बृहन्मुंबई महानगरपालिका
Municipal Corporation of Greater Mumbai




Mithi River Water Quality Improvement Project

Package 3: Dry Weather Flow Interception at Tidal Outfalls (including Gate Pumps), Transfer Sewer, Training of River (Retaining wall and Service Road), Beautification including Promenades and Allied Works from Prem Nagar outfall, Kurla to Mahim Causeway.

Design Build Operate Contract

Volume 2B - General Mechanical Specification

Employer:
Municipal Corporation of Greater Mumbai
Municipal Head Office Building, Mahapalika Marg, Fort, Mumbai - 400 001.

Consultant:
Frischmann Prabhu (India) Pvt. Ltd.
315, Balgovind Wadi, New Prabhadevi Road, Prabhadevi, Mumbai - 400 025

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India

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1 GENERAL

1.1 Scope

The General Mechanical Works Specification covers the minimum requirements for design, procurement, testing at manufacturer's works, supply, site testing and commissioning of the Mechanical Works. This specification shall be read in conjunction with the relevant data sheets, drawings and other relevant sections of the Contract.

Compliance with this specification shall not relieve the Contractor from any of his contractual obligations and responsibilities towards fulfilling the performance requirements.

No deviation from this specification shall be allowed, unless specifically approved in writing by the Employer.

1.2 Reference Standards

The Contractor shall comply with relevant Reference Standards including those listed in Appendix A in accordance with the requirements detailed elsewhere in this Contract.

Except where otherwise specified, all materials and workmanship shall comply with the current national standards of the country of manufacture provided that these standards are not less stringent than the equivalent specified British Standards or Codes of Practice or provided that they comply with the requirements of the International Organisation for Standardisation or the International Electrotechnical Commission as appropriate.

1.3 Abbreviations

Wherever the following abbreviations are used they shall have the meanings below:

ABS	Acrylonitrile Butadiene Styrene
ADWF	Average Dry Weather Flow
AFBMA	Anti-Friction Bearing Manufacturers Association
AGA	American Gas Association
AGMA	American Gear Manufacturers Association
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASA	American Standards Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials

ACE	Annual Conference Exposition
AWWA	American Water Works Association
BS	British Standards Institution
	Combined Heat and Power
COSHH	Control of Substances Hazardous to Health
CPE	Chlorinated Polyethylene
CPVC	Chlorinated Polyvinyl Chloride
CS	Carbon Steel
DAF	Dissolved Air Floatation
DI	Ductile Iron
DIN	Deutsches Industrie Normen
DO	Dissolved Oxygen
DW	Duct Work
DWV	Drain Waste Vent
EPDM	Ethylene Propylene Diene Monomer
ERW	Electric Resistance Weld
FAT	Factory Acceptance Test
FOG	Fat oil and grease
FRP	Fiberglass Reinforced Plastic
GHS	Globally Harmonized System
GLCI	Glass Lined Cast Iron
GLDI	Glass Lined Ductile Iron
GRP	Glass Reinforced Plastic
HAZOP	Hazard and Operability
HI	Hydraulic Institute (US)
HMI	Human-Machine Interface
HRT	Hydraulic Retention Time
HSE	Health, Safety Environment

IBC	International Building Code
IEC	International Electrotechnical Commission
IP	Ingress Protection Rating (EU)
IS	Indian Standard
ISO	International Organisation for Standardisation
MIG	Metal Inert Gas
MLSS	Mixed Liquor Suspended Solids
MS	Mild Steel
MSS	Manufacturers Standard Society (US)
NACE	National Association of Corrosion Engineers
NBC(I)	National Building Code of India
NEC	US National Electrical Code
NEMA	National Electrical Manufacturers Association
OEL	Occupational Exposure Limit
PD	Published Documents
PE	Polyethylene
PFA	Perfluoroalkoxy
PFF	Pass Forward Flow
PLC	Programmable Logic Circuit
PTFE	Polytetrafluoroethylene
PU	Polyurethane
PVC	Polyvinyl Chloride
RMU	Remote Monitoring Unit
SBR	Styrene Butadiene Rubber
SCADA	Supervisory Control and Data Acquisition
SG	Spheroidal graphite
SS	Stainless Steel

SSPC	Steel Structures Painting Council (US) SWD Side wall depth
SWL	Safe working load
TIG	Tungsten Inert Gas
TEFC	Totally Enclosed Fan-Cooled
TFT	Thin Film Transistor
TSS	Total Suspended Solids
PE	Polyethylene
UHMWPE	Ultra-High-Molecular-Weight Polyethylene
UPS	Uninterruptible Power Supply
US-EPA	United States Environmental Protection Agency
UV	Ultra Violet
VFD	Variable Frequency Drive
WAS	Waste Activated Sludge
WIS	Water Industry Specification
WRC	Welding Research Council

2 MECHANICAL WORKS DESIGN

2.1 General Arrangement of the Works

The Contractor shall provide and arrange the Works to comply with the following general guidelines:

- Sufficient space shall be provided between items of Plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance. In general, spacing of not less than 1 m shall be considered sufficient. This applies to all walkways, platforms, equipment walkways, process tank walkways etc. The walking space between the handrails shall be 1m clear and shall not be taken up (or blocked) by such items as piping;
- Layout of the site structures/equipment shall comply with code distances required between non-hazardous and hazardous structures/plant/equipment, etc.;
- Plant shall be arranged to permit the removal of individual Plant items or packages;
- An area adjacent to all mechanical Plant shall be provided as a maintenance lay down area;
- Electrically operated cranes, fixed runways, lifting eyes or other means shall be provided to permit the removal of larger items of Plant that may have to be removed during the course of their normal operational life for maintenance or replacement purposes;
- Areas where leakage of water 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 drain or to a sump from where it can be pumped to an appropriate place for safe disposal;
- Where necessary, Plant shall be provided with removable acoustic coverings to limit the noise produced during normal operation to the limits detailed elsewhere;
- Pipework shall be designed and installed to prevent blockages and to permit their clearance without dismantling pipework or equipment;
- Valve and penstock actuators located outdoors shall not be of the pneumatic type;
- The treatment works shall be designed such that all potential spillages and overflows resultant from single failures are either contained within structures or sufficient alarms and controls are incorporated to prevent spillages and overflows from escaping;
- When selecting materials for pipework, the Contractor shall give consideration to the deteriorating effect of the action of ultra-violet light on materials.

2.2 Pumping Systems (Not Used)

2.3 Chemical Storage and Dosing Systems (Not Used)

2.4 Chemical Safety Facilities (Not Used)

2.5 Materials of Construction

All materials of construction for tanks, vessels, pipelines, pumps, valves etc. shall be suitable for long term contact with the liquid or chemical concerned and at the prevailing concentrations. Equipment shall be coated and protected in accordance with Volume 2A Section 21 Painting and Protective Coatings, and Section 3.21 Surface Protection

All pipework employed shall comply with the schedule below unless agreed with the Employer's Representative. The Employer's Representative shall be under no obligation

to accept alternative pipeline material. It is the responsibility of the Contractor to ensure compatibility of all pipelines with fluids or sludge carried and with external and internal loadings and pressures.

Table 2-1 Pipe Materials

Service	Size range	Pipe material
Potable and raw water including supernatant	Up to and including DN 300	Ductile Iron (DI) Un-plasticised Polyvinyl Chloride (uPVC) Poly-ethylene (PE) Molecular Orientated (MoPVC)
	DN 300 – DN 600	Ductile Iron (DI) Steel Poly-ethylene (PE) Molecular Orientated (MoPVC) uPVC
	Greater than DN 600	Ductile Iron (DI) uPVC
Sewage (pumped below ground)	All diameters	Ductile Iron (DI) Polyethylene (PE) Molecular Orientated (MoPVC)
Sewage (gravity below ground not underneath structures)	All diameters	RCC Ductile Iron (DI) Polyethylene (PE) Molecular Orientated (MoPVC) Steel
Above ground pipe-work and within structures	Up to and including DN 300	Ductile Iron (DI) uPVC Stainless steel (304L)
	Greater than DN 300	Ductile Iron (DI) Steel
All sewage pipework underneath structures	Up to and including DN 300	Ductile Iron (DI)
	Greater than DN 300	Ductile Iron (DI) Steel Stainless Steel (316L) All pipes under roadways & structures to be concrete encased.
Sampling	All diameters	uPVC ABS
Raw water including supernatant	Up to and including DN 1100	Ductile Iron (DI), K9 class
	Greater than DN 1100	Carbon Steel with cement mortar lining and external guniting as per IS code.

Service	Size range	Pipe material
Sewage	Up to and Including DN 1100	Ductile Iron (DI), K9 class
	Greater than DN 1100	Carbon Steel with cement mortar lining and external guniting as per IS code.)
Sampling	All Diameter	uPVC ABS

2.6 Isolation and Drain Down

The Contractor shall provide facilities for isolating and draining down all pipework, chambers and storage tanks. Wherever duty/standby equipment is provided, it shall be possible to isolate and drain-down each of the duty or standby items while the other items are in service.

3 MATERIALS, WORKMANSHIP AND DESIGN

3.1 Introduction

This section of the General Mechanical Specification sets out the general standards of materials, workmanship and design to be used by the Contractor and reference to any specific material or equipment does not necessarily imply that such material or equipment is included in the Works.

All component parts of the Works shall, unless otherwise specified, comply with the provisions of this section or be subject to the approval of the Employer's Representative.

3.2 Plant Design

The Plant shall be designed to conform to the Employers requirements and employ the best standard practices.

The Plant shall be new, of sound workmanship and robust design and of a grade and quality suitable for the climatic conditions at the Site.

The Plant shall be suitable for operating throughout the ranges of conditions described in the project requirements and operational duties. Particular attention shall be given to expansion due to temperature changes, the stability of paint finish for high temperatures, the rating of engines, electrical machinery, thermal overload devices, cooling systems, the choice of lubricants for the possible high operating temperatures and suitability of materials and coatings to resist corrosion due to immersion in high-strength wastewaters (with H_2S present) and storm conditions (the latter seen during the wet monsoon season).

The Plant shall be designed to incorporate protection against the entry of vermin and dust and to minimise the risk of fire and consequent fire damage. It shall also be protected against dampness, storm water ingress and condensation.

All manually controlled Plant located outside a building shall be provided with facilities for making it tamper and vandal proof by the installation of lighting, security fencing and security cameras. This is in addition to any requirements of the Specification for securing Plant under operational conditions.

All component parts of the Plant shall be manufactured to strict limits of accuracy and shall be interchangeable with the component parts of similar Plant where possible.

The Plant shall be designed to operate continuously over prolonged periods of time with a minimum of maintenance and the Contractor may be called upon to demonstrate reliability for any component part either by producing evidence such as the service records of similar equipment, or by the records of extensive type tests.

The materials for construction of the Plant shall be selected taking into consideration their location and purpose. In the case of Plant conveying water, particular attention shall be given to the risk of electrolytic reaction between differing materials of construction and to the effects of corrosion and where there are impurities in the water, abrasion or chemical erosion.

To ensure the effects of corrosion and erosion are kept to a minimum, the plant shall be designed to employ suitable components, materials and protective finishes.

The Plant shall be constructed to enable any component part to be replaced without replacing the whole component. No part subject to wear shall have a life from new to replacement or repair of less than two years of continuous operation. Where major

dismantling to replace a part cannot be avoided, the life shall be not less than five years. For major plant items, dismantling joints shall be provided for ease of removal.

3.3 Castings

The structure of the castings shall be homogeneous and free from non-metallic inclusions and other defects. All surfaces of castings which are not machined shall be smooth and shall be carefully fettled to remove all foundry irregularities (special attention should be given to flanged faces). Castings shall be crack/blow holes free.

Minor defects not exceeding 2.5 mm in depth or 12% of total metal thickness, whichever is less and which will not ultimately affect the strength and serviceability of the casting, may be repaired by approved welding techniques and subsequent heat treatment for stainless steel. The Employer's Representative shall be notified of larger defects and no unauthorised repair welding of such defects shall be permitted. The Employer's Representative shall be invited to perform FAT of castings. The Employer reserves the right to accept third party inspection. The Inspecting agency shall be approved by the Employer.

If the removal of metal for repair should reduce the stress resisting cross-section of the casting by more than 25%, or to such an extent that the computed stress in the remaining metal exceeds the allowable stress by more than 25%, then that casting shall be rejected.

Castings repaired by welding for major defects shall be stress-relieved after such welding, or as otherwise instructed in writing by the Employer's Representative.

Non-destructive tests may be required for any casting containing defects whose effect cannot otherwise be established or to determine that repair welds have been properly made.

Unless otherwise specified, castings shall be produced to the following standards or equal:

1.	Grey-iron	IS 3005 Part 1 to 4
2.	Carbon steel	IS 1030:1998
3.	Stainless steel	IS 3038:2006
4.	Copper and copper alloy	IS 3288:1986 Part 1 to 8

3.4 Forgings

All major stress-bearing forgings shall be made to a standard specification which shall be submitted to the Employer's Representative for approval before work is commenced. They shall be subject to internal examination and non-destructive tests for the detection of flaws and shall be heat treated for the relief of residual stresses. The name of the manufacturer and particulars of the heat treatment proposed for each such forging shall be submitted to the Employer's Representative.

3.5 Non-metallic Materials

Fabrics, cork, paper and similar materials which are not subsequently to be protected by impregnation, shall be treated with an approved fungicide. Sleeving and fabrics treated with linseed oil varnish will not be permitted.

The use of organic materials shall be avoided as far as possible but where these have to be used they shall be treated to make them fire resistant.

The use of wood shall be avoided unless specifically approved by the Employer's Representative. If used, woodwork shall be thoroughly seasoned teak or other approved hardwood which is resistant to fungal decay and free from blemishes. All woodwork shall be treated to protect it against damage by fire, moisture, fungus, vermin, insect, bacteria or chemical attack. All joints in woodwork shall be dovetailed or tongued and pinned. Metal fittings on wood shall be of non-ferrous material. Adhesives shall be specially selected to ensure the use of types that are impervious to moisture and fungal growth. Synthetic resin cement shall be used for joining wood.

3.6 Nuts, Bolts and Washers

Nuts, bolts, studs and washers for incorporation in the Works shall conform to IS 10238:2001, IS 1363:2002, IS 1364:2002,IS 1367, IS 2016:1967, IS 3757:1985 and IS 3138:1966.

Nuts and bolts for pressure fittings shall be of the best quality steel machined on the shank and under the head and nut. Fitted bolts shall be a light driving fit in the reamed holes they occupy, shall have the screwed portion of such a diameter that it will not be damaged in driving and shall be marked in a conspicuous position to ensure correct assembly at site.

Washers, locking devices and anti-vibration fittings shall be provided where necessary to ensure that no bending stress is caused in the bolt. Two washers shall be supplied and fitted with each bolt.

The bolts should be of sufficient length that between two and four threads shall show past the nut when tightened (including allowance for the washer).

Before tightening, graphite grease or PTFE tape shall be applied on the bolts.

When there is a risk of corrosion, bolts and studs shall be designed so that the maximum stress in the bolt does not exceed half the yield stress of the material under all conditions.

Installation of high strength friction grip bolts in joints shall comply with IS 4000:1992. The diameter of the bolt holes must not be more than 1.5 mm larger than the nominal diameter of the bolt. All contact surfaces in a connection including those associated with the nut heads, nut in washers, shall be free of scale, burrs, dirt and other foreign matter tending to inhibit uniform sealing of the joint components/ nuts and washers need not be removed.

When nut or bolts heads bear on tapered/angled surfaces, corresponding levelled or tapered or angled washers/shims shall be provided.

3.7 Fixings

The Contractor shall supply all anchor bolts, holding down bolts, fixing bolts, washers, nuts, straps, supports, brackets, spacers and fixtures, which are necessary for the satisfactory installation and erection of the Works.

The Contractor shall make all holes required for fixings before final plastering and decorating is carried out.

3.8 Fixing in Concrete

Where items of Plant are required to be fixed in concrete, the Contractor shall be responsible for its positioning. This shall entail shimming, temporary fixing and final checking as necessary to satisfy himself of its correctness.

3.9 Threads

All threads shall be of preferred metric sizes with the standard coarse form of medium fit to IS 4218:2001 Part 1 to 4, IS 14962:2001 Part 1 to 5, BS 3643:2007 except for special applications for which the metric fine thread may be utilised, or other thread forms subject to the approval of the Employer's Representative.

3.10 Protection against Electric Shock

Terminals and conductors that may be live at greater than 50 Volts shall be protected to IP2X by physical barriers that require a key or tool to remove. Appropriate warning labels indicating the voltage present and the means by which it shall be isolated shall be affixed in prominent positions.

3.11 Guarding of Machinery

The Contractor shall ensure that all designs and equipment for which he is responsible are safe. Nothing in this Specification shall remove the Contractor's obligation from drawing the attention of the Employer's Representative to any feature of the Specifications or Employer's Requirements which is not consistent with safety, or to prevent making proposals for incorporating equipment or designs which would increase the safety of the Plant.

The installation layout and plant design shall not allow any item of Plant to be so positioned that danger to operating personnel could arise during normal operation and maintenance. Particular attention shall be paid to the position of hot pipes, air vents and rotating machinery.

All rotating shafts, couplings, gears, flywheels, belt drives or other moving parts shall be fully guarded in accordance with PD 5304:2005 and IS 9474:1980. Guards shall be designed to provide access to bearings, grease points, thermometer pockets and other check points and to allow safe routine observation and servicing to be executed without the need to dismantle any part of their structure.

3.12 Machine Alignment

Where separate items of interconnected plant such as motors, coupling, gearboxes, equipment, machinery, pumps etc., depend upon correct alignment for satisfactory operation then each item shall be positively located by either solid steel dowels or fitted bolts to ensure that correct alignment can be easily obtained when re-assembling the items following overhauls.

The Contractor's drawings shall indicate tolerances on alignment for all shafts, couplings etc., due allowance being made for thermal expansion or other movement that can occur under all operational conditions.

Alignment shall be checked by means of dial gauges, or other method as approved by the Employer's Representative. Final alignment shall be performed by certified millwrights and witnessed by the Employer's Representative and copies of alignment records, signed by the Contractor's representative, forwarded to the Employer's Representative for record purposes.

3.13 Rating Plates, Name Plates and Labels

Each main and auxiliary item of Plant shall have permanently attached to it, in a conspicuous position, a nameplate and rating plate. The plates shall be engraved with the manufacturer's name, direction of rotation, type and serial number of Plant, details of

the loading and duty at which the item of Plant has been designed to operate and such details as deemed necessary including the Purchaser's plant number.

All field items shall be tagged with 50 x 25 mm engraved traffolyte labels. These shall state the item tag number and hazardous area classification and shall be attached by a corrosion resistant ring to a fixed portion of the item. The ring shall retain the tag securely but shall allow transfer to a replacement item when necessary.

Instruction labels shall be provided where safety procedures such as wearing of protective clothing are essential to protect personnel from hazardous or potentially hazardous conditions. These labels shall have inscriptions or graphic symbols in white on a blue background.

Plant liable to start automatically without warning shall be clearly labelled in a prominent position with red letters on white background. The label shall read:

DANGER

THIS ITEM OF PLANT IS AUTOMATICALLY CONTROLLED AND MAY START WITHOUT WARNING.

ISOLATE BEFORE INSPECTION.

or other approved wordings. A second, similar label shall also be provided with the equivalent wording in Marathi.

Where groups of plant items are under automatic control a common notice may be acceptable where it can be clearly defined which drives are under automatic control.

3.14 Provision of Lubricants

A complete schedule of recommended oils and other lubricants shall be furnished by the Contractor using the specifications for gear lubricants referred to in IS 1118:1992, IS 8406:1993 and IS 2297:1997.

The number of different types of lubricants shall be kept to a minimum. Lithium-based grease is preferred for grease lubricated roller bearings for electric motors. Where grease is the lubricant, preference shall be given to a pressure system which does not require adjustment or recharging more than once weekly. Where necessary for accessibility, grease nipples may be placed at the end of short extension piping and when a number of such points can be grouped conveniently, the nipples shall be brought to a battery plate mounted in a convenient position. Hydraulic button-head type nipples, in accordance with IS 4009: 1981 Part 1, shall be used for normal grease and all grease nipples shall be of the same size and type throughout the Plant for the same lubricant. Arrangements shall be provided to prevent bearings being overfilled with either grease or oil.

The Contractor shall supply two sets of permanently labelled grease-gun equipment for each type of nipple supplied.

Oil reservoirs shall be fitted with oil-level indicators of the sight glass type, or where this is not practicable, with dipsticks. The indicators shall show the level at all temperatures likely to be experienced in service. The normal maximum and minimum levels shall be clearly visible to an operator standing on the normal access floor to the particular item of plant. The sight glasses shall be made from toughened glass easily dismantled for cleaning and where in exposed situations, fitted with guards.

3.15 Colour Coding and Identification of Pipework

Pipes shall be colour coded for identification in accordance with IS 2379:1990. Pipes shall be marked at points where they enter or leave a building or room and where they connect with plant. Where pipe runs are of length 10 m or more, pipes shall also be coded at 5 m intervals. Unless otherwise required by code/standard - identification wording shall be generally black letters on white background on UV resistant plastic material, the plastic material strapped to the piping (along the centreline axis) with plastic or wire ties. The Contractor shall provide a schedule indicating the pipe function, pipe colour, identification wording (showing size of lettering, colours etc.)

3.16 Noise and Vibration

The design of the Works shall include for sound insulating materials, resilient mountings or other appropriate devices to ensure that the Plant runs without undue noise or vibration in its final installed positions. Noise levels from machinery shall not exceed 75 dB at any point on the site boundary lines. The Contractor shall incorporate all noise absorption measures specified and shall advise the Employer's Representative if he considers that noise from the plant will exceed the level specified after incorporation of the noise absorption measures.

Noise level measurement when required shall be made with a sound level meter which complies with BS EN 61672:2003 Part 1 to 2.

All revolving parts shall be properly balanced both statically and dynamically so that in running up to at full normal operating speeds and at any loads up to the maximum in each case there shall be no undue vibration anywhere in the machine or transmitted to the adjacent structure. The criteria adopted for vibration severity shall be the RMS value of the vibration velocity in millimetres per second.

Instruments for measuring vibration severity shall be in accordance with BS ISO 10816:2009 Part 2. Limits of vibration severity for rotating electrical machines shall be in accordance with BS EN 60034:2005 Part 9. This level shall not be exceeded when connected to the driven plant in the service position.

3.17 Corrosion and Erosion

Unless otherwise specified, the Contractor shall make provision in accordance with standard practice, for the prevention of corrosion and erosion in any part of his Plant. Such provision shall include the use of suitable materials, choice of operating speeds, design of components and type of protective coatings and finishes. Such provision shall be in accordance with IS 8629:1977, BS EN ISO 12944 parts 1 to 8, BS EN ISO 14713:2009 parts 1 to 3.

3.18 Precautions against Damp

Special precautions shall be taken to prevent corrosion due to humidity, rainfall and moisture as per the climatic conditions of the region.

All wall mounted equipment shall be fitted with spacers to provide a minimum gap of 5 mm. All holes in equipment shall be effectively sealed against the ingress of water. All items exposed to the weather, or water shall be free of water traps and where necessary drain holes shall be provided to prevent the accumulation of water.

All fixings, fastenings and spacers which may be submerged in the wastewater or a similar corrosive liquid shall be made of 316L stainless steel, unless otherwise approved.

All electrical equipment which is not sealed against free movement of air shall be protected from condensation with suitable anti-condensation heaters and ventilation fans, if required. In general the heaters shall be thermostatically controlled and switched off where heat is generated by operation of the Plant.

Where electrical equipment/plant is installed outdoors, the equipment shall be designed and suitable for wet weather and wash-down conditions a suitable canopy over the top of each plant item shall be provided.

All motors shall be of TEFC type.

3.19 Locks

Where locks are specified or provided they shall be of the cylinder type and three keys shall be provided for each lock. Specification of padlocks shall be as per IS 15275:2003. Where locks are provided for a particular group of items (e.g. instrument cabinets) keys shall be interchangeable.

Locks and padlocks shall be made of brass.

Lockable keyboards of approved design shall be provided for the storage of groups of keys and padlocks for particular items, or groups of items, of plant when not in use.

All locks and keys shall be clearly engraved and be provided with engraved labels stating their purposes and the keyboards shall be provided with labels, identically engraved, to enable each key and padlock to be identified and located.

3.20 Welding

3.20.1 General

All structural, shop fabricated and on site welding of steel shall be metal arc unless otherwise specified and shall comply with the requirements of IS 816:1969. All welds shall be continuous. When tack welds and temporary attachments are used they shall be incorporated in accordance with the procedures specified in IS 816:1969.

All welding electrodes for use with carbon or carbon manganese steel shall comply with the requirements of IS 15769:2008, including the requirements for storage prior to use.

The welding of metals other than mild steel by oxyacetylene or other approved methods shall be carried out in accordance with the appropriate Indian Standard.

Welding of pipework shall be in accordance with IS 10234:1982 or IS11790:1986 to suit the pressure rating of the pipes.

3.20.2 Standards

Site welding shall not be commenced without the prior approval of the Employer's Representative. The Contractor in requesting approval shall provide full details including safety precautions suitable for the location of the welding.

Welding shall be in accordance to the following Indian standards as applicable.

Standard	Description
IS 816	Code of practice for metal arc welding for general construction in mild steel
IS 822	Code of practice for Inspection of welds
IS 1024	Code of practice for welding in bridges and structures subject to dynamical loading

Standard	Description
IS 819	Code of practice for resistance spot welding for light assemblies in mild steel
IS 1261	Code of practice for seam welding in mild steel
IS 1323	Code of practice for oxyacetylene welding for Structural Work in mild steel
For welding any particular type of joint, welders shall submit evidence acceptable to the Employer's Representative of having satisfactorily completed appropriate tests as described in the following relevant Indian standards	
IS 7307	Approval tests for welding procedures Part 1 fusion welding of steel
IS 7310	Approval tests for welders working to approved Welding procedures

Special standards are required for welding aluminium and stainless steel.

3.20.3 Welding Consumables

Covered electrodes shall conform to IS 814:2004 or IS 1395:1982 as appropriate. Filler rods and wires for gas welding shall conform to IS 1278:1972.

The bare wire electrodes for submerged arc welding shall conform to IS 7280:1974. The combination of arc and flash shall satisfy the requirements of I.S. 3613:1974.

The filler rods and bare electrodes for gas shielded metal arc welding shall conform to IS 6419:1971 and IS 6560:1996 as appropriate.

3.20.4 Size of Electrode Runs

The maximum gauge of the electrodes for welding any work and the size of run shall be based on the following table.

Average thickness of plate or section	Maximum gauge or diameter of electrodes to be used
Less than 3/16"	10 SWG
3/16" and above but less than 5/16"	8 SWG
5/16" and above but less than 3/8"	6 SWG
3/8" and above but less than 5/8"	4 SWG
5/8" and above but less than 1"	5/16"dia
1" and above thick section	3/8" dia

Note : On any straight weld the first run shall not ordinarily be deposited with a larger gauge electrode than No. 8 SWG For subsequent runs the electrode shall not be increased by more than two electrode sizes between consecutive runs.

3.20.5 Welding Contractors

The contractor shall ensure that each welding operator employed on fabrication or erection is an efficient and dependable welder, who has passed qualifying tests for the types of welds to be used. Sample test shall have to be given by the contractor to the entire satisfaction of the Employer's Representative.

Welding shall be carried out only under the direction of a competent supervisor.

3.20.6 Welding Procedure

Welding procedure specifications shall be prepared according to IS 2825:1969 and submitted to the Employer's Representative. They shall detail steel grades, joints design and material thickness, welding processes, consumables, principal welding positions, working/preheating temperature and post-weld heat treatment. No alterations shall be made to any previously approved procedures without the approval of the Employer's Representative.

All welding procedures shall be arranged to suit the details of joints as designed and the position in which the welding is carried out shall be such as to ensure that the weld is fully and satisfactorily deposited throughout the length of all joints.

Members to be welded shall be securely held in their relative positions during welding, either by jigs or tack welds or any other means and distortion of finished parts shall be minimized.

Welding should be done with the structural steel in a flat position in a down hand manner wherever possible. Adequate steps shall be taken to maintain the correct arc length, rate of travel, current and polarity for the type of electrode and nature of work. Welding plant capacity shall be adequate to carry out the welding procedure laid down. Adequate means of measuring the current shall be available either as a part of the welding plant or by the provision of a portable ammeter. In checking the welding current, a tolerance of 10% or 30 amperes from the specified value whichever is less shall be permitted.

The welding procedure shall ensure that the weld metal can be fully and satisfactorily deposited through the length and thickness of all joints so that distortion and shrinkage stresses are reduced to the minimum and thickness of welds meet the requirements of quality specified.

3.20.7 Preparation of Fusion Faces

Profiles of fusion faces may be prepared by shearing, chipping or gas cutting. In all cases, the faces should be dressed by chipping, filing or grinding and made regular.

Each lead of metal shall have slag removed by light hammering and wire brushing before the next lead is deposited. The weld must show a good, clean contour and on a cut specimen, good fusion with the parent metal. Before applying paint, the weld shall be carefully chipped and wire-brushed.

Fusion faces shall be cut by steering machine or gas cutting and later dressed by filling or grinding so that they shall be free from irregularities such as would interfere with the deposition of the specified size of weld to cause the defects.

Fusion faces and the surrounding surfaces for a distance of not less than 20 mm shall be free from heavy slag, oil paint or any substance which might affect the quality of the weld or impede the progress of welding. The welding face shall be free of rust and shall have metal shine surfaces.

The parts to be welded shall be brought into as close contact as possible and the gap due to faulty workmanship or incorrect fit up shall not exceed 1.6 mm. If a separation of 1.6 mm or more occurs locally, the size of the fillet weld shall be increased at such position by an amount of equal to the width of the gap.

The parts to be welded shall be maintained to their correct position during welding. They shall be securely held in position by means of tack welds, service bolts, clamps or rings before commencing welding to prevent relative movement due to distortion, wind or any other cause.

3.20.8 Step Back Method

The Step Back Method should be used to avoid distortion. The minimum leg length of a fillet weld as deposited should not be less than the specified size and the throat thickness as deposited should be not less than that tabulated below:

Angle between fusion faces	60^O-90^O	91^O-100^O	101^O-106^O	107^O-113^O	114^O-120^O
Throat thickness (mm)	7	6.5	6	5.5	5

In no case should a concave weld be deposited without the specific approval of the Employer's Representative unless the leg length is increased above the specified length so that the resultant throat thickness is as great as would have been obtained by the deposition of a flat.

All welds shall be deposited in a pre-arranged order and sequence taking due account of the effects of distortion and shrinkage stresses.

After making each run of welding, all slag shall be removed and final run shall be protected by clean boiled linseed oil until approved.

The weld metal, as deposited, shall be free from cracks, slag, excessive porosity, cavities and other faults. The weld metal shall be properly fused with the parent metal without overlapping or serious undercutting at the toes of the weld.

The surfaces of the weld shall have a uniform and consistent contour and regular appearance.

In welds containing cracks, porosity or cavities in which the weld metal tends to overlap on the parent metal without proper fusion, the defective portions of the welds shall be out cut and re-welded. Where serious under cutting occurs, additional weld metal shall be deposited to make good reduction.

3.20.9 Welded Joints for Steel Pipelines

Welding of joints in steel pipes shall be carried out manually by the metal arc welding process complying with AWWA Standard C206 and in accordance with IS 816:1969 arc welding, or BS 2633 to suit the pressure rating of the pipework. Before starting the welding of any pipe joints in the Works, the Contractor shall submit for the Employer's Representative approval details of the plant, methods and materials he proposes to use, including make and size of electrodes, number of runs, current strength and arrangements for air testing of individual joints.

Pipework shall be radio-graphed as required in accordance with IS 1182:1983 or BS EN 1435, the technique number to be subject to the approval of the Employer's Representative.

All parts to be welded shall have loose scale, slag, rust, paint and other foreign matter removed by means of a wire brush and shall be left clean and dry. All scale and slag shall be removed from each weld run when it is completed. Pipes manufactured with longitudinal or spiral welds shall be lined up before jointing so that these welds are at least 15^O apart around the joint circumference.

Sealing of cable entries shall only take place after the satisfactory testing of joints for which the cable entry is required. Cable entries shall be closed with the screwed plug provided and the plug welded in place. Lining and coating shall be applied to the area of the entry to the same standard as the pipe.

3.20.10 Butt Welded Joints

Unless otherwise agreed by the Employer's Representative, welded joints shall be of the butt welded type. The Contractor must submit his proposals and his welding procedures for butt welding to the Employer's Representative for approval and shall not commence any butt welding jointing work until he receives the Employer's Representatives approval.

Butt welded joints shall be single groove or double groove welded and shall be full penetration butt welds. Unless otherwise approved by the Employer's Representative, welds shall be single run welds.

Pipe ends for butt welding shall be plain end pipe in accordance with API Spec 5L (Addendum). They shall be bevelled to an angle of 30^{O} measured from a line drawn perpendicular to the axis of the pipe and with a root face of 1.6 mm ± 0.8 mm. The root face shall be located to suit whether the pipes will be welded from the inside or from the outside.

Any internal backing rings used shall be removed after the welding operation.

3.20.11 Lap Welded Sleeve Joint

Lap welded sleeve type joints shall be welded inside and outside. The internal weld shall be a full depth structural weld, whilst the exterior weld shall be a small fillet weld to seal the joint and to allow gas testing of the joint.

For pipes larger than 900 mm diameter, a triple run convex fillet weld shall be used. For pipes of 900 mm diameter or less, a double run convex fillet weld shall be used.

The minimum length of the fillet, as deposited, is to be equal to the full thickness of the pipe wall. The actual throat depth shall not be greater than 9/10 and not less than 7/10 of the minimum leg lengths as deposited. The depositing of the weld metal shall be carried out in such a manner as to ensure that all the welds have adequate root fusion and are of good clean metal free from cracks, gas holes, slag inclusions and all other impurities. The surface of the weld shall have an even contour with regular finish and shall indicate proper fusion with the parent metal. All slag shall be thoroughly removed after depositing each run of welding by light hammering with a chipping hammer followed by wire brushing. Any welds showing cracks or other cavities or in which the weld metal tends to overlap onto the parent metal without proper fusion or containing any other defects whatsoever shall be cut out and re-welded to the satisfaction of the Employer's Representative.

3.20.12 Lap Welded Collar Joint

Where the Employer's Representative permits two plain-ended pipes to be joined by a welded collar joint, the gap between the two ends shall not exceed 75 mm. An external steel sleeve collar, of a thickness not less than that of the pipe itself and approximately 300 mm in length, shall be placed centrally over the two ends to be jointed. The end of each pipe shall then be fillet welded to the sleeve collar, inside and outside, in accordance with the above procedure for a lap welded sleeve joint.

3.20.13 Welder Performance Test

The Contractor shall submit for the Employer's Representative's approval, the names of the proposed welders together with evidence that they have passed appropriate qualifying tests and possess certificates from an independent testing authority. Weld specimens from each of the welders shall be submitted for the approval of the Employer's Representative, who may also require satisfactory test welds to be carried out under Site conditions and on materials similar to those for use in the Works. The

Contractor shall maintain an up-to-date list of welders that have been approved by the Employer's Representative.

The Contractor shall remove from the approved list any welder whose workmanship is, in the opinion of the Employer's Representative, below a reasonable standard of quality or consistency.

3.20.14 Inspection and Testing

Testing of welded joints shall be done as per relevant Indian standards IS 3600:1985 Part 1 to 2, IS 3600:2009 Part 3, IS 3600: 1984 Part 4, IS 3600:1983 Part 5 to 6, IS 3600:1985 Part 7 to 9, IS 3613:1974, IS 7307:1974 Part 1, IS 2595:2008, IS 4260:1986 or British standards BS Codes BS EN 1321:1997, BS EN 895:1995, BS EN 10208:2009 Part 1 to 2, BS EN 10208-2:2009, BS EN ISO 15614-1:2004+A1:2008, BS 4871:1985 Part 2, BS 4872:1985 Part 1.

All inspection and testing shall be carried out by certified inspectors appointed by the Contractor. Reports on inspections and tests shall be submitted to the Employer's Representative promptly.

All welds shall be visually inspected.

The first 10 joints made by each welder shall be 100% tested; thereafter 10% of the joints made by the welder shall be tested. If a weld is found to be defective, the welder concerned will have his previous and subsequent weld 100% tested, if a further defect is found the next three welds will be 100% tested.

Non-destructive testing methods:

Weld Type	**Testing Method**
Butt welds	Radiographic Testing
Part penetration and fillet welds	Magnetic particle testing

Radiographic inspection of welds shall be made by the Contractor, in the presence of the Employer's Representative, in accordance with IS 4853:1982, IS 1182:1983 or IS 2595:2008 to a maximum of 10% of the total run of weld. Each joint to be radio graphed shall be cleaned and any weld spatter removed. Any defective weld shall be repaired by approved means or cut out if necessary. If, in the opinion of the Employer's Representative, excessive repair work is necessary, the radiographic inspection may be increased beyond 10% of the total run.

Spherical and other forms of sleeve welded joints shall be gas tested.

Gas Testing

The Contractor shall carry out nitrogen tests on a number of completed welded sleeve/ collar type joints, at the discretion of the Employer's Representative.

A tapped hole (approximately 6 mm diameter) made in the socket end of the pipe to be tested shall be fitted with a suitable non-return valve. Moisture free nitrogen gas, at a pressure of 1 bar shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

If no drop in pressure occurs over the ensuing test period the test shall be deemed to be successful. The duration of this test period shall be 30 minutes unless otherwise approved by the Employer's Representative. 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. Once the joint has successfully passed a gas test, the tapped hole shall be sealed with a threaded steel plug, which is tack welded in place.

The Contractor shall provide all items necessary for the nitrogen gas tests including compressor, gas bottles, valves, gauges, tubing and so forth.

3.21 Surface Protection

3.21.1 Consideration for Electroplating/Galvanising

Piping systems: Corrosion protection of pipelines by methods other than those described in BS EN ISO 1456:2009, BS EN ISO 12540:2000, BS EN ISO 12944-5:2007 may be suitable. Consideration of such systems will be given provided that the Contractor can demonstrate a level of performance and durability equivalent to coating systems complying with BS EN ISO 12944-5:2007.

Other components: Electroplating or hot dip galvanising may be acceptable as an alternative to some components made of stainless steel subject to the Employer's Representative approval.

Should electroplating/galvanising be accepted – it shall be carried out in accordance with IS 2629: 1985 with a deposition rate of at least 610 g/m^2. After galvanising, all parts shall be passivated to minimise discoloration.

Where galvanized coatings are damaged, repairs shall be undertaken using one of the methods given in IS 2629: 1985.

Zinc or cadmium electroplated components shall be in accordance with IS 3655:1985, IS 3656:1968. Cadmium coating shall not be used where the component might come into contact with food or water supplies.

Chrome electroplating shall be in accordance with BS EN ISO 6158:2011 and the minimum coating thickness shall be 85 microns.

If the chosen method of repair uses a zinc rich primer, the primer shall comply with the requirements of IS 13238:1991. Repairs to galvanized coatings shall not be made using materials that are applied from an aerosol can.

3.21.2 Painting and Protection

(i) General Requirements

Protective coatings to steel structures and pipelines shall be appropriate for the local climatic and soil conditions and heavily reinforced.

The Contractor shall consider climatic conditions especially heat and high humidity and stresses which could contribute to the performance of the coating. The stresses to be considered resultant from internal pressure, temperature and mechanical stresses from particle entrainment as in BS EN ISO 12944-5:2007 or the equivalent Indian Standard.

All protective coating systems are required to achieve high durability and perform for more than 15 years.

In formulating a coating system, the Contractor shall take due account of health and safety requirements with respect to the handling and application of the selected coating system. The proposal shall include full details of the measures to be adopted to protect the safety and wellbeing of operatives and for the disposal of unused materials etc.

Painting shall be applied strictly in accordance with the direction of the manufacturer and according to IS 1477-1971 (Part I – Pre-treatment) and IS 1477-1971 (Part II-painting).

Paints, including primers and undercoats, shall be obtained as far as possible from a single manufacturer and shall, except where application has to be made within a limited time of mixing, be ready for use and compatible with one another. Only paint which is delivered in sealed containers, bearing the name of the manufacturer and properly labelled as to its quality, date of manufacture, shelf life and instructions for use, will be acceptable.

Where dissimilar metals are mated and where the possibility of galvanic or similar corrosion exists, the mating surfaces shall be insulated from one another. One coat of shop paint (red oxide) shall be applied on steel, except where it is to be encased in concrete or where surfaces are to be field welded.

Test plates carrying finishes from the actual coating used may be requested by the Employer's Representative for test and inspection purposes.

Name plates, rating plates, labels etc. shall not be painted over. All rotating bearing and gland surfaces shall be protected during final painting.

Site painting shall not be carried out unless the surface to be painted is completely dry, the air temperature above 13 ^{O}C and the relative humidity less than 85%. Immediately before painting, all dirt, oil, grease etc. shall be removed from the surface by hand wire brushing and a suitable degreasing agent or approved alternative may be adopted. The surface to be painted must have a temperature of at least 3 ^{O}C above the dew point.

Black bituminous solution for cold application shall comply with BS 3416:1991 Type 1 for general purpose, Type II where in contact with potable water.

Hot applied bituminous based coating shall be as specified in accordance with BS EN 10300:2005.

(ii) Requirements Specific to Plant

The requirements of this clause shall apply to all items of mechanical and electrical equipment including above ground pipework, valves and steel fabricated vessels.

Stove enamelled plant, e.g. control panels, switchboards etc. and other plant delivered to site with the final finish applied, shall have the finish protected before delivery with a temporary coating of plastic material sprayed on to a thickness of not less than 0.25 mm and in accordance with the manufacturer's recommendations.

All surfaces of plant shall be protected against corrosion and/or erosion. In the case of mating surfaces, the primary coats shall be applied to the mating surfaces prior to assembly. Care shall be taken to ensure that rotating gland or bearing surfaces are not coated with paint.

Small iron and steel parts (other than stainless steel) of all instruments and electrical equipment, the metal parts of relays and mechanisms shall be chromium or copper-nickel plated or have some other approved finish to prevent rust. Cores etc., which are built up of laminations or cannot for any other reason be anti-rust treated, shall have all exposed parts thoroughly cleaned and heavily enamelled, lacquered or compounded.

Immediately after the erection of plant, any damage to paint finishes shall be made good in a manner approved by the Employer's Representative. Damaged areas of galvanised metal or metal sprayed plant shall be made good by wire brushing, degreasing with a suitable solvent followed immediately by the application of appropriate etching and primer containing not less than 90% zinc or aluminium in the dried film thickness. The colour of the touch-up paint shall match that of the original finish.

(iii) Schedule of Protection Systems

Unless otherwise specified or approved (e.g. if protection is of a special nature giving equal or better protection), the plant and pipework shall be protected in accordance with the Schedule of Protection Systems.

Paint finish - Specification sub-clause and paragraph reference in Clause (iv) below.

Plant	External Surfaces	Internal Surfaces
Exposed plant installed outside of buildings		
Ferrous castings	1b, 1a, 3a, 4a	1b, 1a, 3a. 4a
Non-ferrous castings	1b, 1c, 3b, 4a	1b
Steel hand-railing, floor plates, brackets, kerbing etc.		1b, 1a, 2b
Electrical switchgear and panels	1b, 1c, 1a, 2a, 3b, 4i	1b, 1c, 1a. 2a, 3b, 4f
Mechanical plant where not covered by above	1c, 1d, 3a, 4a	as appropriate
Electrical plant where not covered by above	1c, 3a, 4a	as appropriate
Nuts, bolts and fixings (other than for pipeline purposes)	2d or 2b as appropriate	-
Plant installed within buildings		
Steel floor plates, brackets, Kerbing etc.	1b, 1a, 2b	
Mechanical plant where not covered by above	1c, 1d, 3a, 4j, 4i	as appropriate
Electrical plant where not covered by above	1c, 3a, 4j, 4i	as appropriate
Nuts, bolts and fixings (other than for pipe fittings)	2nd or none as appropriate	-
Electrical switchgear and panels	1b, 1c, 1d, 4i	1b, 1c, 1d, 4g
Pipework installed outside buildings above ground		
Steel pipe and fittings	1b, 1a, 4m	1b, 1a, 4m
Ductile iron pipes and fittings	1b, 1a, 4m	1b, 1a, 4m
Nuts, screws, washers and bolts	1b, 1a, 4m	
Pipework installed inside buildings		
Steel pipes and fittings	1b, 1a, 4m	1b, 1a, 4m
Ductile iron pipes and fittings	1b, 1a, 4m	1b, 1a, 4m
Nuts, screws, washers and bolts	1b, 1a, 4m	-
Pipework installed below ground		
Steel pipes >DN80	1b, 1a, 4m	1b, 1a, 4m
Steel pipes >DN80	1b, 4j, 4i	As appropriate
Ductile iron pipes	1b, 4j, 4i	As appropriate
Ductile iron push fit joints	1b, 4j, 4i	-
All bolted joints	1b, 4j, 4i	-
Nuts, screws, washers and bolts	1b, 4j, 4i	-

(iv) Description of Paint and Protection Systems

This clause contains specifications of the paint and protection system requirements tabulated in the Schedule of Protection Systems above.

1. Surface Preparation

   a. Blast cleaning shall use air that is clean, dry and free from oil or other contamination. The type of abrasive used shall be selected to achieve a blast profile of 75 microns maximum and 25 microns minimum. Blast cleaning shall be to the requirements of SSPC - SP5 - 1966 (Swedish Standard SIS 05 59 00 - 1967 Sa 3) or CP 3012 - 1972 as appropriate.

   b. All flash, weld spatter, sharp and rough surfaces shall be removed by use of hand operated tools.

   c. Surfaces shall be cleaned and rust, scale, dirt, loose paint etc. removed by use of a powered hand operated wire brush or similar.

   d. Surfaces shall be degreased by the use of solvents which are compatible with and of the same manufacture as the paint finishes.

   e. Bright parts and bearing surfaces shall be thoroughly polished and protected from corrosion by the application of a corrosion preventing lacquer or similar.

2. Metal Coatings

   These coatings shall only be applied where approved by the Employer's Representative.

   The specified or appropriate metal coating shall be applied in a manner as scheduled below within four hours of surface preparation:

   Zinc metal spray to a thickness of 0.1 mm or greater in accordance with BS EN ISO 2063:2005.

   Hot dip galvanise IS 2629:1985.

   Aluminium metal spray to a thickness of 0.1 mm or greater in accordance with EN ISO 2063:2005.

   Chrome electroplate in accordance with BS EN ISO 6158:2004 or BS EN ISO 1456:2009 as appropriate.

   Cadmium plate in accordance with IS 3655:1985.

3. Priming

   Within four hours of the final surface preparation and when all traces of grease have been removed, specified primer shall be applied as scheduled below:

   a. Red oxide primer to give a minimum film thickness of 80 microns.

   b. Polyamide cured epoxy fabrication primer, preferably containing zinc phosphate corrosion inhibitor to be applied to give a total film thickness not less than 50 microns above surface profile. The over coating interval should not be less than eight hours and not more than seven days. No thinners are to be used and the ambient temperature for curing should not be less than 13 ^{O}C.

   c. Polyamide cured epoxy zinc primer containing at least 90% zinc is dried film to give a minimum film thickness of 80 microns.

   d. Appropriate polyamide cured epoxy etch primer to give a minimum film thickness of 50 microns.

e. Aluminium sealer to give a minimum film thickness of 50 microns.

f. Cement wash on any surface prepared as in (1) above that is to be cast into concrete works.

g. Rub down all surfaces with grade 120 wet and dry rubbing down paper and apply coat of synthetic grey primer to give a dry film thickness of not less than 50 microns. Stop all blemishes and irregularities having a depth greater than 2.5 mm and apply coat of high build/filler primer.

h. Rub down all surfaces with grade 120 (rough) followed by grade 240 (finish) wet and dry paper.

4. Final Finish

Surfaces shall be fully prepared before the application of a final finish. Damaged areas shall be made good by powered or hand operated wire brush and degreased and cleaned with a suitable solvent or as otherwise appropriate. Further coats of the original finish shall be applied to obtain the correct quality and thickness.

Any previous finish shall be thoroughly cleaned of all grease, dirt and dust as appropriate and the specified finish shall be applied within two hours.

Specifications for finish

a. Polyamide cured epoxy micaceous iron oxide to give a dry film thickness of not less than 100 microns.

b. Polyamide cured epoxy resin incorporating inert pigments to be applied to give a dry film thickness of not less than 100 microns.

c. Alkyd resin based gloss finish paint to give a dry film thickness of not less than 30 microns.

d. Alkyd resin based undercoat paint to give a dry film thickness not less than 30 microns.

e. Black bitumen coating in accordance with BS 3416 type II.

f. Polyurethane enamel to give a dry film thickness of not less than 35 microns.

g. White anti-condensation paint to give a dry fill thickness of not less than 35 microns.

h. White stove enamel to give a dry film thickness of not less than 35 microns.

i. Stove dried enamel primer and gloss finish to give a dry film thickness of not less than 50 microns.

j. Polyamide cured epoxy gloss coat to give a dry film thickness of not less than 35 microns.

k. Polyamide cured epoxy undercoat to give a dry film thickness of not less than 35 microns.

l. Surface to be given single wash coat, followed by one full coat embedded with a Duraglass or similar matting and one further coat of polyamide cured epoxy coal tar to give a dry film thickness of not less than 300 microns.

m. Apply coats of intermediate synthetic finished enamel in final colour to give a dry film thickness of not less than 50 microns. Apply one coat of final colour synthetic finishing enamel. Between each coat of finish rub down surface gently with fine steel wool.

n. Fusion bonded, dry powder epoxy coating in accordance with BGC PS/CW6 Parts 1 and 2 or equal and approved standard, to give a thickness of between 0.3 mm and 1.6 mm.

5. Colour

   Equipment - Manufacturer's standard unless otherwise specified. Piping systems: Shall be in accordance with IS 2379:1990.

4 PIPE WORK, COUPLINGS, VALVES, PENSTOCKS AND STOP-LOGS

4.1 General

The installation of all piping, fittings, couplings, valves etc. shall comply with IS 4111:1968 (Part IV), IS 2065:1983, IS 7634 (Part 3).

All pipes passing through walls between dry structures and underground or sewage bearing tanks must have a complete circumferential puddle flange acting as an anchor/water-stop in compliance with BS-4622:1970, BS-2035:1966.

Identification: All pipe and fittings shall bear the markings of the manufacturer's data, such as: manufacturer's name, material type, pressure rating, material standard(s), year of manufacture etc. The markings shall be permanently run along the entire length/side of the pipe/fitting. No piping shall be allowed on site without these markings.

All piping systems shall be cleaned out before pressure testing.

All piping/sewer systems shall be pressure tested in the presence of the Employer's Representative with a test pressure of at least 1.5 times the system working pressure, or minimum 5 bar, except for gravity/sewer systems.

Valves shall not be operated during the pressure tests.

After all testing is complete and accepted, all piping systems shall be flushed out and temporarily capped at each end until put into working service.

Below ground piping systems shall not be fully backfilled until all pressure testing has been completed and witnessed by the Employer's Representative.

All buried plastic piping systems shall have continuous runs of tracer wires (no. 10 solid copper TWU white coloured insulation) taped to the piping runs at 1 m intervals using fibre glass reinforced tape. All sludge and scum piping systems, exposed or buried, shall be of a metal pipe as per specified herein.

All buried piping crossing under roadways shall be protected with a minimum 150 mm thick full surround concrete encasement.

4.2 Buried Metal Piping Protection

All buried metal piping systems, shall be protected with a specially designed cathodic protection system and/or a continuous plastic sheathing wrap consisting of a tubular polyethylene film conforming to IS 8329:2000 Annexure D.

All buried valves shall be protected with two coats of an approved bitumen material and final protection with a proprietary petroleum based paste and wrapping system.

4.3 Carbon Steel Pipe and Fittings

Carbon steel pipe and fittings shall generally comply with IS 3589:2001 and 1239 (Part 1 & 2) for steel piping for water and sewage use, including the standards as noted below.

Pipes up to 65 mm dia shall be mild steel Sch. 80 seamless for screwed connections, conforming to ASTM A53-Gr.B, with screwed fittings/unions to ASTM A197/A338, ANSI B16.39, Class 300.

Pipes 80 to 300 mm dia shall be mild steel Sch. 40 minimum seamless, conforming to ASTM A53- Gr B.

Pipes 350 mm dia and larger, shall be welded seam steel minimum Sch.40 wall thickness, conforming to ASTM A283-Gr. C, AWWA C200.

The coatings for pipework shall be shop prime: red oxide primer on exterior. For the finish coating: see section 2.21 Surface Protection.

4.4 Ductile Iron Pipe and Fittings

Ductile iron pipes and fittings shall generally comply with IS 8329:2000 and AWWA C151/A21.51, Class 53/54/55 for centrifugally cast DI pipes and other standards as noted below.

Exposed piping inside structures and flanged pipes etc. shall comply with IS 1536:2001, AWWA C110/A21.10. Fittings shall comply with IS 9523:2000.

Buried process piping, rising mains etc. shall comply with IS 9523:2000. Fittings shall comply with IS 9523:2000, AWWA C110/A21.10

All ductile iron pipes and fittings, unless otherwise indicated, shall be cement mortar lined complying with: IS 8329:2001 Annex B, AWWA C104.

All ductile iron pipe and fittings shall have a shop applied exterior coating of bitumen complying with IS 8329:2000 Annex C, AWWA C151.

4.5 Galvanized Pipe and Fittings

Galvanizing shall conform to ASTM A153.

Pipes up to 65 mm diameter shall be carbon steel Sch. 80 ERW for seamless or screwed connections, conforming to ASTM A53-Gr.B.

Pipes 80 to 250 mm diameter shall be carbon steel Sch. 40 ERW for seamless, bevelled ends for butt welding conforming to ASTM A53-Gr.WPB.

Pipes 300 mm diameter and larger shall be carbon steel, minimum 10 mm wall thickness, ERW or seamless, bevelled ends for butt welding conforming to ASTM A53-Gr. WPB.

Screwed fittings up to 65 mm diameter shall be malleable iron and comply with ASTM A197/A338, ANSI B16.3, Class 300 (2 MPa).

Butt welded fittings 80 to 250 mm diameter shall be Sch. 40 and comply with ASTM A 234 Gr-WPB, ANSI B16.9 Class 150 (1 MPa).

Butt welded fittings 300 mm diameter and larger shall conform to ASTM A234 Gr. WPB, ANSI B16.9 Class 150 (1 MPa).

Grooved fittings 80 to 300 mm diameter shall conform to ASTM A234 Gr. WPB, ASTM A536, ASTM A53 Gr. B, AWWA C606.

Unions up to 65 mm diameter shall be malleable iron, screwed, brass to iron seat, conforming to ASTM A197, A338, ANSI B16.39 Class 300 (2 MPa).

4.6 Stainless Steel Pipe and Fittings – Liquid and Air Service

Stainless steel pipe shall be 316L stainless steel to ASTM A240 and A778, Gr. TP.

Pressure rating shall be up to 1220 kPa maximum pressure. Fabrication shall be welded seam or seamless

Sizing shall conform to ANSI B36.19 as required. Gauge, schedule or plate material shall be used according to the application. Where grooved type couplings are used on gauge material, the material thickness at the ends of the pipe shall be equal to Sch. 10S to suit the grooving/coupling requirement.

For seamless piping up to 65 mm and for use with threaded connections wall thickness shall be in accordance with Sch. 40. Threaded couplings shall conform to ASTM A182, A276 and rated for 435 kPa.

Fittings shall conform to ASTM A774, MSS SP43, with smooth flow (pressed type) bends. If mitred bends are used, 90 degree bends shall have five sections and 45 bends three sections. All discharge fittings such as tees, bends, laterals etc. shall be reinforced and braced to suit the dynamic forces/pressures accordingly.

The internal diameter of pipes and fittings shall not be less than the connection sizes for valves, equipment etc.

All piping and fittings shall be of Number 1 or 2B finish.

4.7 Stainless Steel Pipe and Fittings – Digester Gas Service (Not Used)

4.8 PVC Pipe and Fittings

Polyvinyl chloride (PVC or CPVC) shall conform to IS 4985:2000 and the PVC resin to ASTM D1784, ASTM D1785 Type 1 – Gr.1 (PVC cell compound 12454-B) in Sch. 40 or 80 suitable for solvent welding for exposed and buried use.

Fittings shall be smooth flow type conforming to IS 4985:2000 and ASTM D2467 PVC Type 1, Gr. 1 (PVC cell compound 12454-B).Threaded joints shall conform to ASTM D2464.

Joining shall be solvent weld socket type or threaded or flat faced flanges (with 3 mm thick full face gaskets all drilled to ANSI B16.5 Class 150 and 316L stainless steel nuts and bolts). For threaded connections, Sch. 80 pipe and fittings shall be used.

Solvent cement shall conform to ASTM D2564.

PVC piping shall not be used for sludge, scum or compressed air or gas systems.

4.9 Polyethylene Pipe and Fittings

Piping for liquid pressure service shall be black and conform to BS EN 12201:2011 (Part 1 & 2), IS 4984:1995 AWWA C901 (PE 2406) and AWWA C906 (PE 3408).

Piping for natural and digester gas service shall be yellow and conform to conform to BS EN 1555:2002 (Part 1 to 5), IS 14885:2001,ISO 4437:2007 and AWWA C901 (PE 2406). Design pressure shall be Series 160 as a minimum.

Fittings shall be PE or GRP mitred or smooth flow type, except 90 deg bends shall not be mitred. GRP fittings shall conform to ASTM D2996. Ductile iron fittings shall conform to IS 12709:1994, AWWA C110 or AWWA C153.

Main PE piping runs and fittings shall be fusion jointed. Other fittings maybe flanged to other materials, valves, equipment etc.: using galvanized iron or galvanized steel flanges and a PE pipe stub thermally fused to the pipe. PE piping of less than 75 mm dia may use compression type joints.

4.10 Copper Tubes and Fittings

Fittings for water service shall comply with ANSI B16.18 and B16.22.

Joints shall be capillary/solder/sweat joints using wrought copper or cast bronze fittings. Capillary/solder/sweat joints for clean water service shall use 95/5 antimonial tin solder conforming to ASTM B32.Capillary/solder/sweat joints for DWV service shall use 50/50 tin/lead solder conforming to ASTM B32.

Above ground pipes shall comply with BS EN 12449:1999 and BS EN 1254:1998 Part 1 to 2, ASTM B88, Type L hard drawn seamless. Below ground pipes shall comply with IS 2501:1995 or BS EN 12449:1999, ASTM B88, Type K soft drawn, seamless.

Drain waste vent pipes shall conform to ASTM B306.

4.11 Glass Lined Ductile or Cast Iron Pipe and Fittings – Pressure Pipe

Generally the ductile iron and cast iron piping, fittings, couplings etc. shall comply with the piping specifications as specified herein.

Glass lined piping shall conform to: ASTM D-792, ASTM C-283, NACE RP 0188-99, SSPC Coating Manual Vol. 1 Section X1V.

The glass lining shall be of abrasion and corrosion resistant inorganic material, vitreous applied for an integral molecular bond, equal to Porcelain Enamel at 250 microns minimum thickness. Lining hardness not less than 5-6 on the MOHS scale or 73 on the Rockwell scale. The lining shall have a minimum Hazen-Williams C of 150. The lining shall be suitable for a pH range of 3 to 10 and be capable of a temperature resistance to 427 ^{O}C and a thermal shock resistance of 182 ^{O}C.

Exposed process piping inside structures shall have flanged connections. Process piping below ground shall have flexible joints.

Damaged lining shall be repaired with the use of a proprietary repair kit as supplied by the pipe manufacturer.

4.12 Cast Iron Drainage/Vent Pipe and Fittings

Cast iron drainage/vent pipes and fittings shall generally comply with IS 1536:2001, IS 3114:1994, IS 1538:1993, ANSI/AWWA C110/A21.10, ANSI B16.12.

Joints (exposed or below ground) shall be self-locking neoprene gasket joints.

For plain end pipe connections, couplings shall comprise a continuous sleeve around the pipe with stainless steel sheath and gear clamps for exposed piping. Mechanical type couplings shall be used for below ground piping.

4.13 Joints and Couplings

Flexible type joints for ductile iron pipe of the mechanical compression rubber gasket type or the push-on socket & spigot rubber gasket type shall conform to AWWA C111-A21.11.

Dismantling joints shall comply with AWWA C-219.

Flanged joints for ductile iron pipe shall conform to IS: 8329 - IS: 1536 & AWWA-C110/A21.10. Stainless steel flanged joints shall conform to ANSI B16.1, B16.5, MSS SP42. Flanges shall be welded conforming to ANSI B16.1, B16.5. Back-up type flanges shall not be used.

Ductile iron split body couplings for grooved cut pipes shall conform to ASTM A536 Gr 65-45-12, AWWA C606 and have a galvanized body coating. Gaskets shall be of EPDM flush-seal design. Grooved couplings shall be one class higher than the minimum recommended for coupling of ductile iron pipes. Roll press type grooves shall not be used.

Flanged joints for carbon steel pipes up to 300 mm diameter shall be of the weld neck type conforming to ASTM A105/A181/A182/A350, ANSI B16.5. For larger pipes, slip on weld type flanges conforming to ASTM A181/A105 Gr. I or II shall be used.

Gaskets for flange joints shall conform to ASA B16.21, BS 7874, BS EN 681-1 & 2, IS 12820:2004, IS 11149:1984, 3 mm thick red rubber or neoprene full face type or rubber in accordance with BS 1154 CLASS y-3 or BS 494 of hardness proven in practice to form a watertight joint. Joining paste shall not be used. Flange adaptors and mechanical couplings shall not be used on gas systems. Neoprene gaskets shall be used on gas systems.

Gaskets for buried flexible joints shall comply with IS 5382:1985, AWWA C111/A21.11, of Styrene Butadiene Rubber (SBR).

Flange adaptors and plain-end to end couplings shall conform to IS 2062:2011 Grade B, BS EN 10311:2005, BS EN 10224, ASTM F1476. Each flange adaptor assembly shall be epoxy coated mild steel to AWWA C-213, with an EPDM rubber seal and complete with all necessary, nuts, bolts, studs and washers.

Unions for steel pipes up to 80 mm diameter shall be malleable iron, screwed ends, brass to iron seat, conforming to ASTM A197/A338, ANSI B16.39, Class 300.

Bolt holes shall be drilled in accordance with BS EN 1092-1:2007, IS 6392:1971.

Loose flanges (or companion flanges) shall match the adjoining flange on valves, equipment and plant in all respects to dimensions, sizes, strength etc.

4.14 Pipe Hangers and Supports

Pipe hangers and supports shall conform to IS 8324:1988, IS 9323:1991, MSS SP-58/SP-69/SP-89 and ANSI B31.1.

Where the ceiling design allows, liquid filled piping up to 600 mm diameter and more than 1800 mm above floor level may be supported from the ceiling with approved pipe hangers.

Where the wall design allows liquid filled piping up to 600 mm diameter and more than 1800 mm above floor level may be supported from approved wall brackets or pipe rack systems.

If the pipe work is to be supported from floor level, then:

- Light-weight non-liquid filled piping up to 600 mm diameter shall be supported on approved vertical pipe stanchions complete with tie-down straps.
- Liquid filled piping and piping subject to dynamic forces shall be supported on approved reinforced concrete columns complete with tie-down straps.

The maximum spacing of pipe supports shall be determined with due consideration to the spacing of joints, the prevention of sagging and the need to accommodate dynamic forces.

All metal support systems shall be galvanized.

All floor mounted metal supports shall be founded on 25 mm thick grout.

4.15 Valve Keys

Valve keys shall be provided by the same supplier as the valve.

Identification letters conforming to the valve or penstock numbering code shall be clearly engraved on the keys.

4.16 Valve/Penstock Extension Spindles and Guide Brackets

Extension spindles for remote operation of valves and penstocks shall be complete with guide brackets for bolting to walls at centres not greater than 2 m or as recommended by manufacturer.

Extension spindles shall be fabricated in 316L stainless steel of the same diameter as the original spindles and sufficient to transmit the opening/closing torque.

Valve caps and couplings shall be secured by hexagonal headed setscrews.

The length of the extension spindle shall be such that the top of the cap is not more than 225 mm below cover or wellhead level.

Guide brackets for motor operated valves and penstocks shall be copper alloy bushed.

Design the spindles with a maximum L/r ratio of 200 in concert with the extension guides. Spindles with full length double start square or trapezoidal threads, 400 mm longer than the penstock opening height.

Rising spindle penstocks shall have rising spindles external to the gate unless otherwise specified or detailed on the Drawings. Rising spindles shall have robust clear protection tubes with gate-position indicators.

One piece spindles are preferred but where sectionalised, couplings shall be 316L stainless steel with sufficient tolerance to permit alignment of all sections. All couplings shall be designed or shrouded to prevent collection of rags and debris.

Sectionalised spindles shall have the minimum number of couplings adequately supported at the penstock frame, actuator or intermediate brackets.

All spindles having a total unsupported length in excess of 2 m shall be fitted with robust intermediate guide brackets, at not greater than 2 m centres or as recommended by manufacturer.

Spindle nuts, collars and guide brackets shall be securely located with lubrication points easily accessible.

4.17 Valves

4.17.1 General

Valves shall comply with IS 14846:2000 and be suitable for use with wastewater and/or other processes as required. The Contractor shall provide a test certificate confirming that the valves have been tested in accordance with IS 14846:2000, stating the actual pressures and medium used in the test.

Valves of the same type and size and designed for the same service shall be obtained from a single manufacturer and shall be strictly interchangeable.

All valves shall be designed, manufactured and tested in accordance with the standards specified. Valves shall be arranged to facilitate operation from ground level. Where necessary, extension spindles, chain wheels and operating platforms shall be provided. Valves shall not be installed in an inverted position.

Valves shall normally be double flanged in accordance with ANSI B 16.5 or shall be suitable for bolting between flanges and fitted with an integral locking device. Screwed fittings may be used where the fluid handled is non-aggressive. Welded connections shall not be used unless authorised by the Employer's Representative.

In general, line buried valves shall be with either a valve spindle terminating just below ground level in a suitable valve box or a surface mounted actuator in a suitable enclosure complete with power, controls and telemetry.

Sleeved, positively attached, valve spindle extensions shall be installed as necessary on main valves and bypass valves to bring the valve spindle to the surface where it shall be located in a standard valve surface box. Each box shall be in the centre of a level concrete plinth at least 3 m wide by 3 m long, or if circular 3 m in diameter, slightly raised 50 mm above the surrounding ground to avoid the valve box becoming over-grown. The thickness of the plinth shall be determined by the Contractor as part of his detailed design.

The contractor shall provide a valve identification numbering/tagging system. All valves shall be fitted with a metal tag showing identification number and details of services controlled and an index of all valves, their line function and number/tags shall be provided.

Unless otherwise specified, all valves, including actuated valves, shall be appropriately geared to facilitate manual operation by one person. Valves shall close by clockwise rotation and this shall be indicated on the hand-wheel. Hand-wheels shall be sized such that under normal conditions, the maximum load required at the rim is 20 kg.

All Valves should be of at least PN 10 pressure rating.

Valve of diameter 450 mm and above shall be provided with lifting eyes and shall have detachable bolted covers for inspection, cleaning and servicing.

All valves in the plant shall be provided with dismantling joint/Flexible joint/SS bellows for ease dismantling.

All the valves on the suction side shall be manually operated knife gate valve and delivery side of the Raw Sewage (IPS shall be of Motorised Knife gate type.

All the valves shall be provided with Bypass valve arrangement 10% of main valve size.

4.17.2 Gate Valves

Gate valves shall comply with IS 14846:2000 or BS EN 1171:2002 and be of the solid wedge gate type with non-rising stems. Where gate valves are used on the suction side of pumps, they shall be of the rising stem type.

Valves below 250 mm diameter may be of the resilient seated type.

The body tappings shall be to IS 554:1999 & IS 8999:2003 and fitted with bronze or gunmetal plugs.

The valves shall not contain any brasses which have more than 5% zinc. They shall incorporate cast iron bodies and gates fitted with gunmetal BS EN 1982:2008 LG2 aluminium bronze or nickel copper alloy components.

Valves 450 mm and over shall be fitted with integral bypasses and gate jacking screws. The valve bodies shall have straight through bores (without seating recess).

Cast iron operating hand-wheels not greater than 450 mm in diameter shall form part of the valve's equipment. The required operating torque for opening and closing the valves shall be such that one man shall easily be able to perform these operations.

Gate valves shall be provided with hand-wheels or for below grade or below grating, square nut heads for tee-key operation.

A gate valve shall be fitted between risers and air valves. This shall be fitted with a suitable bevel gear arrangement to bring the operating spindle up to the chamber roof

away from the access cover area such that the valve can be operated from on top of the chamber roof with a standard bar and valve key. The valve shall be drop tight and the fixings shall permit removal of the air valve whilst the main is under full operational head.

The material of construction of valve shall be as follows:

Body	:	Ductile (SG) Iron IS 1865 Gr.500/7.
Gate	:	Ductile Iron with EPDM rubber encapsulated.
Spindle	:	Stainless Steel BS:970 Gr 431.
Bush	:	Bronze IS: 318 Gr LTB2.
Internal Fasteners	:	SS 316L.

4.17.3 Non-return Valves (Swing Check Pattern)

Check valves shall comply with IS 5312 or BS EN 12334:2001swing type Class PN10 and shall be of the swing type suitable for either vertical or horizontal use. With clean water, multi-flaps or split disc check valves may be used.

The valve design shall ensure closure in the shortest possible time following deceleration of the water column, ideally reaching its seat without slamming at the instant forward motion of the column cases.

Flow velocity through the valve shall not exceed 2.5 m/s.

They shall have Ductile Iron/Cast Iron bodies, discs and covers, fitted with gunmetal BS EN 1982:2008 LG2 seats and stainless steel SS 316L hinge pins. The End bearing shall be gunmetal and soft packed glands shall be fitted.

Valves for wastewater shall be fitted with external levers and balance weights complete with guards. Check valves used in association with pumps shall be fitted with limit switches operated by external cams secured to extended spindle. A positive action of the limit switch shall be obtained within 10^{O} of the valve seating position. Limit switch housings shall have an Index of Protection rating IP 55.

4.17.4 Knife Gate Valves

Knife gate valves shall be bi-directional, of the bolted bonnet type with wafer face-to-face flange connections. The knife gate valve shall be as per MSS SP-81-2001, ANSI/AWWA C520-10

The valve body, flanges, stuffing box and superstructure shall be cast iron IS: 210 Gr FG 260/Ductile (SG) Iron BS 2789 Grade 420/12. All wetted components consisting of body lines, gate and seat, raised portion of flanges face, packing chamber and chest areas shall be of type ASTM A 240 type 316L stainless steel. Packing Material shall be of Graphite Synthetic yarn.

The gate shall have a round bottom with a knife edge. Both sides of the gate shall be finish ground. The valve stem shall be stainless steel and shall have double pitch threads. Stem and gear shafts shall be of IS: 6603-2001 Gr.304, Cr-18, Ni, 10. Seal shall be PTFE.

The hand wheel shall conform to IS:210 FG 260.and be grey cast iron. The packing gland shall be plastic coated. Removal and replacement of worn or deteriorated packing shall be accomplished without necessitating removal of the valve from the pipe line. The valve body port shall be no less than 95% of nominal pipe diameter. Body of the valve shall be designed for 1.5 times the rating of the valve. Valve shall close with clockwise rotation of the hand wheel. The direction of closing shall be marked on the hand wheel. Valves shall be non-rising spindle type.

4.17.5 Pinch Valves

Pinch valves shall be of the full bore type employing a natural rubber sleeve surrounded by a cast iron or aluminium body as per BS EN 13397:2002. Valve closure shall be effected by applying compressed air directly to the annulus surrounding the sleeve. Sleeves shall be readily replaceable. An air filter and pressure regulator shall be provided on the air line to each valve.

4.17.6 Non-Return Valves (Lift Pattern)

Lift pattern check valves shall be used only for clean water service and small bore pipework. Valves shall be manufactured in accordance with BS 5154:1991 and shall incorporate bronze bodies and guided bronze discs. Bodies shall be screwed with BS 21:1985 taper threads.

4.17.7 Backflow Preventer

Backflow preventers for use on city/potable water shall conform to IS: 2065 -1983 Code of Practice for water supply in buildings and National Building Code of India – 2005, The Indian Plumbing Code and all local requirements.

Backflow preventers: Continuous pressure zone type with dual check valve design, dual isolation gate valves, bronze internals, inlet strainer, intermediate atmospheric vent and drain.

4.17.8 Ball Valves

Ball valves shall be of the lever operated quarter turn top entry pattern and shall comply with IS 9890:1981, BS EN 1983:2006, BS EN ISO 16135:2006, BS ISO 7121:2006.
Valves may be flanged or fitted with double union ends to suit the size and type of connecting pipework. Materials shall be compatible with the service fluid.

4.17.9 Automatic Air Relief Valves

Air Relief Valves shall be double orifice pattern and shall be designed to meet the following conditions automatically:

a) Discharge air during charging of the pipework
b) Admit air during emptying of the pipework
c) Discharge air accumulated at local peaks along pipelines under normal operating conditions.

Conditions (a) and (b) shall be met by the employment of a large orifice capable of handling large volumes of air at a high flow rate and condition (c) by a small orifice capable of discharging small quantities of air as they accumulate. The area of the large orifice of the valve shall be at least 1.5% of the area of the main pipeline. An array of air valves will be provided on large diameter pipelines to provide the required orifice area.

Double orifice air valves shall combine both large and small orifices within one valve. All air valves valve shall be of a kinetic design including features to avoid premature closing of the valve by the discharging air. The sealing surfaces shall be remote from contact with wastewater and the valve shall be operated by means of a stainless steel stem from a float in large chamber specifically designed to preclude interference by debris in the wastewater.

The valves shall be fitted with flanges compliant with BS EN 1092-2 1987 PN16 and the nominal diameter of the flange shall be equal to the diameter of the large orifice. Only in

exceptional cases shall the Engineer's Representative approve a valve design where the large orifice is smaller than the nominal diameter of the flange.

Air valves shall be fitted with an isolating gate valve which shall comply with BS5163 or other approved equivalent standard and have mitred gearing and end flanges to BS EN 1092 or ISO 2531. In case where an array of air valves is provided each valve shall have an individual isolating gate valve.

Fixing nuts and bolts supplied by the manufacturer shall be as specified.

All air valves shall be provided with a tapping point in the body of the valve (above the isolating gate valve suitable for connecting a pressure gauge and shall also have a body drain plug of an approved tamper proof design on the liquid float chamber.

All air valves shall be factory tested to 24 bars and be suitable for a working pressure of 16 bars.

All materials used in the manufacture of the valves shall conform to the following minimum standards:

Material Specification – Air and Gas Relief Valves

Float chamber, flange and cover	Cast iron to BS EN 1561 or ductile iron to BS EN 1563 or other approved equivalent standard
Liquid float and guide	Copper, polycarbonate or approved equivalent
Air Valve Float and Guide	Polycarbonate or approved equivalent
Orifices, guides and mechanisms	316L stainless steel to BS EN 10088 type 1.4404 or 1.4432 or other approved equivalent standard
Sealing Rings	Moulded Rubber (EPDM) or suitably approved equivalent.

Air valves shall be coated internally and externally with fusion bonded epoxy at the place of manufacture. The coating shall be a minimum of 305 microns thick and shall be approved for contact with potable water for temperatures up to 50 ^{O}C.

4.17.10 Pressure Relief Valves

Relief valves shall be of the poppet type. The valves shall be rated to pass at least 200% of the rated flow at the point of connection, at 150% of the working pressure.

Safety valves shall comply with BS 6759:1984 part 3, BS EN ISO 4126-1:2004. They shall be designed to blow off at the specified pressure and re-close and prevent further flow of fluid after normal pressure conditions of service have been restored. The pressure/temperature rating shall be in accordance with Table PE-1 in BS 1560: Part 2.

Shell material shall be from the materials listed in Table PE-1 BS 1560: Part 2.

The pressure setting of the valve shall be manually adjustable and secured with a brass padlock. The valve shall be adjusted to the maximum safe working pressure at the manufacturer's works and the setting secured with a brass padlock. A test certificate and duplicate keys shall be provided. A wire lock and lead seal, stamped with the pressure setting, may be used in place of the padlock.

4.17.11 Automatic Drain Valves (Air Service)

Automatic drain valves shall be of the float-operated plug type designed to automatically and continuously drain oil, water and other condensate from the pipework.

They shall be sized for continuous operation at the maximum stated working pressure.

Where shown on the Drawings, the drain valves shall incorporate a manual condensate drain facility.

4.17.12 Diaphragm Valves

Diaphragm valves shall generally comply with BS EN 13397:2002 and shall be of the non-rising spindle type.

Valves shall be suitable for tight shut-off applications and shall be suitable for operating at PN 10 unless otherwise specified. Valves suitable for manual operation shall be provided with a hand-wheel with indicators to show the position of the valve.

Where valves are to be actuated, it shall be supplied complete with integral mounting flange for the actuator. Actuators shall be fitted at the valve manufacturer's works. The valve body shall be of a two piece design, to facilitate the easy removal of the diaphragm.

Valves specified for use with acid shall be of the weir type and shall be manufactured from cast spheroidal graphite (sg) iron with a perfluoroalkoxy (PFA) lining. External parts of the body shall be coated in a phosphate primer and alkyd paint finish. Diaphragms shall be manufactured from polytetrafluoroethylene (PTFE) faced butyl rubber. Bonnets shall be sealed.

Valves specified for use with lime slurry or other abrasive materials shall be of the ‘full bore’ or ‘straight through’ type. The body shall be fabricated from cast sg iron, with a grade AA soft rubber lining and diaphragm as supplied by Saunders Valve Company Ltd or equal and approved. External surfaces shall be coated in a phosphate primer and alkyd paint finish.

Valves specified for use with polymer, urea and phosphate shall be of the full-bore or straight-through type. The body shall be fabricated from cast sg iron, with a polypropylene rubber lining. The diaphragm shall be fabricated from a butyl-rubber blend or similar and approved. External parts of the body shall be coated in a phosphate and alkyd paint finish.

(i) Full Bore Diaphragm Valves

Diaphragm valves shall generally comply with BS EN 13397:2002 and shall be of the non-rising spindle type.

Valves shall be suitable for tight shut-off applications and shall be suitable for operating at PN 16 unless otherwise specified. Valves suitable for manual operation shall be provided with a hand wheel with indicators to show the position of the valve.

Where valves are to be actuated, it shall be supplied complete with integral mounting flange for the actuator. Actuators shall be fitted at the valve manufacturer's works. The valve body shall be a two piece design, to facilitate the easy removal of the diaphragm.

Valves specified for use with lime slurry or other abrasive materials shall be of the ‘full bore’ or ‘straight through’ type. The body shall be fabricated from cast sg iron, with a grade AA soft rubber lining and diaphragm as supplied by Saunders Valve Company Ltd or equal and approved. External surfaces shall be coated in a phosphate and alkyd finish.

4.17.13 Corporation Cocks

Corporation cocks shall be suitable for installation in a tapped boss and shall comply generally with the requirements of BS 2580:1979.

4.17.14 Plug Valves

Plug valves shall be of the cast iron or cast steel regular pattern, complying with BS 5158:1989, IS 10459:1983.

Plug valves for liquid/sludge application shall be non-lubricated type with gland or other approved shaft seal.

Plug valves for digester bio-gas application shall be lubricated type with gland or other approved shaft seal. Lubrication shall be by using a portable forced high pressure grease gun with Alemite spring loaded button head type (threaded type) on the shaft end(s) and machined ports/channels in the shaft/plug as required. All valves suitably approved for the application.

Valves below 125 mm NB shall be wrench or hand-wheel operated, larger valves shall be gear operated.

Alternative to lubricated seal type plug valves: High performance leak-less type, all suitably approved for the application.

4.17.15 Flap Valves - Cast Iron

Non-return flap valves shall be designed as per DIN 87101 to suit the hydrostatic conditions at a particular location, automatically to open when the downstream level falls below the upstream level and close when the water levels equalise.

Valves specified as cast iron construction shall be heavy pattern manufactured of cast iron complying with BS EN 1561:1997 not less than Grade 220 to the dimensions indicated on the Drawings.

They shall be drilled for bolting to concrete, flanged or socketed to suit pipework. Flaps shall be double hung with non-ferrous hinge pins.

Seating faces shall be of cast iron, gunmetal to BS EN 1982:2008 - LG2 or bronze to, (BS 2874) – CZ121 hand scraped for a watertight finish.

4.17.16 Flap Valves - Plastic

Plastic non-return flap valves shall be suitable for either wall or pipe flange mounting.

Doors shall be constructed from flexible reinforced plastic with the hinge forming an integral part. Frames shall be of epoxy coated mild steel or welded stainless steel grade 304 S16 and all fasteners shall be of stainless steel.

Flap valves shall withstand a maximum seating head of 6 m.

4.17.17 Foot Valves and Strainers

Foot valves shall be the vertical lift disc pattern incorporating upper and lower guides with IS 4038:1986. Flow velocity through the valve shall not exceed 2.5 m/s. Valves shall have ductile iron bodies and discs with gun metal seats.

Valves shall be fitted with a galvanised sheet metal strainer with an open area equal to at least three times the cross-sectional area of the valve bore.

4.17.18 Solenoid Control Valve

The solenoid control valve shall be of the two way, normally closed type and shall be suitable for mounting at any angle. The solenoid shall be rated for continuous duty. A

manual override facility shall be incorporated. The valve body shall be brass and the internal parts, stainless steel or brass.

For valves suitable for pressures up to 16 bar, the opening and closing time shall be adjustable to minimise surge effects.

4.17.19 Butterfly Valve

Butterfly valves shall be of double eccentric and metal seated type generally as per BS EN 593 and IS 13095.

Butterfly valves shall be suitable for bi-directional pressure testing. The valves shall be of double flanged long type.

The valves shall be electrically/pneumatically/manual operated to suit the process requirement mentioned elsewhere in this tender document. The valve shall be free from induced vibrations. Valve shall be suitable for mounting in any position. The valve seat shall be of metal to metal seated design for Process Air and Backwash Air application. All fasteners shall be set flush so as to offer the least resistance possible to the flow through the valve.

Rings shall be bi-directional self-adjusting suitable for pressure or vacuum service. Valve shafts shall be a one-piece unit extending completely through the valve disc, or of the "stub shaft" type, which comprises two separate shafts inserted into the valve disc hubs.

Body	Ductile (SG) Iron IS 1865 Gr.500/7.
Disc	Ductile (SG) Iron IS 1865 Gr.500/7.
Shaft	Stainless Steel BS 970 Grade 431 S 29.
Body Seat	Stainless Steel ASTM A 276 Gr.316L / CF3M.
Disc seat	Stainless Steel ASTM A 276 Gr. Gr.316L/ CF3M.
Shaft Bearing	Bronze backed with PTFE.
Internal Fasteners	Stainless steel AISI 316L.
Nuts, bolts & washers for pipe flanges	High tensile steel hot dip galvanized.

Valve of diameter 450 mm and above shall be provided with enclosed gear arrangement for ease of operation. The gear box shall be of worm and worm wheel design type, totally enclosed, grease filled and weather proof. The operation gear shall be such that they can be opened and closed by one man against an unbalanced head of 1.15 times the specified rating. Valve and gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 200 N. 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.

Material of construction of valves shall comply with following requirement:

The disc shall be designed to withstand the maximum pressure differential across the valve in either direction of flow. The disc shall be contoured to ensure the lowest possible resistance to flow and shall be suitable for throttling operation.

Valves shall be capable of closing against the maximum flow that can occur in system. The shaft shall be designed to withstand the maximum torque that will be imposed by the operator. It shall be secured to the discs by tapered stainless steel cotter pins.

Valves shall be provided with position indicator to show the position of the disc, mounted on the driven shaft end.

Rigid adjustable stop mechanism shall be provided within the gear box or elsewhere on the valve to prevent movement of the disc beyond the fully open or closed position (i.e. set points).

4.18 Operator Headstocks/Pedestals

All penstocks and valves fitted with a hand wheel or actuators and not mounted directly on the penstock or valve shall be provided with cast iron headstocks/pedestals. The height from the operating floor to the top of the hand wheel (centre line for vertically mounted hand wheel) shall be 750mm to 800 mm and conform to IS 3042:1965, IS 13349:1992, IS 9737:1981.

Headstocks shall be complete with indication as described below:

- Rising spindle penstocks and valves: A graduated transparent plastic cover tube shall be fitted over the spindle.
- Non-rising spindle penstocks and valves with support pillars: An indicator of the slot and pointer type integral with the support pillar shall be provided.

Hand wheels shall be of cast iron and shall have the words OPEN and SHUT and direction arrows cast-in on the upper side of the rim. Where operational conditions dictate the hand wheel shall operate through an enclosed grease lubricated bevel gear. Hand wheels shall be painted red.

Where headstocks are structurally mounted above a valve chamber, or not aligned with the penstock or valve then operating spindle extensions shall be provided between the penstock or valve and the headstock. These shall be suitable for length adjustment during assembly on site and shall be fitted with at least two universal couplings adjacent to the valve and to the headstock. The two couplings shall be so orientated as to give a linear transmission of rotational movement between headstock and valve stem.

Where headstocks are not mounted on a flat concrete surface, provide each headstock with a structural support bracket fastened to both the side and top of the concrete wall.

4.19 Electric Valve and Penstock Actuators

Electric valve and penstock actuators shall be in accordance with the Electrical General Specification.

4.20 Pneumatic or Hydraulic Actuators

Pneumatic or hydraulic actuators shall be of compact reliable construction and shall be in accordance with BS EN 15714:2009 part 3 & 4, BS EN ISO 5211:2001 sized to guarantee valve operation at maximum possible differential pressure.

Piston actuators shall be double acting with an adjustable air cushioning device to prevent piston slam.

The barrel shall be of cold drawn chrome-plated steel, the piston rod of precision ground steel and the piston head of aluminium alloy or malleable iron. Fixing bolts shall be of high tensile stainless steel.

Diaphragm actuators shall be the spring opening or spring closing type and shall incorporate a rolling diaphragm and coil springs within a spring case. Additional equipment for hand operation, positioning and indication shall be provided where specified.

4.21 Penstocks

This specification shall apply to all penstocks for use with sewage and/or water. And conform to IS 3042:1965, IS 13349:1992, BS EN 1561:1997 Grade 220, ANSI/AWWA C 560-07.

Frames and doors shall be of robust construction, suitable for the duty for which they are intended. With the exception of Plastic Gate Penstocks, they shall be capable of withstanding the impact of floating debris. Unless weir penstocks are required, penstock frames shall be of the continuous (closed top) design.

All surfaces shall be self draining and shall not readily collect rags, grit or faecal matter. The design shall allow for cleaning the frames and doors by water jet.

Where penstocks are to be channel mounted then the frame, aperture and gate shall be profiled to suite the channel, e.g. square or rectangular. All channel mounted penstocks shall be provided with resilient seated flush inverts where the frame design allows.

Unless the penstocks are meant to be fully submerged (i.e.: acting as submerged port), the top of the gate opening, when the gate is in the open position, shall be at least 300 mm above the maximum liquid level.

All penstocks shall be supplied with cast-in-place 'F' type wall thimbles of same material as the penstock.

Unless stated otherwise in the Employer's Requirements or data sheets, where penstocks are to be wall mounted they shall be suitable for an on or off seating pressure up to a maximum given below. The following leakage rates shall apply for all penstocks whether wall or channel mounted:

Penstock Type	Head	Maximum Leakage Rate
Metal seated penstocks	6 m	30 l/m of sealing perimeter per hour
Plastic / rubber seated penstocks	4 m	20 l/m of sealing perimeter per hour
Plastic gate penstocks	3 m	20 l/m of sealing perimeter per hour

Wedges, where fitted, shall be adjustable, faced with bronze and shall have a large contact area. All wedges and/or sub-components shall be readily renewable. The Contractor shall ensure that the wedge adjustment is unaffected by vibration and normal use.

The Contractor shall ensure that all materials used in the construction and installation of penstocks, valves and actuators are selected to prevent galvanic corrosion. Special precautions shall be taken to prevent corrosion at joints or points of intimate contact between metals of differing electrochemical potential. Wherever possible, electrochemically compatible materials shall be used. Contact between stainless steel fixings and galvanised fittings shall be prevented by plastic sleeve washers.

All parts shall be of adequate section and ribbed where necessary to withstand the hydraulic and operating forces.

Particular types of penstocks shall be constructed in accordance with the requirements detailed below:

4.21.1 Cast Iron Penstocks (Not Used)

4.21.2 Cast Iron Penstocks Using Plastic and/or Rubber Seals

The penstock frame, gate, spindles and all other accessories shall be of materials as specified above for Penstocks. Sealing shall be provided by suitable nitrile or neoprene rubber fitted between the frame and gate.

Material of Construction:

Wall Thimble, Frame and Gate	:	Cast Iron as per IS 210 FG 260.
Seating faces, Stem	:	SS 316L
Seals	:	UHMWPE/Suitable as per service fluid.
Fasteners, Stem Coupling, Stem Nut	:	SS 316L
Lifting mechanism, Pedestal gear house cover and stem guide	:	Cast Iron as per IS 210 FG 260.
Lift nut	:	Bronze ASTM B 148 (CA952, CA954 or CA958).

4.21.3 Stainless Steel Penstock

Doors and frames of stainless steel shall conform to BS EN 10088:1995 grades 1.4404, 1.4432 or 1.4435 (316L stainless steel) dependent on application. 316L stainless steel is the minimum required for chlorinated potable water and coastal situations. Sealing faces shall be of continuous seal design resilient low friction UHMWPE or equivalent material.

Material of Construction:

Frame	:	SS 316L stainless steel.
Gate	:	SS 316L stainless steel.
Stem	:	SS 316L.
Seals	:	UHMWPE/Suitable as per service fluid.
Fasteners	:	SS 316L

4.21.4 Plastic Doors

The door frame shall be made from Mild steel to BS EN 10025:1993 grade S275 or stainless steel to BS EN 10088:1995 grades 1.4404, 1.4432 or 1.4435 (316L stainless steel). Mild steel frames shall be protected for either sewage, potable water, or seawater. Doors shall be manufactured as a composite sandwich construction comprising a lightweight cellular core with a fully welded steel box section matrix between two other skins of rigid, compressed plastic which is asbestos free, ultra violet stabilised and non-toxic. All materials shall be chemically bonded and sealed. Non rising spindle doors shall have a stainless steel lining tube inside the central vertical box section of the inner matrix. Seals shall be fitted to the frame.

4.21.5 Lightweight Penstocks

Deleted

4.21.6 Weir Penstocks

Materials of construction shall be as for conventional penstocks.

The weir penstocks shall be the screw-down type with unobstructed openings. The rising spindle shall be attached to a horizontal lifting beam above the opening and operate by lifting rods fitted to each side of the gate.

Indicators with metric graduations shall be fitted for the application.

Motor Operated weir penstocks shall be lockable at any position.

Material of Construction:

Wall Thimble, Frame and Gate	:	Cast Iron as per IS 210 FG 260.
Seating faces, Stem	:	SS 316L
Seals	:	UHMWPE/Suitable as per service fluid.
Fasteners, Stem Coupling, Stem Nut	:	SS 316L
Lifting mechanism, Pedestal gear house cover and stem guide	:	Cast Iron as per IS 210 FG 260.
Lift nut	:	Bronze ASTM B 148 (CA952, CA954 or CA958).

4.22 Stoplogs

Stoplogs shall be wall mounted or located in channels as required. The logs shall be constructed from steel reinforced rigid polyester based urethane foam covered in a high tensile strength composite plastic or equivalent. The frame shall be fabricated from epoxy coated mild steel. Sealing between logs shall be maintained by a neoprene strip overlaid by a strip of low friction plastic to facilitate log removal. Under normal operating conditions, the leakage rate shall not exceed 20 1/hr for each metre of the periphery.

Unless otherwise specified, logs shall be provided in two sizes to provide different height combinations. Each log shall have a stainless steel lifting pin near both ends. Lifting equipment suitable for the size of stoplog shall also be provided.

4.23 Pressure and Vacuum Gauges

Gauges shall comply with IS 3624:1987, BS EN 837-1:1998, ANSI/ASME B40.1 with fail safe blow - out backs and shall, unless otherwise specified, be of not less than 100 mm diameter. Scales shall be calibrated in both psi and bar with zero representing atmospheric pressure. The maximum scale reading shall be 150% of the working pressure. Lettering shall be black on a white background. Where the working fluid is of a dirty or corrosive nature, gauges shall be protected from the working fluid by an all stainless steel diaphragm or similar arrangement. All gauges shall be fully protected from dust and water ingress and shall be provided with a suitable isolation valve on the supply line adjacent to the gauge. Gauges on the suction side of equipment (e.g. pumps) shall be compound type.

4.24 Thermometers

Temperature gauges shall be provided at all points on equipment/piping systems (inlet/ outlet) where heat is used and monitored.

5 PUMPING PLANT (NOT USED)

6
6
6
6
6

6 SEWAGE TREATMENT PLANT

6.1 Screening Plant

6.1.1 General

All necessary appurtenant fittings, materials, components etc. not specifically mentioned herein or elsewhere, but necessary to ensure the complete and proper installation shall be provided, commissioning and working operation of the process equipment and systems.

All screens shall be designed to operate in concrete open channels passing raw sewage and storm water containing solids and faecal matter.

All metal components of the screening equipment **in the channel and in contact with sewage** shall be made from grade 316L stainless steel.

The electric drive motors shall be suitable for outdoor wet weather conditions, TEFC and explosion proof.

Each Screen shall have a means of isolation (upstream and downstream) via the use of Thimble mounted Rising spindle, upward opening motorised Penstocks.

All screening equipment shall be provided with a common collection conveying system, screenings organic washer system and screenings dewatering compactor.

The screen control panels shall also control the operation of the compactors and common screen conveyor systems.

Screen shall have Auto Jam Removal feature.

6.1.2 Raked Bar Screens

Raked Screens shall be of the inclined bar type, with an inclination no greater than 15 degree to the vertical and designed to remove solids up to **75mm** in diameter conforming to IS 6280:1971.

(i) General Design Data

All mechanical bar screens shall be provided with all accessories and control panels from a single source supplier with sole responsibility for all equipment of this specification.

The screens shall be automatic mechanically operated, self cleaning inclined bar screens of the chain operated rake type, designed to retain and remove floating matter and other debris from a channel flow. The screenings are to be cleared by an ascending series of rakes positively engaging the bar rack from the upstream side, starting at channel invert and travelling upwards to the chute where screenings are discharged on the downstream side of the screen in to a screenings conveyor.

The screen shall be supplied as one complete assembled unit without need for field assembly.

All the screen equipment shall be suitable for continuous operation in a highly corrosive atmosphere. The screen shall be installed by lowering down into the channel with the main side supports bolted/ anchored in the channel side walls and the base of the channel. All components will be constructed from 316Lstainless steel or better for corrosion and wear resistance, strength and a long useful life. All fasteners, including anchor bolts for assembly and installation, will be supplied with the screen and shall be in 316L stainless steel.

All replaceable and wearing parts shall be of standard, accurate dimensions. The complete bar screen shall be factory assembled and tested prior to delivery to site.

The equipment shall be designed for minimum maintenance, repair or replacement. Components needing periodic maintenance should be easily accessible from the operating level.

The screens shall generally be manufactured from of non-sparking materials, especially where moving components touch.

(ii) Stainless Steel Finishes

The support framework, bar rack, rakes and other areas not totally visible shall have a mill finish. Side protection panels and other areas visible shall have a No 1 or 2B finish.

The dead plate and discharge chute shall have a smooth polished finish. The discharge chute top surface shall have a coating of Teflon or a 1.5mm thick Teflon sheet riveted in place.

(iii) Frame and Supports

Screens shall have a side frame width to match the channel width designed for bolting to the channels concrete walls. Recessed frames cast into the concrete are not acceptable.

The screen framework shall be constructed of 316L stainless steel with a minimum thickness of 5 mm. Parts fastened by welding or bolting shall be braced as necessary to ensure a rigid structure. The side frames shall be a minimum of 5mm formed to a U channel profile. The frame shall include cross-connect support beams with U channel-profiles with a minimum thickness of 5 mm on the front above the maximum water line.

The frame shall include horizontal supports at the operating floor level. The horizontal supports shall extend beyond on the walls of the concrete channel. The horizontal supports shall be designed to allow at least 100mm horizontal distance between the vertical face of the channel wall and the anchor bolts. The supports shall sit on a 25-50mm grout bed.

The base part of the frame shall be of the flush bottom type with a minimum 8mm thick flat plate resting directly on the channel invert.

The top of the frame shall be provided with at least four heavy duty lifting lugs/eyelets, permanently attached.

(iv) Bar Rack

Screen bars shall be continuous and constructed of 316L stainless steel bars.

The bars shall be minimum 12 mm x 6 mm width x 50mm deep trapezoidal shape.

The bars shall be individually fastened to the framework (not welded) for easy replacement. Bars shall extend from bottom of the screen grid at the channel invert to at least 200 mm above the maximum water level where they will be fastened to the lower side of the dead plate.

(v) Dead Plate

The dead plate shall be fabricated from minimum 5 mm thick 316L stainless steel plate with 316L stainless steel reinforcement on the downstream side. The plate shall extend from the top of the rack bars up to the top of the discharge chute.

(vi) Chute

A discharge chute with side panels shall be provided to divert screening discharged from the screen to the portable screening container. The discharge chute shall be fabricated from minimum 4mm thick plates of 316L stainless steel and shall be mounted at an angle of not less than 30 degrees to the vertical. Panels shall be positioned on both sides to protect from splashing.

Easily removable transparent covers of 6mm thick impact resistant long lasting polycarbonate material shall be provided to prevent screenings from flying out from the chute.

(vii) Rake

The screen shall be of multi rake bar type and shall be of shovel shaped design such that screening will not wrap around its line or the stationary bars and will not fall back in to the channel during the cleaning cycle. Number of rakes shall be based on depth of screening.

Screenings transported to the top of the screen shall be discharged positively by means of a scraper mechanism to the discharge chute.

The rakes shall run in guides on both sides to ensure proper engagement. The rake shall be fabricated in 316L stainless steel a minimum 12 mm thick with minimum 6 mm thick reinforcement profiles and 10 mm thick side plates. The raking tines shall have the tooth profile precision cut from a single piece of sufficient thickness and depth to ensure adequate stiffness and strength to cope with the loads and forces encountered.

The rake tines shall penetrate into the screen bar spacing to ensure that screenings are completely cleared during each lifting operation. Rake tines shall be mechanically engaged into the screen bars. During each cleaning stroke, the raking tines shall engage into the bottom of the bar screen grids at the channel invert.

(viii) Potable Screening Container

Portable screenings containers made of galvanized steel shall be provided to store the screenings until time of pick up. Minimum two Screenings Containers shall be provided at the screening chamber. 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 containers shall have hinged covers and their design shall permit their being lifted by an overhead hoist or packer truck. The container will have four wheels each of about 20 cm diameter and two of which shall be swivel castors. The maximum height of container including wheels shall be 66 cms. The sides shall be constructed of 12 gauge steel. The bottom of container shall be made of 5 mm plate steel. The containers shall be reinforced with 50 mm x 50 mm x 5 mm angle.

(ix) Rake Drive Mechanisms

The mechanism the travel of the rake and engaging and disengaging the rake with the bar rack will be located in the side frames. The machined components such as shafts, sprockets, chains, guided bearings etc. shall be of corrosion resistant steel duly hardened and stress relieved.

The drive design should be such that the movement of the rakes is smooth and the engagement of tines with the bar rack and dead plate is firm and uniform along the width of rake throughout the rake travel without requiring frequent adjustments.

The rakes, drive chains, chain guides, chain sprockets, bearings and axles shall be fully replaceable without having to remove the screen from the channel.

The drive shaft shall be 316L stainless steel having high corrosion resistance, tensile and torsion strength.

The upper and lower sprockets should be solid single piece sprockets with tooth width of minimum 25 mm. The sprocket teeth shall be hardened to withstand wear.

The chain shall be roller type with minimum 125 mm pitch. The rollers shall be of 316L stainless steel and shall have high corrosion and wear resistance. The chain links of high tensile strength and hardened pins shall be of 316L stainless steel. The ultimate strength of the chain shall be a minimum of 14,000 kg force.

The chain tightening frame, with heavy duty tensioning screw, shall house flange type grease lubricated heavy duty bearings for the upper shaft. The frame assembly shall be fabricated in grade 316L stainless steel.

Each of the lower sprockets, mounted on two separate single piece stub shafts with bonded ceramic collars, will have self lubricating bearings of high wear resistant material such as polyethylene or better and will be suitable for being submerged in sewage.

The chain guide shall be of minimum 65 x 35 x 5 mm L-section in 316L hardened stainless steel to withstand wear and abrasion shall be fixed to the screen frame for full height of travel.

(x) Scrapers

The scraper mechanism shall have a scraper blade of wear resisting, strong synthetic material that shall positively discharge the screenings from the rake, at the top of the screen dead plate, to the chute and return to its resting position by means of a compression spring.

(xi) Screen Side Panels

Where moving parts of the screen are accessible from the operating floor level, 316L stainless steel cover panels shall be provided for maintenance access. The panels shall be removable or hinged.

(xii) Elevated Platforms

Where certain components of the screen are 3.0m or greater above the operating floor level, an elevated work platform shall be provided for maintenance access. The platform shall be provided complete with its own support system, hand railing, checker plate flooring and access ladder. All materials shall be of 316L stainless steel.

(xiii) Electrical Motors and Drives

The electrical drive motor shall be TEFC, explosion proof, premium efficiency operating on a 415 volt, 3 phase, 50 Hz electric supply. The drive motor shall be an inverter duty rated motor with a 1.0 service factor, rated for continuous duty. The motor shall be controlled by a VFD (variable frequency drive) rated for continuous operation. An oil filled type gear box drive shall be provided if necessary.

(xiv) Electrical

All electrical components (i.e. junction boxes, terminal boxes, conduit/wiring etc.) to be mounted on the screen to shall meet the explosion proof requirements of a hazardous area Zone 1.

(xv) Controls and Control Panels

A free standing control panel shall be provided suitable for an outdoor wet weather location and padlock-able. The Control panel shall be of 316L stainless steel, floor

mounted with IP 65 protection and shall be rated NEMA 4x. The control panel shall include all equipment required to operate and control the bar screen.

An explosion proof rated ultrasonic differential level sensor system shall be provided complete with 316L stainless steel mounting for installation in channel. The sensors shall form part of the automated controls of the screen operation.

A VFD (variable frequency drive) and a PLC (programmable logic controller) shall be provided inside the control panel along with other components as specified herein. The VFD shall have solid state overload integral and shall include discrete and analogue input and outputs.

(xvi) Operation Control and Instrumentation

The control panel shall include a main 3-way selector switch for auto/ manual/stop modes of operation. In the auto mode there shall be a sub-selector switch provided for automatic level differential mode or timer mode.

Automatic Level Differential Control System

In this mode, PLC shall control the VFD to operate the screen for variable torque loads at two speeds and through the automatic reversing/forward shuttle sequence.

The rake drive will start operating at low speed in the forward direction when a preset differential in the upstream and downstream levels across the bar rack is sensed by the ultrasonic level sensors.

If the level differential reaches the higher set point the drive will move at higher speed.

When an obstruction is encountered in the rake operation and over-current is detected, the rake drive shall move to low speed then stop and then run in reverse for set distance and again move forward to clear the obstruction. This forward reverse cycle shall repeat twice and if the obstruction is still not cleared, the drive shall stop and the alarm shall sound. Mechanical over-load sensing for initiating the alarm shall not be acceptable. If the obstruction is removed in forward/reverse operation the screen shall resume operation in the normal forward mode.

Timer Control System:

In the timer mode, the screen will operate at preset intervals for set time durations and stop for a fixed time period. The on/off times shall be adjustable and set depending on the rate of accumulation of screenings.

In this mode of operation, when an obstruction is encountered the automatic reversing operation will occur as described above.

Manual Control System:

In the manual mode a 3-way sub selector switch is to be provided for forward-stop-reverse operation.

(xvii) Control Equipment:

The control panel shall include, but not be limited to:

- Heavy duty power on/off switch;
- Programmable controller, relays, necessary transformer starters, two solids state timers;
- Main selector switch for auto/manual/ stop;
- Sub-selector switch for level differential/timer with indicating light;
- Sub-selector switch for manual mode: forward/reverse/stop;
- Indicating light Auto

- Indicating light Manual
- Indicating light Level differential control
- Indicating light Timer control
- Indicating light Forward operation
- Indicating light Reverse operation
- Indicating alarm High water level
- Indicating alarm Drive over load
- Alarm horn
- Alarm silence button push type
- Red emergency stop mushroom push button
- Ultrasonic differential control
- Limit switch for high water.

(xviii) Fasteners

All fasteners, bolts, nuts, washers, screws, anchors etc. shall be 316L stainless steel.

6.1.3 Step Screens (Not Used)

6.1.4 Fine Rake Bar Screen (Not Used)

6.1.5 Screenings Dewatering Screw Compactors (Not Used)

6.1.6 Screen Organics Washing (Not Used)

6.1.7 Common Screenings Conveyor System (Not Used)

6.2 Grit Removal Plant (Not Used)

6.3 Fat, Oil and Grease Removal (Not Used)

6.4 Sedimentation Plant (Not Used)

6.5 Aeration Plant (Not Used)

7 SLUDGE SYSTEM PLANT (NOT USED)

8 BLOWERS AND COMPRESSORS (NOT USED)

9 CRANES & LIFTING EQUIPMENT

9.1 Portable Davit

Portable davits shall comprise a removable pillar with a swinging jib arm sized to span the pick-up and set-down points. The pillar shall fit into a flush mounted socket set in concrete. A self-sustaining block and tackle or enclosed drum winch shall be provided with a safe working load of not less than twice the weight of the item to be lifted. A safety hook and quick coupling device for attachment to the lifting chain shall be fitted to facilitate rapid removal of plant. All lifting equipment shall be clearly marked in accordance with safety standards. Portable davits shall not be used for loads exceeding 2 tonnes.

9.2 Manually Operated Overhead Crane/Hoist

Cranes shall be designed in accordance with IS 3177:1999 or BS 2573-1:1983 and runway beams shall comply with the requirements of the design of steel structures as set out in the Civil General Specification.

Manual hoists shall be complete with hand-chain, trolley, pulley block, hook, hand and load chains, brake and other accessories. Each hoist shall be operated on a monorail (I-beam). The factor of safety shall not be less than 5. The load chain shall be heat-treated to give ductility, toughness and shall conform to IS 3109:1982 (Part 1). The load wheel shall be made from heavy duty malleable castings.

The hand chain shall conform with IS 8324:1988 and 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 or heat treated alloy steel. Strength, quality of steel, heat treatment, face, pitch of teeth and design shall conform to IS 2535: 2004 Part 1 & 2.

Spur and helical gears must comply with IS 4460:1995 Part 1 to 3 and worm gears with IS 7403:1974. Bearings shall be ball and roller type conforming to I.S. 2513:1963.

Proper lubricating arrangements are to be provided for bearings and pinions. The brake for the lifting gear shall be automatic and always in action.

The safe working load is to be marked in such way that it is clearly visible from the operating level.

9.3 Electric Overhead Travelling Crane/Hoist

Cranes shall be designed and manufactured in accordance with IS 4137:1985, IS 3177:1999, IS 807:2006.

Electric 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, contractor panel, all wiring, limit switches etc. Electric hoists shall conform 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.

Rope drums shall be either cast or welded to sustain concentrated loads resulting from rope pull. Drums shall be machine grooved right and left with grooves of a proper shape for the rope used. 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. Hoist ropes shall be extra flexible, improved plough steel rope with a well lubricated hemp core and having six strands of 37 a wires per strand.

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.

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. Brake shall apply when either the motor controller or the main power switch is in 'OFF' position or in the event of power failure. Drive motors shall be designed for frequent reversal, braking and acceleration and shall be as per IS: 325. Pendant control switch, controllers and resistors, controls, electrical protective devices, cables and conductors, earthing guards etc. shall be as per IS:3938. Limit switches shall be provided for over hoisting and over-lowering. The electric hoists shall be of Class II duty. 25% overload test, speed tests, limit switch tests and brake test shall be conducted for the hoist and trolley at manufacturer's works.

9.4 Jib Cranes

Jib cranes shall be provided as necessary for the placing/removal of equipment etc. to/from areas not otherwise served by cranes/hoists. Jib cranes shall be as per IS 15419: 2004. Jib crane capacities shall be 1.25 times the maximum weight to be handled or 1.5 tonnes, whichever is the greater. The lift and reach of the cranes shall be suitable for location. The crane shall be capable of being swivelled 360 degrees. All materials used in the construction shall be corrosion resistant. Mild steel shall be galvanized. Ropes, chains and pulleys shall be of stainless steel construction.

9.5 Lifting Accessories

Lifting accessories shall include chains, slings, shackles, eyebolts etc.

Lifting accessories for submersible plant shall be stainless steel. Submersible plant includes submersible pump sets and mixers for both water and wastewater applications.

Lifting chains shall be of the short link type to BS EN 818-1 Short Link Chain for Lifting Purposes (Part 1 – Safety General Conditions of Acceptance) and BS 4942 Short Link Chain for Lifting Purposes: Parts 2 and 3.

Lifting chains shall be manufactured from short link stainless steel chain to EN 1.4404 (316L stainless steel) specification. The chains shall be of fully welded construction with rings or master links at each end and at approx. one metre intervals. Forged components such as rings, transition links or master links shall be manufactured from 316L stainless steel.

Lifting accessories shall have a safe working load equal to at least twice the weight of the plant to be lifted but not less the 500kg.

Submersible plant for wastewater applications less than 500kgs in weight may be supplied with 1 metre length lifting chain assemblies with blue rope extension. All other items of plant shall be supplied with full length chain assemblies. Chains (full length or one metre) shall be rated to lift twice the weight of each plant item, subject to a minimum SWL of 500kg.

Where 1 metre chains are specified, the pump set shall be extracted from the wet-well by using a certified snatch device to catch the one metre chain. The snatch device shall be attached to a suitably rated full length chain and shall catch the one metre chain by sliding down the blue rope extension.

Full length chains shall incorporate larger links with a minimum internal diameter of 50mm, spaced at a maximum of one m intervals along their length.

Where the chains remain attached to the plant during operation, they shall be securely fixed to the plant with corrosion resistant fittings. For full length chains, the loose ends of the chains shall be attached to a corrosion resistant hook, readily accessible from outside the wet well or wellhead. For 1 metre chains attached to blue rope, the loose ends of the blue ropes shall be attached to a corrosion resistant hook, readily accessible from outside the wet well or wellhead.

The length of the chains or ropes shall be such that when the pump sets are in position, the chains or ropes extend at least 1 m above the top of the wet well or wellhead.

10 STRUCTURAL STEELWORK AND FLOORING

10.1 General

Safe access, including flooring, handrails, staircases, ships ladders, ladders and step-irons, as appropriate, shall be provided as necessary to all areas and items of plant and equipment requiring any attention for operation and/or maintenance.

Any small areas of chequer plating or similar covering that are necessary to cover gaps between items of plant and the surrounding structure and any access ladders, platforms and handrails that must be attached to items of plant to facilitate operation, inspection or maintenance, shall be supplied and erected by the Contractor.

The Contractor shall provide adequate means of access to all hand-wheels, sight glasses, gauges, lubrication points and any other items to which access is necessary for routine operation and maintenance.

In damp and/or corrosive environments, flooring, handrails etc. shall be of GRP or Stainless Steel. Unless otherwise specified all areas of the Works shall be considered permanently damp and/or corrosive.

All walkways, stairways, including platforms shall have a clear space of 1m between the handrails.

All items supplied under this section shall be permanently stamped with the manufacturer's identification markings and the manufacturer shall be ISO Certified."

10.2 Open Grid Flooring (Open Mesh/Grating)

Open mesh decking shall be in accordance with IS 15836:2008 Part 1 & 2 / IS 2062:2006. The panels shall be constructed with bearer bars, depths to suit the span but not less than 38 mm deep. Adjacent panels and panels at the same level shall span in the same direction, unless specifically required for frequent access and shall be secured together by stitching bolts with a minimum of two fixing clips when supported on structural steelwork. The top edge of the bearer bars shall be serrated and shall be in addition to the bearer bar minimum depth.

Each panel shall be designed for a uniformly distributed load of 10 kN/m^2 with a maximum deflection of 1/240th of the span.

Open grid flooring (open mesh/grating) shall be structural grade stainless steel alloy AISI Type 316L. The stainless steel open grid flooring (open mesh/grating) shall be of the welded or pressure-locked style. Squeeze-locked or riveted styles are not acceptable.

Where grid flooring (grating) is to be installed for openings in concrete slabs or across concrete channels, the grid flooring (grating) shall rest on continuous 'L' shaped angles of stainless steel AIS 304 cast-in-place complete with anchors at 450 mm c/c. The 'L' shaped angle shall provide a minimum bearing surface width of 25 mm each direction."

10.3 Steelwork

Not Used.

10.4 Walkway Platforms, Access Steps, Ladders and Hand railing

10.4.1 Walkways and Access Platforms

Standard structural steel sections shall be used for supporting structures.

Toe plates shall be fitted along the outer edges of all walkways and shall be part of the structure and not the floor panels. Toe plates shall extend 100 mm above the top level of the floor panels. Floor panels shall be sized so that each panel does not weigh more than 50 kg.

The support structure shall be constructed so that it can readily be dismantled. Provisions shall be made in the design for adjustment to eliminate irregularities in structural floor levels.

All components including floor fixings shall be hot-dip galvanised after fabrication to IS2629:1985.

All assemblies shall be marked at the factory with distinguishing numbers, letters or marks corresponding to those of Approved Drawings or parts lists. Such marks if impressed before painting shall be clearly readable afterwards. Any temporary bolts for field erection shall be readily distinguishable from any bolts used for permanent connections.

Where dissimilar materials come into contact with each other, an insulating membrane or paint coating shall be applied to minimise direct contact.

10.4.2 Access Ladders

The cross-section of stringers shall be suitable for the weight of the ladder, taking into consideration the spacing of the points at which they are fixed to supporting steelwork or floors. The minimum thickness of the stringers shall be 13mm. The stringers shall be drilled to take 25mm diameter rungs, which shall be uniformly spaced at 250mm centres. The rungs shall pass through and be welded to the stringers at each side of each stringer and each weld shall be continuous. Supports shall be arranged to allow a minimum clearance of 230mm behind the rungs to the wall or other obstruction.

All components of the access ladders shall be structural grade stainless steel alloy AISI Type 316L.

10.4.3 Hand-railing

Hand-railing shall be double rail 1,100 mm high and 900 mm high on stairs measured vertically from the nose of the tread.

Standards shall be continuous 38 mm minimum nominal OD x 3.7 mm thick structural grade stainless steel alloy AISI 304L tube/pipe with 60 mm diameter solid stainless steel AISI 304L balls. Balls shall be drilled to give 1.5 mm clearance to handrails. Each ball shall incorporate a concealed grub-screw with Allen-type head to secure the rails. Standards shall have a minimum base width of 65 mm, drilled for M16 fixing bolts and be set at maximum 1800 mm centres.

Handrails shall be 33.7 mm OD x 3.2 mm thick structural grade stainless steel alloy AISI 304L tube/pipe. Joints shall be arranged to coincide with the spacing of standards and shall have mitred type joints with a tubular ferrule, plug welded or fixed with a 5 mm diameter countersunk head pin.

Removable sections of handrail shall have half-lap joints secured with a countersunk head pin.

Chains across openings shall be oval shaped proof coil chain links with inside dimensions 12 mm x 28 mm x 4.7 mm thick of stainless steel alloy AISI 304L. The chains shall have 304L SS snap-hooks. 304L SS eye-lets shall be securely fixed to the balls of the standards.

10.4.4 Chequer Plating

Chequer plating complete with cut-outs and in sizes suitable for removal by hand shall be structural grade stainless steel alloy AISI 316L plate of minimum 6 mm thickness to carry a uniformly distributed loading of 10 kN/m^2. Deflections shall not exceed 1/240 of the span and if the spans are over 1 m stiffeners shall be used.

Plating top surface shall be of non-slip, raised oval/diamond, self-draining pattern securely fixed to the supporting structure. The sections shall fit without gaps and squarely on the supporting structure.

The weight of each removable section shall not exceed 50 kg.

Each length shall have two formed holes for lifting keys. Two pairs of lifting keys shall be supplied for every 50 m^2 of plating. Where a single area is covered by several pieces of plating, the direction of the pattern on all plates shall be the same and the pattern shall be continuous.

Kerbing shall be built-in so as not to reduce the width of the opening and it shall provide a minimum of 25 mm bearing surface for the chequer plating. It shall be supplied with fixing lugs at centres, not exceeding 1 m. kerbing and chequer plating shall be finished flush with the surrounding finished floor.

Chequer plating shall be screwed to its kerbing or supporting steelwork by countersunk screws so that individual plates cannot rattle or move. At the edges of raised floors, gangways and platforms, toe plates 100 mm high shall be provided.

Where chequered plate is to be installed for openings in concrete slabs or across concrete channels, the plate shall rest on continuous inverted 'L' shaped angles of stainless steel AISI 304 cast-in-place complete with anchors at 450 mm c/c. The angles shall provide a minimum bearing surface width of 25 mm each direction.

10.4.5 Step Irons

Step irons shall be provided to provide access to all manholes and chambers without alternative means. Vertical spacing between step irons shall be 225 mm. Step irons shall be manufactured from 12 mm diameter stainless steel bar incorporating a non-slip tread.

11 TANKS, VESSELS AND RECEIVERS (NOT USED)

12 CHEMICAL DOSING SYSTEM (NOT USED)

13 COMBINED HEAT AND POWER (CHP) UNITS (NOT USED)

14 VENTILATION

14.1 General

Effective and suitable provision must be made to ensure that every enclosed workplace is ventilated by a sufficient quantity of fresh or purified air.

Due to the variety of operational workspaces on the works, it is likely that no single solution will be possible and the Contractor shall be responsible for selecting the most suitable methods.

The function of the building or enclosure shall determine the level of comfort which is required. Comfort depends on the inter-relationship of the following factors: -

- Air Temperature
- Relative Humidity
- Mean Radiant Temperature of the enclosing space
- Ventilation Rates

The Contractor shall determine the air temperature and relative humidity for each enclosed space. Generally, humidity will depend on the operational requirements of the equipment and activities undertaken within the enclosed space. Where close control is required de-humidifiers may be required.

The mean radiant temperature of the enclosed space will be determined by the selection of materials and form of construction of the enclosure.

Ventilation rates shall be determined by the following factors: -

- Occupancy levels
- Requirement to control the temperature or remove excessive heat
- Requirement to avoid contamination with foul air migrating from other areas
- Requirement to pressurise a particular workspace (positively or negatively)
- Openings in the enclosing space and frequency of operation
- Infiltration

Ventilation can be by natural draught or forced ventilation provided by mechanical means. Where mechanical ventilation is employed, standby systems shall be used with audible and/or visible warnings when abnormal conditions exist.

Prior to discharge to the atmosphere, the exhaust stack shall be designed to ensure that noise shall be below 65 dBA 1metre from the unit.

14.2 Fans and Ductwork

14.2.1 General

Fans shall be sized to provide the required air volume at the point of use. The Contractor shall be responsible for determining the fan performance requirements. Prior to delivery to site, fans shall be tested in accordance with BS 848:2007 (Part 1 & 3).

Belt driven fans shall be fitted with V-belt drives complying with BS 3790:1995. The drives shall be capable of transmitting the rated motor output with provision for adjustment of belt tension.

Guards shall be provided for all unprotected inlets and outlets to fans and fan belt drives. Guards shall be galvanised steel wire mesh with apertures not greater than 12 mm

attached to a rigid galvanised frame. Belt guards shall be galvanised steel sheet and designed for easy removal for belt replacement. Access holes shall be provided to allow tachometer readings to be taken from the fan and motor shaft and for belt tension to be checked.

Where protective coatings are specified for use with corrosive gases, the coating shall cover all contact surfaces of the fan, motor and shaft.

Flame proof enclosures shall comply with the requirements of BS EN 60079.

14.2.2 Centrifugal Fans

Small centrifugal circulating fans shall comply with the requirements of BS 5060:1987. Fans larger than 7.5kW output shall be the backward bladed type having a total fan efficiency of not less than 78%.

Fan casings shall be constructed from steel sheet with angle stiffeners to ensure freedom from drumming and to withstand the maximum differential pressure of the system. Casings shall allow fan impellers to be withdrawn, their outlets shall be flanged and a drain plug shall be fitted at their lowest point.

Impellers shall be fabricated mild steel or aluminium with robust hubs and shall be capable of running at 10% above normal operating speed.

Shaft bearings of single inlet fans shall be mounted on a common pedestal. Bearings shall be the ball or roller type. Pedestal bearings shall be insulated from the fan casing.

14.2.3 Axial and Propeller Fans

Axial flow fans shall be single stage or multistage with each impeller mounted on an independent motor to suit the duty requirements.

Propeller fans may be ring mounted, diaphragm mounted or mounted in a casing.

Casings shall be rigidly constructed from mild steel stiffened and braced to obviate drumming and vibration. Mounting feet shall be provided for bolting to the base or supports. Inlet and outlet ducts shall terminate in flanged rings for easy removal. An inspection door shall be provided.

The length of the duct casing shall be greater than the length of fan and motor(s) to facilitate removal from ductwork. Electrical connection to the motors shall be through an external terminal box secured to the casing.

Impellers shall be steel or aluminium with the hub keyed to the drive shaft and the assembly statically balanced. Blades shall be of aerofoil section. Shafts shall be carried in ball or roller bearings. Lubrication points shall be extended to the outside of the casing.

14.2.4 Ductwork

The design, manufacture and erection of ductwork shall be in accordance with following Building and Engineering Services Association (formerly the Heating and Ventilation Contractor's Association) Codes of Practice:

- DW/142 Galvanised and Stainless Sheet Steel Ductwork (low pressure Class A)
- DW/154 Un-plasticised Polyvinylchloride and Polypropylene Ductwork
- DW/191 Resin-bonded Glass Fibre Ductwork

The Contractor shall base his design on these codes as a minimum requirement.

The mean air velocity in any section of ductwork shall not exceed 10m/s and maximum static pressure (positive or negative) shall not exceed 500N/m^2.

Where flexible ductwork is required the internal diameter of the flexible duct shall be equal to the external diameter of the adjoining ducts. Flexible ducts shall consist of a liner and cover of tough tear resistant fabric. It shall be reinforced with a bonded galvanised spring steel wire helix between the liner and cover. An outer helix of glass fibre cord shall ensure regular convolutions. Non-metallic materials shall comply with BS 476 for fire resistance.

14.3 Odour Control (Not Used)

15 WATER AND WASH WATER SUPPLIES

15.1 Type of Facility

The provision of wash water facilities shall be based on the size of works and of individual tasks.

15.2 Potable Water System

Where potable water is abstracted from the public mains supply, this shall comply with current regulations for use of potable water on contaminated sites and provide for a break tank incorporating an air gap to prevent the possibility of back-contamination of the public water supply.

Where the final effluent quality is unsuitable for use in wash water systems and where operational requirements for periodic hosing down of plant and equipment are required a potable water supply shall be provided.

15.3 Final Effluent Utilisation System

Final effluent may be used as wash water on a site specific basis, including pressurised wash water systems for specific applications e.g. screen washing, provided that the process guarantees are not compromised and that the health and safety and specification requirements can be met. Final effluent shall be filtered prior to use. The filter shall be a self-cleaning strainer with a 500 micron mesh and capable of handling a solids loading of 100mg/l.

15.4 Skid Mounted Pump Sets

The flow into the break tank shall be controlled by a float operated isolating valve. The arrangement of the pumps shall be such that there shall be a flooded suction at all times. The pumping station shall be fully automated.

The pumps shall be required to pump water around the works wash water radial feed or ring main.

A pressurised system incorporating a suitable hydro-pneumatic vessel shall be provided to maintain the rated pressure. The pressurised vessel shall be of the bladder type, with a replaceable EPDM membrane.

The pumps shall be uniformly sized and shall be configured on a duty/assist/standby basis. The pump size and number shall ensure that pump starts are limited to 15 starts per hour under the worst case conditions.

Pump casing and impeller materials shall be suitable for use with potable water or final effluent. Motor speed shall not exceed 3000rpm.

Any leakage or spillage in the pumping station shall be directed to a suitable drain. There shall be no possibility of the station flooding.

Each pump shall be equipped with gate valves on the suction and discharge sides and a non-return valve on the pump side of the discharge valve.

15.5 Control

A fully automatic control system shall be provided. Pumps shall start and stop automatically in response to demand and shall maintain the required pressure and flow at the outlet flange from the distribution manifold.

15.6 Pipework

A radial feed or ring main shall be installed for use with a skid mounted pump-set. The pipework shall be constructed from ductile iron or polyethylene and shall have sufficient spurs so that water can be delivered at any location around the site on demand. Each spur shall have an isolating valve so that maintenance work can be carried out on any hydrant.

The water take-off points shall generally be underground fire hydrants of the integral valve and screwed outlet type set in a pre-cast concrete chamber with cast iron cover.

The maximum distance between hydrants shall be 80m. The minimum diameter of the main shall be 75mm.The main shall have cross-links so that sections can be isolated for maintenance without affecting the operation in other areas of the site.

15.7 Process Water

Where individual processes require process water at specific rates and pressures, the contractor shall make appropriate arrangements in his design to ensure that the water supplied is secure and neither compromises nor is compromised by the wash water requirements stated above.

15.8 Fire Protection Water System

15.8.1 Pumps

Pumps shall be exclusive for firefighting purposes and be of the following types:

- Electric motor driven centrifugal pumps
- Compression ignition engine driven centrifugal pumps

Pumps shall be direct-coupled.

The diameter of the suction pipe/header shall be based upon a velocity of flow not exceeding 2 m/s. The pumping arrangement shall incorporate jockey pumps to ensure the system remains under the correct pressure. The capacity of the jockey pumps shall be not more than 5% or less than 3% of the installed pumping capacity, subject to a minimum capacity of 3 l/s.

Where pumps operate automatically, they shall be connected to an audible alarm located prominently outside the pump house.

Each pump shall be provided with a non-return valve and an isolation valve on the delivery side. A pressure gauge shall be provided between the pump and the non-return valve. The size of the non- return valve and cut off valve shall be not less than the size of the initial delivery pipe and not less than the delivery outlet of the pump. Butterfly valves shall not be used.

15.8.2 Mains

The pipework shall be constructed from buried ductile iron or polyethylene. Pipes shall be run at least 2 m away from the face of the buildings and open storage areas. Mains shall not be laid under open storage areas.

The system shall be capable of withstanding a pressure equivalent to 150% of the maximum working pressure.

The fire main shall not have any dead ends and its size shall be not less than the internal diameter of the delivery outlet of the pump.

15.8.3 Hydrants

The maximum distance between hydrants shall be 80m. The minimum diameter of the main shall be 75 mm. Before final inspection, the hydrant system shall be flushed thoroughly.

Except where impracticable, all hydrant outlets shall be situated 1 m. above ground level.

The stand posts shall be 80 mm in diameter for single headed hydrants, 100 mm for double-headed hydrants and monitors of 63 mm or 75 mm size and 150 mm for monitor of 100 mm size. Stand posts shall be painted fire red (IS:5, shade no 536) and numbered for easy identification.

Hydrants shall be the oblique type conforming to IS: 5290 Type A with outlets angled towards ground. The hydrant couplings shall be gunmetal or stainless steel of the instantaneous spring-lock (female) type, 63 mm diameter and the valves shall be of the screw down type.

Hydrants shall be easily accessible. Where hydrants are situated in remote locations, they shall be approachable by means of paved pathways.

Hydrants located in situations where they are likely to be damaged by vehicular traffic shall be suitably protected on all sides against possible damage.

Hydrants shall be located according to the attendant fire hazards at the different locations to be protected to give the most effective service. Hydrants shall be distributed to provide protection for all sides of the buildings and need not necessarily be equally spaced.

Hydrants shall be positioned not less than 2 m from buildings or edge of any storage plot to be protected, except in the case of high hazard occupancies wherein the hydrant heads shall be located not less than 7.5 m from the face of the building, edge of the storage plot or from the plant battery limits.

In cases where, owing to the size or layout of the building, or the building being divided by internal walls, any point within the building is at a distance of more than 45 m from an external fire hydrant, an internal hydrant system shall be provided so that no portion of the floor is more than 45 m from an external hydrant or 30 m from an internal hydrant.

A hydrant shall be provided on every floor landing which shall not be less than 1.5 m x 1m. The mains feeding the landing hydrants shall be provided with a cut-off valve at ground level

Alternate hydrants for the protection of loading bays shall be replaced by water/foam monitors

15.8.4 Fire Hoses

In the case of yard hydrants, hose pipes and nozzles shall be installed near each hydrant in glass fronted hose boxes of an approved design.

In the case of hydrants on upper floors or internal hydrants, hosepipes and nozzles shall necessarily be installed near each hydrant in glass fronted hose boxes of an approved design

If hoses are kept in hose boxes alongside hydrants, each box shall contain two lengths of 15 m each. All hoses shall be of 63 mm diameter of one of the following types -

- Unlined flax canvas complying with Indian Standard IS: 4927.
- Rubber lined woven-jacketed complying with Type A of Indian Standards IS: 636.
- Controlled Percolation type complying with Indian Standards IS: 8423.

All couplings shall be of the instantaneous spring-lock type and the nozzles shall be of not less than 16 mm in diameter, nor more than 25 mm in diameter except in the case of high hazard occupancies where the maximum nozzle diameter may be 32 mm, subject to approval. All couplings, branch pipes and nozzles shall be of gunmetal or stainless steel and shall comply with IS: 903, 1984.

Spare hoses to the extent of 10 percent of the above requirements, with a minimum quantity of 30 m shall be provided. Such spare hose shall be in 15 m lengths and complete with couplings.

15.8.5 Nozzles

The number of nozzles to be provided shall be equivalent to half the number of hose pipes installed on the premises.

In locations where a jet of water directed from a normal type nozzle is likely to cause excess damage or where a gentle spray of water is essential for the extinguishing of a fire, a fog or spray type of nozzle complying with IS: 2871 shall be used.

Spare nozzles to the extent of 10% of the above requirements, with a minimum of two, shall be provided.

15.9 Marking

Each appliance incorporating an air gap shall be clearly and permanently marked (Air gaps are non-mechanical backflow preventers to be used where either back siphonage or backpressure conditions may exist.).

Marking shall indicate:

- Manufacturer’s brand or logo;
- Air gap type;
- Nominal diameter;
- Reference to the relevant standard;
- Model or type reference;
- Serial number.

16 CHLORINATION SYSTEM (NOT USED)

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17 SBR SYSTEM – GENERAL REQUIREMENTS (NOT USED)

18 MBR SYSTEMS – GENERAL REQUIREMENTS (NOT USED)

19 UV DISINFECTION (NOT USED)

20 WEIGHBRIDGE (NOT USED)

21 STANDBY GENERATOR (NOT USED)

22
22
22

22 APPENDIX A – STANDARDS RELEVANT TO THE WORKS

Section		Current Standard
2.	Materials, Workmanship and Design	
2.3	Castings	
	1. Grey-iron	IS 3005 Part 1 to 4
	2. Carbon steel	IS 1030:1998
	3. Stainless steel	IS 3038:2006
	4. Copper and copper alloy	IS 3288:1986 Part 1 to 8
2.6	Nuts, Bolts and Washers	IS 10238:2001
		IS 1363:2002 Part 1 to 3
		1364:2002 Part 1 to 6
		IS 3138:1966
		IS 1367
		IS 2016:1967
		IS 1363:2002 Part 1 & 2
		BS 4320:1968
		SP 6:1969 Part 4
		IS: 3757:1985
		IS 4000:1992
2.9	Threads	IS 4218:2001 Part 1 to 4
		IS 14962:2001 Part 1 to 5
		BS 3643:2007
2.11	Guarding of Machinery	PD 5304:2005
		IS 9474:1980
2.14	Provision of Lubricants	IS 1118:1992
		IS 8406:1993
		IS 2297:1997
		IS 4009: 1981 Part 1
2.15	Colour Coding and Identification of Pipework	IS 2379:1990
2.16	Noise and Vibration	BS EN 61672:2003 Part 1 to 2
		BS ISO 10816:2009 Part 2
		BS EN 60034:2005 Part 9
2.17	Corrosion and Erosion	IS 8629:1977
		BS EN ISO 12944:parts 1 to 8

Section		Current Standard
		BS EN ISO 14713:2009 parts 1 to 3
2.19	Locks	IS 15275:2003
2.20	Welding	
2.20.1	General	IS 816: 1969
		IS 15769: 2008
		IS 10234:1982
		IS 11790:1986
2.20.2	Standards	IS 816
		IS 822
		IS 1024
		IS 819
		IS 1261
		IS 1323
		IS 7307
		IS 7310
2.20.3	Welding Consumables	IS 814 :2004
		IS 1395-1982
		IS 1278:1972
		IS 7280-1974
		I.S. 3613-1974
		IS 6419-1971
		IS 6560-1972
2.20.5	Size of Electrode Runs	BS EN ISO 14171:2010
2.20.7	Welding Procedure	IS 2825:1969
2.20.10	Welded Joints for Steel Pipelines	AWWA Standard C206
		IS 816:1969
		BS 2633
		IS 1182:1983
		BS EN 1435
2.20.11	Butt Welded Joints	API Spec 5L
2.20.15	Inspection and Testing	IS 3600:1985 Part 1 to 2
		IS 3600:2009 Part 3
		IS 3600: 1984 Part 4

Section		Current Standard
		IS 3600:1983 Part 5 to 6
		IS 3600:1985 Part 7 to 9
		IS 3613:1974
		IS 7307:1974 Part 1
		IS 2595:2008
		IS 4260:1986
		BS EN 1321:1997
		BS EN 895:1995
		BS EN 10208:2009 Part 1 to 2
		BS EN 10208-2:2009
		BS EN ISO 15614-1:2004+A1:2008
		BS 4871:1985 Part 2
		BS 4872:1985 Part 1
		IS 4853:1982
		IS 1182:1983
		IS 2595:2008
2.21	Surface Protection	
2.21.1	Consideration for Electroplating/ Galvanising	BS EN ISO 1456:2009
		BS EN ISO 12540:2000
		BS EN ISO 12944-5:2007
		IS 2629: 1985
		IS 3655:1985
		IS 3656:1968
		BS EN ISO 6158:2011
		IS 13238:1991
2.21.2	Painting and Protection	
	(i) General Requirements	BS EN ISO 12944-5:2007
		IS 1477-1971 (Part I – Pre-treatment)
		IS 1477-1971 (Part II-painting)
		BS 3416:1991 Type 1
		BS EN 10300:2005
	(i) Description of Paint and Protection	

Section		Current Standard
	Systems	
	1. Surface Preparation	SSPC - SP5 - 1966 (Swedish Standard SIS 05 59 00 - 1967 Sa 3)
		CP 3012 - 1972
	2. Metal Coating	BS EN ISO 2063:2005
		IS 2629:1985
		EN ISO 2063:2005
		BS EN ISO 6158:2004
		BS EN ISO 1456:2009
		IS 3655:1985
	3. Final Finish	BS 3416 type II
		BGC PS/CW6 Parts 1 and 2
3.	Pipework, Couplings, Valves, Penstocks and Stop-logs	
3.1	General	IS 4111:1968 (Part IV)
		IS 2065:1983
		IS 7634 (Part 3)
		ANSI/ASME B31.1
		ANSI B 16.1
		BS-4622:1970
		BS-2035:1966
3.2	Pipe Threads	IS 554:1999
		ISO 7-1:1994
		BS EN 10226-1:2004
		BS 21:1985
3.3	Below Grade Metal Piping Protection	IS 8329:2000Annexure D
3.4	Carbon Steel Pipe and Fittings (CS or MS)	IS 3589:2001
		IS1239 (Part 1 & 2)
		ASTM A53-Gr.B
		ASTM A197/A338
		ANSI B16.39
		ASTM A234-Gr. WPB
		ASTM A105
		ASTM A181

Section		Current Standard
		ASTM A182
		ASTM A350
		ASTM A536
		ANSI B16.5
		ANSI B16.9
		AWWA C606
		ASTM A283-Gr. C
		AWWA C200
		AWWA C208
		ASTM A536
		AWWA C606
		IS 5382:1985
		ASA B16.21
		BS EN 681-1 & 2
		IS 12820:2004
		BS 1154:1992
3.5	Ductile Iron Pipe and Fittings (DI)	IS 8329:2000
		AWWA C151/A21.51
		IS 1536:2001
		AWWA C110/A21.10
		IS 9523:2000
		AWWA C111-A21.11
		IS 5382:1985
		ASA B16.21
		BS EN 681-1 & 2
		IS 12820:2004
		BS 1154:1992
		AWWA C104
		AWWA C151
3.6	Galvanized Pipe and Fittings (GI)	IS 3589:2001
		IS 1239 (Part 1)
		ASTM A53-Gr.B
		ASTM A153

Section		Current Standard
		ASTM A53-Gr.WPB
		ASTM A197
		ASTM A338
		ANSI B16.3
		ASTM A 234 Gr-WPB
		ANSI B16.9
		ASTM A536
		AWWA C606
		ASTM A105-Gr. I or II
		ASTM A181
		ASTM A182
		ASTM A350
		ANSI B16.5
		IS 5382:1985
		ASA B16.21
		BS 7874
		BS EN 681-1 & 2
		IS 12820:2004
		BS 1154:1992
		BS 494
		ANSI B16.39
3.7	Stainless Steel Pipe and Fittings (SS) – Liquid Service	ASTM A240
		ASTM A778, Gr. TP
		ASTM A269
		ANSI B36.19
		ASTM A182
		ASTM A276
		ASTM A774
		MSS SP43
		ANSI B16.1
		ANSI B16.5
		MSS SP42
3.8	Stainless Steel Pipe and Fittings (SS) – Digester Gas Service	ASTM A240

Section		Current Standard
		ASTM A778, Gr. TP
		ASTM A269
		ANSI B36.19
		ASTM A182
		ASTM A276
		ASTM A774
		ANSI B16.1
		ANSI B16.5
		MSS SP43
		ANSI B16.5
3.9	PVC Pipe and Fittings	IS 4985:2000
		ASTM D1784
		ASTM D1785
		ASTM D2467
		ASTM D2464
		ANSI B16.5
		ASTM D2564
3.10	Polyethylene (PE) Pipe and Fittings	BS EN 12201:2011(Part 1 & 2)
	High Density Polyethylene Pipes For Water Supply	IS 4984:1995
		AWWA C901 (PE 2406)
		AWWA C906 (PE 3408)
		BS EN 1555:2002 (Part 1 to 5)
		IS 14885:2001
		ISO 4437:2007
		AWWA C901 (PE 2406)
		ASTM D2996
		IS 12709:1994
		AWWA C110
		AWWA C153
3.11	Copper Tubes and Fittings	BS EN 12449:1999
		BS EN 1254:1998 Part 1 to 2
		ASTM B88
		ANSI B16.18

Section		Current Standard
		ANSI B16.22
		IS 2501:1995
		BS EN 12449:1999
		ASTM B88
		ASTM B306
		ANSI B16.29
		ASTM B32
3.12	Glass Lined Ductile or Cast Iron Pipe and Fittings – Pressure Pipe (GLDI or GLCI)	ASTM D-792
		ASTM C-283
		NACE RP 0188-99
		SSPC Coating Manual Vol. 1 Section X1V
3.13	Cast Iron Drainage/Vent Pipe and Fittings – Plumbing	IS 1536:2001
		IS 3114:1994
		IS 1538:1993
		ANSI/AWWA C110
		ANSI A21.10
		ANSI B16.12
3.14	Joints and Couplings	AWWA C-219
		AWWA C151 A21.15/51
		ANSI B16.1
		ASA B16.21
		BS 7874
		BS EN 681-1 & 2
		IS 12820:2004
		IS 11149:1984
		ASTM A105
		ASTM A181
		ASTM A182
		ASTM A350
		ANSI B16.5
		BS 1154
		BS 494

Section		Current Standard
		ASTM A536 Gr 65-45-12
		AWWA C606
		IS 2062:2011
		BS EN 10311:2005
		BS EN 10224
		ASTM F1476
		AWWA C-213
		ASTM A197
		ASTM A338
		ANSI B16.39
		BS EN 1092-1:2007
		IS 6392:1971
		BS 4190:2001
3.15	Pipe Hangers and Supports	IS 8324:1988
		IS 9323:1991
		MSS SP-58/SP-69/SP-89
		ANSI B31.1
3.18	Valves	
3.18.1	General	IS 14846:2000
		BS EN ISO 9001:2008
		ANSI B 16.5
3.18.2	Gate valves	IS 14846:2000
		BS EN 1171:2002
		IS 554:1999
		IS 8999:2003
		BS EN 1982:2008 LG2
3.18.3	Non-return Valves (Swing Check Pattern)	IS 5312:1986 Part 2
		BS EN 12334:2001
		BS EN 1982:2008
3.18.4	Knife Gate Valves	MSS SP-81-2001
		ANSI/AWWA C520-10
		IS: 210 Gr FG 260
		ASTM A 240

Section		Current Standard
		IS: 6603-2001
3.18.5	Pinch Valves	BS EN 13397:2002
3.18.6	Non-Return Valves (Lift Pattern)	BS 5154:1991
		BS 21:1985
3.18.7	Backflow Preventer	IS: 2065 -1983
		National Building Code of India – 2005
3.18.8	Ball Valves	IS 9890:1981
		BS EN 1983:2006
		BS EN ISO 16135:2006
		BS ISO 7121:2006
3.18.9	Pressure Reducing and Pressure Sustaining Valves	IS 9739:1981
3.18.10	Automatic air relief valves	BS EN 1092-2:1997
		BS 5163:1986
		ISO 2531:1998
		BS EN 1561:2011
		BS EN 1563
		BS EN 10088
3.18.11	Pressure Relief Valves	BS 6759:1984 part 3
		BS EN ISO 4126-1:2004
		BS 1560: Part 2
3.18.13	Diaphragm Valves	BS EN 13397:2002
3.18.14	Corporation Cocks	BS 2580:1979
3.18.15	Plug Valves	BS 5158:1989
		IS 10459:1983
3.18.16	Flap valves – Cast iron	DIN 87101
		BS EN 1561:1997
		BS EN 1982:2008
		BS 2874
3.18.18	Foot Valves and Strainers	IS 4038:1986
3.19	Operator Headstocks/Pedestals	IS 3042:1965
		IS 13349:1992
		IS 9737:1981
3.21	Pneumatic or Hydraulic Actuators	BS EN 15714:2009 Part 3 & 4

Section		Current Standard
		BS EN ISO 5211:2001
3.22	Penstocks	IS 3042:1965
		IS 13349:1992
		BS EN 1561:1997 Grade 220
		ANSI/AWWA C 560-07
3.22.3	Stainless steel	BS EN 10088:1995
3.22.4	Plastic door	BS EN 10025:1993
		to BS EN 10088:1995
3.22.5	Lightweight Penstocks	SSPC Standards
3.24	Pressure and Vacuum Gauges	IS 3624:1987
		BS EN 837-1:1998
		ANSI/ASME B40.1
4.	**Pumping Plant**	
4.2	Pump Performance Guarantees	BS EN ISO 5198:1999
		BS EN ISO 9906:2000
		ISO 3555:1997
4.3	Submersible Sewage Pumps	IS 9283 - 1995
		ASTM - A48
		ASTM - A572
		AISI Gr. 316
		ASTM A-48 Class 35B
		ISO-10816
		AISI 420
		IEC245
		IS 9968 Part I
4.4	Vertical Mixed Flow Bowl Pump	BS EN 1561:2011
		BS 970
4.5	End Suction Pump	BS EN ISO 2858:2010
		IS 13139:1992
		IS 13518:1992
4.6	Split Casing Centrifugal Pump	BS EN ISO 5198:1999
		BS 292: Part 1:1982
		BS ISO 355:2007

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4.7	Sump Drainage Pump	IS 5600:2002
4.8	Progressive Cavity Pumps	IS 210 GR. FG220
		API 676
4.9	Chemical Dosing Pumps	ANSI/HI 7.1 – 7.5:2006
4.11	Mixer Pumps	ISO 21630:2007
5.	**Sewage Treatment Plant**	
5.1	Screening Plant	
5.1.2	Raked bar screen	IS 6280:1971
5.1.6	Screening Dewatering Screw Compactor	ISO 20474 – 11:2008
		BS EN ISO 1461:2009
		BS EN 10226-1:2004
		BS 21:1985
5.1.7	Common Screening Conveyor System	IS 7155 (Part 3)-1986
		ISO 20474 – 11:2008
		IS 11592:2000
		IS 4776(Part 1):1977
		IS 8531:1986
		ISO 1536:1975
		ISO 1537:1975
		IS 8598:1987
		ISO 1537:1975
		BS 8438:2004+A1:2010
5.4	Sedimentation Plant	
5.4.1	General	
		BS 4360:1990
		BS EN ISO 1461:2009
		ISO 1460:1992
		ISO 1461:2009
5.5	Aeration Plant	
5.5.3	Jet Aerators	AWWA ACE 95275
6.	**Sludge System Plant**	
6.4	Sludge Dewatering Centrifuges	IS 4092:1992, Part 1
		DIN 17007

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6.6	Sludge Gravity Thickeners	BSEN 61672:2003 Part 1 &2
6.6.1	General	WRC
		US-EPA
		ASTM Type 50
6.9	Sludge Digestion Plant	
6.9.2	Safety Requirements	BS 6651:1999
		BS EN 60079-10-1:2009
		BS EN 62305 Part 1 to 5
		BS EN ISO 14122-4
7.	**Blowers and Compressors**	
7.1	Aeration Air Supply and Associated Plant	
7.1.3	Blowers (Centrifugal Type)	IS 4894:1987
		IS 210:2009
		BS EN 1561:2011
		IS/ ISO 11342:1998
		IS/ ISO 1940-1:2003
7.1.4	Lubrication	BS ISO 19378:2003
7.1.5	Cooling	BS 1571:1975 part 2
7.1.6	Valves & Pipework	BS 1387:1985
		BS EN 10255:2004
7.2	Compressed Air Systems	
7.2.2	Compressors	IS 5456:2006
		BS ISO 1217:2009
		BS 1571-2:1975
		BS EN 1012-1:2010
7.2.3	Air Receivers	BS 5169:1992
		IS 7938:1976
7.2.4	Pipework for Compressed Air	BS EN 10255:2004
		BS 143
		BS 1256:2000
		BS EN 10242:1995
		ISO 49
		BS EN 1092-1:2007

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		ISO 7005-1:1992
7.2.5	Pressure Relief Valves for Compressed Air	BS 6759:1984
7.2.6	Non-return Valves for Compressed Air	BS EN 12334:2001
7.2.7	Drain Valves for Compressed Air	EN ISO 17292:2004
		BS ISO 7121:2006
7.2.8	Isolating Valves for Compressed Air	BS 5351:1986
		BS EN 1171:2002
		ISO 5996
7.2.11	Compressed Air Dryer	ISO 8573-1:2001
		ISO 7183:2007
		ISO 8573-3
8.	**Cranes & Lifting Equipment**	
8.2	Manually Operated Overhead Crane/ Hoist	IS 3177:1999
		BS 2573-1:1983
		IS 3109:1982 (Part 1)
		IS 8324:1988
		IS 2535: 2004 Part 1 & 2
		IS 4460:1995 Part 1 to 3
		IS 7403:1974
		I.S. 2513:1963
8.3	Electric Overhead Travelling Crane/ Hoist	IS 4137:1985
		IS 3177:1999
		IS 807:2006
		IS:3938
		IS:325
8.4	Jib Crane	IS 15419:2004
8.5	Lifting Accessories	BS EN 818-1 (Part 1)
		BS 4942(Part 2 &3)
9.	**Structural Steelwork and Flooring**	
9.2	Open Grid Flooring (Open Mesh/ Grating)	IS 15836:2008 Part 1 & 2
		IS 2062:2006
		IS 2629: 1985
9.3	Steelwork	IS 2629: 1985

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		IS 736: 1986
		IS 737:2008
9.4	Walkway Platforms, Access Steps, Ladders and Hand railing	
9.3.2	Access Ladders	BS 4211:2005+A1:2008
		IS 8172:1976
		BS EN ISO 1461:2009
9.3.3	Hand railing	IS 4912:1978
		IS 3601:2006
9.4.4	Chequer Plating	IS 3502:1994
10.	**Tanks, Vessels and Receivers**	
10.1	General	
		IS 875: 1987 Part 3, BS 5169
		IS 875: 1987 Part 1
		IS 875: 1987 Part 2
		IS 803: 1976
		IS 804: 1967
		IS 14399: 1996 Part 1 and 2
		IS 7938: 1976
		IS 2825: 1969
10.2	Glass Coated Steel Tanks	
10.2.1	General	BS1449
		BS EN 10025
		WIS 4-25-01
10.2.5	Glass Coatings	BS7793: Part 2
10.2.7	Epoxy Liquid Coatings (Paint)	BS EN ISO 12944
10.3	Roof Design	
10.3.2	General	IS 875: 1987,Part 2
10.3.2	Roof Loads	IS 875: 1987 Part 2
10.3.3	GRP Material	BS4549 Part 1
		BS 4994
		BS EN 14118
		BS 3749
		BS EN 14020

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		BS 3532
10.4	Testing	BS 6001: Part 1
10.4.1	Testing of Glass coating	
10.6	Stainless Steel Storage Tanks	BS EN 12285
		BS EN 14015
		BS EN 10088: Part 2
10.7	Reinforced Plastic Tanks	BS 4994:1987
		DIN DVS 2205
		BS 6399: Part 1
		BS 4211
10.9	Air Receivers	BS EN 286-1
10.10	Silos	BS 5950
		BS 449
		BS 1449
		BS 7668
		BS EN 10029
		BS EN 10113
		BS EN 10210
		BS 4604, Part 1, 2 &3
		BS EN 1011
		BS 4211
11.	**Chemical Dosing System**	
11.7	Safety Showers and Eyewash	IS 10592:1982
		DIN 12899:2009 Part 3
		ANSI Z 358.1:2004
		DIN 12899:2009 part 3
12.	**Combined Heat & Power Units**	ISO 3046
13.	**Odour Control and Ventilation**	
13.3	Fans and Ductwork	
13.3.1	General	BS 848:2007 (Part 1 & 3)
		BS 3790:1995
		BS EN 60079
13.3.2	**Centrifugal Fans**	BS 5060:1987

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13.3.4	**Ductwork**	DW/142
		DW/151
		DW/191
		BS 476