour, tools, equipment, rigging materials and incidental materials such as bolts, wedges, anchors, concrete inserts etc. required to completely install, test and adjust the equipment.
- 5.1.3. Drawings, instructions and recommendations shall be correctly followed in handling, settling, testing and commissioning of all equipment and care shall be exercised in handling to avoid distortion to stationary structures, the marring of finish, or damaging of delicate instruments or other electrical parts.
- 5.1.4. The Contractor shall erect and commission the equipment as per the instructions of the Employer/ Engineer In Charge and shall extend all co-operations to him.
- 5.1.5. In case of any doubt/ misunderstanding as to correct interpretation of drawings or instructions, necessary clarification shall be obtained from the Engineer's Representative. The Contractor shall be held responsible for any damage to the equipment consequent to not following instructions correctly.
- 5.1.6. The Contractor shall move all equipment into the respective buildings through regular doors or floor openings provided specifically for the equipment. The Contractor shall make his own arrangement for lifting of equipment.
- 5.1.7. Where assemblies are supplied in more than one section, the Contractor shall make all necessary mechanical and electrical connections between sections including the connections between bus bars/ wires. The Contractor shall also carry out the adjustments/ alignments necessary for proper operation of the circuit breakers. All insulators and bushings shall be protected against damage during installation. Insulators or bushings chipped, cracked or damaged due to negligence or carelessness shall be replaced by the Contractor at his own expenses.
- 5.1.8. The Contractor shall take utmost care in handling instruments, relays and other delicate mechanisms. Wherever the instruments or relays are supplied separately, they shall be mounted only after the associated control panels have been erected and aligned. The blocking material/ mechanism employed for the safe transit of the instruments and relays shall be removed after ensuring that the panels have been completely installed and no further movement of the same would be necessary. Any damage to relays and instruments shall be immediately reported to the Engineer In charge.
- 5.1.9. Equipment furnished with finished coats of paint shall be touched up by the Contractor if their surface is spoiled or marred while handling.
- 5.1.10. Foundation work and grouting of fixing bolts or channels for all transformers, switchgear, motors, and control panels shall be carried out by the Contractor.

5.2. POWER/ DISTRIBUTION TRANSFORMERS:

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Inspection, storage, installation, testing and commissioning of transformers shall be in accordance with the latest Indian Standards Code of Practice IS: 10028. All commissioning tests as applicable, vide Appendix B of IS: 10028 (Part II) shall be carried out. Fire Wall of 4 Hr fire rating shall be provided between two transformers.

### 5.3. HV/ LV SWITCHGEAR CONTROL PANELS:

5.3.1. Switchgear control panels shall be installed in accordance with the latest Indian Standard Code of Practice 10118. The switchgear panels shall be installed on finished surface or concrete or steel sills. The Contractor shall be required to install and align any channel sills which form part of the foundations. Tape or compound shall be applied where called for. The base of outdoor type units shall be sealed in an approved manner to prevent ingress of moisture.

5.3.2. Following minimum clearances shall be observed while finalizing the HV/ LV panel layouts-

- a) Minimum clearance of 1.0 meter shall be maintained from the rear of the panel to the nearest wall /structure.
- b) Minimum clearance of 2.0 meter between panels facing opposite to each other.
- c) Side clearance for LV panels shall be either  $\leq 200\text{mm}$  or  $\geq 800\text{ mm}$ .
- d) For HV metal enclosed, indoor panels, Minimum 1 meter clearance from all sides & 1.5 meter in the front.

5.3.3. Emergency Exit doors shall be provided for electrical room, complying with the requirements of NBC 2005 latest edition.

5.3.4. After installation of all power and control wiring, the Contractor shall perform operating tests on all switchgear and panels to verify the proper operation of switchgear/ panels and the correctness of the interconnections between various items of equipment. This shall be done by applying normal a-c or d-c voltage to the circuits and operating the equipment. Megger tests for insulation, polarity checks on the instrument transformers, operation tests on equipment, and installation tests shall be carried out by the Contractor who shall also make all necessary arrangements for proper functioning of the equipment.

### 5.4. EARTHING AND LIGHTNING PROTECTION SYSTEM:

5.4.1. The Contractor shall install copper/ steel conductors, braids, etc., required for the system and individual equipment earthing. All work such as cutting, bending, supporting, painting/ coating, drilling, brazing/ soldering/ welding, clamping, bolting and connecting onto structures, equipment frames, terminals, rails or other devices shall be in the Contractor's scope of work. All incidental hardware and consumables such as fixing cleats/clamps, anchor fasteners, lugs, bolts, nuts, washers, bituminous compound, welding rods, anti-corrosive paint as required for the complete work shall be deemed to be included by the Contractor as part of the installation work.

5.4.2. The quantities, sizes, material of earthing conductors and electrodes to be installed as per requirement. Routes of the conductors and locations of electrodes shall be shown in the earthing layout drawings, which are to be prepared by Contractor & approved by Employer's representative.

5.4.3. The work of embedment of earthing conductor in RCC floors/ walls along with provision of earth plate inserts/ pads/ earth risers shall be done by the Contractor when the floors are

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cast or during construction of walls. Contractor's scope of installation shall also include, laying the conductors in position with 60 mm concrete cover, making welded connections to inserts/pads/risers above the floor near the equipments. The embedded conductors shall be connected to reinforcing rods wherever necessary.

- 5.4.4. If the tap connections (earthing leads) from the floor embedded main earthing grid to the equipment are more than 500 mm long then the same shall be embedded in floor by the Contractor where required, together with associated civil work such as excavation/chasing, concreting and surfacing. The concrete cover over the conductor shall not be less than 60 mm.
  - 5.4.5. Installation of earth conductors in outdoor areas, buried in ground, shall include excavation of earth up to 600 mm deep 450 mm wide, laying of conductors at 600 mm depth, brazing/ welding as required, of main grid conductor joints as well as risers of length 500 mm above ground at required locations and then backfilling material to be placed over buried conductor shall be free from stones and other harmful mixtures. Backfill shall be placed in layers of 150 mm, uniformly spread along the ditch, and tampered utilizing pneumatic tampers or other approved means. If the excavated soil is found unsuitable for backfilling, the Contractor shall arrange for suitable material from outside.
  - 5.4.6. Installation of earth connection leads to equipment and risers on steel structures/ walls shall include laying the conductors, welding/ cleating at specified intervals, welding/ brazing to the main earth grids risers, bolting at equipment terminals and coating welded/ brazed joints by bituminous paint. Galvanized conductors shall be touched up with zinc rich paint where holes are drilled at site for bolting to equipment/ structure.
  - 5.4.7. Electrodes shall be installed in constructed earth pits, and connected to main buried earth grid, The scope of work shall include excavation, construction of the earth pits including all materials required for construction of earth pits, placing the rod and fixing test links on those pipe/ rod/ plate electrodes in test pits and connecting to main earth conductors.
  - 5.4.8. Installation of lightning conductors on the roofs of buildings shall include laying, anchoring, fastening and cleating of horizontal conductors, grouting of vertical rods wherever necessary, laying fastening/ cleating/ welding of the down comers on the walls/ columns of the building and connection to the test links to be provided above ground level.
  - 5.4.9. Installation of the test links shall include mounting of the same at specified height on wall/column by suitable brackets and connections of the test link to the earth electrode.
  - 5.4.10. Whenever main earthing conductor crosses cable trenches, they shall be buried below the trench floor.
  - 5.4.11. Suitable earth risers shall be provided above finished floor/ ground level. If the equipment is not available at time of laying of the main earth conductors, the minimum length of such riser inside the building shall be 200 mm and outdoors shall be 500 mm above ground level. The risers to be provided shall be marked in project drawings.
  - 5.4.12. Earth leads and risers between equipment earthing terminals and the earthing grid shall follow as direct and short a path as possible.
  - 5.4.13. An earthing mat shall be provided under each operating handle of the isolator and operating mechanism of HV breakers. Operating handle of the isolator and supporting structure shall be bonded together by a flexible connection and connected to the earthing grid.
  - 5.4.14. A separate earth electrode bed shall be provided adjacent to structure supporting lightning
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arrestors. Each connection shall be as short and as straight as practicable. For arrestors mounted near transformers, earth conductors shall be located clear off the tank and coolers.

5.4.15. Wherever earthing conductors passes through walls, galvanized iron/PVC sleeves shall be provided for the passage of earthing conductor. The pipe ends shall be sealed by the Contractor by suitable water proof compound.

5.4.16. Earthing Connections:

- a) All connections in the main earth conductors buried in earth/ concrete and connection between main earthing conductor and earth leads shall be of welded type.
- b) Connection between earth leads and earthing terminal provided on the equipment shall be bolted type.
- c) All bimetallic connections shall be treated with suitable compound to prevent moisture ingress.
- d) Metallic conduits and pipes shall be connected to the earthing system.
- e) Lightning protection system down conductors shall not be connected to other earthing conductors above ground level. Also no intermediate earthing connection shall be made to lightning arrester and transformer earthing leads which shall be directly connected to pipe electrode.

5.4.17. Earth Electrodes:

- a) Electrodes shall as far as practicable, be embedded below permanent moisture level.
- b) Test pits with concrete covers shall be provided for periodic testing of earth resistance. Installation of pipe electrodes in test pits shall be suitable for watering. The necessary materials required for installation of test pits shall be supplied and installed by Contractor. The installation work shall also include civil work such as excavation and connection to main earth grid.
- c) Earth pits shall be treated with salt and charcoal. In case found necessary, then with the approval of Employer's representative, Back fill compound of suitable composition may be used. Back fill material shall not be water soluble & shall retain moisture & enhance conduction around electrode. Back fill compound shall be low resistance & non corrosive earth enhancement compound which shall provide safe discharge path to fault current & lightening current.
- d) Ohmic value shall be within safe limits & it shall be stable & not fluctuating.
- e) Soil, salt and charcoal placed around the electrode shall be finely graded, free from stones and other harmful mixtures. Backfill shall be placed in layers of 250 mm thick uniformly spread and compacted. If excavated soil is found unsuitable for backfilling, the Contractor shall arrange for a suitable soil from outside.

## 5.5. INSTALLATION OF CABLE RACKS AND CABLE TRAYS:

### 5.5.1. General

- a) Lines and grade for trays may be measured from building steel and finished floor elevations. Change in line or grade, or the addition of offsets by means of cutting standard tray sections and inserting additional tray fittings to match with the existing arrangement shall be considered as a normal part of the work.
- b) Where embedded steel inserts in concrete floors/ walls for welding the supports for cable racks/ trays are not available, Contractor shall provide suitable anchor fasteners at no extra cost.
- c) Cable shall be clamped to the cable trays at every 750 mm distance.
- d) Flexible metallic conduits shall be used for termination of connection to equipment such as motors, limit switches and other apparatus.

### 5.5.2. Cable Trays: All the cable tray shall be hot dipped galvanized with minimum galvanization thickness as per mentioned in this specifications.

- a) Cable tray shall be of perforated sheet steel with formed flanges and of minimum thickness not less than 1.25 mm for trays up to 100 mm width, not less than 1.5 mm for trays from 100 mm to 150 mm width and not less than 2.0 mm for trays from 150 mm to 300 mm width.
- b) All the cable trays above 300 mm width shall be of ladder type with minimum thickness of 2.5 mm.
- c) Cable tray for use in areas where chlorine gas may be present shall be constructed from U-PVC or GRP. Cable tray supports shall be of a compatible finish with the associated cable tray.
- d) All cable trays tees, intersection units, bends, turns and sets shall be prefabricated (made by the manufacturer) and shall be of a matching design to the main section of cable tray.
- e) Tray shall only be joined by couplers supplied by the manufacturers. The joint shall be secured in accordance with the manufacturer's instructions.
- f) Cable tray supports supplied by a manufacturer or made up on Site shall have adequate strength to maintain rigid support to the fully laden cable tray along its entire length and shall ensure that the deflection of any one section does not exceed 15 mm at mid span.
- g) 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 or damaged section of the tray shall immediately be given a coat of zinc rich cold galvanized paint. All site manufactured accessories, supports and metal fittings required to ensure correct installation of the cable trays shall be similarly treated.
- h) All cables shall be firmly secured to the tray using purpose made saddles, as approved by the Employer's Representative, together with proprietary nylon fasteners and/or cable cleats. Following installation of cables, the tray shall remain rigidly supported and the deflection of any section shall not exceed 15 mm at mid span. All

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brackets and tray work shall be suitable for withstanding a temporary weight of 125 kgs.

- i) Cable trays shall not be cut to allow the passage of cables through the surfaces of the tray
- j) The sizing of the cable tray shall provide a minimum of 20% spare capacity.
- k) The tray shall be run at least 300 mm clear of plumbing and mechanical services.
- l) Bends in the installation shall take account of the minimum bending radii of cables to be installed.
- m) All the cable trays shall be supplied with cable tray supports (of adequate size) at no more than 1.2 meter interval.
- n) Other cable tray details & cabling system shall be as per typical drawings attached with the specifications.

#### 5.5.3. Cable Trunking – Metal:

- a) Cable trunking shall be manufactured from mild steel of not less than 1.25 mm and shall be hot dipped galvanized. The Contractor shall ensure that the size of the trunking is adequate for the number of cables to be installed together with 50% spare capacity and shall in any case be 50 mm x 50 mm minimum size.
  - b) Segregation of cables shall be carried out if required using continuous sheet steel barriers with the bottom edge welded to the trunking.
  - c) The trunking shall have two return flanges for rigidity. Where necessary, additional strengthening straps shall be fitted internally. The cover shall overlap the trunking and be made of the same gauge. Fixing screws for covers shall be recessed and be of the self retaining 'quick fix' type. All bends, tees and intersections shall be of the gusset type and shall, wherever possible, be purpose made by the manufacturer and of a matching design to the main trunking.
  - d) Cables shall be retained in the trunking when the cover is removed by means of straps. Internal connecting sleeves shall be fitted across joints in the trunking and earth continuity ensured by bonding each section of trunking to a continuous earth wire.
  - e) Non-flammable fire barriers shall be inserted where the trunking passes through walls or floors. Conduit connections to trunking shall be made by flanged couplings and male bushes.
  - f) Trunking shall be supported at intervals not greater than 2 meter horizontally or 2.5 meter vertically.
  - g) Crossings over expansion joints shall be made in flexible conduit.
  - h) Should it be necessary to cut or drill a section of trunking or a trunking fitting the bared ends shall immediately be given a coat of zinc rich cold galvanizing paint.
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- i) Cable and conduit/ trunking runs shall be determined by the Contractor and agreed by the Employer's Representative before any work is started. The run shall be at least 300 mm clear of plumbing and mechanical services.
- j) Conduit/ trunking systems erected outside a building shall be weatherproof.

## 5.6. CABLE INSTALLATION:

### 5.6.1. General:

- a) Cable installation shall be in accordance with IS 1255: 2001- latest edition.
- b) Cables shall be installed in such a way that the minimum bending radii are not reduced when installed or during installation. Cables shall not be installed in ambient temperatures below that recommended by the cable manufacturer.
- c) Cables grouped together shall have insulation capable of withstanding the highest voltage present in the group.
- d) Cables of different categories shall be installed so as to maintain satisfactory clearances for safety and in order to reduce the possibility of electrical interference. The following Table details the distances in mm that shall be maintained between the different categories of cable.

Table of Separation Distances in mm between different Categories of Cable

<b>Cable Category</b>	<b>HV Power</b>	<b>LV Power</b>	<b>C&amp;I/ Protection</b>	<b>Tele-communication</b>
HV Power	N/A	300	600	600
LV Power	300	N/A	300	300
C&I/ Protection	600	300	N/A	200
Tele-communication	600	300	200	N/A

- e) These separations are minimum and special circumstances such as the presence of high current flows, or harmonic content may necessitate larger separation distances.
- f) A distance of minimum 300mm shall be maintained between the cables to be laid on trays/ conduits carrying low voltage AC and DC signals and a distance of minimum 600 mm shall be maintained between cables carrying HV and LT signals.
- g) In order to make economic use of the cable support system, cables shall be arranged in groups of 50 mm maximum overall diameter. These groups shall be securely tied to the cable support system at intervals not exceeding 900 mm for horizontal runs and 300 mm intervals on vertical runs.
- h) In order to make the most economic use of cable tray and duct capacity, multicore cabling shall be utilized in order to connect instrumentation groups by using suitably located sub-distribution junction boxes. The junction boxes shall be suitable for the area in which they are to be installed and for the type of circuit. They shall be readily

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accessible for maintenance and clearly labeled junction boxes shall be constructed of die cast Aluminium and provide degree of protection IP 65.

- i) Instrumentation cables shall be continuous without any joints. Separate cables shall be used for digital and analogue signals at all times. Digital and analogue signals shall be segregated within junction boxes.
- j) Cables shall be laid in a manner such that any electrical interference between cables shall not have a detrimental effect on the life and operation of Plant.
- k) Where practical a separate cable support system shall be provided for power and non-power cables. Where this is not practical a separation as per indicated in above table shall be maintained between power and non-power cables when run on the same support system.
- l) Heavy duty galvanized iron cable tray and ladder racking shall be used for cable support systems. FRP/ GRP cable support systems shall be used in areas used for the storage and handling of chlorine. These systems shall be used to route cables around walls and within cable trenches. Cables shall be securely fixed to the support systems. Bundling of cables shall be permitted where allowance for this practice has been made in sizing the cables.

#### 5.6.2. Laying of Cables:

- a) Each instrumentation and power supply cable shall be terminated to individual panel/ terminal box.
  - b) Identification of each cable shall be by proper ferrules at each junction as per cable schedule to be prepared by Contractor.
  - c) Cables shall be laid in accordance with layout drawings and cable schedule which shall be prepared by Contractor and submitted for approval.
  - d) All cable routes shall be carefully measured and cables cut to the required lengths, leaving sufficient amount for the final connection of the cable to the terminals on either end.
  - e) Various cable lengths cut from the cable reels shall be carefully selected to prevent undue wastage of cables.
  - f) A loop of 1.0 meter shall be left near each field instrument before terminating the cable.
  - g) Cables shall be complete uncut lengths from one termination to the other.
  - h) Separate cables shall be used for digital and analog signals.
  - i) All cables shall be identified close to their termination point by cable numbers as per cable interconnection schedules.
  - j) Identification tags shall be securely fastened to the cables at both the ends.
  - k) Cable shall be rigidly supported on structural steel and masonry, using individually cast or malleable iron galvanized clips, multiple cable supports or cable trays.
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- l) The Contractor shall take the actual measurement of the cables and the associated accessories such as cable trays, conduits etc required at site, prior to the placement of order on the cables.

#### 5.6.3. Cables Laid Direct in Ground:

- a) Buried cable up to 1.1 kV shall have a laid at a minimum depth of 750 mm measured from FGL to the top of the highest cable. On crossing roadways the cable shall be run through a PVC-U duct of minimum diameter 100 mm with a minimum of 1000 mm cover and encased on all sides by 150 mm of concrete.
- b) Cables of greater than 1.1kV shall be buried at a minimum depth of 1 meter.
- c) The bottom of the cable trench shall be freed of sharp stones and such like and 75 mm of sieved sand laid below the cable. After cable laying 75 mm of sieved sand shall be laid above the cable. For HV cables sand bedding shall be of 150 mm & cables shall be covered with half round Hume pipes of twice the diameter of cable.
- d) Interlocking cable protective covers, minimum 1 m long x 300 mm wide, marked 'Danger-Electric Cable' in English and the vernacular shall be laid on top of the sieved sand. Covers shall extend the whole length of the cable trench and shall overlap cables by a minimum of 50 mm.
- e) Warning tape shall be laid a minimum of 200 mm above the protective covers.
- f) Cables are to be installed without tees or through joints unless otherwise approved by the Employer's Representative. Single core cables shall be run in trefoil formation.

#### 5.6.4. Cables Laid in Underground Ducts:

- a) Underground ducts shall be constructed of impact resistant PVC-U and laid at a minimum depth of 750 mm, ducts shall be surrounded by at least 75 mm of sieved sand except at road crossings where it shall be 1.0 meter deep and encased on all sides by 150 mm of concrete.
- b) The Contractor shall ensure that sufficient draw-in points have been provided and that adequate room has been allowed for installation of cables. Drawstrings shall be provided in all ducts to enable additional cables to be installed when required.
- c) 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 means of duct stoppers and bituminous compounds or by any other method approved by the Employer's Representative. The stopper shall have a fire resistance of at least 30 minutes. Single core cables in trefoil formation shall pass through the same duct and shall not be separated. However, for two different trefoil formations, they shall be laid in separate ducts.

#### 5.6.5. Cables installed in Conduit:

- a) Conduits shall be galvanized heavy gauge solid drawn or welded screwed steel type and be in accordance with IS 9537, Part 2 or BS 4568. Accessories shall either be malleable cast iron screwed type or pressed steel and galvanized.
- b) A space factor of 40% shall not be exceeded, but in any case conduit of less than 20 mm diameter shall not be permitted. The tubing shall be perfectly smooth inside and



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out and free from flaws and imperfections of any kind. Both ends of every length of tubing shall be properly reamed with all sharp edges removed before erection.

- c) Where a number of conduits converge, malleable cast iron or heavy gauge sheet steel adaptable boxes shall be employed in order to avoid crossings. Conduits shall be connected by means of male brass bushes and couplings.
- d) Where conduits are greater than 25 mm, straight through joint boxes shall be of the trough type. Where conduit and/ or fittings are attached to equipment casings, the material or case of the casing shall be tapped for a depth of not less than 10 mm or male bushes and flanged couplings shall be used.
- e) Heavy hexagonal lock nuts shall be used at all positions where running joints are required and care shall be taken to ensure that they seat firmly and evenly on to the mating faces of coupling or other adjacent accessories. All junction boxes, draw-in boxes, and inspection fittings, shall be so placed that the cables can be inspected and, if necessary, withdrawn and re-wired throughout the life of the installation.
- f) Generally not more than two bends or offsets or one coupling will be permitted without a suitable inspection accessory. Fish wires shall not be left in conduits after erection. The whole of the installation shall be arranged for a loop-in type of system with joints being carried out at switches, isolators, etc. Intermediate joints in the cable will only be allowed by arrangement with the Employer/ Employer's Representative.
- g) Ends of conduits which are liable to be left open for any length of time during building operations shall be plugged to prevent the ingress of dirt, cement, etc. and covers, either temporary or permanent, shall be fitted on all boxes.
- h) Generally, conduits shall not cross expansion joints of buildings, but where they cannot be installed in any other manner then a flexible conduit shall be used across the expansion joint. A total 150 mm movement shall be allowed.

#### 5.6.6. Surface Installation:

- a) Surface conduits shall be secured and fixed by means of distance spacing saddles or approved purpose made clips at every 500mm, which allow the conduits to be taken directly into accessories without sets or bends. Conduits shall be run in a square and symmetrical manner. An efficient means shall be adopted to provide for the drainage of condensation and the runs shall be properly ventilated. All surface conduit runs shall be marked out for approval by the Employer's Representative before the installation is carried out. Where large multiple parallel conduit runs would occur, use may be made of galvanized cable trunking. Conduits installed on structural steelwork shall be secured at spacing not exceeding those for surface conduit by girder clips, otherwise fixing shall be as for surface conduits on walls, drilled and tapped to the metalwork. Power driven fixings shall only be used with the express permission of the Employer's Representative. Any drilling or access which is required through any structural member of the building shall be agreed with the Employer/ Engineer in Charge before carrying out the work.
- b) Exposed threads and places where galvanizing has been damaged shall be cleaned and then painted with two coats of an approved metallic zinc based paint. This treatment shall be applied as the work proceeds.

#### 5.6.7. Concealed Installation:

- a) Concealed conduits shall be securely fixed to prevent movement before laying of screeds, floating of plaster, casting of columns or other building operations necessary after the conduit installation. Crumpets or similar fixings shall be used for attaching the conduit to blockwork, etc. Building nails will not be accepted.
- b) At least 15 mm cover shall be allowed for finishes over the conduit. Where this cover cannot be maintained then expanded metal shall be fitted with the conduit. Conduit cast into reinforced concrete floors shall be fixed to the steel reinforcing with binding wire and the conduit boxes filled with expanded polystyrene or enclosed in a plastic bag to prevent the ingress of concrete when poured. Where possible, the conduit boxes shall be fixed to shuttering to give a flush finish.
- c) Conduit installed in voids, false ceilings, and other concealed routes shall be installed as specified for the surface conduits. Wiring shall be carried out after the false ceiling or permanent ducts have been completed. Conduit installed in floors shall be sealed against ingress of moisture.
- d) The conduit installation shall be inspected by the Employer's Representative before the building operation conceals the work.

#### 5.6.8. Cable Installed in Flexible Conduit:

- a) Flexible conduit shall be of the waterproof galvanized type or PVC wire-wound type with cadmium plated mild steel couplings. Lengths of flexible conduits 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.
- b) Where conversion from rigid conduit to flexible metallic conduit is to be made, the rigid conduit shall terminate in a through type box and the flexible conduit shall extend from this box to the equipment, the earth continuity cable shall be secured to the box and to the piece of equipment by properly designed earthing screws. The use of lid facing screws, etc., will not be permitted. Adapters shall incorporate a grub screw or a gland to prevent the flexible conduit becoming loose.

#### 5.6.9. Cable Clipped Direct:

- a) All cable hangers, clips, cleats and saddles shall be of an approved type and appropriate to the type and size of cable installed. Their spacing shall be such as to ensure a neat appearance and prevent sagging of the cables at all times during their installed life.

#### 5.6.10. Cable Installed in Internal Floor Trench:

- a) In shallow trenches (width 1000 mm x depth 1000 mm or as per approved layout)
- b) In shallow trenches used for electrical services only, cables may be laid in a neat and orderly manner on the floor of the trench. One layer only shall be allowed. Additional cables shall be installed on the walls of the trench in an acceptable manner & such a way that, in no case the distance between two different types of cable shall not be less than the separation distance tabulated above.

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- c) Where the trench is shared by other services, cables shall be installed on the walls of the trench in an acceptable manner & such a way that, minimum separation distance of 300mm shall be maintained.
  - d) All other trenches including walk through service ducts
  - e) Cable trenches & cable installation shall be in accordance with the attached typical cabling system drawings.
  - f) Where other services are present the cables shall be segregated from them by separation distances as mentioned above and wherever possible kept above 'cold' wet services. Cables should not be run if at all possible above or in close proximity to 'hot' services.
  - g) The cabling shall be installed in such a manner as to allow access to the other services for normal maintenance without disturbance of the electrical installation

#### 5.6.11. Cable Terminations and Joints:

- a) Power Cable Terminations
  - i. Power cables shall be terminated in suitable boxes arranged for bolting to switchgear, motor starters and motors.
  - ii. Cores shall have either crimped lugs or sleeves to match either post terminals or bolted clamp terminals.
  - iii. Each cable entry into a terminating box shall be made through a suitable gland, which shall have provision for securing the armour where applicable. Where single core glands are required these shall be of the non-magnetic type and the associated box bottom plate, where the core passes through, shall not have a continuous magnetic path.
  - iv. Adequate provision shall be made to bond the cable armouring to the box and/or switchgear casing of a suitable size to withstand the prospective short circuit fault current of the system, glands shall be fitted with earth bonding tags where intimate screwed contact between gland and cable box is not possible.
  - v. Where cable glands are exposed to the weather these shall be protected by heat shrink plastic sleeve or purpose moulded sleeves covering the gland continuously from overall sheath to the gland neck.
  - vi. Where terminations of multicore type have to be made on to items of Plant which have to be dismantled for maintenance, these shall be made off through glands into an adaptable box containing terminals and flexible single cores taken into the equipment via flexible waterproof plastic covered conduit, and a separate earth core linking the box to the equipment.
  - vii. Where single core cables are glanded to or pass through cabling plates the gland plate or cabling plate shall be constructed of non-magnetic material.
- b) Power Cable Joints:
  - i. Through joints shall only be allowed with the approval of the Employer's Representative. Where such joints are necessary in thermoplastic and

elastomeric cables, the cables shall be jointed with epoxy or acrylic resin cold setting compound, which has been premeasured and pre-packed ready for use. The boxes shall preferably be of split, moulded plastic type with filling vents for compound. Bonding straps shall be fitted with armour clamps across the joint and inspected by the Employer/ Employer's Representative prior to filling the box with compound. Wrapped pressure type joints will not be accepted.

c) Multi-core or Control Cable Terminations:

- i. A sufficient number of terminals shall be provided to terminate all cable cores. For control and auxiliary wiring an additional 20% of this number shall be provided as spares.
- ii. 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.
- iii. Terminals which remain energized when the main equipment is isolated shall be suitably screened and labeled.
- iv. Terminal blocks for different voltages or circuit type shall be segregated into groups and distinctively labeled.

5.6.12. Cable Fixings:

- a) Ties and strapping shall be suitable for securing cable and cable groups to cable tray or ladder. They shall be resistant to chemical and marine corrosion. Plastic coated metal ties used in order to obtain corrosion resistance shall not be acceptable. Nylon ties shall be resistant to the effects of ultra-violet light and shall be self-extinguishing.
- b) Large single cables shall be secured with cable clamps or cable cleats.

5.6.13. Cable Identification:

At each end of each cable, in a uniform and visible position a label shall be fixed on the cable in accordance with the cable schedule. Labels shall be made of PVC and shall be indelibly marked to the approval of the Employer's Representative. The label shall be retained using proprietary nylon strips passing through two fixing holes at either end of the label. If the cable gland is not normally visible, then the label shall be fixed inside the panel by means of screws.

5.6.14. Marking Locations of Underground Cables:

- a) The location of all underground cables shall be engraved on brass or other non-corrodible plates to be fixed to the exterior surface of all walls of buildings 300 mm above ground level and directly above the point where cables pass through the wall.
- b) Cable route markers as per the attached drawing shall be installed at an interval not more than 30 meter & at bending/ road crossings the interval shall be at every 10 meter.
- c) The minimum depth for laying of underground cable route markers shall be as per indicated in the typical drawings attached with this tender.

#### 5.6.15. Additional Requirements for Cable Installations:

- a) The Contractor shall install, test and commission the cables specified in the specification. Cables shall be laid directly buried in earth, on cable racks, in built up trenches, on cable trays and supports, in conduits and ducts or bare on walls, ceiling etc. as per drawings, which are to be prepared by Contractor & approved by Employer's representative. Contractor's scope of work includes unloading, laying, fixing, jointing, bending, and termination of the cables & all related accessories. The Contractor shall also supply the necessary materials and equipment required for jointing and termination of the cables.
- b) All apparatus, connections and cable work shall be designed and arranged to minimize risk of fire and any damage which might be caused in the event of fire. Wherever cables pass through floor or wall openings or other partitions, suitable bushes of an approved type shall be supplied and put into position by the Contractor.
- c) Standard cable grips and reels shall be utilized for cable pulling. If unduly difficult pulling occurs, the Contractor shall check the pull required and suspend pulling until further procedure has been approved by the Engineer's Representative. The maximum pull tension shall not exceed the recommended value for the cable measured by the tension dynamometer. In general, any lubricant that does not injure the overall covering and does not set up undesirable conditions of electrostatic stress or electrostatic charge may be used to assist in the pulling of insulated cables in conduits and ducts.
- d) After pulling the cable, the Contractor shall record cable identification with date pulled neatly with waterproof ink in linen tags. Identification tags shall be attached securely to each end of each cable with non-corrosive wire. The said wire must be non-ferrous material on single conductor power cable. Tags shall further be attached at 10 meter intervals on long runs of cables on cable trays and in pull boxes. Cable and joint markers and RCC warning covers shall be provided wherever required.
- e) Sharp bending and kinking of cables shall be avoided. The bending radius for various types of cables shall not be less than those specified below:
  - i. 11 kV, XLPE insulated, multicore : 15 times the overall dia of the cable armoured cables
  - ii. 1.1 kV, XLPE insulated, multicore : 12 times the overall dia of the cable armoured cables
  - iii. (If shorter radius appears necessary, no bend shall be made until clearance and instructions have been received from the Employer/ Engineer in charge)
- f) Power, control and instrumentation cables shall be laid in separate cable racks/ trays.
- g) Where groups of HV, LV and control cables are to be laid along the same route, suitable barriers to segregate them physically shall be provided.
- h) Where cables cross roads and water, oil, gas or sewage pipes, the cables shall be laid in reinforced spun concrete or steel pipes. For road crossings the pipe for the cables shall be buried at no less than one meter depth.
- i) Cables laid in ground shall be laid on a 75 mm riddled earth bed. The cables shall then be covered on top and at their sides with riddled earth of depth of about 150 mm.

This is then gently filled up to a depth of about 100 mm above the top of uppermost cable to provide bedding for the protective cable covers which are placed centrally over the cables. The protective cable covers for LV cables may be of earthenware and for HV cables of reinforced concrete. The RCC covers shall have one hole at each end, to tie them to each other with GI wires to prevent displacement. The trench is then backfilled with the excavated soil and well rammed in successive layer of not more than 300 mm in depth, with the trenches being watered to improve consolidation wherever necessary. To allow for subsidence, it is advisable to allow a crown of earth not less than 75 mm in the centre and tapering towards the sides of the trench.

- j) In each cable run some extra length shall be kept at a suitable point to enable one or two straight through joints to be made, should the cable develop a fault at a later date.
- k) Cables on cable racks, on cable trays and conduits shall be formed to avoid bearing against edges of trays, racks, conduits or their supports upon entering or leaving trays, racks or conduits. Cables shall be racked or laid directory into cantilevered cable trays where practicable, but in some cases it may be necessary that cables are pulled or threaded into trays. To facilitate visual tracing, cables in trays shall be laid only in single layers and unnecessary crossing of cables shall be avoided. Cables on trays shall finally be clamped in an approved manner.
- l) Cable splices will not be permitted except where permitted by the Employer/ Employer's Representative. Splices shall be made by Contractor for each type of wire or cable in accordance with the instructions issued by cable manufacturer's and the Engineer's Representative. Before splicing, insulated cables shall have conductor insulation stepped and bound or penciled for recommended distance back from splices to provide a long leakage path. After splicing, insulation equal to that on the spliced conductors shall be applied at each splice.
- m) Jointing of cables shall be in accordance with relevant Indian Standards Codes of Practice. Materials and tools required for cable jointing work, including cold setting bituminous compound shall be supplied by the Contractor. Cables shall be firmly clamped on either side of a straight through joint at a distance of not more than 300 mm away from the joints. Identification tags shall be provided at each joint at all cable terminations.
- n) At cable terminal points where the conductor and cable insulation will be terminated, terminations shall be made in a neat, workmanlike and approved manner by men specialized in this class of work.
- o) Control cable termination shall be made in accordance with wiring diagrams, using colour codes established by the Employer's Representative for the various control circuit, by code marked wiring diagram.
- p) When control cables are to be fanned out and cabled together with cord, the Contractor shall make connections to terminal blocks, and test the equipment for proper operation before cables are corded together. If there is any question as to the proper connection, the Contractor shall make a temporary connection with sufficient length of cable so that the cable can be switched to another terminal without splicing. After correct connections are established through operating the equipment, cables shall be cut to their correct lengths, connected to terminals in the specified manner, and corded together where necessary to hold them in place in a workmanlike manner.
- q) Cable seals shall be examined to ascertain if they are intact and that cable ends are not damaged. If the seals are found to be broken the cable ends shall not be jointed

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until after due examination and testing by the Employer/ Employer's Representative. Before jointing is commenced, insulation resistance of both sections of cables to be jointed shall be checked by megger.

- r) After installation and alignment of motors, the Contractor shall complete the conduit installation, including a section of flexible conduit between motor terminal box and trench/ tray. The Contractor shall install and connect the power, control and heater supply cables as per equipment manufacturer's drawings.
- s) Metal sheath and armour of the cable shall be bonded to the earthing system of the station. The size of conductor for bonding shall be appropriate with the system fault current.

## 5.7. LIGHTING SYSTEM INSTALLATION:

### 5.7.1. This covers the requirements of installation of the following:

- a) Lighting fixtures complete with lamps and accessories
- b) Main Lighting distribution board
- c) Lighting panels
- d) Receptacles and lighting control switches
- e) Point wiring
- f) Street lighting poles and flood light towers
- g) Multi core cables for street and boundary lighting
- h) Maintaining equipment/ materials during storage and being responsible for the equipment/ material until they are handed over to Employer.
- i) Installation, testing and commissioning shall be carried out in accordance with the drawings and as stipulated in this specification.

### 5.7.2. Applicable Standards for lighting system installation

Electrical wiring installations	:	IS: 732
(System voltage exceeding 650 V)		
Code for practice for interior illumination (Part-1)	:	IS: 3646/ BS: 8206
Code of practice for street lighting installation	:	IS: 1944
Code of practice for industrial lighting	:	IS: 6666
Code of practice for fire safety of building	:	IS: 1646
Boxes for enclosure of electrical accessories	:	IS: 5133(Part-1)
Guide for safety procedures and practices in	:	IS: 5216

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electrical work

Ceiling roses : IS: 371

5.7.3. Lighting Fixtures:

- a) The installation of lighting fixtures shall be based on the mounting arrangement shown in the drawings. The rates quoted for installation shall include all materials required to mount the fixtures. Hooks in RC slabs for suspension of high bay fixtures shall be provided wherever not already provided. Cost of supply and installation of such hooks shall be included in the cost of installation of lighting fixtures. Rate for installation of lighting fixtures shall include cost of installation of control gear box wherever applicable.
- b) Installation of receptacles and switches shall be carried out suitably. Switch shall be mounted in flush with the front cover plate. Cost of supply and installation of necessary hardware shall be included in the lump sum rates quoted for installation of receptacles/ switches.
- c) Lighting distribution boards shall be installed at the suitable location. Installation shall include supply and installation of base channels, foundation bolts, etc.
- d) Outdoor lighting distribution boards shall be installed on a concrete plinth. The top of plinth shall be 1000 mm (min.) above the grade level. Cost of construction of concrete plinth shall be included in Contractor's scope. No cement and steel will be supplied by Employer. Installation cost of lighting distribution board shall include cost of installation of earthing conductor from LDB to the nearest earthing grid.

5.7.4. Point Wiring:

- a) Contractor has to prepare the detailed conduit layout drawing showing primary & secondary point wiring points. Point wiring also covers the wiring of the associated control switches of lighting fixtures/control switches of receptacle units.

- i. Primary Point Wiring:

- Primary point wiring covers the wiring between a circuit of the lighting panel to the junction box of the first lighting fixture/receptacle unit and between junction boxes of the subsequent lighting fixture connected to that circuit of the lighting panel. In some cases where there are junction boxes, the primary point covers the wiring between junction box and the first lighting fixture/receptacle unit in that circuit.

- ii. Secondary Point Wiring:

- Secondary point wiring covers the wiring of the remaining lighting fixtures/receptacle unit other than that covered under primary point of that circuit in the lighting panel. Secondary point wiring also covers the wiring of the associated control switches of lighting fixtures/control switches and control switches of receptacle units.

- b) Supply and Installation of Conduit Point Wiring:

- i. The point wiring shall include supply of necessary materials for the conduit wiring such as galvanized rigid steel conduit, galvanized M.S. fixing saddles



with spacer plates, nylon/fiber fixing plugs, galvanized M.S. fixing screws, 12 SWG galvanized steel earthing wire, FRLS PVC insulated Copper conductor wires, control switches and pulling, termination of the earthing/ FRLS PVC insulated wires as required, installation of control switches, drilling holes in brick walls/ RCC roof slabs for taking the wiring conduits and refinishing and any other works/material necessary for making point wiring complete in all respects.

- ii. Wires used for conduit point wiring of lighting fixtures/ceiling fans, 5A receptacles and receptacles above 15A shall be 1.1 kV grade, FRLS PVC insulated, single core, multistranded Copper conductor wires of sizes not less than 1.5 sq. mm and 2.5 sq. mm respectively. Wires shall conform to IS: 694 and shall bear the ISI mark.
- iii. Contractor shall take into consideration necessary galvanized MS fixing clamps when the wiring conduits are to be supported from steel roof truss/structural members.

c) Supply & Installation of cabling for Street and Flood Lighting

- i. Work includes supply and installation of cables required between LDB and junction box mounted on street lighting pole/flood lighting tower and also between junction box mounted on flood light tower to metal enclosed control gear box located near flood light fixture, supply and installation of all the termination accessories such as crimping type cable lugs and double compression cable glands at each junction box and fixture, termination, testing and commissioning of cables. Contractor's scope of work also includes excavation, preparation of riddled soil bedding, supply and installation of protective covers over the cable, backfilling, ramming, supply and installation of route markers, supply and installation of HDPE / Hume pipes for road crossing, etc, supply and installation of necessary cleating arrangement for cabling on flood light tower, supply of labour, supervision, welding equipment, all tools and tackles and testing equipment as required.
- ii. Contractor shall plan and cut the cables in such a way that there is no wastage and no cable jointing is required in any run. However, should any joint become necessary the same shall be provided by the Contractor and a joint marker shall also be provided at no extra cost. Earthing of street light pole/flood light tower, lighting fixtures, etc. are included under Contractor scope.

d) Point wiring shall also include/ hold good for the following :

- i. Supply and installation of lighting control switches and switchboxes complete with fixing accessories.
- ii. Drilling holes in brick/ RCC wall and roof for taking cable or conduit, sealing and refinishing with cement plaster.
- iii. Testing, commissioning and handing over the lighting system in commercial working condition.
- iv. Marginal shifting of any fixture/accessory from the location indicated in the lighting layout drawings.

5.7.5. Outdoor Lighting (Street and Flood Lighting): The following shall be deemed to be included as part of the installation work for outdoor lighting point wiring.

- a) Installation of multicore/ single core cables between LDB and junction box mounted on street light pole/flood lighting tower, from junction box to metal enclosed control gear box.
- b) Supply and installation of crimping type cable lugs, double compression type cable glands at each junction box and fixture, termination, testing and commissioning of cables.
- c) Contractor's scope shall also include excavation and preparation for buried cables. Supply and installation of route markers, supply and installation of HDPE/ Hume pipes for road crossing shall also be included in the scope of installation of point wiring.
- d) Supply and installation of necessary cleating arrangement for cabling on flood light poles.
- e) Contractor shall provide necessary foundation for erecting street light pole/ flood light tower and install the same. Contractor shall prepare foundation drawings with necessary details & Employer Representative's approval shall be obtained.
- f) Contractor shall plan and cut the cables in such a way that there is no wastage and no cable jointing is required in any run. However, should any joint become necessary, the same shall be provided by the Contractor and joint marker shall also be provided at no extra cost.
- g) Earthing of street light pole/flood light tower, lighting fixtures, control gear boxes, junction boxes, etc. are also included in the scope of installation of point wiring. Contractor shall earth street light pole/flood light poles and junction box with 25x3 mm G.S. flat tap off from the 25x3 mm M.S. flat earthing grid along the street lighting included in scope. The Contractor shall interconnect earthing grid to plant main earthing grid at first and last pole of each feeder circuit and at one intermediate pole.
- h) Installation of lighting Poles and Towers for Outdoor Lighting (Street and Flood Lighting)-
  - i. Work includes supply and installation of street light poles and flood light towers including associated junction boxes with fuses, links and terminals for junction boxes and junction boxes near each flood light fixtures.
  - ii. All street light poles and towers shall be painted with one shop coat of red oxide oil primer followed by two coats of aluminium alkyd paint.

5.7.6. Installation of Lighting Distribution Board, Lighting Panels (AC & DC), 230 V, AC 1- Ph Distribution Boards.

Installation of above items shall include necessary foundation channels, bolts/ nuts, etc. for grouting lighting distribution boards, iron brackets/ grouting brackets, bolts/nuts for wall/ column mounted panels and associated civil works.

5.7.7. Details of work requirements are covered in lighting installation notes and details and typical drawings which form the part of specification. Any changes, if necessary due to site conditions/requirements shall be carried out after obtaining approval of Employer/

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Employer's Representative. The changes carried out shall be marked clearly in the layout drawings by Contractor and 'AS BUILT DRAWING' shall be prepared by the 'Contractor' and this shall be forwarded to Employer's site / design office.

a) Wiring

- i. Wiring shall be carried out strictly as per project drawings and technical specification. All exposed conduit wiring shall have provision for easy inspection. Where cable wiring is specified cable shall be cleated on to the wall as close to the ceiling as possible. In all types of wiring due consideration shall be given for neatness and appearance.
- ii. Wherever DC emergency lighting is provided, emergency lighting wires shall run in a separate conduit. Colour of the wires used shall be as follows; white for positive, black for negative.
- iii. Wherever lighting system has three phase distribution, separate conduits shall be used for different phases. For easy identification of phases and neutral wires the following colour wires shall be used.

R - Phase	-	Red
Y - Phase	-	Yellow
B - Phase	-	Blue
N – Neutral	-	Black

- b) There shall be a circuit breaker on each live conductor of supply mains at the point of entry.
- c) Conductors not arranged for connection to the same system or supply different phases of the same supply, shall be kept apart throughout their entire run.
- d) Receptacles and lighting fittings in general shall be fed from different Circuits. Five amps receptacles for toilet or small rooms can be fed from the lighting circuit with proper isolating arrangement.
- e) Each final sub-circuit from a lighting panel shall be controlled by a single pole switch connected to the live conductor.
- f) For long conduit wiring runs, inspection/ pull boxes shall be provided at intervals not exceeding 10 meter. Such facilities shall also be provided at conduit bends.

5.7.8. General Practices for lighting:

- a) All receptacles and switches to be installed in offices and control rooms shall be flush mounted within the wall and those in other areas shall be wall or column mounted.
- b) Ceiling roses shall not embody fuse terminals as an integral part. For voltages exceeding 250 volts, a ceiling rose or any similar attachment shall not be used.
- c) All exposed metal parts of the plug, when the plug is in complete engagement with the socket outlet, shall be in effective electrical connection with the earthing pin.

#### 5.7.9. Earthing for lighting:

Conduits and fittings shall be earthed by 12 SWG GI wires run along the length of the conduit and secured by means of suitable clamps efficiently fastened to conduit tip. To achieve perfect electrical continuity, the conduits shall be bonded effectively on either end of a coupling and other joints.

- a) Conduits shall be earthed at the ends adjacent to switch boards at which they originate or otherwise at the earth clip, clamp or gland, in effective electrical contact with the conduit.
- b) For outdoor lighting poles & mast 8 SWG GI earth wire shall be run buried in ground at a depth of 600 mm along-with lighting cables and shall be terminated up to the junction box on the pole and 12 SWG wire shall be taken up to the pole fitting. In case of lighting poles where the main earth grid is far away from the pole, local pits shall be provided for pole earthing.

#### 5.8. INSTRUMENTATION, CONTROL & AUTOMATION SYSTEM:

##### 5.8.1. General:

- a) Instrumentation, Control & Automation installation shall be in accordance with manufacturer's recommendation, approved drawings and best engineering practices. A Centralized Control Room (CCR) shall be provided to house PLC based control equipment.
- b) The test equipment, meters, instruments etc. used for testing shall be calibrated at recognized test laboratory at regular intervals and valid certificates shall be made available to the Employer at the time of testing. The calibrating instruments used as standards shall be traceable to international standards. Calibration certificates for test instruments shall be produced from a recognized laboratory for the Employers consent in advance of testing and if necessary the instruments shall be recalibrated or substituted before the commencement of the test.

##### 5.8.2. Commissioning/ Site Acceptance Test:

- a) At site, the system shall be properly installed taking care of manufacturer's recommendation, after which Site Acceptance Tests (SAT) shall be carried out taking into the actual field instruments/ equipment in the loops.
  - b) The Site Acceptance Test shall be held at site after the system has been installed as per the finalized SAT procedures. The tests shall be witnessed by Employer.
  - c) The minimum tests to be carried out shall be as indicated in table below.
  - d) A log of all failed/ mal-operating components/ modules in a sub-system shall be maintained by Contractor, with description of the affected components/ modules, cause of failure, effect of failure on the sub-system and number of hours of operation before it failed. This will start from the date of powering 'ON' of the system for cold commissioning.
  - e) Test & Acceptance Criteria: Following tests shall be performed as a minimum for automation system, during both FAT & SAT, in presence of authorized representatives and documented test results shall be compiled:
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Sr. No.	Description of Test	FAT	SAT
1.	Check of supply completeness	√	√
2.	Visual & dimensional check	√	√
3.	Check of complete system configuration loading	√	-
5.	Check of system diagnostic features. These shall include failure of any sub-system, module, power supply, interface unit, failure of transfer to redundant module on main module failure etc.	√	√
5.	Power-off and power-on of any single unit	√	√
6.	Test of alarm system	√	√
7.	Check of correct functionality of keyboards	√	√
8.	Testing of proper working of the printers	√	√
9.	Simulation of power failure and restart. Self-booting up of system configuration & program after power restoration.	√	√
10.	Analog / digital input / output check	√	√
11.	Check of scan time for PLC	√	√
12.	Check of scan time, screen update time and loop cycle time.	√	√
13.	Check of loop configuration for correct entry of ranges, limits etc.	√	S
15.	Check of HMI displays (all kind of displays)	√	S
15.	Checking of HMI screen refresh rate, data base update and display call-up time.	√	S
16.	Check of system internal loading (processor, communication system etc.)	√	-
17.	Check of various log formats, shutdown reports etc.	√	S
18.	Demonstration of all PLC system builder functions including addition/deletion of an input/output, addition/deletion of a rung or an element in a rung generation of dynamic graphics and other views, report generation etc.	√	√

19.	100% checking of logic configured in the PLC by connecting switch/lamp at input/output.	√	-
20.	Checking of output status on processor failure for PLC & checking of first-out alarm generation.	√	√

FAT= Factory Acceptance Test; to be performed at Contractor's workshop. SAT= Site Acceptance Test; to be performed at site. √= Complete test; 100% of devices/ functionality will be tested. S= Sample test All the necessary simulation kits as may be required for testing of software shall be arranged. Acceptance of any equipment or the exemption of inspection shall in no way absolve the Contractor of the responsibility for delivering the equipment meeting the entire requirement specified in this specification and also as may be required for satisfactory operation of the process.

- f) Acceptance Criteria: Automation system shall be suitable to meet the below minimum acceptance criteria, which are to be demonstrated by the successful tenderer during testing of the system.

Sr. No.	Description of	Criteria
1	Availability of Automation System	99.8% [calculated over a period of seven (7) working days]
2	HMI screen refresh time	1 sec
3	I/O scan time/ data upgradation time	250 milisec for analog signals 100 milisec for digital signals  Priority processing shall be provided for the data requiring faster scan rate.
5	Network bandwidth utilization (Average of 5 minutes to be measured over continuous period of 8 hours)	< 10%
5	Spare (free) memory capacity available (for system, server & PCs, PLC controller)	50% (after commissioning)
6	Spare I/O capacity of each type at each location, spare ports of networking switches	20% (after commissioning)

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**6. PRE COMMISSIONING TESTS ON ELECTRICAL & INSTRUMENTATION EQUIPMENT/ SYSTEMS TO BE CARRIED OUT AFTER INSTALLATION:**

**6.1. GENERAL:**

Pre-commissioning tests in addition to mentioned in the specification requirements for various equipments but not limited to following shall be carried out by Contractor in presence of Employer/ Employer's representative. Commissioning shall be carried out only after obtaining satisfactory results, acceptable to Employer/ Employer's representative.

**6.2. ELECTRICAL EQUIPMENT:**

**6.2.1. 11 KV Equipment (Lightning Arrestors, AB Switch/ Isolators & Insulators etc):**

- a) Visual checks for cracks in insulators.
- b) Earth secured continuity check
- c) IR Test with 5KV Megger

**6.2.2. Power/ Distribution Transformer:**

- a) Insulation resistance test HV side, LV side and HV - LV.
- b) Magnetizing current test.
- c) Winding resistance test.
- d) Voltage Ratio & Tap continuity test at all tap.
- e) Vector group test.
- f) Magnetic Balance Test.
- g) Buchholz Relay Test (if any)
- h) Neutral CT Test (if any)
- i) Winding Temperature Indicator/ Oil Temperature Indicator Test
- j) Polarization Index Test (For LV windings 3.3 KV and above)
- k) Local/ Remote operations of OLTC (if any)
- l) Operational tests of RTCC panel (if any) as per schematic drawing.
- m) No load test and performance observations

**6.2.3. HV Metal Enclosed Switchgear:**

- a) IR values of power and control circuits
  - b) Local/ Remote operations in test as well as service position including all electrical interlocks
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- c) Control circuit and operational tests as per schematic drawing.
  - d) Tripping through relays and trip circuit health.
  - e) Anti pumping device operation
  - f) Protection system operation stability and sensitivity by primary injection testing method including testing of metering circuits
  - g) HV Test on switchboard
  - h) Panel indication, annunciation, space heater circuits
  - i) Spare contact for customer use
  - j) Termination correctness & proper installation.

6.2.4. LT Metal Enclosed Switchgears:

- a) IR Values of power & control circuits.
- b) Mechanical charging - closing - tripping of breaker.
- c) Electrical charging - closing - tripping of breaker.
- d) Trip circuit healthiness and tripping through relays.
- e) Remote closing/ Tripping/ Interlocks circuits
- f) Indication/ Annunciation/ Panel space heater circuit/ Spare contacts for customer use
- g) Secondary injection testing of protective relays/ releases.
- h) CT testing for polarity, ratio, IR values and magnetization for class PS characteristics
- i) PT testing for ratio, IR values.
- j) IR Values of breaker.
- k) Testing of modules for DOL/ Star-Delta/ ATS/ Soft Starter starting or any other starting method as per the schematic drawings applicable.

6.2.5. Power and Control Cables:

- a) IR Values before Hi-pot
- b) Hi-pot Test - Measurement of leakage current
- c) IR Values after Hi-pot

6.2.6. Induction Motors:

- a) IR Values
- b) Polarization Index Test



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- c) Interlocks and simulation tests local / remote operations
  - d) No load test

6.2.7. Control Panels for Miscellaneous Equipment:

- a) IR Values of all power circuits
- b) Operational test and scheme - wiring testing as per control schematics

6.2.8. Lighting System:

- a) Visual inspection for operating problems
- b) System activation -burning in the lamps for 100 Hrs
- c) Measuring light level & reflectance.

6.2.9. Earthing System:

- a) Earthing resistance of each electrode.
- b) Earthing resistance of grid.

6.3. INSTRUMENTATION EQUIPMENT:

- a) Calibration Test on Instruments/ Analyzers
  - b) Site Acceptance Test on automation system
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## **Section - 5e**

### **Inspection, Testing & Commissioning Requirements**

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## **1. Inspection and Testing During Manufacture:**

### **1.1. General**

1.1.1. All inspection and testing shall be carried out in accordance with the Specification and in absence of Specification relevant Indian Standard. After award of contract, Contractor shall furnish a QA plan for approval by Employer. QA plan shall include testing for supply of raw materials and bought out items, stage inspections and tests on finished products at manufacturer's works / appropriate testing station. QA plan shall clearly indicate tests which are intended to be witnessed by the Contractor alone and those by both Contractor and Employer.

1.1.2. Inspection and tests schedule shall be as follows;

- a) Manufacture tests
- b) Acceptance inspection / Quantity checking
- c) Install /site inspection
- d) Site acceptance test
- e) Tests on Completion
- f) Process Wet Tests (by Raw Sewage)
- g) Operation Test (Tests After Completion)

1.2. The Contractor shall carry out at the place of manufacture tests of the Plant/ Equipment at any part of the Works.

1.3. The Employer and/or duly authorised and designated representative(s) shall be entitled to attend the aforesaid inspection and/or tests.

1.4. The Employer and his duly authorised representative shall have access to the Contractor's premises at all times to inspect and examine the material and workmanship of the plant and equipment during its manufacture there. If part of the plant and equipment is being manufactured on other premises, the Contractor shall obtain permission for the Employer or his duly authorised representative, to inspect as if the plant and equipment was manufactured on the Contractor's own premises. Testing (including testing for chemical analysis and physical properties) shall be carried out by the Contractor and certificates submitted to the Employer or his authorised representative who will have the right to witness or inspect the above mentioned inspection/ testing at any stage desired by him. Where inspection or testing is to be carried out at a subcontractor's works, a representative of the Contractor shall be present.

1.5. Contractor shall provide test procedure, pre-factory test results, and calculation sheet, photo in advance and provide all of test result with necessary document including its data and photo to show Employer that test is carried out in proper condition and the its test results.

1.6. The procedure for the testing and inspection to be carried out during or following the manufacture of the materials to ensure the quality and workmanship of the materials and to further ensure that they conform to the Contract in whatever place they are specified shall be as described below.

1.6.1. The Contractor shall give the Employer at least 15 clear days notice in writing of the date and the place at which any plant or equipment will be ready for inspection/testing as provided in the Contract. The Employer or his duly authorised representative shall thereupon at his discretion notify the Contractor of his intention either to release such part

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of the plant and equipment upon receipt of works tests certificates or of his intention to inspect. The Employer shall then give notice in writing to the Contractor, and attend at the place so named the said plant and equipment which will be ready for inspection and/ or testing. As and when any plant shall have passed the tests referred to in this section, the Employer or his authorised representative shall issue to the Contractor a notification to that effect.

- 1.6.2. The Contractor shall forward to the Employer 5 duly certified copies of the test certificates and characteristics performance curves for all equipment.
  - 1.6.3. If the Employer or his authorised representative fails to attend the inspection and/or test, or if it is agreed between the parties that the Employer shall not do so, then the Contractor may proceed with the inspection and/ or test in the absence of the Employer and provide the Employer with a certified report of the results thereof as per (b) above.
  - 1.6.4. If any materials or any part of the works fails to pass any inspection / test, the Contractor shall rectify or replace such materials or part of the works and shall repeat the inspection and/or test upon giving a notice as per (i) above. Any fault or shortcoming found during any inspection or test shall be rectified to the satisfaction of the Employer before proceeding with further inspection of that item. Any circuit previously tested, which may have been affected by the rectification work, shall be re-tested.
  - 1.6.5. Where the plant and equipment is a composite unit of several individual pieces manufactured in different places, it shall be assembled and tested as one complete working unit, at the maker's works.
  - 1.6.6. Neither the execution of an inspection test of materials or any part of the works, nor the attendance by the Employer, nor the issue of any test certificate pursuant to (c) above shall relieve the Contractor from his responsibilities under the Contract.
  - 1.6.7. The test equipment, meters, instruments etc., used for testing shall be calibrated at recognised test laboratories at regular intervals and valid certificates shall be made available to the Employer at the time of testing. The calibrating instrument used as standards shall be traceable to National/International standards. Calibration certificates or test instruments shall be produced from a recognised Laboratory for the Employer's Representative approval in advance of testing and if necessary instruments shall be recalibrated or substituted before the commencement of the test.
  - 1.6.8. Items of plant or control systems not covered by standards shall be tested in accordance with the details and program agreed between the Employer and Contractor. If such materials or works are found to be defective or not conforming to the Contract requirements, due to the fault of the Contractor ~~or his sub-contractors~~ the Contractor shall defray all the expenses of such inspection and/or test and of satisfactory reconstruction.
  - 1.6.9. Tests shall also be carried out such that due consideration is given to the Site conditions under which the equipment is required to function. The test certificates shall give all details of such tests.
  - 1.6.10. The Contractor shall establish and submit a detailed procedure for the inspection of materials or any part of the works to the Employer for approval within the date indicated in the Programme Details. The detailed procedure shall indicate or specify, without limitation, the following:
    - a) Applicable code, standard, and regulations.
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- b) Fabrication sequence flow chart indicating tests and inspection points.
- c) Detailed tests and inspection method, indicating the measuring apparatus to be used, items to be measured, calculation formula, etc.
- d) Acceptance criteria.
- e) Test report forms and required code certificates and data records.
- f) Method of sampling, if any sampling test to be conducted.
- g) Contractor's or Employer's witness points.

1.6.11. The Contractor shall not pack for shipment any part of the Plant until he has obtained from the Employer or his authorised representative his written approval to the release of such part for shipment after any tests required by the Contract have been completed to the Employer's satisfaction.

1.6.12. The following Inspection and Testing procedures shall be carried out for the equipment as applicable. The detailed procedure shall indicate or specify, without limitation, the following:

- a) Visual Inspection.
- b) Dimension Checking
- c) Dynamic balancing for all rotating parts
- d) Hydrostatic / Leak testing for all pressure parts, Pneumatic Leak Test wherever applicable
- e) Operation check
- f) Liquid penetrant tests or magnetic particle tests for all machined surfaces of pressure parts.

1.7. The Contractor shall maintain proper identification of all materials used, along with reports for all internal/ stage inspection work carried out, based on the specific job requirement and or based on the datasheets/ drawings/ specifications.

1.7.1. **For inspections within and outside India, all the expenses of Employer and Employer's Representative shall be borne by Employer.**

1.7.2. Witnessed testing will normally be waived on standard types of equipment such as small motors made by approved manufacturers, individual standardised instruments, small mass produced components used in the manufacture of Plant items, small bore pipe work and fittings, minor installation materials and low voltage cable. In order to remove doubt this shall not relieve the Contractor of his obligation under the Contract to ensure that all Plant is tested at the manufacturer's works prior to delivery to Site.

1.8. As a guide to the Contractor the Employer reserves the right to witness testing of the following but not limited to the following Plant items:

1.8.1. Electrical:

- a) Transformers
  - b) HV Switchgear
  - c) LV Metal enclosed switchgears (PCC/ MCCs)
  - d) LV Power capacitor and control panel
  - e) Diesel Standby Generator with AMF Control Panel and Synchronizing panel
  - f) Variable Frequency Drives
  - g) Power & control cables
  - h) Cable carrier system
  - i) Lighting system
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- j) Earthing and lightning protection systems

1.8.2. Mechanical:

- a) Thickener bridges, drives, and sludge/scum mechanisms
- b) Mixers, pumps and blowers including their motors rated above 18.5 kW
- c) Valve and penstock actuators
- d) Valves greater than 300 mm diameter
- e) Pipes more than 200 mm diameter
- f) Sluice Gates
- g) Weir Gates
- h) SPS Coarse Screens and STP Fine Screens, Decanters
- i) Dewatering Centrifuge, Centrifuge Feed Pump
- j) Fine Bubble Diffuser systems
- k) Chlorination system and Gas Scrubbers
- l) Process Air Blowers
- m) EOT Cranes and Hoists
- n) Screw Pumps
- o) Grit Mechanism
- p) Patented items

1.8.3. Instrumentation and Control:

- a) Level, Flow, Pressure & Temperature Measuring System
- b) Online Analyzers
- c) Instrumentation Cables
- d) Instrument Control Panel
- e) Programmable Logic Controller
- f) SCADA / HMI System
- g) Battery Charger/ Uninterruptible Power Supply System
- h) Wireless GPRS gateway testing
- i) FAT & SAT for complete ICA system

1.9. All destructively tested samples shall be replaced with new.

1.10. The Employer reserves the right to be present during the testing and inspection of all Plant items.

**2. Materials, Plant, and Equipment:**

2.1. The Contractor shall place orders for the material and the equipment only after approval of the Employer or Employer's Representative. The Contractor shall submit the detailed drawings from the approved manufacturer and the procedure of submission, review and revision shall be as specified herein below.

2.2. The Contractor shall inform the Employer about the likely dates of manufacturing, testing, and dispatching of any material and equipment to be incorporated into the Permanent Works. The Contractor shall notify the Employer for inspection and testing, at least twenty-eight (28) days prior to packing and shipping and shall supply the manufacturer's test results and quality control certificates. The Employer will decide whether he or his representative will inspect and test the material/ equipment or whether he will approve it on the basis of the manufacture's certificate.

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- 2.3. The following inspection and test categories shall be applied prior to delivery of the equipment, of various categories as indicated in the technical specifications for each type of the equipment:
- 2.3.1. **Category A:** The drawings have to be approved by the Employer before manufacture and testing. The material has to be inspected by the Employer or a third party inspecting agency approved by the Employer at the manufacturer's premise before packing and dispatching. The Contractor shall provide the necessary equipment and facilities for tests and the cost thereof shall be borne by the Contractor.
- 2.3.2. **Category B:** The drawings of the equipment have to be submitted and approved by the Employer prior to manufacture. The material has to be tested by the manufacturer and the manufacturer's test certificates are to be submitted and approved by the Employer before dispatching of the equipment. Notwithstanding the above, the Employer, after examination of the test certificates, reserves the right to instruct the Contractor for retesting, if required, in the presence of the Contractor's representative.
- 2.3.3. **Category C:** Samples of the materials and/or equipment shall be submitted to the Employer for pre-construction review and approval. Following approval by the Employer, the material may be manufactured as per the approved standards and delivered to the Site.
- 2.3.4. For material/ equipment under Category "A" and "B", the Employer will provide an authorization for packing and shipping after inspection. The testing and approval for dispatching shall not absolve the Contractor from his obligations for satisfactory performance of the plant.

### **3. Factory Acceptance Test (FAT) Document:**

- 3.1. Fifteen (15) days prior to commencement of inspection of each Plant item/ equipment the Contractor shall supply a Factory Acceptance Test (FAT) Document for approval. This shall comprise four copies of the following:
- 3.1.1. Copy of the Contractors order for the Plant item/ equipment concerned:
- 3.1.2. Details of the inspection and test procedures to be carried out.
- 3.1.3. Pre-factory test results and its photos.
- 3.2. The FAT Plan shall provide comprehensive details of the tests to be carried out, the purpose of each test, the equipment to be used in carrying out the test and the methods to be adopted in carrying out the tests. The FAT shall provide space within the documentation for results of the tests to be added and for each test and for the FAT as a whole to be signed off by the Contractor and the Employer or his authorized Representative.
- 3.3. On completion of the tests the Contractor shall provide four copies of all test certificates, performance curves etc. for the inspected Plant item. To remove doubt test certificates shall be provided for the Plant item as a whole plus certificates for the relevant component parts such as:
- 3.3.1. Motors;
- 3.3.2. Mixers, pumps and Blowers;
- 3.3.3. Instruments;
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- 3.3.4. Gear boxes;
- 3.3.5. Electrical switchgear rated in excess of 250 A;
- 3.3.6. Integral control and switchgear panels;
- 3.3.7. Valve gear;
- 3.3.8. Castings.
- 3.3.9. Actuators
- 3.3.10. Cranes and Hoists
- 3.3.11. Screens
- 3.3.12. Diffusers
- 3.3.13. Storage and process vessels
- 3.3.14. Pumps /blowers
- 3.3.15. Air blowers
- 3.3.16. Centrifuge Decanters

#### **4. Inspection and Testing Programme:**

- 4.1. The Contractor shall submit to the Employer not later than 15 days prior to the commencement of the first inspection and test during manufacture a programme detailing the inspection dates for all Plant. Those items of Plant that the Employer has specifically identified for witness testing test shall be highlighted in the programme. The Contractor shall keep the Employer informed of any changes to the programme.
  - 4.2. The Employer shall not be requested to inspect an item of Plant until the Contractor has satisfied himself that the equipment meets all requirements of the Employer's Requirements.
  - 4.3. The Contractor shall inform the Employer in writing at least 15 days in advance regarding readiness for carrying out inspection of equipment/ material etc. at manufacturer's works or at places of inspection. The programme for inspection shall be finalised by the Employer's Representative after the receipt of the above. In case inspection cannot be carried out due to non-readiness of equipment/material etc. a subsequent date shall be finalised for carrying out the inspection in which event all expenses incurred by the Employer for such visits shall be recovered from the Contractor. In case equipment/material etc. is found not to comply with the specification, dates for re-inspection shall be finalised and expenses incurred by the Employer for such visits shall also be recovered from the Contractor. Contractor's Representatives shall essentially be present during all inspections of Plant items. The following information shall be given in the inspection call letter mentioned above:
    - 4.3.1. Name of manufacturer/ supplier;
    - 4.3.2. Address of place where inspection is to be carried out;
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- 4.3.3. Proposed date/s and equipment to be inspected;
- 4.3.4. Name/s of contact personnel at manufacturer's/ supplier's works with their telephone and fax numbers.
- 4.3.5. Name of Contractor's Representative who will be present during the inspection.
- 4.3.6. Confirmation that internal testing has been completed.
- 4.4. The Contractor shall provide all the necessary instruments, test facility, water / electric power, test piece, samples, Employer's Representative/ workers, all cost and others to carry out the tests after assembly. All instruments used for such tests shall be calibrated and certified by and approved by an independent testing authority not more than one month prior to the tests in which they are used. Calibration certificates with expire date and name of authorization agency for instruments used for such tests shall be produced for the approval of the Employer's Representative and if necessary, instruments shall be recalibrated before the commencement of the tests.
- 4.5. No material shall be delivered to the Site without inspection having been carried out or waived in writing by the Employer.
- 4.6. If during or after testing, any item of plant fails to achieve its intended duty or otherwise proves defective, it shall be modified or altered as necessary and retested and re-inspected as required by the Employer's Representative.

## **5. Tests on Mechanical Equipment:**

### **5.1. Tests at Manufacturer's Works – Mechanical Equipment:**

#### **5.1.1. Sewage/ Sludge Pumps-**

- a) All pumps shall be assembled completely in the shop to ensure correct fitting of all parts and shall be match-marked before shipment.
- b) All pumps shall undergo witness performance tests at the pump manufacturer's Works. Testing shall be undertaken with the respective motors for all the pumps being supplied under the Contract.
- c) All tests such as Q/H curve, efficiency of pumps, power consumption, vibration and noise level shall be conducted, and NPSH tests one for each pumping station shall be undertaken to verify that the pumps meet the specified criteria. The pumps shall be run at constant flow capacity and speed.
- d) Pump casings shall be subject to hydrostatic pressure testing as an assembly at 150% of the pump shut-off head or 200% of the pump rated head whichever is higher. The hydrostatic pressure shall be held for not less than 30 minutes after all leaks have been stopped between attachments.
- e) Impeller and pump rotating assembly shall be dynamically balanced as per ISO 1940 / Gr. 6.3 / VDI 2060.
- f) Standard running test shall be conducted as per BS 5316 Part 2 Class B/ ISO 3555 at the rated speed at manufacturer's works to measure the capacity, total head, efficiency and power. These tests shall form the basis for pump acceptance except for vibration and noise. The pump shall be tested over a range comprising shut off

head to maximum flow. Minimum five readings approximately equidistant shall be taken for plotting the performance curve.

- g) The following formula shall be taken for computing the power input to the pump:

$$\text{Power input to the Pump in kW: } \frac{Q \times H \times 1.02}{367.2 \times \eta_p}$$

Where,  
Q = Discharge in cum/hr  
H = Total head in mwc  
 $\eta_p$  = Efficiency of pump

- h) If the vibration, noise level readings taken during performance test show higher than that permitted, vendor shall guarantee to show that the values shall be maintained at site after erection. Any cost of rectification needed on this count shall be borne by the Contractor.

#### 5.1.2. **Motors:**

- a) Routine Tests- All routine tests shall be carried out on all motors as per the latest edition of IS 325.
- b) Acceptance Tests- Full load test to determine efficiency, power factor and slip shall be conducted on all the motors.
- c) Type tests- The following type tests shall be carried out on one motor of each rating above 18.5 kW.
- i) Isolation resistance test
  - ii) Temperature rise test
  - iii) Momentary overload test
  - iv) Vibration measurement test
  - v) Noise level test
  - vi) Over speed/ over load test
  - vii) Starting current, starting torque, and pull out torque at reduced voltage

#### 5.1.3. **Valves:**

- a) During testing there shall be no visible evidence of structural damage to any of the valve component.
- b) Motorized valves shall be tested with their actuators, with a differential head equivalent to their maximum working pressure, to prove that the actuators are capable of opening and closing the valves under maximum unbalanced head condition within the specified opening or closing period.
- c) Hydrostatically tested shall be as per relevant IS/BS standard for each type of valve.
- d) The following test shall be carried out for sluice valves, Knife Gate valves:
- i) Pressure test
  - ii) Leakage test
  - iii) Seat leakage test.
  - iv) Body hydrostatic test.

- v) Valve operation
- e) The following test shall be carried out for non-return valves:
  - i) Pressure test
  - ii) Leakage test
  - iii) Seat leakage test.
  - iv) Body hydrostatic test.
  - v) Valve operation

#### 5.1.4. **Pipe-work:**

- a) Testing of pipes and fitting shall be carried out in accordance with relevant Indian Standard and internationally approved standard. Pipes, fittings and expansion bellows shall be hydrostatically tested for 1.5 times the rated pressure.
- b) The following test shall be carried out for pipelines:
  - i) Pressure test
  - ii) Leakage test
  - iii) Colour check for welding pipeline
  - iv) Welding beat check

#### 5.1.5. **Compressors and Blowers:**

- a) Tests shall be carried out in accordance with the relevant international standard. All compressors and blowers shall be tested with their ancillaries to confirm design performance particularly in respect of flow and pressure. The test shall demonstrate that vibration and noise are within the specified limits and that the pressure relief valve operates correctly.
- b) Air receiver shall be tested in accordance with the relevant section of B.S. 5169.
- c) All pressure vessels shall be inspected and hydro water tightness tested.

#### 5.1.6. **Process Plant Items:**

- a) All process plant items shall be tested to ensure they meet the Employer's Requirements for quality of workmanship, construction, and performance.

#### 5.1.7. **Crane & Hoists:**

- a) The cranes shall be completely assembled in the Contractor's or subcontractor's Works and shall be subjected to the tests as specified in IS 807/IS 3177 or relevant internationally approved standard. The Contractor shall provide the test weights.
- b) Hoists and lifting equipment shall be assembled and tested at the place of manufacture in accordance with IS 3938.
- c) Each and every rotating part/assembly/sub-assembly shall be dynamically balanced as per grade G16 of ISO 1940/1 - 1986.

#### 5.1.8. **Sluice Gates:**

- a) Seat Clearance Check - With the gate fully closed, the clearance between seating faces when checked with the thickness gauge, shall not exceed 0.1 mm.
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- b) Movement Tests - Each gate shall be shop operated three times from the fully open position to the fully closed position and return to fully open, under no flow conditions to demonstrate that the assembly is workable.
- c) Leakage Tests - With the gate in closed position design pressure shall be applied for a period not lesser than 5 minutes to the unseating side of the sluice gate and the leakage shall not exceed the maximum leakage permissible as per IS 13349.
- d) Hydrostatic Tests - Finally a differential of one and a half times the design pressure shall be applied to the unseating side of the gate. Under these tests no part shall show any deflection or deformation.

#### **5.1.9. Fine Screens:**

- a) All screens shall be checked for overall dimensions, clearance between the bars / aperture size and its material as well as painting works.
- b) Conveyor shall be checked for dimensions and physical conditions, belt joint portion, travelling accuracy of belt, motors and its power consumption, performance of safety device.
- c) At least one screen of each type shall be tested for efficiency and operation by employing screenings. For the screen having depth of channel more than 3 metres, testing with reduced depth is acceptable. Test shall be carried out at site during commissioning of the plant.

#### **5.1.10. Fine Bubble Diffusers:**

- a) Clean water Standard Oxygen Transfer Efficiency (SOTE) tests shall be performed for each different diffuser grid geometry/arrangement proposed in the design. These tests shall be performed by the diffuser Manufacturer at the Manufacturer's testing facility or an equivalent facility appropriately equipped with an adequately sized testing tank and other required appurtenances. The testing shall be performed in full compliance with the latest version of the applicable standard testing protocol. These tests shall be witnessed by Employer's Representative per procedures set forth for witnessing elsewhere in this document.
- b) All diffusers including 10 % spares shall be thoroughly inspected by Contractor for physical damage to the membrane or any other part of the diffuser and results of the inspection shall be reported to Employer's Representative.
- c) All Fine bubble diffused aeration systems will be field tested.
- d) Testing will verify the installation as well as the diffuser's ability to deliver the specified air flow rates at the manufacturer's stated pressure loss. Testing will also verify the uniformity of mixing provided.
- e) Levelling tests:
  - i) Introduce clear water into each tank to the top of the diffuser elements.
  - ii) Check the level of the diffusers to verify that all element horizontal surfaces are within 10 mm of a common horizontal plane and at the specified elevation.

- f) Leakage and distribution of flow tests:
  - i) After successful completion of the levelling tests, raise the water level to 50mm above the manifold.
  - ii) Visually inspect the water surface to ensure that the airflow is uniformly distributed across the tank.
  - iii) Repair any leaks in the elements holders, elements, pipes or the like.
  - iv) Repeat the test until the installation is essentially void of air leaks.

5.1.11. **Miscellaneous Pump-sets-** All the pump-sets other than sludge pumps shall be tested for performance as per IS 5120.

5.1.12. **Reinforced Cement Concrete Pipes:**

- a) All pipes for testing purposes shall be selected at random from the stock of the manufacturer and shall be such as would not otherwise be rejected under the criteria of tolerances as mentioned in IS: 458.
- b) Contractor shall provide laboratory test /analysis results of cement and aggregate component and cement vs. aggregate vs. water mixing ratio and concrete mixing time and mixing method.
- c) During manufacture, tests on concrete shall be carried out as per IS: 456. The manufacturer shall supply, when required to do so by the Employer's Representative the results of compressive tests of concrete cubes and split tensile tests of concrete cylinders made from the concrete used for the pipes. The manufacturer shall supply cylinders or cubes for test purposes required by the Employer's Representative and such cylinders or cubes shall withstand the tests prescribed as per IS: 458. Every pressure pipe shall be tested by the manufacturer for the hydrostatic test pressure. For non-pressure pipes, 2 percent of the pipes shall be tested for hydrostatic test pressure.
- d) The specimen of pipes for the following tests shall be selected in accordance with relevant clause of IS: 458 and tests in accordance with the methods described in IS: 3597.
  - i) Hydrostatic test
  - ii) Three edge bearing test
  - iii) Absorption test
  - iv) Dimension and colour of surface
  - v) Damage

5.1.13. **Sampling and Inspection:**

- a) In any consignment, all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of this Employer's Requirements shall be ascertained on the basis of tests on pipes selected from it.
  - b) The number of pipes to be selected from the lot for testing shall be in accordance with Table 15 of IS: 458.
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- c) Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every  $r$ -th pipe be selected till the requisite number is obtained,  $r$  being the integral part of  $N/n$  where  $N$  is the lot size and  $n$  is the sample size.
- d) All pipes selected shall be inspected for dimensional requirements, finish and deviation from straight. A pipe failing to satisfy one or more of these requirements shall be considered as defective.
- e) The number of pipes to be tested shall be in accordance with column 4 of Table 15 of IS: 458. These pipes shall be selected from pipes that have satisfied the requirements mentioned in the above clause.
- f) A lot shall be considered as conforming to the requirements of IS: 458 if the following conditions are satisfied.
- g) The number of defective pipes shall not be more than the permissible number given in column 3 of Table 15 of IS: 458.
- h) All the pipes tested for various tests shall satisfy corresponding requirements of the tests.
- i) In case the number of pipes not satisfying requirements of any one or more tests, one or two further samples of same size shall be selected and tested for the test or tests in which the failure has occurred. All these pipes shall satisfy the corresponding requirements of the test.
- j) All destructively tested samples shall be replaced to new.

#### **5.1.14. Steel Cylinders Pipes and Specials:**

- a) Welding beat check Remove all scale on the welding points and welding beat and its thickness shall be checked by the Employer's Representative.
- b) Penetration Test- A suitable penetrating liquid (kerosene oil/Dye) is applied to the surface of the portion under examination and is permitted to remain there for sufficient time to allow the liquid to penetrate into any defects open at the surface. After the penetrating time, the excess penetrant, which remains on the surface, is removed. Then a light coloured powder absorbent called a developer is applied to the surface. This developer acts as a blotter and draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out it diffuses into the coating of the developer, forming indication of the surface discontinuities or flaws.
- c) Each steel cylinder shall be subjected before lining/coating to a hydrostatic test under a water pressure equivalent to the test pressure in accordance with Clause 10 of IS:1916 and relevant provisions of IS:3597, provided that the whole of the area of the calculated reinforcement is used in the steel cylinder. In the case of pipes where a part of the principal reinforcement is provided in the cage, the steel cylinder shall be subjected to proportionately less hydrostatic test pressure.
- d) Manufacturer's standard specials shall be hydrostatically tested before lining/coating. Where feasible, other specials shall be hydrostatically tested (before lining/coating) at factory. However, when this is not practicable, at the discretion of

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the Employer's Representative, the unlined specials shall be tested by penetration test as per IS: 3658 or other approved means.

**5.1.15. Cast Iron/ Ductile Iron Pipes:**

- a) **Mechanical Tests-** Mechanical tests shall be carried out during manufacture of pipes and fittings as specified in relevant IS codes. The results so obtained shall be considered to represent all the pipes and fittings of different sizes manufactured during that period and the same shall be submitted to the Employer. The method for tensile tests and the minimum tensile strength requirement for pipes and fittings shall be as per relevant IS codes.
- b) **Brinell Hardness Test-** For checking the Brinell hardness, the test shall be carried out on the test ring or bars cut from the pipes used for the ring test and tensile test in accordance with IS 1500.
- c) **Retests-** If any test piece representing a lot fails in the first instance, two additional tests shall be made on test pieces selected from two other pipes from the same lot. If both the test results satisfy the specified requirements, the lot shall be accepted. Should either of these additional test pieces fail to pass the test, the lot shall be liable for rejection.
- d) **Hydrostatic test-** For hydrostatic test at works, the pipes and fittings shall be kept under test pressure as specified in relevant IS codes for 15 seconds, they may be struck moderately with a 700 g hammer. They shall withstand the pressure test without showing any leakage, sweating or other defect of any kind. The hydrostatic test shall be conducted before coating the pipes and fittings.

**5.1.16. Chlorination and Gas pipeline system:**

- a) All items of plant shall be tested at manufacturer's works and test certificates shall be provided.
  - b) All chlorine gas piping from chlorine drums to chlorinator shall be pressure tested with dry air/nitrogen to a pressure of 15 kg/sq.cm.
  - c) The chlorine gas piping from the chlorinators up to injectors shall be pressure/vacuum tested with dry air/nitrogen to a pressure/vacuum equal to 1.5 times the maximum pressure/vacuum to be encountered during operation.
  - d) The motive water piping shall be hydrostatically tested for a pressure of 1.5 times the operating pressure or the maximum pump discharge pressure at pump shut off whichever is higher.
  - e) After the chlorine system has been completely tested as above leak tests shall be conducted admitting chlorine gas. Leakages if any shall be identified using ammonia stick. During this test all chlorine leak detectors shall be in place and all safety procedures shall be adhered to.
  - f) Gas cylinder shall provide the pressure test certificate issued by authority and manufacture year.
  - g) Chlorine gas detector sensors shall be tested, and results shall provide to the Employer's Representative.
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- h) Ventilation system- The ventilation fans shall be tested at manufacturer's works to verify the design flow and pressure.
- i) Process Plant Item- All process plant items shall be tested to ensure they meet the Employer's Requirements for inlet and outlet quality of workmanship, construction and system performance.

## **5.2. Tests at Site - Mechanical Equipment:**

5.2.1. In addition to the progressive supervision and inspection by Employer and his authorised Representative, the Contractor shall offer for inspection to Employer's Representative, the completely erected plant/part of Plant on which tests are to be carried out. After such inspection, each equipment/sub-system shall be tested by the Contractor in accordance with the applicable standards in the presence of Employer's Representative. Such tests shall include but not be limited to the tests specified in following clauses.

5.2.2. The Contractor shall possess during the entire working period the Electrical Contractor's licence of appropriate class from the concerned statutory authorities governing the area of work place. The Contractor shall fully comply with the relevant statutory rules and regulations. On completion of the installation or at intermediate stages, if required by the statutory authorities, the Contractor shall arrange for inspection and obtain the approval from the concerned statutory authorities. If any fees are to be paid to statutory authorities for testing, inspection and calibration these shall be paid by the Contractor and shall be included in his erection and commissioning charges.

### **5.2.3. Pumps, piping and valves:**

- a) The erected pipe work shall be subjected to a hydraulic test at 1.5 times the maximum pressure or twice the working pressure whichever is higher to test the soundness of the joints. Provision of the necessary pumps, gauges, blank flanges, tapping etc. for carrying out these tests shall be included in the Contract. All gas piping shall be air tested to twice normal working pressure.
- b) Leakage tests shall be carried out on all erected pipe work, pumps and valves immediately after erection and where possible before being built in.
- c) Operating tests shall be conducted on valves.
- d) The pump set shall be tested for satisfactory operation. The vibration and noise level shall be checked to be within the specified limits.

5.2.4. **Motors** - Condition of winding insulation be tested and insulation values shall be restored to required level by suitable heating arrangements locally.

5.2.5. **Cranes & Hoist** - The crane and lifting tackle shall be tested to 125 % of the safe working load. The Contractor shall arrange the test load.

5.2.6. **Screens** - After erection, all screens screen shall be tested for smooth operation and capability to handle typical wastewater solids including stringy materials. Clearance between the dead plate and tines shall be checked as applicable.

### **5.2.7. Gates:**

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- a) Leakage test shall be performed by the Contractor after installation of all Gates.
- b) Under the design seating head and unseating head the leakage shall not exceed the limit specified in IS: 13349, for shop testing.

#### **5.2.8. Laying of Reinforced Cement Concrete Pipes:**

- a) After laying and jointing of RCC pipes is completed the pipe line shall be washing out with sufficient water and be tested at work site as per the Employer's Requirements and as directed by the Employer's Representative. All equipment for testing at work site shall be supplied and erected by Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be contractor's responsibility and shall be rectified by him to full satisfaction of the Engineer in charge. Water used for the test shall be removed from pipes and not released to the excavated trenches.
- b) After the joints have thoroughly set and have been checked by the Engineer in Charge and before back filling the trenches, the entire section of the sewer or storm water drain shall be proved by the Contractor to be water tight by filling in pipes with water to the level of 1.50m above the top of the highest pipe in the stretch and heading the water up for a period of one hour.
- c) The apparatus used for the purpose of testing shall be approved by the Employer or Employer's Representative. Contractor if required by the Employer shall dewater the excavated pit and keep it dry during the period of testing. The loss of water over a period of 30 minutes should be measured by adding water from a measuring vessel at regular 10 minutes intervals and noting the quantity required to maintain the original water level. For the approval of this test the average quantity added should not exceed 1.0 litre/ hour/100 linear metres/ 10mm of nominal internal diameter. Any leakage including excessive sweating which causes a drop in the test water level will be visible and the defective part of the work should be removed and made good.
- d) In case of pressure pipeline, the completed stretch of pipeline shall be tested for site test pressure. The site test pressure should not be less than the maximum operating pressure plus the calculated surge pressure, but in no case should it exceed the hydrostatic test pressure as specified in IS: 458.

#### **5.2.9. Laying of Steel Cylinder Pipes and Specials:**

- a) After laying and jointing of steel cylinder pipes and specials with concrete lining and coating is completed the pipeline shall be washing out with sufficient water and be tested at work site as per the following Employer's Requirements and as directed by the Engineer in Charge. All equipment for testing at work site shall be supplied and erected by Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be Contractor's responsibility and shall be rectified by him to the full satisfaction of the Employer's Representative. Water used for test shall be removed from pipes and not released to the excavated trenches.
- b) Each section of the pipe line shall be slowly filled with clean water and all air shall be expelled from the pipeline. The pressure in the pipeline should then be raised and maintained by means of pump to the test pressure. The test pressure should not be less than 1 1/2 times the working pressure at the lowest point or the static head pressure, whichever is higher. Under the test pressure no leak or sweating

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shall be visible at the welded joints. The duration of test shall be not less than 24 hours. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be rewelded. Any cracked or defective pipes and specials in consequences of this pressure test shall be removed and replaced by sound material by Contractor and the test shall be repeated to the satisfaction of the Engineer in Charge.

- c) Hydrostatic shop test for pipes and fittings shall be as per code/standard requirement. After erection at site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times operating pressure.
- d) Where directed by the Engineer in Charge welded joints on pipes larger than 675 mm diameter shall be subject to a nitrogen gas test after welding.
- e) A tapped hole (approximately 6 mm diameter) shall be made in the socket end of each pipe by the Contractor and shall be fitted with a suitable non-return valve. Nitrogen, at 400 kPa pressure, shall then be pumped into the annular space between the spigot and socket and the pump disconnected.
- f) If no drop in pressure occurs over the ensuing period of 30 minutes the test shall be deemed to be successful. If the test pressure cannot be maintained for 30 minutes all defects in the weld shall be cut back and re-welded and the test reapplied until successful. The cost of initial and subsequent testing of defective welds shall be at the Contractor's own expense.
- g) The Contractor shall provide all items necessary for the nitrogen tests including compressor, valves, gauges and tubing.

#### **5.2.10. Laying of Cast Iron, Ductile Iron Pipes and Fittings:**

- a) After the pipes and fittings are laid, jointed and the trench partially backfilled except at the joints the stretch of pipe line as directed by Engineer in Charge shall be subjected to pressure test and leakage test after washing the pipe line out with sufficient water.
  - b) Where any section of the pipeline is provided with concrete thrust blocks or anchorages, the pressure test shall not be made until at least five days have elapsed after the concrete was cast. If rapid hardening cement has been used in these blocks or anchorages, the tests shall not be made until at least two days have elapsed.
  - c) Each section of the pipe line shall be slowly filled with water and all air shall be expelled from the pipe by tapping at points of highest elevation before the test is made and plugs inserted after the tests have been completed. The specified test pressure based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge shall be applied by means of a pump connected to the pipe as directed by the Employer's Representative.
  - d) The duration of test shall not be less than 5 minutes. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be re-caulked until water tight. Any cracked or defective pipes and fittings in consequence of this pressure test shall be removed and replaced by sound material by Contractor at no extra cost to the Employer and the test shall be repeated to the satisfaction of the Engineer in Charge.
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- e) After the satisfactory completion of pressure test, the section of pipe line shall be subjected to leakage test. The duration of test shall be 2 hours. No pipe installation shall be accepted until the leakage is less than the number of cm<sup>3</sup> /h as determined by the formula:

$$q_L = \frac{ND\sqrt{P}}{115}$$

Where,

- $q_L$  = the allowable leakage in cm<sup>3</sup>/hr  
N = Number of joints in the length of the pipeline  
D = Diameter in mm, and  
P = the average test pressure during the leakage test in Kg/cm<sup>2</sup>

- f) Should any test of pipe laid indicate leakage greater than that specified above, the defective joints shall be repaired by Contractor at no extra cost to the Employer until the leakage is within the specified allowance.
- g) Necessary equipment and water used for testing shall be arranged by Contractor at his own cost. Damage during testing shall be Contractor's responsibility and shall be rectified by him at no extra cost to the Employer. Water used for testing shall be removed from the pipe and not released in the excavated trenches.
- h) After the tests mentioned above are completed to the satisfaction of the Engineer in Charge, the backfilling of trenches shall be done as per the Employer's Requirements specified elsewhere.

## **6. Tests on Electrical Equipment:**

- 6.1. The following equipment/ items shall be subjected to inspection, routine /acceptance tests as per latest edition of relevant Indian/ International standards in the presence of Employer/ Employer's Representative.

6.1.1. Transformers

6.1.2. HV Switchgear

6.1.3. LV Metal enclosed switchgears (PCC/ MCCs)

6.1.4. LV Power capacitor and control panel

6.1.5. Diesel Standby Generator with AMF Control Panel and Synchronizing panel

6.1.6. Variable Frequency Drives

6.1.7. Power & control cables

6.1.8. Cable carrier system

6.1.9. Lighting system

6.1.10. Earthing and lightning protection systems

- 6.2. Copies of test Certificates for the type tests and Special tests not later than 5 years conducted as per relevant Indian / International Standards for all the equipment /items of above shall be furnished for the perusal of Employer or his authorised Representative. If type tests and special tests have not been conducted on any of these items, the same shall be carried out in the presence of Employer/ Employer's Representative at no extra cost.

## **7. Tests on Instrumentation and Control Equipment:**

### **7.1. General:**

- 7.1.1. Each item of plant shall be subjected to the manufacturer's own tests which shall be certified.
- 7.1.2. Each item of plant and its installation shall be subject to inspection and testing at the place of manufacture.
- 7.1.3. The Contractor shall be responsible for the provision of all necessary test equipment. The Contractor shall demonstrate to the Employer or his authorised Representative, the correct operation of any item of plant and the Employer or his authorised Representative may witness any test. Tests which, in the opinion of the Employer or his authorised Representative, were failed or not performed correctly shall be repeated.
- 7.1.4. Calibration tests for field instruments and analytical instruments should be conducted on site after installation and the same should be witnessed by the Employer/ Employer's Representative.
- 7.1.5. Before any test is made, the Contractor shall submit to the Employer a full list of test equipment & test procedures (method statements) 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 Employer/ Employer's Representative. Test equipment shall be checked frequently during the period of the tests.
- 7.1.6. 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 on his own expense.
- 7.1.7. Any fault or shortcoming found during any inspection or test shall be rectified to the satisfaction of the Employer's Representative 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.
- 7.1.8. Once the preliminary inspection and testing is complete to the satisfaction of the Employer/ Employer's Representative, functional testing shall commence. The purpose of the functional tests is to demonstrate that instrument panels enclosures and mounting boards (assemblies) conform to requirements of the Specification.
- 7.1.9. Not less than 30 days before the commencement of functional tests, the Contractor shall submit to the Employer, 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

7.1.10. Witness signatures- All applicable drawings and data shall be provided at the place of inspection by the Contractor.

7.1.11. The Contractor shall provide all test instruments and equipment necessary to test the assemblies in their entirety. The following is a typical list of the equipment required:

- a) Switch boxes;
- b) Indicator light boxes;
- c) Analogue signal sources;
- d) Dummy loads;
- e) Meters;
- f) Simulators;
- g) Desk-top computers;
- h) Programmers for DCS or outstations;
- i) Insulation test equipment

## **7.2. Preliminary Inspection and Testing at the Works of Manufacture:**

### **7.2.1. Field-mounted instruments:**

- a) 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 Employer/ Employer's Representative and the Contractor. 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.

### **7.2.2. Instrument panels, enclosures and mounting boards:**

- a) 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 Employer/ Employer's Representative. The Contractor shall give not less than 7 days' Prior notice in writing that he has completed.
- b) His tests and inspection and is ready for the witnessed tests and inspection. Where this notice period is different in the Conditions of Contract this shall take precedent.
- c) The witnessed inspection and testing shall include the following:
  - i) A visual inspection of the panel assembly to show that the design, construction and finish are satisfactory and in accordance with the Specification;
  - ii) A check that equipment is securely mounted, accessible for removal or calibration without damage to or undue disturbance of other components, wiring or piping;
  - iii) That all engraving and labels are correctly positioned, fixed and designated in accordance with the Specification;
  - iv) Panel power-distribution circuits have the correct breaker/fuse rating coordination and designation;
  - v) Power-isolation facilities meet the Specification;

- vi) The main incoming supply voltage, frequency and/or pneumatic supply pressure is within the required limits, these being checked at the beginning and end of the test and the results recorded on test certificates;
  - vii) The output of all power supply units again at the beginning and end of the testing with results being recorded;
  - viii) The power supply voltage or air pressure of all component instruments of the assembly(s), these voltages/pressures being recorded on the test certificate;
  - ix) The insulation resistance of all circuits except sensitive electronic equipment which is liable to damage by application of the test voltage, such circuits being disconnected before making the insulation resistance tests and these tests being carried out in accordance with IEE Wiring Regulations;
  - x) That the clean earth bar is isolated from main frame of the panel.
- d) Internal lighting and anti-condensation heaters and associated thermostats, isolators, limit switches and wiring shall be checked for compliance with the Specification.
- e) 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.

### **7.3. Factory Acceptance Test (FAT) on Programmable Logic Controller (PLC) and SCADA System:**

- 7.3.1. The Contractor shall carry out specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.
- 7.3.2. The tests shall be carried out on the fully assembled control panel containing the PLC and associated equipment in order to demonstrate correct functional operation of the hardware and software systems.
- 7.3.3. The Contractor shall conduct a full programme of tests of the PLC & SCADA system at the Contractor's testing facility in the presence of the Employer's Representative to verify that all features of the system have been provided, are operating correctly and are in full compliance with the Specification. FAT shall include PLC based SCADA system for STP and PLC based control system with panel mounted HMI for SPS with wireless communication system for the all of the above. Unless otherwise specified or agreed by the Employer/ Employer's Representative, the entire PLC & SCADA system shall be assembled and tested together as an integrated system, including all master station equipment, all operators' consoles, all outstations and telemetry equipment all instrumentation panels and uninterruptible power supplies included in this Specification. The scheduled date for the factory acceptance test shall be as agreed by the Contractor and the Employer at least two weeks before the test. FAT shall be conducted with a hardwired simulation panel connected to the PLC based SCADA system. Contractor shall note the importance of the requirement. No software based simulation testing shall be accepted or allowed.
- 7.3.4. Not less than one month before the scheduled factory acceptance test, the Contractor shall submit to the Employer for approval two copies of a comprehensive manual detailing each test to be conducted. The manual shall include a results form on which the results of each test will be entered, including spaces for numerical values where appropriate and witness signatures.
- 7.3.5. Not less than 7 days before the scheduled factory acceptance test, the Contractor shall give written notification to the Employer that a complete dry-run of the factory acceptance

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test has been performed successfully and that, in the opinion of the Contractor, the system exhibits stable operation and is ready for the formal factory acceptance test.

- 7.3.6. The factory acceptance test will be considered successfully completed only when the system has successfully passed all factory tests. The system shall not be delivered to Site until the successful completion of the factory acceptance test is certified by the Employer/ Employer's Representative or unless otherwise approved by the Employer/ Employer's Representative. Delay in the delivery of the system due to failure of the factory acceptance test shall not constitute an unavoidable delay. If the system fails the factory acceptance test, the test shall be extended or rescheduled at the discretion of the Employer.
- 7.3.7. All hardware to be used in the testing of the system shall have passed an agreed preliminary hardware performance test to ensure known hardware operability before software testing begins.
- 7.3.8. After successful completion of the factory acceptance test, no software changes shall be made to the system without written authorisation by the Employer/ Employer's Representative. Any changes to the system which effect the system software documentation, such as input scale modifications or changes to the control logic shall be entered into the system documentation before delivery of the system to Site. All instruments under ICA scope has to be tested 100%.
- 7.3.9. **Factory Acceptance Test Procedures-** The scope of the tests shall include the proving of every aspect of hardware and software operation and functions as detailed below.
- a) **Hardware tests:**
    - i) Verify the correct inventory of hardware including cables and printed circuit boards;
    - ii) Demonstrate that all spare-memory, disk-capacity and system-expansion requirements have been met;
    - iii) Demonstrate all hardware and software diagnostics;
    - iv) Verify all power supply voltages are within tolerance;
    - v) Verify proper earth connections and isolation of instrumentation earth for all equipment;
    - vi) Demonstrate operation of test simulation and indication equipment and its Suitability for adequate functional testing of all system functions.
  - b) **Software tests:**
    - i) Demonstrate the editing of all system parameters including set-points, timers and the like;
    - ii) Demonstrate system configuration capabilities including the addition and deletion of input and output points, outstations, and all data base parameters;
    - iii) Demonstrate the addition, deletion and modification of mimic displays and report formats;
  - c) **Functional tests:**
    - i) The functional tests shall verify proper operation of every specified system function as an integrated system. These tests shall be conducted in conjunction with functional tests of instrumentation and control panels as specified elsewhere. All failures or discrepancies found shall be documented in the test manual.
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ii) Following a failure of any functional test, should software or hardware modifications be required it shall be the decision of the Employer/ Employer's Representative whether the factory acceptance test is to continue, re-start or be aborted. If testing is allowed to continue, any changes which are required shall be described in a system modification document, signed by both Contractor and Employer/ Employer's Representative and be incorporated into the final factory acceptance test documentation. The failed test shall be re-conducted and the Employer/ Employer's Representative may require the retest of functions which may be affected by the modification.

iii) The functional tests shall include, as a minimum, the following:

- Demonstration that the system meets the requirements of the Specification for response time and speed of screen update
- Verification of the accuracy of all analogue input points in the system. The procedure shall include applying the appropriate signal to each analogue input at a minimum of three points within the range of the input, checking for expected numerical results, and verifying appropriate update of related mimic displays. Proper sensing and action by the system to high and low out-of-range inputs shall also be verified
- Verification of the proper logic sense, pulse accumulation and rate computation where appropriate, of all digital inputs and verifying appropriate update of related mimic displays;
- Verification of all control and sequencing operations and proper operation of all digital and analogue outputs. The procedure shall include simulation of all related process variables for both normal and abnormal conditions, including instrument and component failure, and demonstration of fail-safe response of the system. System outputs shall be indicated with appropriate lamps and indicators;
- Simulation of outstation communications errors and failures and demonstration of error detection and handling, failure detection and handling, and appropriate changes to control actions as designed and specified;
- Verification of fault detection and diagnostics by inducing a sufficient variety of fault conditions in the system to ensure that detection processes and fail-safe operation are adequately tested;
- Demonstration of proper operation of all mimic displays, help pages, reports, operator procedures and historical data accumulation;
- Demonstration of proper operation of all outstations following a simulated master station central processor failure;
- Demonstration of proper operation of all equipment during both a system wide or isolated power failure and following power restoration. The procedure shall include the demonstration of battery backup of both master station and outstation for the full length of time specified, and proper operation of power fail, low voltage warning and all associated alarms.

d) **Reliability test:**

i) After successful completion of the functional tests a 48-hour continuous run of the system shall be performed. The test shall be passed if no system function is lost or no hardware or software failure occurs. Hardware failure is defined for this test as the loss of a major component such as the computer, an outstation, a VDU or a peripheral device. Non-repetitive mechanical failures of loggers, push-buttons and the like are excluded.

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ii) During this test, the system shall be exercised with simulated inputs and conditions in a manner which approximates the on-site operational environment. Unstructured testing by the Employer/ Employer's Representative shall be included during this test. Upon any system failure during this period, it shall be the decision of the Employer's Representative whether the reliability test is to continue or be aborted. If testing is allowed to continue any changes to the system which are required shall be described in a system-modification document, signed by both Contractor and Employer/ Employer's Representative and the document shall be incorporated into the final factory acceptance test documentation.

e) **Factory acceptance test documentation** - As a minimum, the following information shall be included in the factory Acceptance test manual for each test:

- i) Test identification number;
- ii) Test name and description;
- iii) List of all equipment to be tested including any special test equipment required;
- iv) Description of the test procedure broken down into logical steps;
- v) Description of the expected system response verifying the completion of each logical step;
- vi) Space for recording the results of the test and the time and date of the test;
- vii) Space for signatures of the Contractor and the Employer's Representative.
- viii) In addition, the Contractor shall provide a method for recording and tracing all problems, discrepancies, queries and suggestions regarding the system and software, and for formalised control of any modifications to the system.

#### 7.4. Manufacturer's Works Acceptance Tests on Uninterruptible Power Supplies

7.4.1. The Contractor shall carry out further specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.

7.4.2. The tests shall be carried out on the fully assembled unit utilising the batteries that are to be supplied with the unit.

7.4.3. The Contractor shall demonstrate the following:

- a) Change-over from full load with mains present to full load on battery supply
- b) Carry out a discharge test on the system at full load and for the specified duty bridging time period.
- c) Carry out recharge test after operation for the specified duty bridging time at full load. The UPS shall supply the full load during the recharge cycle.

#### 7.5. **Site Acceptance Test (SAT) on Programmable Logic Controller (PLC) and SCADA System:**

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#### **7.5.1. Pre-commissioning tests:**

- a) The Contractor shall perform pre-commissioning, or preliminary, testing of the SCADA system in accordance with that specified for instrumentation. The purpose of pre-commissioning tests is to confirm readiness of the system for commissioning.
- b) The scope of pre-commissioning tests shall be generally as specified for factory acceptance tests but real field inputs and final control elements shall be used wherever practical to provide inputs to the system and to confirm proper outputs.
- c) Where this is impractical, simulation signals shall be injected as near as possible to their ultimate sources so as to include in the tests as much of the cabling system as possible.
- d) Each process system shall be set to work under manual control and the system tested to confirm proper operation. After proper operation of manual control mode has to be verified, tests of automatic controls of each process system shall be conducted wherever practical.

#### **7.5.2. Commissioning Tests:**

- a) The Contractor shall submit all relevant draft operating manuals for the PLC & SCADA System to the Employer/ Employer's Representative for approval prior to commissioning tests.
- b) Any faults or failures of the system detected during the previous tests shall be noted and corrected to the satisfaction of the Employer's Representative before commissioning is allowed to commence.
- c) As part of commissioning, the PLC & SCADA system shall be tested for availability for a continuous period of 60 days. During this period, the system will perform the normal functions according to the procedures described in the SAT documentation approved by the Employer's Representative.
- d) The system shall have passed the SAT if all major components have been free from fault or failure and exhibit full error-free functionality for 100 % of the total duration of the test, unless otherwise agreed by the Employer's Representative. Major components include all master station equipment, outstations, communications facilities and instrument panel components, excluding push-buttons, switches and lamps and any equipment not supplied by the Contractor.
- e) During SAT, no modifications to the system shall be made by the Contractor without the written approval of the Employer's Representative. Erroneous functioning which requires software modifications or re-configuration to correct, other than set-point or parameter changes, shall constitute a failure of the availability test. Any changes to the system which are required and approved shall be described in a system-modification document, signed by both Contractor and Employer's Representative and the document shall be incorporated into the final test documentation. The test shall be restarted after corrections have been made.

### **8. Contractor's Equipment, Materials and Appurtenances:**

- 8.1. The Contractor shall have available on the Site sufficient suitable equipment and machinery, as well as all other materials and appurtenances required by him, of ample
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capacity to ensure the proper erection of Plant and to handle any emergencies such as may normally be expected in work of this character.

- 8.2. The Contractor shall be responsible if any installation materials are lost or damaged during installation. All damages and thefts of equipment/component parts, after takeover by the Contractor, till the installation is taken over by Employer shall be made good by the Contractor to the satisfaction of Employer's Representative.
  - 8.3. Plant shall be erected in a neat and workmanlike manner on the foundation and at the locations and elevations shown on the approved drawings and other Employer's Engineering documents. Unless otherwise directed by the Employer's Representative the Contractor shall adhere strictly to the aforesaid drawings and no departures there from will be permitted.
  - 8.4. All plant shall be correctly aligned, levelled and adjusted for satisfactory operation and shall be installed so that the proper and satisfactory connection can be made readily between the various units and pipe work and equipment installed under the Contract. The mounting arrangements for pump-sets and blowers shall be such that the alignment offset between motors and the driven equipment shall be well within 0.1 mm.
  - 8.5. Erection of Plant shall be phased in such a manner so as not to obstruct the work being done by other Contractors. Before commencing any erection work, the Contractor shall check the dimensions of structures where the various items of plant are to be installed, and shall bring any deviations from the required positions, lined or dimensions to the notice of the Employer's Representative and shall take such measures as are necessary for their correction.
  - 8.6. The Contractor shall take particular care for the correct positioning and alignment of all puddle pipes which are required through concrete structures prior to, and during the pouring of concrete.
  - 8.7. The Contractor shall pin and plug in the holes prepared, all small clips, plugs, screws, nails, sleeves, inserts, etc., required for fixing electric wires and conduits, small pipe work and all other apparatus.
  - 8.8. The Contractor shall align all equipment and holding down bolts and shall inform the Employer's Representative before proceeding with grouting-in the item or item concerned. The Contractor shall ensure that all equipment is securely held and remain in correct alignment before, during and after grouting-in.
  - 8.9. The Contractor shall properly bed in cement grout each item of plant or its supporting base resting on foundations, and shall grout-in where required holding down bolts placed in the holes prepared in the foundations. The materials and workmanship used in grouting shall be such as will result in a solid anchoring of foundation bolts and complete filling of the gaps between the Plant or its base and the foundations, without shrinkage or cracking.
  - 8.10. During erection of the Plant the Employer will inspect the installation from time to time in the presence of the Contractor's Site representative to establish conformity with the requirements of the Specification. Any deviations and deficiencies found or evidence of unsatisfactory workmanship shall be corrected as instructed by the Employer.
  - 8.11. All plant shall be installed in accordance with the recommendations or instructions of the manufacturer, for the particular application. Each mounting position shall be chosen to give
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correct operation of the equipment, ease of operation, access for maintenance and servicing and freedom from any condition which could have adverse affects.

- 8.12. The approval by the Employer/ Employer's Representative of the Contractor's proposals for rigging and hoisting of any item of plant into its final position shall not relieve the Contractor from his responsibility for avoiding damage to completed structures, parts or members thereof or other installed equipment. He shall at his own cost make good, repair or replace any damaged or injured items whether structural, mechanical, electrical, architectural, or of any other description, promptly and effectively to the satisfaction of the Engineer in Charge.
- 8.13. No plant or other loads shall be moved across the floors of structures without first covering the floors with timber of sufficient size so that applied loads will be transferred to floor beams and girders of steel or concrete. If it is required to reduce bending stresses or deflection, the beam and girders shall be provided with temporary supports. Any movement of Plant and other loads over the floor structures shall be subject to the prior approval of the Employer's Representative.

## **9. Inspection of Works Prior to Pre-commissioning Checks:**

- 9.1. After the erection of any item of Plant and its associated equipment has been completed, it shall be offered to the Engineer in Charge for inspection in its static state prior to commissioning the item.
  - 9.2. The mechanical completion of plant under erection shall be deemed to occur if all the units/ systems of the Works are structurally and mechanically complete as noted below:
    - 9.2.1. All rotary, static, structural equipment, piping, electrical/instrumentation and other equipment under the scope of the Contract have been erected, installed and grouted and are as per the specifications.
    - 9.2.2. All systems have been washed/ flushed/ drained/ boxed up where necessary.
    - 9.2.3. All system testing including pressure, vacuum and nondestructive tests, no load tests and such other tests are completed with safety valves/relief valves set to operating conditions installed in position.
    - 9.2.4. All panels, local control desks erected with power/ control cable terminations with all continuity checks, insulation checks and other installation checks are carried out.
  - 9.3. Prior to pre-commissioning checks, the Contractor shall erect the entire Plant and ensure readiness of civil works to the satisfaction of Employer, so that the Works are physically ready to undergo pre-commissioning checks. Pre-commissioning checks will include checks like no-load running of machinery, checks on instruments and electrical including calibration and loop checks, functional checks, inter-lock checks etc.
  - 9.4. At the stage of mechanical completion of erection, the Contractor shall ensure that all the physical, aesthetic and workmanship aspects are totally complete and the Plant is fit and sound to undergo pre-commissioning checks.
  - 9.5. The following documentation shall be completed before the Contractor notifies Mechanical Completion of Erection to the Employer.
    - 9.5.1. All shop inspection records compiled and bound in 2 (two) copies.
    - 9.5.2. All erection and commissioning procedures duly approved.
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9.5.3. All instruction manuals in draft form - with each sheet bearing a stamp to indicate "DRAFT FOR REVIEW ONLY" submitted in 2 (two) copies.

9.6. Upon achieving mechanical completion, the Contractor shall notify the Employer of such completion of section/ units/ systems and readiness for inspection for acceptance of mechanical completion of erection. The Employer/ Employer's Representative shall proceed with inspection of such sections/ units/ systems within 10 days of such notice.

9.7. Consequent to inspection, the Employer will inform the Contractor a list of deficiencies for rectification and the Contractor shall complete the rectification work within a jointly agreed period prior to start of pre- commissioning tests. The erection period allowed by the Contractor shall include all activities of mechanical completion as noted above.

#### **10. Site Acceptance Test (SAT) on completion of Works:**

10.1. Fifteen (15) days prior to commencement of Tests on Completion the Contractor shall supply a Site Acceptance Test (SAT) Document for approval. This shall comprise four copies of the details of the inspection and test procedures to be carried out in testing the Works.

10.2. The SAT Plan shall provide comprehensive details of the tests to be carried out, the purpose of each test, the equipment to be used in carrying out the test and the methods to be adopted in carrying out the tests. The SAT shall provide space within the documentation for results of the tests to be added and for each test and for the SAT as a whole to be signed off by the Contractor and the Employer/ Employer's Representative. The SAT shall categorise tests as follows:

10.2.1. Dry tests:

a) Dry tests are those tests carried out without process fluid being present.

10.2.2. Wet tests which can be further sub-divided into

a) Hydraulic tests- Hydraulic wet tests are those tests carried out with potable water in order to prove the hydraulic capability of the Works.

b) Process tests/ System tests- Process wet tests are those tests carried out with raw Sewage as the feed stock to prove the process capability of the Works.

10.3. The Contractor shall make his own arrangements for water supply, chemical, electric power, fuel, instrument and labour during hydraulic wet tests.

10.4. It shall be assumed that the co-operation of other Contractors in the carrying out of Tests on Completion will not be unreasonably withheld.

10.5. Prior to the commencement of Tests on Completion the Contractor shall submit for approval the following:

10.5.1. Site Acceptance Test Documents

10.5.2. As-Built Drawings

10.5.3. Operation and Maintenance Manuals

10.5.4. Site test results / data sheet and photo

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- 10.6. Tests on Completion shall not be commenced until the aforementioned documents are approved.
- 10.7. The charges of oil, grease, electrolyte, chemical, disposal of cake, electricity charges, generator fuel/ oil etc. necessary for Tests on Completion shall be provided by the Contractor. Raw Sewage required for Tests on Completion will be provided by the Employer free of charge. If necessary, Contractor shall create design loading conditions for testing purposes by testing fewer than the total number of installed units of process tanks or equipment at a time. In such cases, multiple tests shall be conducted to ensure that all installed units are tested. In the event that raw sewage/ influent wastewater is not available at the plant, the Contractor shall defer testing until such time as sewage becomes available for treatment as described elsewhere in these Bid Documents. The Contractor shall provide adequate notice (this notice period shall be determined by the normal lead time for locally purchased chemicals plus at least 28 days) of his chemical requirements prior to commencement of the Tests on Completion involving their use.
- 10.8. The cost of chemicals used for the Tests on Completion shall be met by the Contractor.
- 10.9. The inspection and tests procedure which will be carried out are provided under the general conditions of contract and shall also consist of the following:

**10.9.1. Manual Commissioning Tests:**

- a) Manual Commissioning Tests shall be such preliminary trials, tests and retests on individual items of Plant or complete systems as are required by the Engineer in charge in order to demonstrate that the Plant as a whole is ready to undergo the Manual Operation Tests and that these will take place with a minimum of interruption.
- b) The Manual Commissioning Tests shall demonstrate not only the items of Plant under normal operation, but also their response to abnormal and emergency conditions.
- c) The Engineer In Charge will notify to the Contractor which items of Plant will be tested and the extent to which they will be tested in order to fulfill the requirements of the Specification.
- d) Leakage tests at 1.5 maximum working pressures shall be carried out on all erected pipe work prior to the Manual Commissioning Tests.
- e) Pump curves shall be available for the Manual Commissioning Tests and all instruments essential for the tests shall have been calibrated.

**10.9.2. Manual Operation Tests:**

- a) When the Manual Commissioning Tests have been completed so that the items of Plant have been demonstrated to the satisfaction of the Employer Representative, the Contractor shall commence the Manual Operation Tests.
  - b) These tests shall demonstrate the correct operation of the whole Plant whilst using the minimum quantity of automatic control and monitoring equipment. Such equipment shall be at least that required both for the maintenance of safety and for the normal mode of operation of the Plant.
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- c) The Plant will be required to demonstrate satisfactory operation at all design flow rates.
- d) The tests shall be of seven consecutive days' duration; if the supply of water should fail or other matters interfere outside the Contractor's control, the tests may be of such number of broken days as the Employer/ Employer's Representative considers is the equivalent.
- e) The exact date of commencement shall be subject to the approval of the Engineer in Charge and shall be dependent on the following conditions having been met
  - i) All relevant items of Plant in approved working order
  - ii) All items of Plant correctly identified with labels

#### **10.9.3. Automatic Commissioning Tests:**

- a) The Automatic Commissioning Tests shall be such preliminary trials, tests and retests on individual items of Plant or complete system as are required by the Engineer in Charge in order to demonstrate that the Plant as a whole is ready to undergo the Tests of Completion and that these will take place with a minimum of interruption.
- b) At least one week before the commencement of these tests, the Employer/ Employer's Representative will notify the Contractor which items of Plant will be tested and the extent to which they will be tested in order to fulfill the requirements of the specification.
- c) The Tests on Completion as provided under the general conditions of contract shall not be carried out until the completion of the above tests.
  - i) All pipe work shall be hydrostatically tested at site to a pressure equal to 1.5 times the maximum working pressure likely to be encountered in the system.
  - ii) The Contractor shall carry out all tests on the Plant and shall supply four copies of all test results to the Employer's Representative.
  - iii) All tests shall be to the approval of the Employer's Representative who may require them to be repeated, prolonged or modified as may be necessary to ensure that any or all items of Plant conform to the Contract.
  - iv) The Employer's Representative shall be permitted to inspect all Plant which is undergoing tests and may themselves conduct tests.
- d) Where it is necessary for the Employer to make arrangements for the supply of water, chemicals, power, etc., for any testing, the Contractor shall not commence the tests until after these arrangements have been made on or after a date agreed by the Employer and the Contractor shall make no claim for delay to such testing on this account except as provided under the General Conditions of Contract.
- e) If any item of plant fails during or after testing to achieve its intended duty or otherwise proves defective, it shall be modified or altered as necessary and re-tested and re-inspected as required by the Engineer in charge.



- f) Vibration/ noise level tests shall be carried out at site which will form basis for acceptance of the equipment. If the Contractor is not in a position to meet the requirements given below as per ISO 10816 – 1995, the equipment may either be rejected or the Contractor shall carry out all necessary modifications to keep vibrations within the acceptable limits specified.

Equipment	Noise Level (dBA at 1.86 m from equipment)	Velocity of vibration (mm/sec)
All rotating equipment not having reciprocating parts with motor kW less than or equal to 15 kW	85	1.12
All rotating equipment not having reciprocating parts with motor kW more than 15 kW and less than or equal to 75 kW	85	1.8
All rotating equipment not having reciprocating parts with motor kW greater than 75 kW	85	2.8
All equipment having reciprocating parts viz. compressors, dosing pumps sampling pumps	85	-

- g) The Contractor shall have a minimum of three commissioning Employer's Representative, one for process and plant and the other for mechanical/ electrical/ instrumentation works on site during all tests in order to both demonstrate the Plant and to correct any faults which may occur.

#### **10.10. Dry Test Requirements:**

10.10.1. As a minimum requirement the following dry tests shall be carried out as a general requirement:

- a) A general inspection to check for correct assembly and quality of workmanship
- b) A check on the presence of lubricant, cooling medium, electrolyte, etc.
- c) A check on adequacy and security of Plant fixing arrangements.
- d) A general check to ensure that all covers, access ladders, water proofing, guard railings etc are in place.
- e) A check on damp-proofing, rust-proofing and vermin-proofing and particularly the sealing of apertures between building structures, chambers etc and the outside.

#### **10.10.2. Civil and Building Works:**

- a) As a minimum requirement the following dry tests shall be carried out on the civil engineering and building works:
  - i) Check for the presence of foreign bodies in pipe work and structures.

#### **10.10.3. Mechanical Works:**

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- a) As a minimum requirement the following dry tests shall be carried out on the mechanical systems:
    - i) Carry out preliminary running checks as far is permitted by circumstances in order to ensure smooth operation of Plant.

#### 10.10.4. **Electrical Works:**

- a) As a minimum requirement the following dry tests shall be carried out on the electrical systems:
  - i) Check phasing and polarity.
  - ii) Carry out point to point check on all cables.
  - iii) Check on security of cable terminations.
  - iv) Check on completeness and adequacy of earthing systems.
  - v) Check setting on protection relays, sizes of fuses and motor overload settings.
  - vi) Carry out checks on cabling systems in accordance with the requirements of the relevant standards.
  - vii) Check operation of main circuit breakers by secondary injection methods.
  - viii) Check rotational direction of Plant.
  - ix) Check instrument loop integrity, functionality and calibration.
  - x) Check operation of standby generator installation and mains / generator changeover procedures; a 4 hour load test (using the normal load of the Works) shall be carried out on the generator when the load is available.
  - xi) Check plant functionality.
  - xii) Check functionality of the central MMI and its power supply.

#### 10.10.5. Process Plant/ Equipment:

- a) All process plant items/ equipment shall be tested to ensure they meet the Employer's Requirements for quality of workmanship, construction and performance.

#### 10.11. **Hydraulic Wet Test Requirements:**

10.11.1. Hydraulic wet tests shall be carried out on completion of dry tests.

10.11.2. Clear Water shall be used for hydraulic wet tests. The purpose of the tests is to prove the hydraulic performance of the Works. In order to demonstrate this, the Contractor shall ensure that each part of the Works is hydraulically loaded to its rated throughput for a period of at least four hours. (Refer Section 5b: Technical Specification for Civil Works)

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10.11.3. In order to ensure a sufficient supply of water to carry out these tests the Contractor shall provide all required facilities, including but not limited to any temporary facilities that may be required for storage and recycle of Clear Water or facilities for the disposal of the water off Site in an approved manner.

10.11.4. The following tests inter alia shall be carried out:

- a) Pressure testing of all piped systems laid direct in ground in accordance with the relevant standards.
- b) Fill all structures and check for leaks.
- c) Filling of all storage vessels to check for leaks and distortion.
- d) Running of all pumped systems in order to check for.
- e) Correct functionality.
- f) Absence of leaks.
- g) Correct running temperatures.
- h) Smoothness of running and the absence of undue vibration or stress.
- i) Check drive running currents.
- j) Carry out calibration of instruments where appropriate.
- k) Carry out valve operation, diversions etc. to fully hydraulically load each process element (or where there is a requirement to withstand an over load), overload each process element.
- l) Demonstrate correct functionality of electrical, control and instrumentation systems.

10.11.5. The Contractor shall simulate the conditions that will prevail when operating as a process in order to demonstrate the correct functionality of process control loops etc.

10.11.6. During these tests a check on the performance of Plant shall be made to compare its site performance with the factory test data and to identify any constraints on performance due to site conditions.

10.11.7. Safety Audit- After satisfactory completion of hydraulic wet tests and prior to introduction of process fluid to the plant a safety audit shall be carried out to ensure compliance with the necessary requirement for safety and for operation of Plant. The safety audit shall be documented. The safety audit document shall be approved by the Employer's Representative prior to commencement of Plant commissioning.

#### **10.12. Process Wet Tests (with Raw Sewage):**

10.12.1. On approval by the Employer's Representative the Contractor shall carry out process wet tests. Raw Sewage shall be used as the main feed stock for process wet tests. These tests shall be carried out to demonstrate the process performance of the Works. In order to demonstrate this, the Contractor shall ensure that each part of the Works is loaded to its rated throughput (including a period of overload if required in order to demonstrate

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compliance with the Employer's Requirements) for a continuous stable operating period of not less than 48 hours. If necessary, Contractor shall create design loading conditions for testing purposes by testing fewer than the total number of installed units of process tanks or equipment at a time. In such cases, multiple tests shall be conducted to ensure that all installed units are tested

10.12.2. The Contractor shall provide all required facilities for the disposal off Site in an approved manner.

10.12.3. The following tests inter alia shall be carried out:

- a) Check for leaks on vessels, structures, pumps and pipe work.
- b) Running of all pumped systems in order to check for.
  - ✓ Correct functionality.
  - ✓ Absence of leaks.
  - ✓ Correct running temperatures.
  - ✓ Smoothness of running and the absence of undue vibration or stress.
  - ✓ Check drive running currents where the solution pumped is different from that pumped during hydraulic wet tests.
- c) Carry out calibration of instruments.
- d) Carry out valve operation, diversions etc. to fully hydraulically load each process element (or where there is a requirement to withstand an over load), overload each process element.
- e) Demonstrate correct functionality of electrical, control and instrumentation systems not checked during dry or hydraulic wet tests or which may have changed as a result of the different operating conditions now prevailing.

10.12.4. On completion of the tests on the various parts of the works the Contractor shall run the plant as a whole in order to demonstrate the full functionality and performance of the Works at various throughput rates for a continuous period of not less than 15 days.

10.12.5. During the various process tests the Contractor shall perform sampling and analysis of all the process streams (locations) and parameters listed in the "Sampling/ Analysis Locations and Frequencies" table provided in the "Tests after Completion" Section below. The frequencies listed in this table shall be followed for the Tests after Completion. However, for the Process Wet Tests performed as part of the Tests on Completion, the sampling frequency for all locations and all parameters shall not be less than once every hour. The Contractor shall demonstrate to the Engineer in charge that the Works is functioning in accordance with the Employer's Requirements. Each sample shall comprise two 1 litre (minimum) quantities and shall be labelled to identify the contents, where taken and time and date. The flow recorded at the time of sampling shall also be indicated in the log book or record. One sample shall be used by the Contractor for his analysis; the other shall be handed over to the Employer.

10.12.6. The Employer reserves the right to take additional samples and to carry out his own tests or to check the samples taken by the Contractor.

10.12.7. The Employer/ Employer's Representative shall be given reasonable access to the premises where analysis is taking place in order to check on working practices and the procedures being adopted.

#### **10.13. Effluent Quality Criteria for Passing the Tests On Completion:**

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10.13.1. The Works shall be considered to have achieved the required effluent quality standards for passing Tests on Completion if all samples taken during a 15 day continuous operational period comply with the criteria set down for passing the Tests after Completion. This includes criteria relating to the reliability of the plant.

10.13.2. The Effluent quality Tests on Completion shall not be commenced until all tests associated with the civil/building, electrical and mechanical works and individual process tests have been completed to the satisfaction of the Employer's Representative.

10.14. Co-operation with other Contractors in the Execution of their Tests

10.14.1. The Contractor shall, where required, assist other Contractors in carrying out their tests on completion and or tests after completion.

10.14.2. Where this assistance does not constitute part of the Contractors own work associated with Tests on Completion or Tests after Completion the Contractor shall be reimbursed at the rates approved by the Employer's Representative.

**11. Tests After "Test on Completion":**

11.1. On successful completion of "Test on Completion" the Contractor shall carry out over a period of time not exceeding two months two separate 30 days operational tests. These tests shall be used to prove the operation of the Works at varying flows and with varying raw Sewage quality. During these tests Effluent produced by the Works will be entering the disposal system.

11.2. The timing of the tests shall be determined by the Employer who shall give notice to the Contractor in accordance with the Conditions of Contract. The total time for carrying out the tests shall not be less than two calendar months. One of the tests for each part shall be carried out in a period of high raw Sewage BOD and suspended solids.

11.3. On commencement of each 30-Days test the Employer shall allocate a continuous period of not greater than 60 days to complete the test. Any failure to perform during the 60 days period shall restart the '30 day clock'. If the part of the Works fails to pass the test in the 60 days period the test shall be deemed as a failure and the Contractor shall carry out any necessary remedial work to the satisfaction of the Employer/ Engineer in Charge before the Contractor restarts the test.

11.4. During the tests the Contractor shall take samples to demonstrate that the part of the Works is performing in accordance with the Employer's Requirements. The procedure for taking the samples shall follow the pattern adopted for Test on Completion. Samples shall be taken at locations and intervals detailed below. The results of the Tests after Completion shall be compared and evaluated by the Employer and Contractor.

11.5. The Contractor will not be held responsible for interruptions to the sewage treatment process as a result of Grid power failures (unless as a result of a Plant failure) interruptions in the raw Sewage supply etc. which are out of his control. However, the Contractor shall be required to demonstrate that the Works can cope with these inevitable interruptions in an orderly fashion and recover to a normal operational state with the minimum of manual intervention.

11.6. All consumables needed for operation of the Works and transportation of sludge off site shall be provided by the Contractor.

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- 11.7. The Contractor shall provide all facilities and equipment not supplied under the contract and which are deemed necessary for the Contractor to carry out and monitor the Tests after Completion.

**12. Sampling and Analysis (for Test on Completion and Test after Completion):**

- 12.1. Sampling and analysis shall be performed to measure the parameters indicated in the table below, at the locations and frequencies indicated in the table. In case of multiple units (such as multiple aeration basins or thickeners), the indicated sampling and analyses shall be performed for each individual module.

**12.2. Table for Sampling/ Analysis Locations and Frequencies:**

Sample Location/ Parameters to be Measured	Frequency	Sampling Method
Plant Effluent (outlet of chlorine contact tank): pH, BOD, COD, TSS, NH <sub>4</sub> -N, N-Total, PO <sub>4</sub> -P, Fecal Coliform, Total Residual Chlorine	Daily	Flow-weighted 24-hour composite
Dewatered Sludge: All parameters specified under the "Dewatered Sludge Quality Requirements" specified in <i>Section 5a</i>	Daily	Composite of samples from each container or vehicle filled during the day
Raw Sewage Influent, Plant Effluent, MLR, RAS, WAS, Thickened Sludge, Dewatering Influent, Plant Recycles: Flow	Continuous	Continuous instantaneous flow from recorder
Raw Sewage Influent, Secondary and/ or Tertiary filter effluent: TSS, VSS, Temperature, pH	Daily	Flow-weighted 24-hour composite
Raw Sewage Influent, Secondary Effluent and/or tertiary filter effluent: BOD, COD, TKN, Ammonia-N, Nitrite-N, Nitrate-N, Alkalinity, Total Phosphorus, Soluble Phosphorus	3 times per week	Flow-weighted 24-hour composite
Aeration Basins: MLSS, MLVSS, Temperature, SVI	Daily	Grab
Aeration Basin Zone Profiles (Anaerobic, Anoxic, Aerobic): Ammonia-N, Nitrite-N, Nitrate-N, pH, Soluble Phosphorus, VFAs, rbCOD	3 times per week	Grab
RAS, WAS, Thickened Sludge, Dewatered Sludge TSS, VSS	Daily	Grab
Chemicals/ Scum/ Screenings/ Grit: Specific weight, volume, weight, Chemical consumption	3 times per week	Grab

- 12.3. All costs associated with the taking and analysis of samples shall be met by the Contractor.
- 12.4. The analysis shall be carried out by chemical certified laboratory (Pollution Control Board Certified) and as approved by the Employer/ Employer's Representative, and shall be performed in strict compliance with appropriate analytical methods published in Indian Standards, or in "Standard Methods for the Examination of Water and Wastewater"

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published by the American Public Health Association, or as published by the US Environmental Protection Agency. The Contractor shall submit to the Employer/ Employer's Representative a comprehensive report of the above sampling and analysis, including details of each analytical test as well as a summary of all the data and results in a Microsoft Excel spreadsheet.

**12.5. Criteria for Passing the Test After Completion:**

**12.5.1. Treated Effluent and Dewatered Sludge Quality Criteria-** The Works shall be deemed to have met the Treated Effluent and Dewatered Sludge Quality Criteria if:

- a) at least 95 percent of the plant effluent samples described above meet the requirements specified under the "Treated Sewage Requirements" in Section 5a at least 95 percent of the dewatered sludge samples described above meet the requirements specified under the "Dewatered Sludge Quality Requirements" in Section 5a.

**12.5.2. Operational Cost Criteria-** The plants shall have fulfilled the operating cost criteria if the operating costs determined during the Tests After Completion are in agreement with or less than those detailed in the Contractor's Functional Guarantee or an amount of liquidated damages are agreed by the Contractor and the Employer to compensate for any short fall in performance up to an agreed maximum amount if stated.

**12.5.3. Plant Reliability Criteria:**

- a) A part of the Works shall be deemed to have failed its test if:
  - i) A single item of Plant / equipment fails more than twice during the test.
  - ii) More than four individual Plant items / equipment fail.
- b) An item of Plant / equipment shall be deemed to have failed if manual intervention is required in order to restore the Plant / equipment to its fully operational state: i.e. the failure of a duty drive will be considered as one failure, if the standby drive fails to start that will be considered as a second failure.

**13. Performance Certificate:** The conditions for issuance of a Performance Certificate as detailed in Clause 12 of the General Conditions of Contract shall inter alia comprise:

**13.1.1.** The completion of the two months operation of the Works (Tests after Completion) to the satisfaction of the Engineer in Charge.

**13.1.2.** The O & M Manuals have been updated following one year's operational experience and approved by the Employer/ Employer's Representative.

**13.1.3.** All defects identified prior to Taking Over and defects identified during one year operation of the Works have been rectified.

**13.1.4.** All Tests "After Completion" have been completed to the satisfaction of the Engineer in Charge.

**13.1.5.** All training detailed in the Employer's Requirements has been completed.

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