CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD

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LOAN AGREEMENT NO. ID-P267

JICA FUNDED PROJECT

BIDDING DOCUMENT

FOR

PROJECT FOR CONSTRUCTION OF CHENNAI SEAWATER DESALINATION PLANT (I)

PART-II

(EMPLOYER'S REQUIREMENTS)

(VOLUME 1 OF 5)

PROCUREMENT OF DESIGN/ENGINEERING, CONSTRUCTION, COMMISSIONING OF 400 MLD SEAWATER REVERSE OSMOSIS (SWRO) DESALINATION PLANT AT PERUR, CHENNAI WITH 20 YEARS OF OPERATION AND MAINTENANCE (DBO BASIS)

INTERNATIONAL COMPETITIVE BIDDING

PROJECT MANAGEMENT CONSULTANTS	**SUPERINTENDING ENGINEER**
SMEC International Pty Ltd.	(CONTRACTS & MONITORING)
NJS Engineers India Pvt. Ltd.	CHENNAI METROPOLITAN
Tata Consulting Engineers Ltd.	WATER SUPPLY & SEWERAGE
SMEC India Pvt. Ltd.	BOARD

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1. PROJECT REQUIREMENTS

1.1 Background to the Project

The Chennai Metropolitan Area (CMA) is facing chronic water shortage due to the lack of rainfall and the increasing population and growing economy. The surface water from the rivers and reservoirs, as well as the groundwater, has been the major water resources for the CMA. However, the yields from such conventional water resources are not stable because of the frequent droughts.

The supply of potable water in the CMA is not sufficient to meet the water demand in the area. It is revealed that in wide areas of Chennai, the service continuity is only three to four hours a day. As per the estimate of the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), the estimated water production in 2015 was about 686 million liters per day (MLD) against the demand of 933 MLD. To secure sufficient water supply for the people and industries, the State Government of Tamil Nadu (GoTN) decided to construct seawater desalination plants (DSPs) as one of the reliable water resources, which would not be subjected to the recurring droughts.

At present, two DSPs, one in Minjur (100 MLD) and another in Nemmeli (100 MLD), are already operational in the CMA, but the water demand is not yet satisfied. In order to further augment the water supply, GoTN has awarded a contract for construction of DSP of 150 MLD at Nemmeli and also has initiated construction plan for a DSP of 400 MLD capacity at Perur (Chennai Seawater Reverse Osmosis Desalination Plant). Following the state government's direction, the CMWSSB prepared the detailed project reports (DPRs) for the 400 MLD project, and the Government of India (GoI) approved the DPR and proposed the construction of Perur 400 MLD DSP for Japanese Official Development Assistance (ODA) loan. Subsequently, the Japan International Cooperation Agency (JICA) carried out the Preparatory Survey on Chennai Seawater Desalination Plant Project. After prolonged deliberation, an agreement was signed between GoI, GoTN and the loan provider JICA on March 29, 2018 to construct the 400 MLD desalination plant at Perur, Chennai.

Through this tender, Chennai Metropolitan Water Supply and Sewerage Board intends to construct a Seawater Reverse Osmosis (SWRO) based 400 MLD desalination plant at Perur, Chennai, Tamil Nadu, India to augment further the drinking water supply to the city of Chennai. The said installation shall have a total product water capacity of 400 MLD.

This project involves the construction of intake and outfall structure along with the required pipelines, construction of pre-treatment processes, SWRO desalination plant, remineralisation plant, GIS-based electrical substations and other allied processes and units to build a complete operating plant within the proposed site premises for the production of 400 MLD product water of the required drinking water quality. After successful completion of testing and commissioning of works, the Plant shall be operated and maintained for 20 years under Design Build Operate (DBO) basis. The Contractor shall be responsible for all the works related to the construction and 20 years O&M of the Plant as per the provisions of the contract.

1.2 Description of the Works

1.2.1 The Works

The **Work(s)** is the construction of Seawater Reverse Osmosis (SWRO) Desalination plant at Perur, Chennai with seawater intake and brine outfall, pre-treatment, RO system, post treatment, sludge treatment facility and all other works at the site followed by 20 years of operation and maintenance (O&M) as per the Conditions of Contract to produce net 400 MLD product water of the required quality.

1.2.2 Description of the Works

The main purpose of this project is to construct a 400 MLD Seawater Reverse Osmosis (SWRO) Desalination plant at Perur, Chennai and operate the Plant automatically without any trouble. The contractors are encouraged to visit the plant site and understand the site location and requirements to construct the Plant. The offer should include all works that is required to be completed for the Plant fit for the purpose. If additional works are needed which have not been mentioned in the tender documents or in the Schedule of Costs, then Contractors must identify those additional works separately and include in the offered cost in the corresponding schedules. The Plant will be built in two completely separate streams of 200 MLD each. All the process units, storage tanks, chemical buildings shall be kept separate for the two streams with only a common intake and outfall system, CWR and sludge treatment system. The major areas of works included but not limited to the following are given below:

a) Seawater intake system with Intake head, pipeline, intake well (forebay), band screens and pumping station
b) Pre-chlorination – Shock chlorination, air bursting system, hypochlorite storage and dosing system
c) Inlet structures, flash mixing and distribution chambers
d) Chemical building, acid, coagulant/flocculant storage and dosing systems
e) Flocculation and clarification system with tube settlers
f) Dissolved air flotation system
g) Gravity dual media filtration system
h) Micron cartridge filters
i) Reverse osmosis desalination system with all chemical storage and dosing systems
j) Remineralisation system (limestone filters) with CO_2 storage and dosing system
k) Post-chlorination - Hypochlorite storage and dosing system
l) pH adjustment with caustic soda
m) Product water storage system
n) Sludge treatment with thickeners and belt press filters
o) Brine outfall system with waste tanks, pipeline and offshore diffusers
p) Service water system and all yard pipes at the site
q) All electrical and instrumentation equipment
r) MCC rooms, all substations (230/110 kV, 110/11 kV, 11/0.433 kV) and cable system
s) DG sets for emergency lights and safe shut down of plant in case of power failure
t) Distributed Control System

u) All buildings and all concrete and metal tanks at the site
v) Mechanical and electrical workshop and warehouse
w) All other allied systems, as indicated in the technical specifications and required for the DSP.

Note: Administrative Building should be "Green" certified with a minimum Silver rating as per IGBC norms or equivalent rating in case of certification by other agency.

The detailed technical specifications of the above works have been provided in the following documents of Section VI, Part-2.

Section VI: Employer's Requirements

A. Technical Specifications

1. Project requirements
2. Site details
3. Particular Process Requirements
4. General requirements
5. Particular civil requirements

5A. General civil requirements

5B. Specifications for Architectural, Landscaping and MEP works

6. Pipelines, pipework and fittings
7. General mechanical requirements
8. General electrical requirements
9. General instrumentation, control and automation requirements
10. Inspection and testing requirements
11. General painting and protection requirements
12. Training and advisory requirements
13. Operation and maintenance
14. Hand over
15. Environmental management plan
16. Social management plan

B. Investigation Report

1. EIA Report including CRZ Clearance
2. Bathymetry Survey Report
3. Geotechnical Report

C. Drawings

1. Site Drawings
2. Process Drawings
3. General Arangement Drawings
4. Electrical Drawings
5. Instrumentation, Control and Automation Drawings

1.2.3 Scope of the Works

The Scope of Works under Contract shall include the design, supply, construction and installation, commissioning, testing including process proving of the 400 MLD seawater desalination plant at Perur, Chennai followed by the operation and maintenance for 20 years on Design Build Operate (DBO) basis. The Works shall be executed as per the Technical Specifications. The design criteria and indicative base design parameters have been proposed in the technical specifications and the bid evaluation shall be carried out based on the same. The contractor may propose his own design parameters with sufficient justifications during detailed design phase of the plant subject to the acceptance of the Employer's Representative. This part of the specifications should be read in conjunction with other parts of the specifications, drawings and appendices which provide further scope and details.

The Works include all process, mechanical, electrical, civil, instrumentation and control, and all other allied works required for the construction of the 400 MLD seawater desalination plant with a sludge treatment and waste disposal facilities. The Plant shall be built in two separate similar process streams - each of 200 MLD capacity except the intake, outfall and sludge treatment facilities which are common for both the streams. The Plant shall be fully automated and completed in all respect to the world-class standard. Flexibility to turn down the production capacity up to 50% as advised by the Engineer shall be included in the design. Hereinafter, the "Engineer" means the "Employer's Representative" or the person named as such in the Particular Conditions of Contract, Part-III. Both the words "Employer's Representative" and "Engineer" are used interchangeably in the bidding document and have the same meaning.

The Contractor shall be fully responsible to ensure that the whole of the Works, including each plant component, is designed and constructed in a manner so that the System as a whole operates as a fully integrated system which is capable of achieving the required output efficiently and economically, including all the Plant, equipment and accessories required for the safe and satisfactory operation of the facilities. To achieve this, the Contractor shall ensure that each individual component performs in a manner which is complementary to that of all other components. Accessories which are not specifically mentioned in the specifications but are usual or necessary for the completion of the Works and successful performance of the System and facilities shall be provided by the successful Bidder within the tendered cost. The Contractor shall, to the maximum extent practical and feasible, endeavour to standardise on the manufacture and supply of Plant and equipment to minimise the operation and maintenance requirements. The Contractor shall ensure that his designs are "maintenance-friendly" and that all items of Plant and equipment are designed and installed in a manner which will facilitate routine and periodic maintenance operations.

Apart from the above, the works to be executed by the bidder shall include but not be limited to the following. The details of the works have been covered in the civil, electrical/Instrumentation, mechanical and other specifications of Part-2.

a) Elevating the site land up to CD +6.5m to protect the Plant from strong and high waves during Tsunami.

b) Construction of internal roads, including connecting roads to site from existing East Coast Road (ECR) to have separate and independent entries to plant/site.

c) Stormwater drainage within battery limits and extension up to the nearest drain/point of disposal. Stormwater has to be collected on the plant site and to be used for rainwater harvesting as much as possible and rest to be directed to the sea through outfall pipe.

d) Drinking water & sanitation water system for operation & maintenance personnel, yard lighting and fencing around equipment/ units, etc.

e) Construction of permanent boundary walls and internal fencing, entry gates and lighting including any temporary fencing required during construction as per the contract.

f) Solar Street lighting to illuminate the street as per specification in the contract.

g) Ventilation system for all buildings and units, air conditioning system as needed, cranes and hoists, fire fighting system, workshop, tools & tackles for handling of the equipment during maintenance.

h) Commissioning spares parts

i) The laboratory complete with instrumentations and equipment for testing and efficient operation of the Plant. A list of laboratory items and equipment to be provided by the contractor is as given in this bidding document.

j) Site services as required for the construction, commissioning and O&M of the RO Plant till handover.

k) Lay-down areas, warehouses, workshops for site construction and prefabrication purposes, vehicles, mobile equipment etc.

l) The Plant shall be built with minimal leakage. Water leakage, if any shall be transferred to the plant intake well. Leakages have to be monitored, counted in m^3/d and be part of the reporting. Maximum % of leakages must be stated by the bidders in the process description/ water balance and to be part of the O&M contract.

m) A minimum of 6 Metro Water Engineers/ personnel will be trained every year on-site for at least two months or as advised by the Employer in every plant function during regular O&M period. Necessary staff of the Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) shall be deployed to the site of the Plant for supervision/participation during construction and operation.

n) The Plant shall be connected to the national Tsunami warning system directly. In case of a Tsunami warning, an alert shall be issued. A programme shall be introduced so that the Instrumentation and Control System of the Plant shall set the Plant into a safe mode (including backflushing/ cleaning of membranes with desalinated water, closing all interconnected valves to the membranes and shutting down all electrical devices) with minimum interaction of an operator to minimise the damage to the Plant. The evacuation of the staff shall be planned and executed according to an occupational health and safety system. A yearly mock drill shall be conducted in the presence of CMWSSB officials to secure the operation of the Tsunami Response System. The result of this mock drill shall be reported to CMWSSB. The distributed control system (DCS) shall allow remote access of the Plant from CMWSSB's office.

o) The Contractor shall comply with requirements specified under Environment

(Protection) Act, 1986, and Water (Prevention and Control of Pollution) Act, 1974, Air (Prevention and Control of Pollution) Act, 1981 and Noise Pollution (Regulation and Control) Rules, 2000 and Hazardous Material (Management, Handling and Transboundary Movement) Rules, 2008 as applicable to the project and also with all other applicable current legislation, regulations and specifications, with respect to all measures, operations and administrative steps required for the full protection and safeguarding of the environment.

p) The CMWSSB is responsible for obtaining necessary permits/clearances from the State/Centre Regulatory agencies, namely Coastal Regulation Zone (CRZ) Clearance under CRZ Notification 2011, Consent to Establish from Tamil Nadu State Pollution Control Board (TNPCB) and Approval / NOC from the Forest Department for the Wildlife Conservation and Management Plan. Other than the permits/ clearance as specifically mentioned above, the Contractor shall be responsible for obtaining necessary statutory permits/clearances from the State/Centre Regulatory agencies under the applicable laws namely Consent to Operate from TNPCB and others as applicable to the project and comply with all such requirements during the entire period of the contract, i.e. during Construction Stage and Operation Stage.

q) After award of the contract and before the start of work, the Contractor shall review the Environmental and Social Management Plan (ESMP) for the project available with CMWSSB. The Contractor shall duly update the ESMP to ensure compliance with all applicable legislation and regulations of State / Central Government and also with JICA Environmental and Social Guidelines on Social and Environmental Sustainability. The ESMP shall incorporate the requirements stipulated in the Project's EIA Report and conditions of approval from State/Centre Regulatory agencies. The ESMP shall also clearly define roles, responsibilities, reporting requirement and budgetary allocations for the implementation of mitigation measures. The revised ESMP shall be submitted by the Contractor to CMWSSB for necessary approval before initiating any groundwork.

r) The ESMP updated by the Contractor shall include all required Sub-plans. The Sub-Plans to the ESMP to be prepared by the Contractor shall include but not be limited to:

- *Stakeholder Engagement Plan* which explains interaction with the community, including project information disclosure and emergency response planning relevant for the community. This sub-plan should cover means and methods to inform affected population about construction schedule and expected impacts such as access limitation to properties if any and also spell out the grievance redressal mechanism available to the communities to ensure any concerns brought to the CMWSSB are resolved appropriately and in a timely manner.

- *Waste Management Plan* covering brine discharge / solid disposal and compliance with regulatory standards. The plan shall contain quantities and type of waste as well as the type of disposal. It shall cover all waste generated such as brine, pre-treatment sludge, CIP wastewater, solids, R.O. membrane etc. The design of the outfall shall comply with EIA study and waste disposal regulations as per the

Ministry of Environment, Forest and Climate Change, Government of India (MOEFCC) and State Pollution Control Board (SPCB). The quality of return water to be discharged into the sea shall meet TNPCB requirement (tolerance limit for the discharge of trade effluents into Marine Coastal Areas as per Water (Prevention and control of pollution) Act, 1974). The used RO membranes shall be disposed off in compliance with Indian laws and regulations. The way of disposal will be reported regularly to CMWSSB. Confirmation of official disposal sites shall be provided as and when identified by the Contractor after getting approval from CMWSSB in concurrence with TNPCB.

- *Turtle Nesting Conservation Plan* for the beach in front of the project premises to address threats to the turtle populations from fishing activities, artificial lightening's from anchoring vessels, oil spills etc. The project activity such as pipeline laying is not likely to affect the Turtle nesting as they will be buried more than 1.0 m from the sea bed surface hence, not expected to interfere with the turtle nesting. Also, the water pipe laying is suggested to be undertaken in the non-breeding season to further reduce the impacts. The conservation plan should enlist certain activities and should allot budget to them. Some of the indicative activities for conservation are: minimising impacts from lightings towards the seaside for Turtle hatchlings and cooperation with local Turtle conservation groups in order to conserve a maximum of Turtle eggs laid near the facility. In this regard CMWSSB will extend support to Forest Department/ WWF – India Personnel / Students Sea Turtle Conservation Network (SSTCN) for the conservation of Olive Ridley Turtles as required.
- *Separate E&S Management Plans for Construction and Operations Stages* shall be prepared to address the impacts associated with construction and operation activities on the environment, the workforce engaged and surrounding communities. These plans shall incorporate the requirements stipulated in the Project's EIA Report, applicable legislation and regulations, conditions of approval from State/Centre Regulatory agencies and also considering best practices and good engineering practices, as applicable.
- *Environmental and Social Monitoring Plan* shall be prepared to ensure that the envisaged purpose of the ESMP is achieved across all stages of the project. Performance indicators will be developed for critical environmental and social conditions. For each of the indicators, the monitoring plan will specify parameters to be monitored, the location of monitoring sites along with frequency and duration of monitoring. The monitoring plan will also specify applicable standards, implementation and supervising responsibilities and reporting requirements.

s) The Contractor shall implement all requirements of the ESMP approved by CMWSSB during the entire period of the contract, i.e. during the Construction Stage and Operation Stage of the SWRO based Desalination Plant and associated facilities.

t) Operation and Maintenance of the aforesaid SWRO based Desalination Plant and associated facilities is to be carried out strictly as per the approved ESMP and as directed by the CMWSSB and State/Central Pollution Control Board Norms.

u) The Contractor shall seasonally monitor the environmental quality of the working sites and their surroundings in terms of environmental and social performance indicators as specified in ESMP and submit the monitoring results to CMWSSB. The Contractor shall also be responsible for periodic submission of Monitoring Reports to the regulatory agencies in compliance with requirements of the ESMP.

v) All pressure containing equipment and components shall be designed, fabricated, tested, and inspected in accordance with project specification and ASME Section VIII, Div 1. Material certification to BS-EN-10204:2004 shall be supplied for all items.

w) Inspection and Quality Control of all equipment and civil works, erection, commissioning, trial run, along with all consumables and manpower, project management and monitoring for timely submission of design documents and drawings and timely execution of the project with a demonstration of performance guarantee parameters including the supply of all measuring instruments and manpower.

x) The Bidder's proposal shall include details and references of the recorded operational reliability of the key equipment and systems to be provided. The proposal shall include a description of the RO Plant's ability for flexible operations.

y) Industrial workshop with suitable size EOT cranes for maintenance – area up to 2000 sqm.

z) Sewage Treatment Plant of capacity 20 KLD. The sewage shall be treated to the quality approved by the regulatory authority for reuse/surface discharge.

aa) Garden & Landscaping work shall be done around the Administrative building, control/laboratory building and all open areas at the site as per the contract and to the satisfaction of the Engineer.

bb) Security Cabin – two security cabins each of minimum size 20.0 sq.m floor area with toilets for two plant gates shall be designed & constructed in RCC frame structure with all interior facilities and external finishes.

1.2.3.1 *Summary of the Scope of Works*

The Works shall include the:

- Designing, construction, procurement, installation, commissioning, testing, process proving and 20 years operation and maintenance of a 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis;
- Plant process and hydraulic design and construction for two fully separate process parallel streams of capacity 200 MLD each;
- Raising and preparation of the site ground level at CD +6.5m for civil structure construction and boundary of the plant site.
- Procurement and installation of all mechanical, electrical and instrumentation & control works;
- Design and construction of all civil structures including tanks and building works;
- All piping works including yard piping at the site (including intake & outfall pipes off seashore) and all mechanical/electrical/civil general arrangement and section drawings;

- Full automation of plant processes with distributed control system;
- Design and manufacture, supply, testing at manufacturers' works, storage when required, delivery to site, unloading and site transportation, erection, site testing, painting and finishing of the Plant;
- testing, commissioning, process proving and 20 years of operation and maintenance of the SWRO desalination plant;
- provision of spare parts, special tools, operation and maintenance manuals and As-Built drawings;
- Wastewater treatment and safe disposal of solid and liquid waste as per the local & central government norms;
- All other works as required for 2x200 MLD SWRO desalination plant with all allied works for production of 400 MLD product water of the required quality.

1.3 Raw Water

1.3.1 Raw Water Source

The proposed site for 400 MLD Perur SWRO Plant is within 1 km of the site of 100 MLD Nemmeli desalination plant. The records of seawater quality at 100 MLD Nemmeli desalination plant cover data for a period of 5 years which is the only extended continuous data available for the plant design. It is to be noted that the maximum TDS values up to 39,500 mg/l were recorded on a short period during April 2018 to May 2018, over 5 years of data recording. Apart from this short period, all TDS records at 100 MLD Nemmeli plant are below 38,500 mg/l (plant laboratory operated by Wabag).

The variation of TDS over more than 5 years period is presented below in Figure 1-1.

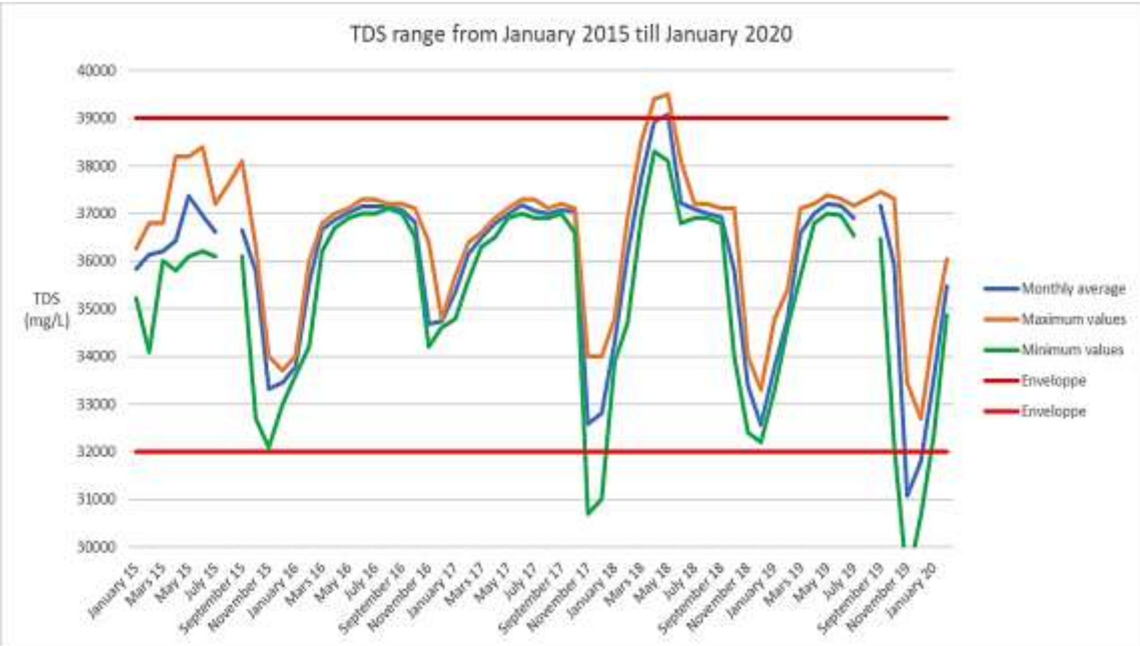

Figure 1-1: TDS profile over a period of 5 years (Nemmeli Data)

The TDS range is quite extensive due to freshwater impact during the Monsoon period. The decrease of TDS (to 32000 mg/l) in November every year is repetitive, and its intensity depends on the rainfalls. Except for two restricted periods in 2015 and 2018, repeatability of TDS values below 37,500 mg/l are observed during spring and summer before the rainy season.

Considering the above, the range of TDS adopted for the Perur RO design is 32000 mg/L to 39000 mg/l, which is quite reasonable.

The variation of TSS in seawater over 5 years period is presented below in Figure 1-2.

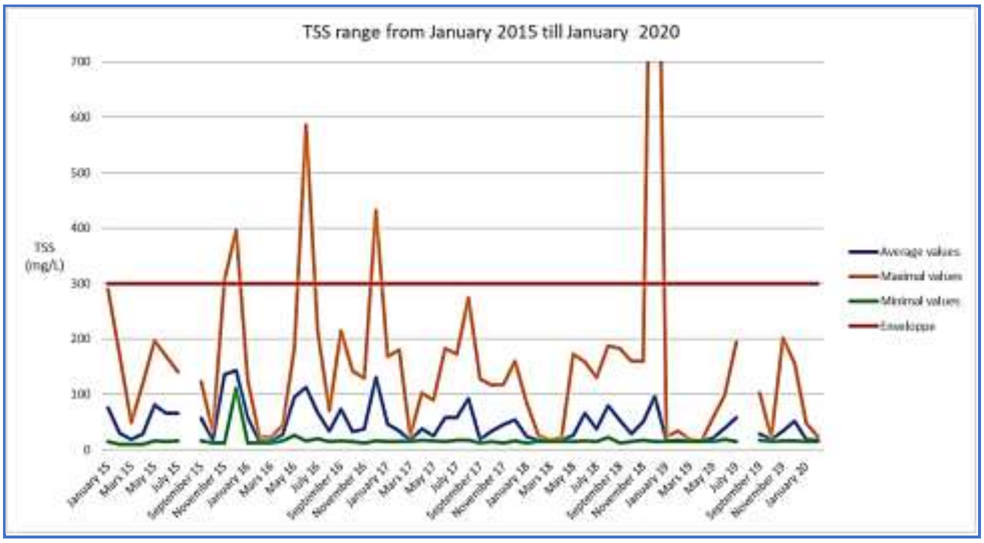

Figure 1-2: TSS profile over a period of 5 years

A peak of TSS reached 1478 mg/l in December 2018. Usually, such abnormal value (one day) is considered an outlier and discarded. The maximum value of TSS in seawater has been considered at 300 mg/L for the pre-treatment design purpose.

TOC (total organic carbon) is an important parameter to monitor since it is responsible for biofouling on the membrane surface. It is also revealed that the seawater in the site vicinity contains small white particles which are organics in nature and result in membrane fouling and frequent cleaning. Bidders are advised to investigate seawater for the TOC content and design the pre-treatment accordingly to avoid membrane fouling.

The desalination plants at Minjur and Nemmeli have recorded specific event of jellyfish attacks, but regarding HABs (Harmful Algae Blooms or "red tides"), they have no specific records. However, such events have been reported in the local press and research papers.

Table 1-1 provides the maximum, minimum and mean values of the seawater characteristics at Perur.

Table 1-1: Raw seawater design parameters

Jan'2015-Jan'2020	Minimum value[1]	Mean value[3]	Maximum value[2]
SWRO parameter envelop			
TDS	32000	36000	39000
pH	8.00	8.13	8.20

Jan'2015-Jan'2020	Minimum value[1]	Mean value[3]	Maximum value[2]
Temperature	26.0	28.3	31.5
Boron	3.2	3.53	3.80
Pre-treatment parameter envelop			
Turbidity	1.0	12	150
TSS	10	75	300
Total Organic Carbon [4] (TOC)	3.0	5	8
Algae count (cells per ml) [4]	100	500	30000
Jellyfish attacks	-	-	Yearly Occurrences

[1] Minimum is the monthly minimum data over Jan 2015 to Feb 2020

[2] Maximum is the monthly maximum data over Jan 2015 to Feb 2020

[3] Mean is the monthly average data over Jan 2015 to Feb 2020

[4] Assumed values, to be confirmed by the bidders.

1.3.2 Product Water Quality

The Product water quality requirements at the inlet of clear water reservoir are specified in the Table below. The product water TDS shall be less than 450 mg/l, Boron < 1 mg/l, turbidity < 0.5 NTU and hardness ≥ 60 mg/l as $CaCO_3$. All other parameters shall meet the drinking water standard in line with BIS:10500-2012.

Table 1-2: Product Water Quality Requirement

Parameter	Required Quality
Turbidity (NTU)	< 0.5
True Colour	< 3
Chlorides (mg/L)	< 250
TDS (mg/L)	< 450 all the time
Boron (mg/L)	< 1.0 mg/l all the time
LSI	> positive
Hardness	≥ 60 mg/L as $CaCO_3$
All other parameters	As per BIS 10500 - 2012

1.4 Design Flow and Capacity

The SWRO desalination plant at Perur shall be able to treat minimum 1040 MLD seawater to produce net 400 MLD product water at the Clear Water Reservoir (CWR). CWR is in scope of Works but the pumping station to transfer water to Porur is not in the scope of this contract. An indicative mass balance of the plant process is provided below.

1.5 Mass Balance for the Proposed Plant

An indicative calculation for mass balance for 400 MLD desalination plant for 42% and 46% recovery are presented in Table 1-3 and Table 1-4. As there are two parallel process streams of 200 MLD each, the flow to each stream will be half of the flow given below. The Plant will be running most of the time at 46% RO recovery, and the recovery will be reduced to minimum 42% in case of an adverse situation of feed water quality and/or during the possibility of vigorous membrane fouling. The plant design shall be based on the production of additional permeate in order to compensate the loss of production during non-availability of the plant. The required plant availability is 97% but the net 400 MLD production shall be maintained every month during the O&M period.

Table 1-3: Indicative Mass Balance for 400 MLD Desalination Plant at 42% RO Recovery

Process Stage	m^3/day	Wastewater	Factor to Feed Flow
Intake Pumps	1,052,180		100.00%
Service Water	2,000		0.19%
Utility and Leakage		2,104	0.20%
Lamella + DAF waste		31,437	2.99%
GMF Backwash		30,706	2.92%
Pre-filtered water	988,145		93.91%
Feedwater RO+ERD	988,145		93.91%
Feed to RO	988,095		93.91%
HP pumps	415,000		39.44%
Recir. Pump	573,095		54.47%
Feed to ERD	573,145		54.47%
RO permeate	415,000		39.44%
RO Reject		573,145	54.47%
CIP & Flushing		2,000	0.19%
Total plant waste discharge		639,393	60.77%
Net Plant Product Water	413,000		
Overall Plant Recovery	39.2%		

Table 1-4: Indicative Mass Balance for 400 MLD Desalination Plant at 46% RO Recovery

Process Stage	m^3/day	Wastewater	Factor to Feed Flow
Intake Pumps	960,705		100.00%
Service Water	2,000		0.21%
Utility and Leakage		1,921	0.20%
Lamella + DAF waste		28,711	2.99%
GMF Backwash		28,043	2.92%
Pre-filtered water	902,224		93.91%
Feedwater RO+ERD	902,224		93.91%
Feed to RO	902,174		93.91%
HP pumps	415,000		43.20%
Recir. Pump	487,174		50.71%

Process Stage	m^3/day	Wastewater	Factor to Feed Flow
Feed to ERD	487,224		50.72%
RO permeate	415,000		43.20%
RO Reject		487,224	50.72%
CIP & Flushing		2,000	0.21%
Total plant waste discharge		547,900	57.03%
Net Plant Product Water	413,142		
Overall Plant Recovery	43.0%		

1.6 Design Criteria for the Proposed Plant

The overall criteria for the Base Process Design of the Plant are given below in Table 1-5. Bidders shall include these design criteria in their proposal for the construction of the 2x200 MLD SWRO desalination plant and the associated works. Technical bids shall be evaluated based on this base design criteria and the associated lowest evaluated price bid will be selected.

Table 1-5: Base Process Design Criteria for 400 MLD Desalination Plant at Perur

Process Stage	Design Criteria (2 x 200 MLD)
Product water	○ *Net 400 MLD product water – with provision of min. 50% turndown capacity as advised by the Engineer.* ○ *TDS ≤ 450 ppm,* ○ *Chlorides ≤250 ppm* ○ *Turbidity ≤ 0.5* ○ *Boron < 1.0 ppm* ○ *Hardness ≥ 60 mg/l as $CaCO_3$* ○ *LSI - Positive* ○ *pH – 6.5 to 8.5* ○ *Other parameters as per BIS 10500-2012*
RO recovery	• *Nominal RO recovery: 46% (provision for 42% in case required)*
Production Turndown	• *Provision for production turndown below 50% to reduce production flow < half as needed.*
The offshore seawater intake header	• *Submerged open-intake @ > 10 m seabed depth* • *Velocity cap type* • *Horizontal velocity at 0.12m/s* • *Screen bar with 10cm spacing with a fishing net* • *Shock chlorination + compressed air system*
Offshore seawater intake pipes	• *2 pipes (buried) of HDPE (2500 mm OD,PE100, SDR <26)* • *Length - 1150m from seashore Same profile/ alignment trench*
Brine outfall system	• *1 pipe in HDPE OD 2500 mm. SDR <26* • *Length – 750m from seashore:* • *Brine diffuser: >30 units; dia-350mm; spaced 6 m.*

Process Stage	Design Criteria (2 x 200 MLD)
Ancillary equipment for the intake system	• *Intake well (4 Chambers)/ 4 sets Band screens (4x 50%)* • *Air bursting and Shock chlorine dosing system* • *The intake pipes are designed to be cleaned by pigging system with a launcher/receiver installed at the pumping station/ intake.*
Seawater intake pumping station – provides water to two streams of 200 MLD each	• *6 + 3SB units of vertical turbine pump for total flow 43333 m3/h (1040 MLD); Minimum flow: 39500 m3/h (948 MLD) @ 46% RO recovery (half of the flow to each stream)* • *Discharge pressure: >18 m* • *VFD required*
Pre-treatment	• *Composed by chemical and physical processes.* • *Main stages:* ○ *Coagulation/flocculation – Flash mixing* ○ *Clarification by Lamella Settler* ○ *Dissolved air flotation* ○ *Dual media gravity filtrations (optional third media as needed)* • *Cartridge filters* • *Alternate bid with change in pre-treatment scheme is allowed as per the condition of the Contract - justification for technical advantage with capital and O&M cost saving must be provided.*
Coagulation stage – Flash mixing	• *Retention time: min. 20 seconds*
Flocculation stage	• *Retention time: min. 20 minutes*
LS Clarification stage	• *Lamella surface loading rate: ≤ 1.0 $m^3/m^2.h$.*
Dissolved air flotation	• *Surface loading rate with recycling: 25 $m^3/m^2.h$* • *15% recycling*
Gravity dual media filters	• *Surface loading rate: < 7.5 $m^3/m^2.h$ with all filters operating* • *The top layer (Anthracite): 1.2 m* • *The bottom layer (Silica sand): 1.5 m*
Cartridge filters	• *Filtration size: 5 µm.* • *Construction material GRP* • *Cartridges: melt-blown polypropylene*
Chemical pre-treatment	• *Sulfuric acid – as required for pH adjustment* • *Ferric chloride 5 – 30 ppm as pure chemical (jar test needed for ppm level)* • *Polymer (0.1- 0.5 ppm Lamella, DAF)* • *Pre Chlorination -Sodium hypochlorite (1-3 ppm)* • *Post Chlorination -Sodium hypochlorite (1-2 ppm*

Process Stage	Design Criteria (2 x 200 MLD)
	disinfectant) • *Sodium bisulphite (10 ppm)* • *Sodium hydroxide (pH control, 10 ppm – as needed for Boron treatment)* • *Antiscalant dosage for SWRO (~1 ppm)* • *Biocide for biofouling control*
Filtered water tank	• *Two RCC tanks – one for each stream with interconnection proposed with 2 compartments/tank for isolation and cleaning:* • *Tank Capacity - 10000 m^3 each (30 min)*
SWRO desalination streams	• *Two main streams (2x 200 MLD)*
SWRO membranes	• *8 elements per vessel* • *Mixed HR and LE membrane/PV allowed.* • *Operating flux: 13.4 $l/h/m^2$* • *Diameter: 8", Length: 40", Area: 440 sq.ft*
High-pressure feed pumps (Booster RO)	• *Design pressure: ~ 4 bar as per design requirement* • *With or without VFD as needed*
High-pressure pumps	• *Suitable for seawater maximum TDS with minimum Temperature; and min TDS with max temperature.* • *With VFD* • *Provision of production turndown.*
Energy recovery system	• *Isobaric pressure exchanger with high reliability. (ERI preferred)*
Booster pumps for energy recovery system (if required)	• *Centrifugal mono-stage horizontal type or as needed.* • *Design pressure: ~ 2.5 bars or as per design requirement* • *As per design requirement*
Recirculation pumps for energy recovery systems	• *Centrifugal mono-stage horizontal type or as needed.* • *Design pressure: ~ 2.5 bars or as per design requirement* • *With VFD*
SWRO skids	• *Each RO train size – 25 MLD* • *Each stream of 200 MLD water production will have 8+1 RO skids (trains)*
SWRO front permeate tank	• *2 metallic tanks – one per stream interconnected* • *Each tank volume: 5,000m^3 per stream*
Post-treatment	• *Composed by remineralisation with CO_2 and limestone beds (at least 48% permeate to be treated)* • *pH adjustments with NaOH* • *Disinfection with sodium hypochlorite*
Limestone bed for remineralisation	• *Upflow / Continuous Feeding Limestone Remineralization system.*

Process Stage	Design Criteria (2 x 200 MLD)
	• *Number of cells: 28 units (14 per stream).* • *Surface loading rate:* 10 $m^3/m^2.h$ • *Contact time: 25 minutes (min)* • *Integrated storage system for limestone with capacity for minimum 30 days* • *Air + water backwash system*
Product water tanks	• *2 metallic or RCC tanks for each stream* • *Total capacity 30,000 m3 (2 hours) – Each stream tanks capacity - 15000 m3 with partition for isolation & cleaning*
Clear water tank	• *1 RCC CWR with partition – with partition and provision to clean one part* • *Total capacity 9,000 m3* • *Two 1600mm DI flanged puddle for feed to CWR and six (6) 900mm DI flanged puddle for discharge from CWR*
Interface with other packages	• *Provide puddle and flange to connect with pipeline of CP2 package for product water transmission.* • *Provide GIS substation for the 230kV cable under CP5 package*
Cleaning (CIP) and flushing system	• *Preparation Tank : as per system requirement* • *CIP pumps flow:1152 m3/h or as required.* • *Flushing pumps flow: 1024 m3/h or as required*
Wastewater treatment	• *physiochemical treatment. At least 1 sludge balance tank, 2 thickeners, 1 sludge holding tank and BFP building with up to 5 BFPs considering average raw water TSS of 75mg/l.*
Specific requirements	• *Pre-treatment pilot plant* • *RO cleaning pilot plant* • *Membrane testing plant*

1.7 Works Life Expectancy

The Contractor shall design the Works for a minimum life expectancy as follows:

- Civil works, buildings and buried pipelines: 50 years
- Concrete tanks, process chambers 50 years
- Heavy mechanical and electrical equipment 25 years
- Other mechanical and electrical equipment 15 years
- Buried earth electrode systems 30 years
- Automation and sensors equipment 15 years
- Control panels 15 years
- Instrumentation systems 15 years

• Metallic reservoir and tanks (not for seawater or brine)	25 years
• Polyethylene tank (or other chemical containers)	10 years
• Pressure vessels	30 years
• SWRO membranes	>5 years

1.8 Turnkey Contract

The implementation of the construction works for the 400 MLD SWRO desalination plant at Perur shall be a 'turnkey contract'. Accordingly, the Contractor shall be required to execute the construction works followed by 20 years of Plant O&M under DBO basis as per the performance requirements of the proposed Plant including civil, mechanical, electrical, and instrumentation components as specified in the Employer's Requirements and elsewhere in the bid documents.

Apart from the scopes described above, the scope of the Contractor who shall execute the works and guarantee plant and process performance shall also include, but shall not be limited to the following:

- All preparatory works including clearing, levelling and compaction of the site, site grading/ dressing of site as per specified formation or finished ground level (FGL), provision of access roads, roads inside and around the site etc., excavation, dewatering as required and disposal of all surplus earth to a suitable location.

- Topographic survey and geotechnical investigation and any other investigation(s) which are considered necessary in the opinion of the Contractor as well as those deemed fit by the Engineer.

- Prepare process and hydraulic design with the layout and hydraulic flow diagram of the complete desalination plant considering two streams, to meet the product water quality parameters.

- Undertake complete detailed engineering design of the desalination plant including process, civil, structural works, mechanical (with intake/outfall pipings), electrical and instrumentation/ DCS system equipment and allied works with construction drawings, to ensure process performance, and submit for the approval of the Engineer and the Employer.

- After approval of the designs and drawings by the Engineer and the Employer, the Contractor shall commence implementation of civil, mechanical, electrical and instrumentation and allied works at the site as per the approved QA/QC and safety plan.

- Placing of orders, manufacture, testing at the place of manufacture, inspection by the Employer's Representatives/Engineer, finishing and painting, packing, transport, supply/delivery, storage, erection/ installation, testing and commissioning of the plant mechanical, electrical and instrumentation equipment as per the tender and with the consent of the Employer.

- Providing as-built drawings for all components in soft and hard copies.

- Contractor shall provide the operation and maintenance manuals for the Plant and shall update them regularly.

- Contractor shall provide all services required to operate the Plant successfully to meet the required product water quality.

The Contractor shall be responsible for all aspects of design and construction to meet the required plant performance and other conditions/standards laid down in the specifications within the plant battery limits.

1.9 Perur Plant Design Philosophy

The Plant shall be designed and operated in 2 plant streams of 200 MLD each. The Contractor shall provide two fully separate streams in all respect. Only the intake pumping station, clear water reservoir and Outfall tanks will be common to both the streams. All pre-treatment units, RO system, post-treatment system, tanks and chemical storage and dosing systems shall be separate to both the streams. The detailed information is given in the indicative plant flow diagram and layout drawing provides in Part-2, Section VI, Drawings.

The Perur project is expected to be the spine of the water production for Chennai and will be operated at its maximal available capacity most of the time; therefore, it shall offer the lowest cost (CAPEX and OPEX combined) compared to the other desalination facilities of lower capacities. The production turndown ratio shall be a minimum 50 % per stream and so all upstream and downstream units shall be sized to meet this requirement.

1.10 Uninterrupted Power Supply (UPS) Systems

The Contractor shall provide an uninterrupted power supply for plant instrumentation and control system. The Contractor shall demonstrate the operation of the UPS systems by actually simulating a plant-wide or localised power failure condition (as agreed with the Employer's Representative) and proving that:

- all the process instruments have continued to measure the plant data
- the PLC has been processing these and posting the data to HMI
- the HMI performing with no interruption and continue to log and trend these data.
- all the instrumentations, including valves, are set in the fail-safe mode.

Refer to Part-2, Section VI, Chapter-8 for detailed information about the UPS.

1.11 Plant Layout

Overall tentative layout for the entire Desalination plant shall be referred from Employer's Requirement – Part-2 Section VI, Drawings enclosed. Final layout of the systems shall be furnished by the Contractor and finalised during detailing.

The general arrangement drawing as proposed by the bidder shall clearly indicate the dimensions of the various equipment, pipe routing, valve locations etc. The pipes shall be laid out in such a way that they are easily accessible for any maintenance or repair and also permit easy movement of the personnel. The exact layout considering the actual equipment dimensions, handling facilities, clearances as required for easy operation and maintenance etc. shall have to be firmed up by the bidder for satisfactory operation of the systems covered under the scope of work.

The drawing shall be prepared on standard-sized drawing sheets not larger than size AO (840 mm × 1190 mm).

1.12 Time for Works Completion

The whole of the Work, including mobilisation, reconnaissance, survey, sub-soil investigations, design, manufacturing, transportation, construction, installation, commissioning, testing and process proving is to be completed within the scheduled Time for Completion as set out in the Part 3, Section VIII, Particular Condition (PC).

1.13 Milestones

The Contractor is to ensure consistent pro-rata progress on all Milestones of the Contract during the entire Contract Period. The Contractor to prepare the Programme based on the key Milestones set out in Table 1-6 and submit the same during the bidding stage. This Programme shall be reviewed after the award of contract duly considering the actual site conditions and approved by the Employer. This approved Programme will be adopted for periodic review of the progress of various Milestones and assessment of any delay in the implementation of the works. Accordingly, this approved Programme is the basis for making decisions of delay damage as per the provisions of Clause 9.6 of the Particular Conditions of Contract – Part 3, Section VIII.

1.14 Interface with Other Contract Packages

The Works under this Contract will physically interface with Works under two other contract packages i.e. Pumping station contract (CP-2) and electrical power supply (CP-5). The Contractor of this contract shall co-ordinate with the Engineer and the contractors of other contracts as required and ensure that all interfaces are designed, constructed, installed, tested, commissioned, operated, and maintained properly to provide a fully functional system meeting all plant performance requirements. The Contractor of this contract shall be fully responsible for independently field-verifying all information he may consider relevant in order to provide a fully functional system.

Table 1-6: Milestones of Works Description for 400 MLD DSP

Sl. No.	**Work Description**	**Time (Months) from Commencement Date**													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
1	**Mobilisation**														
1.1	Establish site offices	100%													
1.2	Set up site laboratory	100%													
1.3	Finalisation of the work plan	100%													
2	**Surveys & Investigations, Design, Drawings and Documentation**														
2.1	**_Survey, Process Design and Drawing*_**	Start	**50%**	75%	**100%**										
2.2	**_Civil Structural, Mechanical, Electrical and ICA Designs and Drawings*_**		Start	**50%**	75%	**100%**									
2.3	As Built Drawings and documents													Start	100%
3	**Intake and Outfall Pipeline (400 MLD) for Procurement, Supply, Construction, Installation/Erection, Testing & Commissioning**														
3.1	**_All works related to laying of HDPE Pipeline for Intake and Outfall works*_**			Start	**50%**					**100%**					
3.2	Fixing of Offshore Velocity Cap type Heads and Offshore Diffusers with all allied works at offshore intake								Start	100%					
3.3	Any other offshore structure/ works to complete at the intake and outfall system									Start	100%				

Sl. No.	**Work Description**	**Time (Months) from Commencement Date**													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
4.	**Civil Works - Supply & Construction, Testing, Commissioning for 2 x 200 MLD Plant**														
4.1	All Intake and Outfall Structures onshore, including pigging.			Start	25%		50%	75%		100%					
4.2	All Chemical Buildings - for Pre, Post and RO feed treatment including Shock Chlorination System						Start	25%	50%	75%	100%				
4.3	***<u>All Pre-treatment System - Coagulation and Flocculation, Lamella Settler, DAF, GDMF including RO feed Tanks and allied System</u>****				Start	**25%**		**50%**		**75%**		**100%**			
4.4	RO System - Housing, CIP, MCC, Tanks and allied Systems				Start	25%	50%	75%	100%						
4.5	Post Treatment System – CO2 storage/dosing area, Limestone Filter Structures, etc.						Start	25%	50%	75%	100%				
4.6	Waste Sludge Treatment System – SBT, Thickeners, Holding Tanks, BPT buildings and allied system.							Start	25%	50%	75%	100%			
4.7	Product Water Tank and allied systems					Start	25%	50%	75%	100%					
4.8	Clear Water Tank and allied systems				Start	25%	50%	75%	100%						

Sl. No.	**Work Description**	**Time (Months) from Commencement Date**													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
4.9	All Electrical Buildings and other related structures				Start	25%	50%	75%	100%						
4.10	Admin, Control and other Buildings at the plant including Workshop and Warehouse						Start	25%	50%	75%	100%				
4.11	Sewage Treatment Plant and allied systems								Start	25%	50%	75%	100%		
4.12	***Site backfilling to CD+6.5m****	Start	**100%**												
4.13	All other works at site including boundary walls, roads, fire-fighting building, Security building, land scaping, plantation etc.										Start	25%	50%	75%	100%
5	**Mechanical Works - Procurement, Supply, Installation/Erection, Testing, Commissioning for 2 x 200 MLD Plant**														
5.1	Intake & Outfall System onshore - All mechanical items pumps, valves, gates, screens and any other items					Start	15%	25%	50%	75%	85%	100%			
5.2	All Pre-treatment chemical dosing systems with allied works.						Start	15%	25%	50%	75%	100%			

Sl. No.	**Work Description**	**Time (Months) from Commencement Date**													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
5.3	***All Pre-treatment Units - Coagulation and Flocculation, Lamella Settler, DAF, GDMF including RO feed Tanks and all allied works****					Start	15%	**25%**	35%	**50%**	75%	**100%**			
5.3	***RO System – RO Skids, Chemical dosing and CIP system including Permeate and Neutralization tanks and all allied works****					Start	15%	**25%**	35%	**50%**	75%	**100%**			
5.4	Post Treatment System – CO2 System, Limestone Filters, Chemical System and all allied works					Start	15%	25%	35%	50%	75%	100%			
5.5	All mechanical works at tanks PWT, CWR, Outfall tank, and all other structures and allied works					Start	15%	25%	35%	50%	75%	100%			
5.6	Waste Sludge Conveyance and Treatment System – all mechanical works including allied works						Start	15%	25%	35%	50%	75%	100%		

Sl. No.	Work Description	Time (Months) from Commencement Date													
		Milestone I		Milestone II		Milestone III		Milestone IV		Milestone V		Milestone VI			
		3	6	9	12	15	18	21	24	27	30	33	36	39	42
5.7	All misc. mechanical works at all buildings, including sewage treatment system, Cranes, motorboat and all other allied works.						Start	15%	25%	35%	50%	75%	100%		
6	**Electrical & ICA Works - Procurement, Supply, Installation/Erection, Testing and Commissioning for 2x200 MLD Plant**														
6.1	All Intake and Outfall works – onshore and offshore							Start	25%	50%	75%	85%	100%		
6.2	All Pre-treatment Chemical Systems and allied works							Start	25%	50%	75%	85%	100%		
6.3	All Pre-treatment Process Units including RO feed tanks and allied works							Start	25%	50%	75%	85%	100%		
	RO System – RO Skids, Chemical dosing and CIP system including permeate and neutralization tanks and all allied works*							Start	**25%**	35%	**50%**	75%	**100%**		
6.4	Post Treatment System – CO2 System, Limestone Filters, Chemical System and all allied works							Start	25%	35%	50%	75%	100%		
6.5	All Electrical works at tanks PWT, CWR, Outfall tank, and all other allied works							Start	25%	35%	50%	75%	100%		

Sl. No.	Work Description	Time (Months) from Commencement Date													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
6.6	Waste Sludge Conveyance and Treatment System – all electrical works including allied works							Start	25%	35%	50%	75%	100%		
6.7	***<u>Substations – all works for transformers, switchyards, Cabling, Grounding & Lightning Protection, and all allied works*</u>***		Start	15%	**25%**	35%	**50%**	75%	**100%**						
6.8	All misc. Electrical works at all buildings including sewage treatment system, UPS, DG sets and all other allied works.						Start	15%	25%	35%	50%	75%	100%		
7	**Miscellaneous Works - Procurement, Supply, and Installation Testing and Commissioning for all works at 2x200 MLD Plant**														
7.1	Chemical Laboratory Items as per schedule and required.										Start	75%	100%		
7.2	Workshop items as per schedule and required.									Start	50%	75%	100%		
7.3	All Heating, Ventilation and Air conditioning systems including Cooling tower etc. as required in all buildings/ structures								Start	25%	50%	75%	100%		
7.4	Complete Firefighting system - fire detection and protection system in all buildings and covered spaces -											Start	100%		
7.5	Security and Surveillance system at the plant as per the contract										Start	50%	100%		

Sl. No.	**Work Description**	**Time (Months) from Commencement Date**													
		Milestone I		**Milestone II**		**Milestone III**		**Milestone IV**		**Milestone V**		**Milestone VI**			
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**
7.6	Any other works required to operate the 400 MLD DSP smoothly as per Contract.											Start	100%		
8	**Commissioning and Testing**														
8.1	Commissioning and initial performance test run													100%	
8.2	Process Proving														100%

* The delay damages shall be applicable if the % completion is not met at every 6 months as per milestones above and the progress shall be monitored quarterly.

CHAPTER-2

2. THE SITE DETAILS

2.1 Location of the Site

The proposed construction site for the Desalination plant is located at Perur village, about 40 km from the Chennai city centre. The total area of the plot is approximately 34 ha. It is situated along the coastal side of the East Coast Road (ECR). Its ground elevation is chart datum (CD) +2.0 to +7.5m with varying topography. ECR is approximately CD + 11m.

There are two graveyards identified within the proposed Site – one located on the Southern side of the seacoast and another on the Northern side towards the East Coast Road. It is understood that the graveyards must be left undisturbed and shall be protected by a compound wall all across, and proper drainage shall be made draining towards the sea. Nevertheless, the unused area available at the proposed Site is enough for the construction of the proposed Plant in all respect. Overall tentative layouts for the entire Desalination plant may be referred from Generalised Site Layout enclosed in Part-2, Section VI-Drawings. The final layout of the systems shall be furnished by the Contractor and will be finalised during detailing.

The climatic conditions are characterised by warm dry winters (27^{o}C average daily max) and hot summers (39^{o}C average daily max) with an annual average rainfall of 1200mm. Cyclones are common in the area, and the Site is expected to be affected by cyclones.

The site land profile is sloping from East Coast Roadside towards the seashore. The site land is to be raised by earth filling with suitable soil to maintain the finished ground level (FGL) at CD +6.5. The mean seawater level is at CD+0.65m. The construction of the Plant will be at FGL CD +6.5. The land topography drawing may be referred as provided in the document.

2.2 Land Ownership Data

The proposed land for the desalination plant identified under survey number – 208/ 2B3 belongs to the M/s. Arulmigu Alavandar Nayakar Trust maintained by The Hindu Religious and Charitable Trust (HR & CT) Department, Government of Tamil Nadu (GoTN). The land is procured by CMWSSB on a long-term lease basis.

2.3 Site Location

The details of the local site conditions are given in table below.

Table 2-1: Details of Site Location for the Proposed DSP Site

Particulars	Details
Site Location	District: Chengalpattu Taluk: Thiruporur Village: Perur
Site coordinates	12°42'44"N, 80°14'26"E
Nearest highway	State Highway SH 49, East Coast Road

Nearest railway station	Othivakkam railway station
Nearest Airport	Chennai Airport
Nearest town/ City	Chengalpattu, Pudupattinam, Tirukalukundram, Nandivaram-Guduvancheri
Archaeologically Important places	Mahabalipuram

2.4 Topography

Based on the preliminary onshore topographic survey and offshore Bathymetry survey, the details are given below. However, the contractor has to independently carry out the requisite study for confirmation.

Onshore topography

The Existing Ground Level (EGL) at the test conditions varied from +2.0m Chart Datum (CD) to + 7.5 m CD. The site is having tree plantation of Casuarina. The site falls under Seismic Zone III as per BIS code IS: 1893 (Part I).

Offshore Bathymetry

Based on the bathymetric survey, buried rocks have been found near the shore that is spread in different direction and depth. Figure 2-1 presents a seabed map indicating the location of buried rocks.

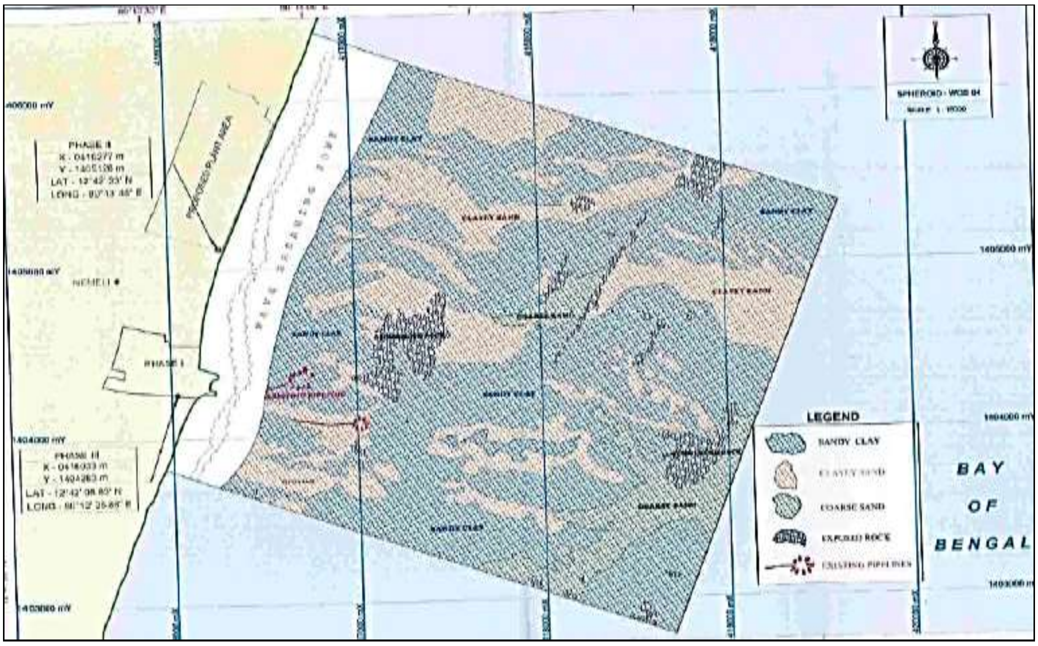

Figure 2-1: Seabed Map

The bathymetry survey shows that the depth contours are generally running parallel to the coast. The depth of the seabed with respect to the distance from the shore as obtained from the DPR report is furnished below.

Table 2-2: Variation of Sea Depth with Distance from Shore

Depth w.r.to CD (m)	Distance from Shore (m)
2	150
3	200
4	225
5	340
6	440
7	520
8	660
9	835
10	1040
11	1360
12	1890
13	2160
14	2480
15	2720
16	2950

Sedimentary layers of silty sand were identified between – 0.0 and -8.0 m below the seabed.

2.5 Climate

Chennai features a tropical wet and dry climate. Chennai lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. Typical meteorological data for Perur DSP is furnished below. Cyclones are more common in the Bay of Bengal, and the proposed Perur site is expected to be affected by cyclones by approximately 3 times per year.

The hottest part of the year is late May to early June, known regionally as Agni Nakshatram, with mean maximum temperature in Pre-monsoon season (May) was observed at 42.2 °C and mean minimum temperature observed at 24.2 °C. The mean maximum temperature in the monsoon season (June) was observed to be 40.6 °C whereas the mean minimum temperature was observed at 23.8 °C. By the end of September with the onset of Northeast monsoon (October), day temperatures decrease slightly with the mean maximum temperature at 35.5 °C with the mean minimum temperature at 22.2 °C. The city gets most of its seasonal rainfall from the north east monsoon which is from middle October to middle December.

The details of Typical Meteorological data for Perur DSP site are furnished below.

Table 2-3: Typical Meteorological Data for Perur DSP

Meteorological Parameters	Unit	Values
Mean annual ambient temperature (min./ max.)	° C	24.5 / 33.5
Barometric pressure	K Pa	100.1/ 101.35
Relative humidity (min./ average/ max.)	%	57 / 70 / 83
Main wind direction		South westerly
Average annual rainfall	mm	1399.3
Average rainfall during Northeast monsoon (June to Sept)	mm	454.3
Average rainfall during Southwest monsoon (Oct to Dec)	mm	837.1
Maximum rainfall within 24 hours	mm	346.6

2.6 Ocean Conditions

The oceanography of the region is influenced by 3 climatic conditions viz., Southwest monsoon (June – September), Northeast monsoon (Mid – October to Mid – March) and a fair-weather period (Mid -March to May). The coast is more influenced by the Northeast monsoon than the other two seasons. Wave action is high during the Northeast monsoon and cyclonic period. The coastal current within a 5 km radius distance is greatly influenced by winds and tides. The nearshore remains more dynamic and turbulent due to persistent action of seasonal wind, high waves and sea currents. The distribution of temperature and salinity indicates that the nearshore water is well mixed without stratification. The influence of littoral drift is significant, and the annual net drift takes place in a northerly direction. However, the Bidder should study the ocean conditions before proceeding with the design works. The tide elevation at Perur with reference to Chart Datum (CD) is furnished in table below:

Table 2-4: Tidal Elevation at Perur

Tidal elevation	Chart Datum (CD) in m	RL (m)
Mean High water spring	1.15	RL 0.5
Mean High water neaps	0.84	RL 0.2
Mean Sea Level	0.65	RL 0.0
Mean low water neaps	0.43	RL -0.22
Mean low water spring	0.14	RL -0.51

Note: Onshore survey levels are recorded as m above sea level. Hence, the mean high water springs conversion of CD to MSL is 1.15 -0.65 m = RL 0.5.

2.7 Geotechnical data

A geotechnical survey was carried out on behalf of CMWSSB during the year 2014. The subsoil is made up of three distinct layers, as indicated below. However, the Contractor is required to independently undertake the geotechnical study to confirm the values.

- Greyish silty fine sand : From - 0.0 to – 10.0 m (SPT N value = 10 to 64)
- Brownish silty stiff clay : From - 10.0 to – 13.0 / - 15 m (SPT N value = 7 to 9)

- Soft Disintegrated Rock : From - 13.0 to -15 m to – 19.0 m (SPT N value $\geq$ 100)
- Hard granite rock : From -17m to -23 m

Note: SPT – Standard penetration test

The groundwater table readings were recorded between 28th October 2014 to 5th November 2014. The groundwater table was encountered within depths of 1.54 m to 1.72 m below the EGL. In general, the groundwater table was almost consistent with the ground surface undulations, which implies that the groundwater is not perched water.

A preliminary geotechnical investigation report is attached in Part-II, Vol-5 of 5.

2.8 Land Development Plan

The height of the project site varies from CD +7 m on the East Coast Road to CD +2-3 m on the seashore side (Figure-5). Hence is it proposed to raise the site by additional earth fill to realize the Finished Ground Level (FGL) at CD +6.5 m. Raising of Finished ground level (FGL) up to +6.5 m CD is warranted to maintain safety factor to protect from strong winds and global warming, Tsunami and other emergency conditions. The boundary of the Perur DSP will be constructed on the raised land with high retaining wall of reinforced concrete. The retaining wall is proposed with pile foundation to keep it stable. A boundary wall of the same height shall be constructed on the ground level around the rest of CMWSSB land area including the burial grounds as indicated in the Plant Layout drawing (7061563/PMC400MLD/CP1/LAY/002) and Retaining wall/ Compound wall drawing (7061563/PMC400MLD/CP1/RET/005)

2.9 Access to the Site

The proposed 400 MLD desalination plant is located on the coast of the Bay of Bengal. Regular access to the Perur site from Chennai is via the East Coast Road.

The Employer will provide access of the Site to the Contractor for carrying out the Works. The bidder shall be deemed to have inspected the Site, including access before submitting the Tender.

The Nemmeli desalination plant is in the vicinity within 1 km of the proposed Site. The Contractor shall ensure that the operation of the Nemmeli plant and production of the potable water for supply to the city shall not be hindered any way due to construction works or mobilisation of the equipment, civil or any contract related works at Perur plant site. The strategy of the work implementation shall be discussed with and approved by the Engineer before any work execution to avoid any unforeseen difficult situation.

2.10 Employer's Requirements

The Contractor shall use the proposed process design given in the Employer's Requirements (Part-2) as a guide to understanding the requirements. However, the final process, mechanical, electrical and civil designs for the required performance of the complete design-build and O&M Works at the Plant with sludge treatment and waste disposal out of the site premises are the responsibilities of the Contractor. The bidders are encouraged to visit the proposed Perur plant site and understand the nature of works and level of site rehabilitation required for the plant construction and smooth operation as per Employer's Requirements. The successful completion of the full design-build Works and O&M Works as per the Contract is the responsibility of the Contractor. If additional works are essential which have not been mentioned in the bid document and Schedule of Price, then the bidders must identify those additional works in the technical schedule and price schedule in the related system and include in their offered project cost accordingly.

2.11 Maintenance of the Site

The Bidders shall include cost for maintaining the accommodation, equipment and all related services during construction, installation and operation of the works until the expiry of the Contract period or until such time as the facilities mentioned above are removed with the permission of the Engineer.

2.12 Areas outside the Site

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

Under these circumstances, the Contractor shall form a working area extending five (5) m from the edge of the Permanent Works or accommodation on all sides. The Contractor shall restrict his activities to within this working area. On completion of the works in this area, the Contractor shall reinstate the area to its original condition and to the satisfaction of the Engineer.

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

2.13 Road Works

The Contractor shall obtain all permits required for carrying out works such as excavation on public roads and shall liaise with the appropriate authorities with regard to the timing and execution of the road works. The Contractor shall be responsible for establishing and maintaining temporary road diversions for the duration of the road works. The road shall be kept open at all times during the road works period, and the work shall be carried out in such a manner as to minimise the disruption to traffic. All costs related to any type of permissions needed during work execution shall be included by the Bidder in his Price Schedule.

2.14 Maintenance of Access Roads

The Contractor shall construct theaccess roads to the Site, which are necessary for the execution of the Works with the consent of the Employer with all necessary permissions from the concerned government authorities. The Contractor shall be solely responsible for the maintenance of the Site access roads. Such maintenance work shall include general up-keep and any necessary repairs to the damaged road surfaces, pavement, drainage, associated slopes, etc. to original condition. While carrying out such maintenance work, the Contractor shall make arrangements to maintain the passage for the Employer's and his staff's vehicles and also those of subcontractors over these access roads, which may comprise temporary diversions all to the approval and satisfaction of the Engineer.

The Contractor shall take every precaution while operating tracked or unsprang vehicles on surfaced roads and shall use planking or some other protective material to protect the road surface.

2.15 Clearance of the Site

The Contractor shall clear the Site to the extent required by the Engineer for checking the setting-out. Clearance of the Site shall also include the landfilling, excavation, demolition and removal of all trees, articles, objects and obstructions which are expressly required to be cleared to the satisfaction of the Engineer. The Employer will assist the Contractor in obtaining the necessary approvals and permits for removal of trees. However, obtaining such approvals and permits shall be the sole responsibility of the Contractor.

The Contractor shall remove the material arising from such clearance and dispose-off it in a manner and at a location, on or off the Site, on the approval of the Engineer.

The Contractor shall not clear the Site of any structure without the prior written permission of the Engineer.

2.16 Clearance and Reinstatement of the Site on Completion

On completion of the Construction Works, the Contractor shall clear any temporary works areas and temporary access roads and reinstate the areas to their original condition/ required landscaping and to the satisfaction of the Engineer.

2.17 Site Records

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

2.18 Access for the Employer and Engineer

The Contractor shall permit the Employer and the Engineer and any person authorised by the Employer or the Engineer including staff of the Employer, other contractors or utility undertakings access for the purposes of the Contract to all areas of the Site and any additional accommodation or temporary wayleave for the duration of the contract period.

2.19 Facilities for Employer during the Contract Period

The Contractor shall purchase 3 new SUVs (top model) and provide them to the Employer for their use during DB Contract period. Additional, two new similar SUVs shall be provided by the Contractor to the Employer for their use through O&M period after 5 years of the Commencement Date of the Contract. All expenses related to driver, insurances, fuel and maintenance of the vehicles shall be the responsibility of the Contractor.

The Contractor shall provide and maintain at his cost, fully furnished airconditioned temporary site office for the Employer and PMC with wifi, toilets, pantry, conference room (No Portacabin will be allowed) along with the following facilities through the construction period of the contract or till the Administrative Building is constructed and fully furnished or till Design-Build Period whichever is later. The drawings for the site offices shall be approved by the Employer's Representative.

Sl. No.	Facility	For Employer	For PMC
1	Common Hall, cabins, work stations and Laptops with latest user software	Hall with 4 work stations, 4 cabins (8 Laptops)	Hall for 14 engineers with all facilities mentioned above and 4 cabins
2	Conference Room with white board and video conferencing facility etc. with marker pens etc.	To seat 25 persons	To seat 25 persons
3	Document storage room with printer, photocopy facilities along with required stationary.	Required	Required

2.20 Water Supply and Disposal on Site

The Contractor shall manage the supply of product water for the purpose of construction of the Works. The Contractor shall ensure the quality of the water is suitable for the purpose for which it is intended and maintain the water meter in proper condition.

Wastewater shall be disposed off, clear of the Site meeting the prevailing statutory requirements to the satisfaction of the Engineer and the government authority so as to avoid no damage or complaint. In any circumstances, the wastewater can't be discharged to the sea.

2.21 Toilets and Washing Facilities

Throughout the period of plant construction, the Contractor shall provide, maintain and cleanse suitable and sufficient latrines and washing facilities for use by his workers. He shall ensure that his workers do not foul the Site and make proper use of the restrooms.

Where practicable the latrines shall be connected to the nearest sewer, or if this is not practicable, the Contractor shall provide an adequately sized septic tank and soak pit. The Contractor shall also provide separate latrines to the above requirements for the entire Employer's/Engineer's staff. After completion of the works, the latrines and washing facilities shall be removed, all ground disinfected and the surface reinstated to the satisfaction of the Engineer.

2.22 Electricity for Contractor's Use on Site

The Contractor shall be responsible for the provision of an energy meter and distribution of an electrical supply at the Site for the purpose of construction Works.

The construction and installation works shall comply with all the relevant regulations, Indian Standards and Codes of Practice, and Health and Safety requirements, etc. The Contractor shall take every possible precaution to ensure that his execution works are safe and any injury to personnel or damage to Plant and buildings are avoided. The Contractor shall be fully responsible for all safety and maintenance aspects including the asset, personnel and material safety insurance etc.

The Contractor shall test the temporary Site electric distribution system, including energy meter regularly for compliance with the relevant standards.

2.23 Camp and Office Facilities

The Contractor shall construct and maintain to the Engineer's satisfaction a camp to provide living accommodation for all Contractor's staff and operatives who have no other local accommodation. The Contractor's camp shall be located close to the Site and at a location approved by the Engineer.

Responsibility for providing all services to the living quarters and compliance with all requisite laws and regulations shall be borne by the Contractor. Security and the fencing of these areas shall be the responsibility of the Contractor.

2.24 Compressed Air Use on Site

The Contractor shall provide the necessary compressed air plant and equipment required for construction of the Works. In case Diesel engine driven compressors are used, it shall not be housed within buildings or at a location that may cause a health hazard to personnel owing to exhaust fumes or noise.

2.25 Refuse Disposal on Site

Refuse, and rubbish of any kind shall be removed from the Site and disposed-off by the Contractor at his own expense, frequently and regularly so as to keep the Site in an approved wholesome and tidy condition to the satisfaction of the Engineer.

2.26 Health, Hygiene and Contamination of Water Supplies

The Site shall be an area of 'restricted operation'. Exemptions may be granted at the discretion of the Engineer for short-term operations involving no risk of contamination.

- All personnel shall be medically accepted
- Strict discipline shall be maintained concerning personal hygiene
- Vehicles, Plant, tools and protective clothing shall be kept clean and disinfected regularly.

To obtain medical acceptance, the Contractor shall require his employees and those of his sub-contractors to undergo medical screening, to ensure that they are not harbouring waterborne pathogenic organisms, before commencing 'restricted operations'.

All potential employees and supervisors who may have contact with the 'restricted operations' shall take a copy of the completed questionnaire together with two colour passport size photographs to the Medical Officer for Environmental Health of the District Health Authority where the person resides.

The Medical Officer will consult the person and return the questionnaire to the Contractor. The

Contractor shall then forward the questionnaires and photographs of those he wishes to employ to the Engineer for approval. Approval in the form of a blue identity card shall be issued for the approved cases. The card is valid for the duration of the contract or one year, whichever is less. Contracts of duration more than one year for 'restricted operations' carried out in the maintenance period will require a reassessment of employees.

If an employee contracts any illness, looseness of bowels or gastric disorder, he must immediately cease work on 'restricted operations', return his identity card, avoid contact with other employees, undergo medical screening and gain fresh approval before continuing work on the `restricted operations' Site.

Works involving both 'restricted operations' and 'non-restricted operations' shall either require (1) all employees to be medically accepted, or (2) separate accommodation with protective clothing is to be provided till they are medically fit.

2.27 Safety and Security on Site

The Contractor shall at all times maintain a safe system of working and shall comply with all enactments, regulations and working rules relating to safety, security, health and welfare of all persons who may be affected by the work. In particular, the Contractor shall ensure that only persons who are appropriately trained for their duties are employed and that the correct tools and procedures are used.

Nothing which has been written into or omitted from this Employer's Requirements shall be taken to relieve the Contractor from his obligations under this Clause. No clause in this Employer's Requirements shall prevent the Contractor from drawing the attention of the Engineer to any feature of the Works which is not consistent with normal safety practices nor prevent him putting forward proposals at any time which would increase the safety of the installations.

Not later than 28 days before work commences on the Site, the Contractor shall submit to the Engineer his comprehensive proposals relating to the safety, health and welfare of all his personnel on the Site.

The Contractor shall appoint a suitably qualified representative as Safety Officer who shall be responsible for the implementation of Site procedures as per relevant standards which shall include but not be limited to:

- safety
- working in hazardous areas
- permit to work
- fire and smoking regulations
- first aid
- warning signs
- trenching scaffolding and other construction structures

- safety barriers
- protective clothing and equipment
- safety training
- safety meetings and inspections
- health and welfare

The proposals shall be appropriate for all grades of labour and personnel who will work on or visit the Site on behalf of the Employer, Engineer or Contractor. The Engineer will have the power to stop any activity or work in any area where there is a breach of the published Site safety rules such that health or life is put at risk.

The Contractor shall, also, comply with the Safety Policy of the Employer, copies of which are available from the Engineer upon request.

The Contractor shall ensure that all employees and subcontractor employees working on the Site are not working in an unsafe manner to endanger themselves, the Contractor's personnel, other personnel or the Plant. The Contractor shall bring any violation of Site safety rules by others to the attention of the Engineer in writing.

2.27.1 PPE and Protection from COVID-19

The Contractor shall ensure that all the Personal Protective Equipment (PPE) are available with each and every worker at the site. It should include:

- Respiratory protection - for example, disposable masks, cartridge, half or full face. It is important to protect workers from transmitting any infection such as COVID-19.
- Eye protection – for example, spectacles/goggles, shields, visors.
- Hearing protection – for example, ear muffs and plugs.
- Hand protection – for example, gloves and barrier creams.

2.28 First Aid and Life-saving Apparatus on Site

The Contractor shall provide on the Site such life-saving apparatus as appropriate and an adequate and an easily accessible first aid outfit or such outfits as required in any government ordinances, factories acts, etc., published and subsequently amended from time to time. Also, an adequate number of persons permanently on the Site shall be instructed in their use, and the persons so designated shall be made known to all employees by the posting of their names and designations in a prominent position on Site.

2.29 Electrical Safety on Site

The Contractor shall be responsible for the electrical safety of all Plant supplied and installed. Whilst any equipment is being installed or tested; the Contractor shall ensure that all necessary precautions are taken to safeguard personnel working on Site. If necessary, this shall include fencing off areas which are considered to pose a risk and erecting warning notices.

The Contractor shall be responsible for ensuring that the electrical installation is carried out by suitably trained competent personnel and that the work is carried out in a safe manner.

The Contractor shall be responsible for the operation on the Site of a permit to work system during the period of electrical equipment installation and testing. This system shall regulate the installation, the energisation and the use of electrical Plant installed and the method of work adopted.

2.30 Noise

The Contractor shall ensure that noise from the operations entailed in the construction of the Works does not cause annoyance to others working on the Site or to persons living adjacent to the Site.

2.31 Warning and Safety Signs

During construction of the Works, statutory safety signs shall be adequately provided throughout the Works, both indoors and outdoors. These safety signs shall be in Tamil and English and shall cover mandatory, prohibition, warning, emergency, fire-fighting and general notices. All signs shall be positioned around the Works at clearly visible points. Provision of signs and the positions of signs shall be subject to the Engineer's approval. Special attention shall be given to areas designated as hazardous.

2.32 Site Working Hours

During the Construction Phase, no work shall be carried out on the Site on locally recognised days of rest, or outside regular working hours, unless:

(a) otherwise stated in the Contract

(b) the Employer gives consent

(c) the work is unavoidable or necessary for the protection of life or property or for the safety of the Works, in which case the Contractor shall immediately notify the Engineer.

The Contractor shall not increase the working hours during the Construction Phase without the prior approval of the Engineer.

During the Operation and Maintenance Period, the Work shall be carried out all 24 hours of a day.

2.33 Delivery to Site

The Contractor shall be responsible for the transporting and handling of all the Plant as required. The storage of all equipment and construction items at the Site shall be the Contractor's responsibility.

The Contractor shall check all items against packing lists immediately on delivery to the Site and shall also inspect for damage and shortages. Damages and shortages shall be remedied with the minimum of delay.

The Contractor may, with the prior approval of the Engineer and at no extra cost to the Employer, make arrangements for any other contractor or agent to take delivery of, unload and store the Plant on the Site on behalf of the Contractor.

All deliveries shall take place during the Contractor's regular working hours.

2.34 Storage and Protection from Weather

Indoor storage for electrical, instrumentation and any other equipment/material likely to be damaged due to moisture and outdoor storage for other plant equipment to be provided at Site for use by the Contractor for storage of Plant prior to erection will be subject to the approval of the Engineer.

The Contractor shall provide all other facilities for the safe and proper storage of Plant particularly cartridge filters, RO membranes, as recommended by the manufacturers, with particular consideration being given to temperature, rain, sunlight, wind and ground conditions the storage area shall be suitably raised to prevent waterlogging.

The Contractor shall remain responsible to the Employer for the care and insurance of the Plant, and the provisions of this Clause shall not relieve the Contractor of any of his liabilities under the Contract.

Stored Plant items shall be laid out by the Contractor to facilitate their retrieval for use in the programmed order. Stacked Plant items shall be protected from damage by spacers on load distributing supports and shall be safely arranged. No metalwork shall be stored directly on the ground. Small Plant items shall be held in suitable bins, boxes or racks and be clearly labelled. Items of Plant shall be handled and stored so that they are not subjected to excessive stresses, and so that protective coatings are not damaged.

The Contractor shall comply with the manufacturer's package and plant markings concerning the use and location of lifting slings, chains and hooks.

2.35 Contract Signboards

The Contractor shall supply and erect signboards at locations to be specified by the Engineer. The layout and dimensions of the signboards and their preparation shall be to the approval of the Engineer and the writing shall be in both Tamil and English.

2.36 Advertising

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

CHAPTER-3

3. PARTICULAR PROCESS REQUIREMENTS

3.1 Introduction

Through this tender, Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) intends to build a Seawater Reverse Osmosis (SWRO) based Desalination Plant of capacity 400 MLD at Perur, Chennai, Tamil Nadu, India to augment its drinking water supply capacity for the city of Chennai. At present two SWRO desalination plants at Minjur and Nemmeli are already in operation.

This project involves the construction of intake and outfall structure along with the required pipelines, construction of pre-treatment processes, RO unit, remineralization plant, GIS-based electrical substation and other processes and units to build a complete operating plant within the plant premises for the production of 400 MLD water of the required drinking water quality.

The Contractor has to do all the works for construction of a 400 MLD SWRO desalination plant including the data collection and studies, survey, design, engineering, manufacture, supply, transportation to site, unloading, storage, construction, installation/erection, testing, commissioning and putting into the successful operation of the Plant on Design Build Operate (DBO) basis including all civil, structural and architectural, mechanical, electrical, instrumentation, control & automation and all infrastructural work covering lighting, drainage, landscaping, all preparatory and temporary works for the purpose of meeting the entire scope of works.

The Process design shall meet the Employer's Requirements and be suitable to achieve the required performance while producing 400 MLD drinking water under all input raw seawater conditions.

3.2 Objectives and Scope

The scope of Works includes complete designing, construction, procurement, installation, commissioning and 20 years operation and maintenance of a 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis. The Works include all process, mechanical, electrical, civil, instrumentation and control, and all other works required for construction of the plant with sludge treatment facility. The Plant shall be fully automated and complete in all respect to produce 400 MLD product water of the required quality.

The Bidder shall be responsible for the design, engineering, construction/ manufacturing, shop fabrication, assembly, testing and inspection at supplier's works, packing, dispatch, shipping, delivery at Indian port/unloading at Indian port/delivery from Indian port to the site in case of imported equipment, and delivery/unloading at the site for indigenous equipment, unloading and safe storing at the site, insurance of all works, handling at the site, complete erection, start-up, commissioning, successful performance testing, process proving, warranty, defect liability and, operation and maintenance period.

Upon completion of the initial performance test and process proving, the Contractor shall be responsible for Twenty (20) years of the operation and maintenance of the 400 MLD plant. The plant design, procurement, construction, performance test and process proving shall be monitored and certified by the Employer’s Representative supported by PMC .

The project aims to deliver a 400 MLD desalination water for the Chennai Metropolitan Area. The Bidder shall include all the works, equipment and services necessary for completing the plant fit for the purpose including safe and reliable operation and maintenance of the Plant in accordance with the terms of the DBO Contract, even if certain works are not explicitly stated in any part of this Bid Document.

The detailed scope of works is presented in Part-2 Section VI- Chapter-1 Project Requirements. The bid document presents the site details, onshore topography, offshore bathymetry, indicative base process designs and environmental conditions for the proposed Perur desalination plant. The Contractor is required to verify these data figures and design the plant suitable for production of 400 MLD potable water of the quality and quantity required as per the contract.

3.3 General Arrangement of the Works

3.3.1 Site Details

The proposed construction site for the Desalination plant is located at Perur, about 40 km from the Chennai city centre. The total area of the plot is approximately 34 ha. It is situated along the coastal side of the East Coast Road (ECR). Its ground elevation is Chart Datum (CD) +2.0 to +7.5m. ECR is approximately at CD +11m.

There are two graveyards identified within the proposed site, one on the Southern side of the site and another on the Northern side of the site. The graveyards must be left undisturbed and shall be protected by a compound wall all across and proper drainage shall be made draining towards the sea. Overall tentative layout for the entire Desalination plant may be referred from Generalised Site Layout enclosed in Part-2, Section VI, Drawings. Final layout shall be furnished by the Bidder and finalised during detailing.

The proposed land has been identified under survey number 208/ 2B3 belonging to the M/s. Arulmigu Alavandar Nayakar Trust maintained by The Hindu Religious and Charitable Endowments (HR & CE) Department, Government of Tamil Nadu (GoTN). CMWSSB procured the land on a long-term lease basis of 30 years.

The details of the site are presented in the Part-2, Section VI, Site Data.

3.3.1.1 *Site Location*

The details of the site conditions are given below.

Table 3-1: Details of Site Location for the Proposed DSP Site

Particulars	Details
Site Location	District: Kanchepuram

	Taluk: Thiruporur Revenue Village: Nemmeli
Site coordinates	12°42'44"N, 80°14'26"E
Nearest highway	State Highway SH 49, East Coast Road
Nearest railway station	Othivakkam railway station
Nearest Airport	Chennai International Airport
Nearest habitations	Chengalpattu, Pudupattinam,Tirukalukundram, Nandivaram-Guduvancheri
Archaeologically Important places	Mahabalipuram

3.3.1.2 *Topography*

Based on the preliminary onshore topographic survey and offshore bathymetry survey, the details are given below. However, the contractor has to independently carry out the requisite study for confirmation.

<u>Onshore topography</u>

The Existing Ground Level (EGL) at the test conditions varied from +2.0m Chart Datum (CD) to + 3m CD indicating the almost uniform condition. The site is having tree plantation of Casuarina. The site falls under Seismic Zone III as per BIS code IS: 1893 (Part I). The topography of the proposed Perur DSP site is furnished below.

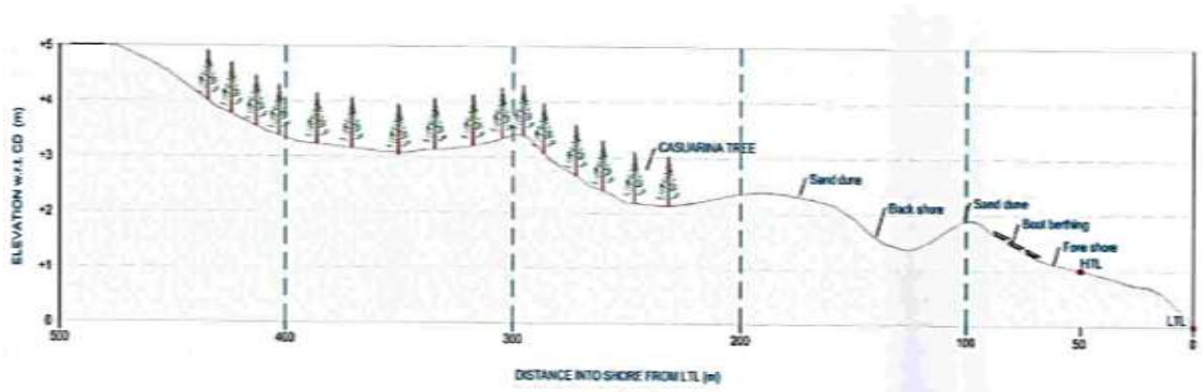

Figure 3-1: Typical Topography of Planned Perur DSP site

<u>Offshore Bathymetry</u>

Based on the bathymetric survey, buried rocks have been found near the shore that is spread in different direction and depth. Figure 2-1 in Chapter-1 presents a seabed map indicating the location of buried rocks.

The bathymetry survey shows that the depth contours are generally running parallel to the coast. The depth of the seabed with respect to the distance from the shore as obtained from the DPR report is furnished in Table 2.2 above. The Contractor is to verify these figures before start of the intake works.

Sedimentary layers of silty sand were identified between – 0.0 and -8.0 m below the seabed.

3.3.1.3 *Climate*

Chennai features a tropical wet and dry climate. Chennai lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. Typical meteorological data for Perur DSP is furnished below. Cyclones are more common in the Bay of Bengal, and the proposed Perur site is expected to be affected by cyclones by approximately 3 times per year. The details of Typical Meteorological data for Perur DSP site are furnished below.

Table 3-2: Typical Meteorological Data for Perur DSP

Meteorological Parameters	Unit	Values
Mean Ambient temperature (min./ max.)	° C	24.5 / 33.5
Barometric pressure	K Pa	100.1/ 101.35
Relative humidity (min./ average/ max.)	%	57 / 70 / 83
Main wind direction		South westerly
Average Annual rainfall	mm	1200
Average rainfall during Northeast monsoon (June to Sept)	mm	440
Average rainfall during Southwest monsoon (Oct to Dec)	mm	760
Maximum rainfall within 24 hours	mm	346.6

Source: Indian Meteorological Department, Chennai, Meenambakkam, 1981- 2010

3.3.1.4 *Ocean Conditions*

The brief of ocean conditions is available at Clause 2.6 of Part-II, Chapter 2. The tide elevation at Perur with reference to Chart Datum (CD) is furnished in table below:

Table 3-3: Tidal Elevation at Perur

Tidal elevation	Chart Datum (CD) in m	RL (m)
Mean High water spring	1.15	RL 0.5
Mean High water neaps	0.84	RL 0.2
Mean Sea Level	0.65	RL 0.0
Mean low water neaps	0.43	RL -0.22
Mean low water spring	0.14	RL -0.51

Note: Onshore survey levels are recorded as m above sea level. Hence, the mean high water springs conversion of CD to MSL is 1.15 -0.65 m = RL 0.5.

3.3.1.5 *Geotechnical data*

A geotechnical survey was carried out by CMWSSB during the year 2014. The subsoil is made up of three distinct layers, as indicated below. However, the Contractor is required to undertake the geotechnical investigation study to confirm the values.

- Greyish silty fine sand : From - 0.0 to – 10.0 m (SPT N value = 10 to 64)
- Brownish silty stiff clay : From - 10.0 to – 13.0 / - 15 m (SPT N value = 7 to 9)
- Soft Disintegrated Rock : From - 13.0 to -15 m to – 19.0 m (SPT N value ≥ 100)
- Hard granite rock : From -17m to -23 m

Note: SPT – Standard penetration test

The groundwater table readings were recorded between 28th October 2014 to 5th November 2014. The groundwater table was encountered within depths of 1.54 m to 1.72 m below the EGL. In general, the groundwater table was almost consistent with the ground surface undulations, which implies that the groundwater is not perched water.

3.3.1.6 *Land Development Plan*

The height of the project site varies from CD +7 m on the East Coast Road to +2-3 m on the seashore side. Hence, it is proposed to raise the site by earth fill to realize the Finished Ground Level (FGL) at CD +6.5 m supported by RCC retaining wall. Raising of FGL up to +6.5 m CD is warranted to maintain safety factor to protect from strong winds, Tsunami and other emergency conditions. The boundary of the Perur DSP will be constructed on the raised land with retaining wall. The retaining wall shall be on pile foundation to keep it stable. A 2.5 m high boundary wall shall be constructed on the ground level around the site area including the burial grounds as indicated in the proposed land development plan for the proposed Perur DSP provided in the Part-2 Section VI, Drawings.

3.3.2 General Arrangement of Plant

It is expected that the Contractor will use his best efforts to optimize the use of Plant land area. A preliminary Plant layout of the desalination plant is shown on drawing 'General Layout Site' Part-2 Section VI, Drawings. The proposed Plant layout is a preliminary layout and is subject to optimization by the Bidders during the preparation of the bid as well as during detail design. The following general rules shall be followed in finalisation of the Plant layout with the consent of the Employer's Representative.

All drawings in this bid document shall be considered indicative only.

The following general rules shall be followed for any construction work of the proposed Plant (to be erected):

- Sufficient space (of not less than 2.0 m wide) shall be allowed between items of Plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance, and provision of appropriate structure foundations. The space between buildings shall be at least 5m to allow movement of the vehicles.
- In the case of areas that require movement of heavy equipment for installation and replacement, sufficient access shall be provided by the Contractor for movement of heavy vehicles. Adequate space shall be provided adjacent to all mechanical equipment as maintenance lay down area.

- Fixed ways, lifting eyes or other means shall be provided to permit the removal of Plant equipment that may logically be required to be removed during the course of its normal operational life for maintenance or any other purpose.
- Areas where the leakage is likely to occur, whether in normal use or during maintenance, shall be provided with an underground drain line or covered RCC drainage channels which shall direct the spillage to a sump from where it can be pumped to the neutralization pit or outfall tank of the plant as per the quality of the leaking fluid.
- Where necessary, Plant shall be provided with removable acoustic coverings to limit the noise produced during normal operation to the specified limits.
- The Plant shall be arranged, and the buildings shall be designed to permit the removal/relocation of Plant items.
- The drain valves from process units with a diameter up to and including 250 mm shall be operated manually and those greater than 250 mm valve shall be operated by an electric motor. For the valves located below ground level, an extended spindle shall be provided for ease of operation.
- The yard pipelines should be laid underground and all flowmeters and dismantling, isolation valves should be kept underground in chambers with an appropriate display above ground so as to avoid any hindrance in the passage of vehicles.
- Chemical pipework shall be secured to racks or trays to be fixed to duct walls or walls of tanks and buildings as necessary. The method of securing the pipes to the racks shall be by clips or something similar, facilitating ease of removal in such a way that individual runs can be changed without dismantling adjacent pipes.
- All chemical pipes shall be colour banded and suitably labelled to enable individual lines to be identified throughout their run. Particular attention shall be paid to the layout of the chemical pipework, which shall be functional and neat in appearance. Generally, where pipework is installed in ducts, it shall be supported not less than 150 mm clear of the floor. When selecting materials for pipework, the Contractor shall consider the deteriorating effect of some of the synthetic materials due to the action of ultraviolet light. Where such materials are employed, they shall be shielded from direct sunlight.
- Chemical storage should be grouped for compatible and non-compatible chemicals with separate bunding.
- Contractor shall prepare and supply a scaled down prototype model showing all main features of the plant as per approved by the Employer.

The Contractor shall ensure that all designs and equipment for which he is responsible for are safe, feasible and durable. Nothing in this Works' requirements shall remove the Contractor's obligation from drawing the attention of the Employer's Representative to any feature of the Works which is not consistent with safety or to prevent him 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 pipes, air vents, electrical cables and rotating machinery. All rotating shafts, couplings, gears, flywheels, belt drives or other moving parts shall be fully guarded. Guards shall be designed to provide ready access to bearings, grease points, thermometer sockets/instrument probes and other checkpoints and to allow safe routine observation and servicing to be executed without the need to dismantle any part of their structure.

3.4 Plant Process Specifications

3.4.1 Seawater Quality

The Contractor shall consider the raw seawater quality provided in Chapter-1, Table-1.1 for the design of the desalination plant. However, the Bidders are advised to carryout the requisite tests to analyse and confirm the seawater quality to design a suitable pre-treatment system. The range of the parameters presented below provides an overview of the seawater quality range for the plant design.

Parameters	Minimum value	Mean value	Maximum value
TDS, mg/l	32000	36000	39000
pH	8.00	8.13	8.20
Temperature, ^{o}C	26.0	28.3	31.5
Boron, mg/l	3.2	3.53	3.80
Turbidity, NTU#	1.0	12	150
TSS, mg/l#	10	75	300
Total Organic Carbon (TOC)* mg/l	3	5	8

*to be confirmed by the bidder.

TSS/turbidity value may be higher than the maximum value during the monsoon period.

3.4.2 Product Water Quality

The water quality requirements in the product water tank shall meet the following parameters and the rest of parameters as per the Indian Standards IS:10500-2012.

- Turbidity (NTU) < 0.5
- Chlorides (mg/l) < 250
- TDS (mg/l) < 450 at plant product water tank exit
- Boron (mg/l) < 1 mg/l all the time
- pH 6.5<pH<8.5
- LSI > Positive
- Hardness ≥ 60 mg/l as $CaCO_3$

3.4.3 Intake and Outfall System

Two number of HDPE intake pipes (PE100) and one outfall pipe each of 2500mm OD at pressure rating of minimum 6.5 bar (SDR ≤ 26) shall be provided. In normal plant operation condition, each intake pipe shall cater to half the intake flow to produce net 400,000 m3/day of product water every month plus 10% extra flow to accommodate for biofouling/incrustation in the intake pipe. The intake system design shall also take into account for the additional pressure drop and resulting decrease in water level in the intake well (forebay) during pig cleaning of one of the pipelines and while maintaining the full intake feed flow. The intake shall comprise of two intake heads linked to the intake pumping station by two intake pipes laid below the seabed with the required cover (>1 m from the pipe crown level) using suitable pipe laying method. The pipe shall pass manufacturing and installation quality controls subject to the Employer's inspection and approval. The intake head shall be made of concrete and comprise a number of vertical openings located between the seabed and seawater surface. The hydraulic analysis for the pipes shall allow for the marine growth of minimum 100 mm on all internal surfaces of the pipes. The intake and outfall pipes shall be laid on the same alignment as much as possible to avoid repeated trenching on different alignments.

The intake shall be provided with the state of art facilities to enable the pipelines to be pigged at the increase in pressure drop along the pipelines or the event of any sort of pipe blockage, preferably without the intervention of the divers entering the Intake system for manual cleaning. The pigging system shall be achieved by the provision of a pull line (launching station) linked to the pig entry point and delivering endpoint. The intake head could be provided with a removable cover on top of the intake head and mounting point for a winch which could then be used to pull the pig. It should then be possible to recover the pig through the removable cover. As the pigging system and divers as needed will be provided by the Contractor, these needs to be priced in the price bid by the bidder. The pipeline shall also have manholes at the suitable intervals for manual pipe inspection and cleaning as needed.

During Marine works and Design-Build works, the Contractor shall make necessary arrangements with prior approval from Employer/concerned authorities to prevent the shore erosion and disruption to the nearby Nemmeli Kuppam Boat Landing / Launching locations.

3.4.3.1 *Intake Head (Tower)*

A 100 mm screen with frame in Duplex Steel 2507 and bars in Cu Ni or equivalent shall be provided at the intake to exclude larger marine life. One intake chamber and screen shall be provided on each conduit. There shall be two intake heads with screen offshore separated by a minimum distance of 5000 mm. The screens will be of >8.5 m diameter, ≤1.5 m high, starting at >3m above the seabed, in ≥ 10metre depth of seawater at low tide. The approach velocity shall be ≤0.12 m/s to minimise the entrapment of marine species.

A fishnet will be provided to minimise the ingress of jellyfish to the intake. Provision shall be made to inspect and replace the net from time to time, as the same is likely to be damaged by marine lives. The head loss through the intake system will also be monitored. In any increase in system losses indicating fouling at the intake, or the growth of biomass within the intake conduit, the same shall be cleaned through pigging. Marker buoys and floating screens shall be provided.

3.4.3.2 *Intake Pipeline*

Two intake conduits, each of 2500mm OD at pressure rating of minimum 6.5 bar, shall extend into the sea where the seawater depth is at least 10 m below the Lowest Tide Level. Water will enter the intake head opening at >3 m above the seabed and minimum 4 m below the top seawater surface during the low tide. The required CRZ clearance is obtained to lay the intake pipe at about 1150m and outfall pipe at 750m from the shore. A brine diffusion analysis shall be carried out by the Contractor to assess the quality of the seawater feed for RO system design. The velocity in the conduit at peak flow shall not exceed 1.5 m/s. Friction losses at this velocity should be less than 1.5 metre head in the pipeline. Incrustation thickness in the pipeline shall be taken 100 mm for calculating friction losses due to the marine growth on the internal periphery of the pipeline. The velocity of water through the intake head openings should be ≤0.12 m/s. The height of the vertical openings shall not exceed 1.5 m. A fish net shall be provided outside the bared head opening to prevent the ingress of fishes.

Pigging system to restore the hydraulic capacity of intakes shall be provided as discussed above to safely clean the intake pipes with better efficiency (a few days per year compared to a few weeks) that serves, of course, the Availability Factor. At least two pigs shall be provided to accelerate the cleaning process.

The bidder needs to provide the detailed Head loss calculation of intake pipes from Seawater intake head to the onshore screen intake chamber and to determine the available water levels in the Screen upstream and downstream and the pumping station. The bidder needs to submit the detailed calculation with a head curve along with the intake and outfall system.

3.4.3.3 *Outfall Pipeline*

One outfall pipe will be provided with 2500 mm OD of the same material as the Intake pipe. For a peak outfall flow of up to 640 MLD, the velocity in the pipeline should be within 1.5m/sec.

The Contractor shall design the outfall system based on the dispersion model to be conducted by him to promote better brine concentration management as per the prevailing environmental guidelines. The final outfall diffuser arrangement shall be determined after the brine dispersion analysis conducted by the Contractor and acceptable to the Engineer / Employer's representative. There may be some increase in concentration of the seawater above its maximum value (as presented in Clause 3.4.1) at the intake head due to discharge of RO brine at the outfall. The Contractor is responsible to design the RO system based on the brine dispersion analysis results and considering the effect of any increase in salinity of the intake feed seawater on the desalination processes.

3.4.3.4 *Intake Screening Station*

Seawater intake well (forebay) will receive the seawater from the offshore intake head under gravity and transfer the seawater to the pre-treatment section. Seawater intake well will have two chambers separated by partition walls. Each of the chambers shall have a capacity to pump adequate sea water to generate a minimum of 200 MLD of Desalinated water. Whenever required, either one of the two chambers can be maintained, cleaned, or repaired while the other chamber is in operation. So, sufficient sluice gates shall be provided to isolate the chambers.

The intake well houses Travelling Band Screens which pass water to the pump chamber. A minimum of 4 (4x50%) screens, shall be provided for the proposed 400 MLD product water plant; such that the full screening capacity is available even if two screens are out of service. Each screen shall be provided with a dedicated screening chamber which can be isolated from the rest of the screening station. Isolation shall be by sluice gates only. Sluice gates shall be provided both on upstream and downstream of each screen chamber made of carrion resistant material.

The screens shall be automatically cleaned and washed. Facilities shall be provided to enable an individual screen chamber to be drained entirely for maintenance.

Either the differential head loss across the screens shall be continuously monitored, or both the upstream level and downstream level shall be continuously monitored, and the differential head continuously derived.

The velocity across the screens shall not exceed 1m/s with the maximum design intake flow rate and the minimum seawater level. The screen mesh size shall not exceed 3 mm. The design should be such that it shall be possible to completely drain a single screen chamber from maximum tide level within 4 hours. The screens shall be made of materials suitable for the seawater use during plant lifetime and shall be structurally designed to withstand the maximum head-loss across the screens.

The differential head across the screens shall be recorded and used to initiate screen cleaning & washing automatically. In the event of the high differential head across the screens, an alarm shall be raised in the control system and the intake pumps shall be tripped by hardwired means. The trip differential head shall be less than the maximum structural design head-loss across the screens.

3.4.3.5 *Intake Pumping Station*

The screened water from the inlet screens shall flow into the intake pumping chamber. A minimum of (6W + 3S) pumps shall be provided for the total plant capacity (4 pumps for each process stream with one pump in store). Pair of 4 pumps shall form one manifold to supply water to one stream of 200 MLD plant. The bidder shall provide the no flow level in the pump well and hydraulic grade line entering into the pump station at both low and high tide conditions at the total inflow of seawater to produce net 400 MLD RO permeate at 42% to 46% RO recovery. The calculation for the static lift at Mean Low Water Springs and Mean High Water Springs shall also be provided.

Vertical Turbine pumps with large clear passages shall be provided in an RCC building where the motors shall be stationed on the first floor and pump discharge header at the ground floor to facilitate easy maintenance. The pump motors shall be with variable speed drive. The material of the pumps will be super duplex stainless steel (PREN No ≥ 41).

It shall be possible to isolate individual pumps for maintenance, whilst the remaining pumps are in service. The height of the pumping and screening chamber shall consider the maximum surge level which can be caused when all the pumps suddenly stop, with the seawater at maximum tidal level, and shall ensure that there is no flooding or damage to equipment under these circumstances. The standby pump shall automatically start in the event of failure of any of the duty pumps.

The bidder is required to carry out a transient analysis of the intake structure to determine the surge levels induced by pumps trip, and a pump starts and provides all calculations in connection of the same before start of intake pump station construction. The system shall be designed considering parallel operation of pumps.

The total flow-rate of water delivered by the pumping station shall be continuously monitored by two Electromagnetic Flow Meter – one in each process stream. All electromagnetic flowmeters in the plant shall be provided with a bypass line with sufficient isolation valves and dismantling joints to facilitate easy maintenance of the flowmeters.

Local indication of pump discharge pressure shall be provided. Low-level probes shall be provided in the pump well. The temperature, pressure, conductivity, oil, turbidity and chlorine residual in the pump discharge header shall be continuously monitored. The residual chlorine shall be measured at the intake well and outlet of pumping main and provision of suitable alarm shall be made in case of higher concentration.

3.4.3.6 *Shock Chlorination System*

A shock chlorination system shall be provided to inject sodium hypochlorite at the intake heads to minimise marine growth at the intake screens and in the intake conduits. The hypochlorite solution shall be injected across the intake head openings using a dosing sparger. All required system and piping shall be provided by the Contractor, including the provision of air pipe at the intake head offshore for the removal of entangled Jelly Fish on an intermittent basis. Suitable air system with compressors and air storage vessels shall be provided on shore for this purpose. The system shall be designed for chlorine residual in the conduit suitable to prevent deposition and growth of the marine organisms on the pipeline inner wall. The material of construction for the system shall be titanium or comparable.

Chlorination system shall also be provided to dose in the intake well to reduce the tendency of bio-growth in the pre-treatment system.

Along with chlorination system air bursting system at the intake head with suitable pressure vessel and compressor system shall be provided for dislodgement of the weeds and barnacles attached to the screen.

3.4.4 **Pre-treatment System**

There will be two separate streams of the pre-treatment, desalination and post-treatment processes - each for 200 MLD product water capacity. The pre-treatment shall consist of a three (3) stage process to ensure sufficient safety in case of adverse Seawater quality conditions.

- Coagulation/flocculation followed by Lamella Settlers as the first stage;
- DAF (Dissolved Air Floatation) system as the second stage; and
- Gravity Dual Media Filtration system (GDMF) as the third stage.

The design of the above processes shall be proven for similar application of salinity, temperature, silt, and organic matter. This configuration is mandatory, and a pre-treatment design consisting of only one or two process stage is not acceptable.

Provision should be made to allow by-pass of DAF during the period of good seawater quality. However, the process design should consider this treatment scheme to be operated continuously throughout the year.

The pre-treatment process shall be reliable to achieve the guaranteed characteristics of seawater suitable to feed the RO Plant. The Silt Density Index (SDI) after DMF shall be <3.0 (95th %ile) and <4.0 (100th %ile) and in any case, will not exceed the value recommended by any of the proposed membrane manufacturers. SDI tests shall be performed in compliance with ASTM D 4189 standard with Millipore filters.

The pre-treatment shall minimize the risk of organic and biological fouling and inorganic scaling on membrane surfaces and any damage to the membranes on account of residual chlorine in the pre-treated feed water.

The Bidder has to carry out seawater testing/analysis to determine the raw seawater properties in order to ensure that the pre-treatment design offered is suitable to achieve the required treated feed seawater quality for RO system. The raw seawater quality provided above in Clause 3.4.1 provides the minimum range for the plant design. The bidder shall take full responsibility for any seawater analysis and plant design within his proposal. The employer shall not be liable for the accuracy or otherwise of the data and takes no liability for any water analysis and plant design.

3.4.4.1 *pH Stabilization*

The raw seawater will be dosed with sulphuric acid in the intake pump discharge line to achieve the optimum pH for coagulation. All concentrated sulphuric acid piping shall be Carbon steel and valves shall be Plug valves of Alloy 20 and butt-weld fittings shall be used. The tank should be carbon steel. Carbon content should be less than 0.25%.

Sulfuric acid chemical storage should be equipped to prevent air moisture reaching the chemical storage tank by the use of desiccant on venting and overflow pipes. All tank outlet nozzles should have double isolation valves. The pH of the dosed water shall be continuously monitored. An alarm shall be raised in the event of the dosed water pH being outside of acceptable limits.

3.4.4.2 *Inlet Chamber*

Each half process stream of 200 MLD product water will start with an inlet chamber followed by flash mixers. Coagulant will be added in this chamber. The flocculant (polymer) shall also be added after coagulant addition for better flocculation. The flash mixer will be a stirred tank (~100 rpm) of sufficient capacity. At least two flash mixing tanks shall be included for proper mixing with total residence time at least 20 seconds. Its design will be such that short-circuiting is eliminated and the coagulant is thoroughly mixed with the seawater. The inlet chamber shall have an overflow line to outfall tank or intake well (forebay).

3.4.4.3 *Coagulant*

The natural particles causing turbidity are negatively charged and repel each other, thus resulting in high stability. In order to be removed, these particles must undergo a destabilization step which is achieved by the use of suitable coagulant. The coagulant injection should be done after pH adjustment and before a dedicated flash mixing chamber. Coagulant should be ferric chloride; the purity of the product should be compatible with RO membrane application especially with regard to heavy metals/pesticides as well as must comply with the discharge norms of sludge/ solids.

Coagulant equipment should be made of plastic material resistant to UV light. Coagulant piping shall be schedule 80 HDPE or any other suitable material. The coagulant preparation and dosing tanks shall consist of two RCC Tanks. Each tank will be designed for 8 hours of service at the maximum dose rate. The coagulant and flocculant tanks shall be housed in a chemical building with RCC service water tank above the building. Tank filling with chemical and service water shall be automatic.

The drive motor shall be equipped with a variable speed drive to vary the speed of the drive mechanism. The design torque for the drive mechanisms shall be a minimum of 200% of the continuous torque. All gears shall be enclosed in housings. The details of the civil and mechanical works are provided in the civil and mechanical specifications.

3.4.4.4 *Flocculant*

Flocculation is designed to generate large aggregates that can easily settle or float. It promotes an increase in the probability of inter collision of the small particles formed during the coagulation stage so as to generate larger aggregates.

The flocculation shall be done in the flocculation tanks before the Lamella Settlers. The residence time for flocculation will be at least 20 min. Provision shall be made to dose polyelectrolyte downstream of the ferric chloride and before Lamella settler and DAF.

For each stream, flocculation will be achieved in two flocculation tanks in series with each tank consisting of one or two vertical mixers so as to have the mixing energy tapered.

Piping should be made of plastic material resistant to UV light.

The Contractor shall provide at least 1200mm wide platform with GI / GRP plate and SS 316 railings along with the Inlet Chamber, Flash mixer, flocculation tanks for close inspection of flocs formation. The Contractor shall make necessary arrangements to provide safe access for the maintenance of flash mixers, gates.

The flocculation tanks shall have tapered bottom with a hopper to discharge any sludge accumulation in the tanks.

3.4.4.5 *Lamella Settlers*

Lamella settlers consist of a series of inclined parallel tubes through which the water passes. The inclined settlers significantly reduce the TSS concentration in water. But it is only partially successful in removing the larvae, algae and jellyfish particles off neutral buoyancy. These materials will be removed effectively by the DAF and media filtration downstream of the Lamella Settler.

The Contractor shall provide integrated self-standing settling tubes made of GRP/FRP/HDPE with 55^{o}-60^{o} inclination. The Lamella tube settler loading rate shall be <1.0 m/hr for better clarification of suspended solids. The Lamella settler and supports shall be of RCC. The bottom of the settler will be hopper type having 45^{o} side walls with sluice and knife valves as needed. The sludge of the settler will be directed to the sludge balance tank under gravity. The diameter of the pipe will be suitable for the sludge transfer without any blockage in the pipeline.

The Settler unit shall be complete with a self-supported access bridge or access bridge supported by the concrete tank. The access bridge shall be designed to safely withstand a live load plus any applicable dead loads and torque and wind loads. A maintenance platform complete with grating and SS316 handrail shall be provided around the drive assembly. The bridge material and coating systems, if applicable, shall be selected to withstand the marine environment. Grating shall be of GRP of functional strength to withstand live load plus any appropriate dead loads and torque and wind loads.

Table 3-4: Indicative Design Parameters for the Lamella Clarifier

Sl. No.	Parameter	Unit	Values
1	Minimum recovery	%	97-98
2	TSS removal	%	90-95
3	DOC removal	%	30-50
4	Tube Settler loading rate	m^3/m^2 h	< 1
5	Mechanism of sludge removal	-	Hopper bottom
6	No. of tanks	-	36 (18 tanks in each stream)
7	Tube settler material	-	HDPE/GRP
8	Shape of tube deck	-	Hexagonal-Chevron
9	Angle of inclination of tubes	degrees	55-60

3.4.4.6 *Dissolved Air Flotation*

Dissolved air flotation (DAF) is a process of liquid-solid separation by upward displacement of particles insoluble in water such as oil or solids. The removal is achieved by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank basin. The released air forms tiny bubbles which adhere to the suspended matter, causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. This process has an advantage, especially in terms of algae removal.

Raw water that has first been flocculated enters the bottom of the structure in a chamber where it is put in contact with pressurized water distributed uniformly across the width. Particular importance should be given to the distribution of the pressurized water (source of the microbubbles) and the water to be treated to ensure that floc is not broken during the process. The sludge accumulated on the surface is removed periodically by scraping or hydraulics removal while treated water is collected at the bottom of the Dissolved Air Flotation area. The clarified water is collected downstream of the work under drilled pipes. Air-water contact is achieved in a pressure vessel.

There will be at least 12 DAF tanks – 6 tanks in each plant stream of 200 MLD. The design of the DAF should take into consideration that one DAF tank is always out of service for maintenance. If some equipment are common to multiple DAF tanks, then additional standby equipment shall be provided.

The size of particles in seawater is much smaller than in freshwater, particularly during algae bloom and so, the average bubble size will be selected within 10-20 µm which can be adjusted to particle size in seawater to be captured. The minimum recycling rate shall be 15% for better particle agglomeration and removal. The DAF design shall be suitable to remove up to 95% of the suspended solids. The surface loading rate will be within 25 $m^3/m^2/h$. Based on the raw seawater quality, the Bidders have to understand the importance of DAF in the presence of upstream Lamella Settler and decide on the loading rate. In case opting for higher loading rate, the Contractor must demonstrate at least two operating reference plants (each ≥100 MLD) handling the similar seawater quality successfully.

Most of the suspended particles will be removed in the Lamella Settler. DAF is an additional barrier to remove the suspended particles and organics in the seawater. The purpose of providing the DAF is to remove the light particles which are not captured in the Lamella settler. Provision of coagulant and flocculant addition before DAF shall be provided to enhance the removal of the light particles during difficult seawater quality situation such as during the presence of oil and fats, organics and algae particles. A bypass line shall be provided to bypass the DAF when raw seawater quality is good.

The indicative design of the DAF is given in table below.

Table 3-5: Indicative Design Parameters for the DAF

S. No.	Parameter	Unit	Values
1	Minimum recovery	%	98-99
2	Flotation loading rate	m^3/m^2 h	20-25
3	White water recirculation flow	%	15-20
4	Air Saturator Efficiency	%	90-95

5	Air Saturator Pressure	kPa	800-900
6	Minimum tanks	No.	12 (6 tanks in each stream)
7	TSS removal	%	85-95
8	DOC removal	%	15-30

3.4.4.7 *Gravity Dual Media Filters*

Gravity Dual Media Filters (GDMF) is a process of liquid-solid separation by media filtration. Clarified water from the DAF outlet shall feed to the inlet channel of the gravity dual media filters.

The GDMF shall be installed within a fully covered building with RCC roof.

The filter should be designed to ensure that filtration run time is not less than 24h in worst water condition and at maximum plant output capacity. Each filter bed shall be capable of being isolated and taken out of service, i.e. for maintenance while adjacent beds are still in operation.

In each plant stream, when two filters are under backwash operation and one under maintenance, the remaining filters shall be able to handle the filtered water flow required for all the RO trains in operation.

Granular media filtration system will consist of about 80 individual filters (40 filters for each plant stream) that will operate in parallel. Each filter inlet shall include an isolation valve/gate, and in filtering mode, the feed water shall be fed into the filter, above the filter media, in such a manner so that the filter media is not disturbed. The water shall flow through the filter media, through filter floor nozzles, and into a chamber underneath the filter floor. The filter design shall be as per standard media filter design.

Filtered water shall flow from the filtrate collection chamber, through a flow control into the RO feed tank. The maximum size of an individual filter shall be within 12.5 MLD based on a successfully proven design and operating plants.

When in backwash mode, water from the backwash tank shall be pumped by dedicated duty/ standby backwash pumps, through control and isolation valves into a single filter filtrate chamber. The backwash water shall flow up through the filter media support, up through the filter media, removing filtered solids from the filter bed, and into the backwash water troughs, running the length of each filter. The backwash water troughs shall be designed to ensure that dirty backwash water is removed evenly from the whole length of the filter. Backwash effluent shall pass from the backwash troughs, through the effluent isolation valve, and to the backwash effluent tank. The system shall ensure that no more than 5% of the top media is lost over a period of one year, and this shall be tested during the performance test. Pre-Treated/Filtered Seawater shall be used for backwashing the media filters. The water shall be withdrawn from the filtered water tank/RO feed tank. However, the use of RO reject brine may be explored for filter backwash. Suitable pumping machinery with necessary standby shall be provided.

The filter underdrain system shall be of monolithic reinforced concrete slab, or SS plates supported on concrete dwarf walls and be designed to tolerate all loads imposed during installation and during operation. The means of collecting filtrate and distributing air shall be by use of nozzles set in the reinforced concrete floor. Nozzles with fine slots shall be used for collecting filtrate and distributing backwash water and air. A uniform distribution of the nozzles of not less than 60 numbers per square metre shall be employed. The nozzles shall be constructed of suitable material and have vertical reverse wedge slots to prevent filter media greater than 0.40 mm from passing through and to be self-cleaning in the filtration mode. The design of the under-drain system shall be based on the successfully proven design and operation of the filters.

All necessary equipment for automatic backwash and operation shall be provided. It shall be ensured that the entire backwash is carried out in the proper way to reach the filter washing without operator intervention. Typically, there will be 8 automated valves/gates in each filter – 1 inlet gate, 1 waste outlet gate, 2 filtrate outlet sluice valves, 2 backwash inlet sluice valves and 2 air inlet scour valves for two beds of one filter. In addition to the automated system, the plant shall be provided of a full backup backwash system that can be operated under the guided control of one operator. Backwash system should be designed for the specific media use and for varying flow requirements with the change in water temperature in summer and winter seasons for effective backwash. Air scour system shall be provided for the better efficiency of the backwash. Blowers should have their acoustical protection and should be located inside the building or under a shade. Design should ensure that safe start-up of the blowers can be achieved automatically and should prevent backflow of water into the air system under all conditions.

For each filter, a filter control desk shall be provided for local operation of the filter in manual or automatic modes. This will allow operator selection of the filters to be backwashed and operator selection for the durations of various steps in the backwashing process. The control desks shall be equipped with selector switches for automatic/manual selection, push buttons for manual opening and closing the filter valve actuators, lights for open/close valve indications and PLCs for automatic time-based step operation of filter valve actuators in backwash operation.

The performance standard may be based on the following criteria:

- The filtrate should be clear with the turbidity <0.5 NTU all the time
- The filtrate should be free from colour (with unit 3 or less on the cobalt scale)
- The SDI of the filtrate should be ≤ 3.0 at 95% of the time and < 4.0 at 100% of the time.
- The filter runs should normally be not less than 24 hours with a loss of head not exceeding 2 m.
- For an efficient filter, the backwash water consumption should not exceed 3 per cent of the quantity filtered in between washing.

The indicative key design criteria for the DMF is given below in Table-3-6.

Table 3-6: Indicative Key Design Criteria for the Gravity Filters

Filter type	Dual media, downflow

Backwash	Air-water
Average filter cell run duration	24hr
Flow distribution to individual cells	Pipe (if a concrete channel is used, the channel depth should be tapered to keep velocity in the distribution channel above 2 m/s at all times)
Filter cell length-to-width ratio	2:1 preferably
Maximum Water depth above filter top	2.5 m (should be equal to or slightly higher than filter bed head loss)
With two filters out of service (N-2) per stream	$\leq 7.8\ m^3/m^2 \cdot h$
Backwash rate	25-40 $m^3/m^2 \cdot h$ – variable speed with temp.
Air Scour rate	50-60 $m^3/m^2 \cdot h$
Duration of backwashing (total air plus water)	30 min (includes filter cell draining and fill-up)

Filter Media

Filter media is defined in terms of effective size and uniformity coefficient. Effective size is the sieve opening size in millimetres that permits 10% by weight to pass. The uniformity coefficient (UC) is the ratio between the opening size of the sieve that will pass 60% by weight and the effective size of the medium. The type, uniformity, size, abrasion resistance and depth of filter media are of key importance for the performance of pre-treatment filters.

Anthracite and sand shall be used in the dual media filters. Deep dual-media filters are to be designed to achieve enhanced removal of soluble organics from source water by filtration.

Sand shall be of high grade, complying with Sections 1, 2.2 and 5 of the Standard Specifications for Filtering Material (ANSI/AWWA B100-09, AWWA Standard for Granular Filter Material). Sand should be of high quality with ignition loss not to exceed 0.7% by weight. Silica content should not be below 90%, and wearing loss should not exceed 3%.

The particle size distribution shall be determined by screening through standard series sieves. The size shall be determined from a plot of the percentage of the material passing each sieve, against the rated opening of the sieve. The filter media and underdrain system shall be designed to achieve uniform distribution of both filtrate and backwash water and air.

The indicative media parameters are given in table below. Bidders are required to fulfil the requirement unless there is sufficient operational evidence to change and which is acceptable to the Engineer.

Table 3-7: Indicative Media Description for the Gravity Filters

Description	**Unit**	**Value**

Top layer		Anthracite
Minimum depth	m	1.2
Effective size	mm	0.6- 0.8
Uniformity coefficient		1.4
Bulk density	ton/m3	0.85
Bottom layer		Silica Sand
Minimum depth	m	1.5
Effective size	mm	0.5-0.6
Uniformity coefficient		1.4
Bulk density	ton/m3	1.8
Specific gravity		2.55-2.65
Below sand layer		Garnet
Depth	m	0.2
Effective size	mm	0.5
Uniformity coefficient		1.4
Bulk density	ton/m3	3.5

Apart from above, the gravel will be used below garnet. Gravel of bigger size will be placed between garnet and the under drainage system to prevent sand from entering the underdrain and to avoid uniform distribution of wash water. The gravel and garnet should accomplish both purposes without being displaced by the rising backwash water. Sizes of the gravel may vary from 50 mm at the bottom to 5 mm at the top with 0.3 m depth. Reference may be accessed at IS 8419 Part (I)-1977 for filter gravel.

The Contractor shall provide a detailed automatic monitoring system in the O&M manuals, to be approved by the Engineer, to ensure reliable control of the performance of the filtration plant. The filter outlet control valve position and head-loss across each individual filter bed shall be continuously monitored from the control room. The flow-rate out of each filter shall also be continuously monitored. The filtered water turbidity and flow rate in filtered water channel leading to RO feed water tank shall be continuously monitored from the control room. The quality of the filtered water from each individual filter shall be routinely monitored by a grab turbidity sample and analysis.

The air scour and backwash flow rates shall be continuously monitored during filter washing. Local indication of each backwash pump discharge pressure shall be provided. Local indication of each air blower discharge pressure shall be provided. Each air blower shall be provided with a high discharge pressure switch. A sample point may be provided on each filter backwash effluent line close to the filter, to enable the duration of the filter backwash to be optimised.

The conductivity and SDI of water in the filter to waste line as a filter is returned to service after a backwash shall be routinely monitored by a grab sample and analysis. The filtrate during the maturation period after backwash is proposed to be recycled to the filter inlet to reduce the per cent waste of filter. An alarm shall be raised in the event of high turbidity in the common filtered water main. Also, an alarm shall be raised in the event of high differential pressure across a single filter.

During filtration mode, the filter outlet valve shall be controlled to maintain a constant level in each filter. The control system shall ensure that in normal filtration mode, the instantaneous outlet flow rate from an individual filter does not vary by more than + 10% from the overall average flow rate of all in service filters even in the event of two filters out of service when the filtration rate will be enhanced to meet the total required filtrate flow rate. This shall be confirmed during the performance test by analysis of the individual filter trends from the DCS/PLC. All filter valves/gates and penstocks shall be fitted with electric actuators with facilities for remote and local manual operation using the local panel to be provided for each filter.

3.4.4.8 *RO Feed Tank*

The filtered water flows to the RO feed tank under gravity. The tank shall be constructed out of RCC and equipped with vents. The RO Feed Tank shall be equipped with an overflow line to the outfall tank or the intake pumping station.

There will be two RO feed tanks – one for each process stream. The capacity of each tank will be designed for 30 minutes of filtered water flow, i.e. about 10000 m3 each. Provision of interconnecting the feed tanks may be explored in order to have an interoperability between the streams pre-treatment system, in case needed. The RO feed tank will serve as control storage between the filtration system and the RO plant. It will ensure that the flow to the RO trains will be constant while the production from the pre-treatment system fluctuates due to backwashing. To ensure gravity filter backwash water is always available and does not disturb the RO feed flow, the tank design will offer a two-compartment design. The first compartment will feed the second compartment by overflow. The first compartment will serve the backwash requirement and provide a capacity of 2,000 m3 (backwash requirement for at least 3 filters). The ERD and HP booster pumps will be connected at the outlet of the second compartment that will offer a minimum working capacity of 8,000 m^3 (at least 25 min residence time). The minimum working volume shall be kept between the high-high level and low-low level. The level in the RO feed tank shall be continuously monitored. The tanks should be partitioned in such a way that one half can be isolated for cleaning while another half tank supplying water for backwash and RO feed.

In case of emergency, this first compartment will have a provision to be fed from the outlet of DAF. As the main process flow reservoir, this two-compartment tanks will be constructed in concrete.

3.4.5 Seawater Reverse Osmosis System (SWRO)

The Bidders shall provide a complete SWRO system suitable to produce net 400 MLD product water with plant availability minimum 97% of monthly average. Bidder's offer shall include RO trains, each consisting of:

- Rack/framing, and power and instrumentation cabling and equipment;
- Feed, permeate, brine, cleaning/flushing piping and equipment including the individual suck back tank for each train (skid);
- RO trains required for providing the rated output at the end of the membrane guarantee period.
- The system shall be capable of producing contracted desalinated water on a 24 hour, 7 days a week basis.
- Provision shall be provided to operate the SWRO system at least at 50% turndown capacity particularly during monsoon period when demand of water will be low.

The trains in both the streams shall be sized for a net production capacity of 400,000 m^3/day of the required product water quality at even the worst-case conditions (i.e. minimum seawater temperature, maximum seawater salinity, maximum seawater turbidity, fouled membranes, aged membranes).

The bidder shall provide RO membrane projections covering the whole range of anticipated seawater quality (especially extremes of temperature and salinity) for new membranes, clean membranes, old membranes and fouled membranes and have to submit along with their bid.

Each RO train shall incorporate pressure drop and regulation devices in the brine reject line to maintain and control conditions within the trains. It shall be possible to measure the product flow rate and feed - brine pressure drop of each individual RO train.

The SWRO system shall be fully automated with auto-transmission and control of all the required parameters. The bidder shall not propose any experimental features for the RO Plant construction. Only proven and well tested RO configuration shall be used. Bidders shall provide the experiences of the successful implementation and working of the plants with the configuration proposed for the 400 MLD SWRO system design.

The Plant shall be flexible to accept and implement the modifications, which may be desirable as a consequence of a rapid technological improvement in RO and its equipment and any changes in feed quality. The Plant shall also have the provision for interchangeability between membranes supplied by various membrane suppliers and incorporate interlocking end caps reducing permeate back pressure drops while providing long term seal integrity. The pressure at membrane inlet shall be designed such that it allows interchangeability of membrane brands and types from different Manufacturers. Furthermore, the Plant shall be designed to be operated with minimum maintenance, requiring minimum operating personnel.

Each train shall have a capacity of 25 MLD and should have its own dedicated RO Booster, ERD Booster, ERD and High-Pressure Pump along with energy recovery system. Stand by train(s) shall be provided to use in case of any train is offline during CIP or for any other maintenance work. There will be 8 duty +1 standby RO trains in each process stream.

The bidder may submit an alternative technical and price bids along with the base bid with any innovative technology for the design of Pre-treatment and RO system. The Alternative bid will be considered only for the successful bidder whose base bid is declared as the lowest evaluated bid and if the bidder has submitted an alternative bid. The bidders should provide the experiences of the successful implementation and working of the alternate RO design and also the sufficient technical and economic advantages of the alternate RO design which will be evaluated after final selection of the Contractor.

The high-pressure shall be designed not to introduce flow and/or pressure pulsation in the feed or brine stream. The reverse osmosis system has to be operated with fluctuating feed salinity, and feed temperature and variation in RO permeate recovery. An appropriate regulation of the feed pressure for each reverse osmosis train separately by a corresponding design of the high-pressure pumps and automatic feed pressure control is required.

Each train of 25 MLD shall include all necessary instrumentation and online monitoring to enable proper operation, early detection of process deviation on the trains, normalization of the trains performances and protection of the unit against the improper operation. The design must include at least instrumentation to measure and display on the HMI system: membranes feed flow, permeate flow, brine flow, ERD feed flow, membranes feed pressure, membranes head losses, membrane brine pressure, feed conductivity, ERD conductivity, permeate conductivity, feedwater temperature.

High-pressure piping and equipment should be designed as per ASME standards. Proper protection against excessive pressure must be provided.

Connection of pressure vessels should be done using Victaulic flexible couplings. Pipe and fittings material including Victaulic couplings for the feed and reject (high-pressure side) shall be suitable for the Seawater and RO brine handling under operating pressures. They shall be in super duplex stainless steel or equivalent with a minimum PREN of ≥43 and CF ≥35. The material of construction and seals for Victaulic couplings shall be suitable for the Seawater and RO brine handling under operating pressures. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability. Couplings shall have a nominal 3:1 Safety Factor over published working pressures. Fittings shall be constructed of super duplex stainless steel material having PREN number equivalent to the pipe system in which it is installed.

Grooved joints shall be installed in accordance with the manufacturer's latest published installation instructions. Grooved ends shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove.

- Gaskets shall be of an elastomer grade suitable for the intended service and shall be moulded and produced by the coupling manufacturer.
- Gaskets must meet potable drinking water standards and be listed by the approving agency. NSF61 approval and listing shall apply as a minimum standard.
- The grooved coupling manufacturer's factory-trained representative shall provide on-site training for the contractor's field personnel in the use of grooving tools and

installation of grooved joint products.

3.4.5.1 *Cartridge Filter*

Cartridge filter shall be used for the safety and protection of the RO system and shall not be operated as a pre-treatment stage.

Carbon steel rubber-lined/GRP vessels shall be provided for housing cartridge filters with quick opening hold-down bolts and having sufficient capacity to meet the maximum flow of the plant without exceeding pressure drop limits when fully fouled. The vessel shall be designed in accordance with ASME Codes design of vessels.

The Cartridge Filter assembly line should be equipped with differential pressure gauges with a pressure transmitter and alarm signal capability. Appropriate means for measurements of differential pressure across cartridge filter shall be provided. Each cartridge filter vessel shall include inlet and outlet isolation valves, as well as drain and vent valves. Each cartridge filter inlet shall include an orifice plate to distribute flow evenly between cartridge filters. The filter vessels shall be equipped to allow the safe and efficient replacement of the expendable cartridge. On-line cartridge filter replacement shall be possible without interruption of the plant operation.

Bidder needs to provide two spare cartridge filter vessels for each train so that filter replacement is done without any impact on water production, such that the maximum loading rate is not exceeded when one vessel is out of service. Micron filter size shall be rated for 5 µm nominal. These filters shall be arranged so that RO train has a filter upstream of the high-pressure pump. Sample points shall be provided on the cartridge filter inlet and outlet headers.

Cartridge elements shall be all polypropylene construction with non-shredding characteristics. The clean cartridge filter unit shall have a maximum differential pressure of 0.035 bar at the rated flow.

For standard size cartridges, a maximum loading of 650 l/hr per 10" round shall be used. For non-standard cartridge sizes, references shall be provided to support the selected loading rate. Bidder may propose standard cartridge filter battery for SWRO Feed & ERD Low-Pressure feed or dedicated cartridge filters for SWRO Feed and ERD Low-Pressure line.

The RO feed must be totally free of residual chlorine to prevent oxidation of the membrane. Antiscalant shall be dosed either upstream or downstream of the cartridge filters. Sodium bisulphite (SBS) shall be dosed both at upstream and downstream of the ORP meter. Dosing lines shall be provided such that the operator can select where the chemical is to be dosed automatically. Static mixer shall be provided after chemical dosing. Mixing shall be provided upstream of the cartridge filters by the cartridge filter orifice plates. Mixing arrangements shall be provided downstream of the cartridge filters. A residual chlorine analyzer and ORP meter shall be located downstream of the cartridge filter to control the SBS dosing rate. A provision to dose Biocide shall also be provided to control the biofouling of the RO membrane. All chemical dosing system shall be provided for the best application in the RO system to the satisfaction of the Employer's representative.

3.4.5.2 *RO Membrane*

The reverse osmosis (RO) membrane shall be thin-film composite 8" spiral wound type. 16" spiral wound membranes are not permitted. The membranes shall be produced by a reputable manufacturer that has successfully provided a similar type of membranes in similar Seawater conditions and plants since at least 10 years. There will be up to 8 elements per pressure vessel.

The reverse osmosis elements shall be high rejection; low fouling seawater spiral wound polyamide membrane units proven for the use under similar conditions of seawater supply at Perur site. Thermal excursions outside the operating temperatures occurring during acid cleaning shall not have any adverse effect on the membrane.

RO Recovery rates shall be selected considering the required quality and the reliability of the system; however, the recovery ratio shall in no case be less than 42% and be more than 46%. The RO section shall be designed for an average flux rate not exceeding 13.4 l/m²/h at the maximum RO recovery of 46%.

Sufficient space provisions shall be considered in the design of the RO Trains to accommodate 10% additional pressure vessels for future requirements. The capacity of each rack should be 25 MLD.

Scope also includes 5% of the installed membranes as emergency replacement stock, to be supplied and be stocked during the complete duration of the contract. Spare membrane should be stored as per supplier recommendation to ensure that maximum allowable temperature, environment and other conditions of storage are not exceeded at any time. A dedicated area should be provided in the workshop or at any other convenient location within the plant. The spare membrane storage area has to be equipped with proper air conditioning (A/C). The A/C shall be designed for the allowable range of the temperature for the membranes, even in case of a more prolonged standstill of the RO Plant.

Membrane performances and replacement rate should be guaranteed by membrane supplier for at least 5 years; such guaranty should be confirmed by selected suppliers in writing and should be provided in the bid.

The expected lifetime of the RO membrane shall be 7 years (+/- 0.5 year) which shall be provided by the bidders in their bid submission. The used RO membranes and cartridge filters shall be sustainable recycle/disposal compliant with Indian laws and regulations. The procedure of recycling/disposal will be reported regularly to CMWSSB.

Plant should be designed to ensure that production and quality can be maintained with at least 3 membrane suppliers without modification of the equipment. Sufficient sampling points shall be provided to test the product water quality from every RO vessel.

3.4.5.3 *Pressure Vessel*

RO membranes shall be installed in GRP pressure vessels. These modules shall be factory assembled and tested, and supplied mounted on and within robust framing, and shall be suitable for landing into a plinth and ready for pipework connections.

The RO pressure vessels shall be designed and manufactured in accordance with ASME Section

X and duly coded and stamped. Each train will have enough space to install enough number of modules to be installed at the end of the guarantee period or 10% free space whichever is greater. There should be a suitable arrangement for the air venting of the pressure vessels. The design of the pressure vessel shall allow interchangeability of membrane elements. The Pressure Vessels may be supplied as either side port side entry Pressure Vessels or multi-port, side entry Pressure Vessels. The Vessel exterior shall have a smooth surface and shall be painted with white polyurethane paint. Paint should have UV resistance properties. Each vessel shall have a resin impregnated identifying number / bar-code.

Each pressure vessel has to be equipped with conveniently accessible sampling points for product water lines. Furthermore, the RO System shall provide a sampling station for each train to take permeate sample from each vessel. Each pressure vessel shall house not more than Eight (8) membranes per vessel. Train should be designed to provide sufficient air venting of the pressure vessels. The vessel interior shall be free of pits or voids that may promote bacterial growth, and the inside of the vessel shall have a smooth and mirrorlike surface to prevent the above.

Tolerance of the pressure vessels should ensure that front port or side port connections are in compliance with Victaulic connection maximum tolerance.

3.4.5.4 *High-Pressure Pump*

High pressure (HP) pumps shall be from a reputable manufacturer who has supplied pumps that have been working satisfactorily for not less than five years. The High-pressure pump shall be designed with Variable Speed Drive (VSD). The casing, Impeller and shaft of the HP pump shall be of Super Duplex with PREN ≥43.

It should be noted that the correct sizing of the RO pumping system is critical, as under-sizing will not achieve the required permeate flows and over-sizing may require excessive pressure to be burnt-off at the throttling valve. Therefore, it is suggested that bidder take due care and full diligence in designing the system. The Bidder, in its bid, needs to submit the operational philosophy for the HP pumping system in totality with RO system over the full range of seawater salinity and temperature.

3.4.5.5 *Energy Recovery Device*

Energy in the high-pressure brine from the reverse osmosis membranes shall be recovered only by an isobaric energy recovery device (IERD). The IERD's shall be arranged such that a single unit can be removed from service and at least 95% of the total work exchanger capacity is available whilst the single unit is isolated. Isolation shall be manually performed, either by operator valves or by fitting end caps. IERD should be made of corrosion-resistant material or in a super duplex or super austenitic stainless-steel material with a minimum PREN ≥41.

The Energy recovery system installation shall in no regard cause a constraint to operate, cleaning, maintenance, preservation or mothballing procedures of the reverse osmosis system. The ERD selection shall be with the least maintenance requirement to improve plant availability. The unit shall be mounted on a skid, valve arrangement and control based as the proprietary design. Adequate support for the equipment shall be provided. The proprietary material used in the construction of such energy recovery devices shall be suitable for the seawater condition specified in the tender document.

The salinity increase at membrane due to ERD should not exceed 3%. This shall be determined from conductivity measurements.

The proposed Energy Recovery Device(s) shall have a minimum of ten (10) years operating history in seawater applications. The expected lifetime of the Energy Recovery Device(s) shall be at least twenty-five (25) years. Efficiency of a single Energy Recovery Device (per unit) must be over 95% throughout the designed operating range. The sound levels emitted from the device should be within the limits prescribed in the national standards. The Energy Recovery Device(s) must be able to operate within all the parameters of this Specification through the water temperature range and through the ambient air temperature range.

3.4.5.6 *Neutralization*

Neutralization system should be provided to neutralize the CIP solutions before it is discharged to the sea along with the RO brine via the outfall tank. The neutralization system should have a dedicated tank with recirculation /mixing facility and allow for neutralisation of the CIP solution in less than 4 hours. Neutralization in the CIP tank is not permitted. There will be two neutralization system (one for each plant stream). The neutralization tank of each stream shall have capacity about 4 times the CIP tank volume to accommodate the total volume of the waste for at least two CIP and flushing. The pump will run in recirculation mode till neutral pH is observed & then it will go to dumping mode.

No manual intervention should be required from the operator to carry out the neutralization. pH should be monitored before discharge into the outfall tank through online pH analyzer with an interface to the recirculation system. The pump will run in recirculation mode till neutral pH is observed & then the pump will run into dumping mode. The system should have 100% redundant (Stand by) pumps and valves for recirculation/dumping.

All the equipment should be designed to withstand the range for high TDS/salt concentration and high-alkaline /low-acidic pH expected, including pH of cleaning used during high fouling or scaling events. If included in the RO building, the neutralization should be covered, and a vent should allow ventilation of the gas outside of the building at a reasonable distance of any access and walkways.

3.4.5.7 *RO Permeate Tank*

RO permeate tank shall be provided to store sufficient permeate water for CIP, flushing and service water. The tank can be either in concrete with corrosion-resistant tiling or glass fused stainless steel with proper internal and external protection.

There will be two RO permeate tanks – one in each plant process stream of 200 MLD (tanks connected to each other with sufficient isolation valves). To ensure membrane flushing water is always available, each tank design will offer a large capacity of 5000 m3 allowing one skid CIP, all trains flushing and one backwashing of the limestone filter. This tank will serve membrane flushing pumps and a service network providing water to limestone bed backwash, chemical building and RO building (flushing all the seawater pumps at the stoppage, rinsing leaks to avoid corrosion).

3.4.5.8 *Clean In Place System*

At least two clean in place (CIP) system shall be provided – one in each process stream of 200 MLD. The cleaning system should enable cleaning of all plant trains. It should consist of a cleaning tank with the capacity necessary for the preparation of the cleaning solution for one complete train.

The CIP Tank shall be sized for a working volume equivalent to the volume of the maximum number of pressure vessels to be cleaned at any one time, plus the volume of the maximum length of CIP pipework in the feed, concentrate and permeate header systems with 20% safety margins.

CIP tank the volume of the tank should be at least

$$V_{\text{CIP tank}} = V_{\text{skid}} + V_{\text{piping}} + V_{\text{minimum suction level for pumps}} + 20\% \text{ safety margin}$$

- CIP pump design to ensure sufficient flow for the membrane cleaning minimum of 9 m3/h per pressure vessel
- CIP Cartridge filter
- Heater design for the minimum seawater temperature (temperature of the CIP solution should be monitored)
- Chemical injection and pH control
- Recirculation loop for CIP preparation and chemical dilution

Permeate from the permeate tank shall be used to fill the CIP Tank. The CIP Tank fill line inlet shall be above the CIP tank overflow and shall include a non-return valve, to ensure that there is no risk of backflow of chemicals into the permeate tank.

The location of the CIP Pump discharge back into the CIP Tank and the CIP pump suction line shall be carefully designed to ensure that when in recycle mode, the contents of the CIP Tank are well mixed. The CIP pump suction line shall also be designed so that air is not entrained into the CIP Pump, even when the tank is running in recycle mode at a low level. The bidder shall calculate the increase in temperature of the water in the CIP tank due to the heating action of the CIP pumps, either in recycle mode or cleaning mode, as well as the heat of solution of the cleaning chemicals. If the temperature of the contents rise above 45^{o}C in normal operation, with the warmest expected seawater temperature, then facilities shall be provided to cool the CIP Tank contents. It is anticipated that this shall be achieved by a heat exchanger on the CIP Pump discharge recycle line, cooled by a suitable stream of process water.

In cleaning mode, the water pumped by the CIP pumps shall pass through nominal 5 µm cartridge filters. The design of the cartridge filters shall be as provided in the RO system, except that no excess capacity is required.

Each RO train stage concentrate header shall be connected to the CIP system concentrate header, separated by a suitable isolation valve. The CIP system concentrate header shall return cleaning fluid into the Neutralisation Tank. In cleaning mode, the RO train concentrate header shall be isolated from its energy recovery device by a suitable isolation valve.

Each RO train stage permeate header shall be connected to the CIP system permeate header, separated by a suitable isolation valve.

The CIP Tank shall be fitted with a drain flush with the tank floor. The drain shall be connected, via an easy to operate isolation valve, to the Neutralisation Tank.

3.4.5.9 *Flushing Unit*

RO train should be automatically flushed after the stop, and the flushing should include HP pump, RO train, ERD and recirculation pump. Flushing water storage (Permeate Tank) should allow to flushing of all the plant trains in one plant stream of 200 MLD while the plant is not producing water. The permeate tanks of both the plant streams shall be interconnected with sluice isolation valves to allow additional permeate water as needed for train flushing.

The flushing system must be independent of the cleaning system to allow flushing and cleaning operation at the same time. Flushing pump, pipings and necessary valves on the train must allow flushing of all the plant trains during an electrical outage. A standby pump should be provided to ensure availability of the flushing system.

Two diesel generator set (2x100%) of suitable capacity shall be provided for each plant stream to run the RO flushing system and to flush the RO trains in case of power failure. The diesel generator set shall be envisaged to supply the UPS charger of the plant as well. The DG set shall be sized for the above and applicable motorized valves etc for safe shut down of the plant in case of power failure.

3.4.5.10 *Membrane Skid Test Unit*

A membrane skid test unit must be provided to enable during operation the test of the individual membrane. Skid test unit should enable to perform test as per ASTM D 4194 standard. The membrane skid test unit should be feed by pretreated water.

It should include cartridge filter, HP pump, single membrane testing unit and all necessary equipment for flow control and sampling points. Pretreated water tank may be used to prepare cleaning for cleaning test on individual membranes.

3.4.6 **Chemical Storage System**

There will be a separate chemical building area for Pre-treatment, RO system and Post-treatment for each 200 MLD plant streams. The allocated area shall be designed to receive and store all of the bulk chemicals safely and to meet the specified performance and technical criteria. All dosing tanks, pumps and allied system of chemical dosing shall be located under chemical building. Bulk liquid chemicals may be stored in well-designed chemical storage tanks and bunded areas close to the chemical building. The solid chemicals shall be housed in the chemical building.

3.4.6.1 *Design Criteria*

The design intent is to ensure safe unloading of chemicals, no losses of containment, and safe operation of the storage. Therefore, the storage area will be:

- Engineered to high standards
- Safe for operators and the environment
- Durable and maintainable
- Compliant with statutory regulations

Chemical area layout will allow sufficient margin between refill points and empty tanks. Control systems will ensure that the tanks do not overflow while filling. Chemical fuming shall be dealt with systems in place to manage fuming. Any heating requirement shall be provided as appropriate to avoid freezing of chemicals such as sodium hydroxide.

All piping and equipment should be suitable for transported chemicals. Chemical pipes should be housed in a trench. Piping of incompatible chemicals should be separated.

Local visual indication of the contents of all storage tanks shall be provided along with level sensors and transmitters. For liquid storage tanks, magnetically coupled type instruments shall be used.

Tank Capacity/Delivery Size

All chemical storage facilities shall be suitable for 30 days of chemicals availability at RO Plant Site. The Long lead chemical shall be provided with 40 days of storage facilities. For Sodium Hypochlorite combined storage & dosing shouldn't exceed 14 days, due to its low shelf life.

For bulk deliveries, complete unloading system shall be provided with all 2x100% pumps, valves and fitting for transfer of chemicals to the storage tanks. The Contractor shall ensure that the design of the reception and storage facilities meets the standard requirements of the chemical delivery.

Unloading areas will be provided sufficient for the movement of road trucks. Unloading areas will be paved and sloped to a drain capable of collecting any spillage, and with a capacity of 9,000 L or the capacity of the largest tank vehicle compartment.

Tank Bunds

Storage tanks should be held in a bund to ensure that, in case of chemical spillage, chemicals are retained. Bund capacity should be at least 110% of the biggest tank or 50% of the total tank capacity whichever is the biggest. Bund should be free from cables, instruments and as far as possible free of piping.

Bund areas will be based on a bund wall height of 1.0 m and the capacity of the bund with this wall height is 100% of the total volume of the tank leaving 1 ft of freeboard.

The bunds shall be lined with acid/alkali-resistant epoxy coatings.

Minimum Separation Distances

The information on minimum separation distances is presented below.

- Between tanks: 0.6 m

- Between a tanker connection point and protected works: 5 m
- Between a tank (3,000 to 50,000 L) and protected works: 5 m
- Between a tank (> 50,000 L) and protected works: 8 m
- Between a bund wall and protected works (from inside the bund wall): 3 m

Segregation

Tanks containing chemicals must be kept in separate bunds and segregated by a suitable distance as the per the appropriate British or Indian Standard.

Liquid Chemical Transfer

Transfer pumps (1W + 1S) with all appurtenances shall be provided for smooth transfer of chemicals.

Level Indication

Each tank shall be supplied with a level transmitter and independent low- and high-level switches. There will be a level indication display visible from the vehicle unloading point during discharge. An independent high-level alarm/switch will be provided in the tank that will be interlocked with the power supply for the delivery tanker. This alarm and switch, which will be below the overflow level, will be activated when the high level is reached. It will also stop power to the GPO, into which the tanker's transfer pump is connected. The contents of all storage tanks shall be continuously monitored on the HMI.

Chemical Area Safety

The design of all chemical storage and dosing systems shall take into account all international standards and safety requirements, and shall ensure the safe reception, transfer and dosing of chemicals. As a minimum, the following safety features shall be included:

a. Chemical delivery, transfer, storage and dosing shall be carried out in bunded areas. Bunds shall be sized to retain at least the contents of the largest storage tank +10%.

b. All bunds shall include provisions for the safe removal and disposal of any spilt chemical, as well as accumulated rainwater, by the use of portable sump pumps.

c. There shall not be a direct connection from bunds to surface drain.

d. Common bunding of two or more chemicals shall not be permitted. Dosing lines shall be sleeved in critical areas.

e. A sufficient number of safety showers and eyebaths shall be provided to allow rapid access from all chemical storage and dosing areas.

f. All confined areas which could potentially be exposed to a toxic gas shall be equipped with a source of safe air, fit for human breathing, for use in the event of a leak.

g. All chemical storage tanks shall be vented externally.

3.4.7 Chemical Dosing System

Facilities shall be provided for the delivery, storage and controlled dosing of all necessary process chemicals separately for the two plant streams.

Dosing systems shall include all the necessary equipment to ensure controlled delivery of the chemical at the required flow rate, irrespective of variations in chemical feed tank level, or delivery point pressure (e.g. pressure sustaining valves at the dosing point).

Chemical dosing system should be designed to allow safe and reliable operation. All chemical system including dosing tank should be clearly identified; chemical piping should be colour-coded.

Each dosing line shall be provided with an isolation valve and a non-return valve as close to the point of injection as possible.

Chemical systems shall be designed to ensure that there is no circumstance in which a dosing pump can generate a pressure which exceeds the design pressure of any part of the system downstream of the pump. All the necessary equipment to protect dosing pumps from unwanted particulate material present in the chemical delivery shall be provided.

All materials shall be compatible with the chemical being used. Standby equipment shall be provided for all dosing pumps. All metering pumps shall be N+2 spared (1 installed and 1 warehouse spare) and comply with API 675 standards. Stand-by should start automatically without operators' intervention. All the metering pumps considered should be of a similar type. The pumps shall be mechanically coupled Diaphragm type metering pumps. These pumps are to include inlet & outlet valves, check valves, discharge relief valves, reciprocating mechanism, gear reducer, coupling and all necessary instruments and drivers, all assembled, aligned and mounted on a standard base plate, ready for installation. Pulsation dampeners shall be provided on the individual dosing pump. All pumps shall be supplied with flow switches or flow detection devices integral with the pump.

All dosing lines and pumps shall be provided with facilities to enable the flushing of pumps and dosing lines with boosted service water. The drain lines shall be provided to drain the suction and discharge pipes of each dosing pump after flushing.

Chemical dosing pump suction should be equipped with filters and isolation valves to allow online filter maintenance. A standby filter must be provided on the shelf to enable proper maintenance while dosing system is in operation.

Chemical dosing rate should be paced with plant feed flow rate and seawater parameters such as turbidity, TSS, pH and organics. A calibration chart based on each quality parameter should be available on the HMI for auto-selection of the most optimum chemical dose rate with change in seawater quality parameters. Flowmeter should be installed on each chemical dosing line. Value should be available on the HMI systems. Chemical pumps suction and discharge pressure should be monitored.

If chemical dilution is required automatic (such as a polymer), safety should be provided to ensure that dilution is in operation during dosage. Stand-by dilution system should be provided.

The flow rate of ferric chloride coagulant, flocculation aid polyelectrolyte, RO antiscalant and other essential chemicals shall be continuously monitored on the HMI systems. These flow meters may be used to generate the low flow signal and auto-switch to the standby pump. It shall be possible to remove the flow meter for maintenance whilst still keeping the system in operation.

All chemical solution preparation and dosing tanks with dosing pumps and appurtenances shall be kept inside the chemical building with proper ventilation. There should be the mechanical lifting of the chemical for solution preparation and ejector system for polymer transfer. The tanks shall be filled automatically with service water for dilution using level transmitters and solenoid valves at the service water inlet pipe. All chemical dosing / storage dyke areas shall also be equipped with eyewash and safety shower at strategic locations.

Agitators shall be provided in each tank as needed for the solutions which require constant stirring.

3.4.7.1 *Sodium Hypochlorite*

Sodium hypochlorite shall be dosed intermittently to the intake header for shock chlorination and continuously at the intake pump discharge to eliminate micro-organism and control bio-fouling in the downstream processes. Only one set of sodium hypochlorite storage and dosing system shall be provided for shock chlorination.

The chemical shall be delivered in liquid form, in tankers. Suitable unloading arrangements shall be provided to transfer the chemical to the storage cum dosing tanks. All pumps and/or blowers for chemical transfer shall be equipped with a standby unit.

The liquid chemical shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby sodium hypochlorite dosing pumps.

The dosing tanks shall be connected to the dosing pumps by a common header. The elevation of the dosing pump shall be below the lowest working liquid level in the dosing tanks. The connection from the header to the dosing pumps shall be taken off the bottom of the header. The connection between the header and the dosing pump shall be kept as short as practical, and shall preferably be straight down (via isolation valve) onto the pump suction. A vent pipe shall be provided on the top of the header in the immediate vicinity of the feed to each dosing pump. Each vent pipe shall vent back into a hypochlorite tank. This arrangement is required because hypochlorite solution tends to generate gas, particularly in warm conditions, which results in dosing pumps losing their prime.

The table below specifies the physical properties for sodium hypochlorite.

Table 3-8: Physical Properties of Sodium Hypochlorite

Sodium hypochlorite	$NaOCl$
Physical form	Clear, yellow-green liquid
Active component	Cl_2
Bulk density (kg/m3)	1170
Liquid viscosity (kg/ms)	~ 0.002 (depending on temperature)

Active conc. of delivered product (% w/w as Cl_2)	10%-12.5%

Each hypochlorite dosing tank shall be sized to retain a minimum volume equivalent to the greater of:

a) 48 hours of hypochlorite solution for intake at maximum flowrate and average dose

b) the maximum quantity of intake shock chlorine required in a single shock chlorination event.

3.4.7.2 *Sulphuric Acid*

- Sulphuric acid shall be dosed upstream of the Lamella Settler for coagulation pH and scale control.
- The chemical shall be delivered in liquid form and stored in dedicated storage tanks.
- The liquid chemical shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby sulphuric acid dosing pumps.
- Undiluted chemical shall always be within a bonded & screened area, or in dual containment pipework, with leaks flowing to containment areas.
- The system shall be designed to ensure that water cannot flow back up into the concentrated acid pipework.

The table below specifies the physical properties for Sulphuric Acid.

Table 3-9: Physical Properties of Sulphuric Acid

Sulphuric Acid	H_2SO_4
Physical Form	Clear liquid
Active Component	H_2SO_4
Bulk Density (kg/m^3)	1840
Active Conc. of the delivered product (% w/w as H_2SO_4)	96 to 98%

The exterior of the tank shall be coated as follows:

- One coat of a two-pack zinc-rich epoxy primer applied to a minimum dry film thickness of 50 microns;
- One coat of a high build polyamide cured epoxy applied to a minimum dry film thickness of 150 microns;
- One coat of a re-coatable polyurethane applied to a minimum dry film thickness of 50 microns.
- The tank shall have a desiccator arrangement of the ventilation pipe to prevent moisture from entering the tank. All the outlet nozzles shall have double isolation valves.

The acid storage tank shall be installed in separate dykes. Each dyke volume shall be capable of holding the gross tank storage volume including board for the free area. The dyke area shall be provided with adequate drainage arrangement. The preferred material of construction for bulk storage of sulphuric acid is Carbon Steel with proper corrosion-resistant internal and external coating. Transfer pumps shall be provided to transfer chemicals from bulk storage tanks to the dosing tanks inside the chemical buildings. All dosing tanks and dosing pumps with all appurtenances shall be accommodated in the chemical building.

3.4.7.3 *Ferric Chloride*

Ferric chloride shall be dosed upstream of the Lamella Settler for coagulation, and also provision shall be kept to dose before DAF as needed.

There shall be two solution preparation & dosing tanks for ferric chloride and two tanks for polyelectrolyte - each of capacity more than 8 hours of maximum chemical dosing. All chemical preparation and dosing tanks, dosing pumps and chemical storage area shall be housed in a concrete building with an RCC service water tank at the top of the building for chemical preparation. There shall be two standby (1 installed and 1 in-store) chemical dosing pumps both for coagulation and flocculation chemicals connected to common header. All pumps, pipes and fittings shall be provided similar to other chemical dosing systems and the satisfaction of the Employer.

The table below specifies the physical properties for Ferric Chloride.

Table 3-10: Physical Properties of Ferric Chloride

Ferric Chloride	$FeCl_3$
Physical form	Clear Dark Red/ Brown Liquid
Active component	Fe^{3+}
Bulk density (kg/m^3)	1420 to 1460
Viscosity (kg/ms)	Approx. 0.0121
Active Conc. of delivered product (% w/w as $FeCl_3$)	40-42.5%

3.4.7.4 *Polyelectrolyte*

Polyelectrolyte shall be dosed upstream of the Lamella Settler and also before DAF if required. The polymer dose shall be approved for use by the manufacturers of RO membranes. All chemical preparation and dosing tanks, dosing pumps and solid chemical storage area shall be housed in a chemical building.

The strength of solution prepared shall be fully adjustable within the range 0.05% w/w to 0.2% w/w.

The polymer solution shall be dosed from the dosing tanks to the dosing point, in a controlled manner, by dedicated polyelectrolyte dosing pumps. The polyelectrolyte shall be dosed into a carrier water stream, to provide a dilution ratio of at least 5:1 or diluted polymer concentration <0.02. There should not be any fish-eye polymer floating in the flocculation tank.

All polyelectrolyte preparation and dosing equipment shall be provided with 100% installed standby.

For sizing the dosing pumps, it may be assumed that the maximum batch strength of polyelectrolyte (0.2% w/w) is used with the maximum dose and that the minimum batch strength (0.05% W/W) is used with the minimum dose. The tank sizing shall also be done based on the maximum dose rate.

The polyelectrolyte dosing tanks (3 tanks) shall be sized to provide at least 8 hours supply under maximum dosing and maximum flow conditions.

3.4.7.5 *Sodium Metabisulphite*

Sodium bisulphite (SBS) ($NaHSO_3$) will be prepared by dissolving sodium metabisulphite (SMBS) ($Na_2S_2O_5$) in water. Dosing of bisulphite is required to remove residual chlorine from the system resulting from intake dosing. Bisulphite may also be used for the RO CIP process and also for RO membrane flushing for storing more than a day.

Sodium metabisulphite shall be dosed upstream of the cartridge filters to allow proper mixing and elimination of the residual chlorine. Provision shall also be done to dose sodium metabisulphite after ORP meter.

The chemical shall be delivered and stored in powder form, in bags. The powder shall be batched up in dilution tanks to prepare a liquid solution for dosing. A minimum of two dilution tanks shall be provided. The tanks and chemical storage shall be housed in the RO chemical building. When a batch needs to be prepared, powder shall be transferred from bags to a discharge hopper. The discharge hopper shall be provided with a sealed lid, which is removed when the hopper is being filled. The powder shall be discharged from the hopper to either of the dilution tanks via a manually operated isolation valve. The dilution tanks shall be covered, and vented to atmosphere outside the chemical building (toxic sulphur dioxide is released when sodium metabisulphite is mixed with water). The dilution tank shall be provided with an overflow which overflows via a water bath within the bunded area of the tank.

Each dilution tank shall be connected to the dosing pump suction manifold via an automatically controlled isolation valve. The liquid solution shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby metabisulphite dosing pumps.

The table below specifies the physical properties for Sodium Metabisulphite.

Table 3-11: Physical Properties of Sodium Metabisulphite

Sodium Metabisulphite	$Na_2S_2O_5$
Physical form	White to off-white, crystalline Powder
Active component	$Na_2S_2O_5$
Bulk density (kg/m^3)	1000 to 1150

Viscosity (kg/ms)	-
Active Conc. of the delivered product (% w/w)	100%

3.4.7.6 *Antiscalant*

Non-polymer based antiscalant shall be dosed upstream of the cartridge filters. The chemical shall be delivered in liquid form and stored in dedicated storage tanks.

The liquid chemical shall be dosed to the upstream of cartridge filter dosing point, in a controlled manner, by dedicated, duty/standby antiscalant dosing pumps.

The table below specifies typical physical properties for an acceptable antiscalant. Details of the selected product are to be obtained from the selected chemical supplier.

Table 3-12: Physical Properties of Antiscalant

Antiscalant	
Physical form	Clear Yellow Liquid
Active component	Product as supplied
Bulk density (kg/m^3)	~ 1- 1300
Viscosity (kg/ms)	-
Active Conc. of the delivered product (% w/w)	100%

Dosing tank of GRP construction. Each tank shall have a cover with charging port, level switches, makeup water pipe connection and a drain with isolating diaphragm valves; the pipework and valves in uPVC Class 15/PN 16; the antiscalant tank shall be installed in separate dykes. Each dyke volume shall be capable of holding the gross tank storage volume including board for the free area. The dykes area shall be provided with adequate drainage arrangement. The dyke area shall also be equipped with an eyewash and a safety shower at a strategic location. The antiscalant dosing plant shall be installed on a concrete plinth in the RO building as approved by the Engineer.

3.4.7.7 *Biocide*

Non-polymer-based biocide storage and dosing system shall be provided to combat the propensity of bacterial infection of the RO membrane. The chemical shall be dose as and when required to prevent biological growth in the RO system. The chemical shall be delivered in liquid form and stored in dedicated storage tanks.

The liquid chemical shall be dosed to the upstream of cartridge filter dosing point, in a controlled manner, by dedicated, duty/standby biocide dosing pumps.

3.4.7.8 *Sodium Hydroxide*

Sodium hydroxide storage and dosing system shall be provided for use in case required to reduce Boron in permeate. The chemical shall be dosed as and when required to limit the Boron concentration in the permeate within 1 mg/l. The chemical shall be delivered in liquid form and stored in dedicated storage tanks from where it shall be transferred to the dosing tanks in the chemical building.

The liquid chemical shall be dosed to the upstream of cartridge filter dosing point, in a controlled manner, by dedicated, duty/standby dosing pumps.

3.4.8 Post Treatment System

The permeate from the RO plant will be treated in the remineralization/ potabilization plant followed by disinfection and pH adjustment. There will be a separate post-treatment system for each plant stream of 200 MLD capacity. The limestone-based potabilization system shall be adopted considering the plant operation and maintenance aspects.

The post-treatment process shall be complete comprising the following stages:

- CO_2 storage and injection system;
- Limestone filter beds;
- pH correction system including an arrangement for pH booster, if required;
- Corrosion inhibitor dosing;
- Product water disinfection by chlorination.

All necessary pumps, compressors, equipment, controls and pipework systems shall be included for the treatment stages. The CO_2 for the potabilization plant shall be procured from external sources and stored at the plant in dedicated storage tanks. A minimum of two storage tanks shall be provided and each to be sized for adequate storage capacity (minimum 15 days storage). Tanks shall be of vacuum-sealed double-walled type. The storage tanks shall be fabricated from ASTM Gr 515/516 plates or equivalent plates as per ASME Section VIII Div I or equivalent international standards.

The dosing system shall consist of the pneumatically operated flow regulating, a flow monitor, a pressure monitor, a pressure gauge and motorised inlet and outlet valves and guard valves. The dosing control system shall be provided with a manual bypass.

Carbon dioxide dosing shall be controlled proportional to the post-treatment feed flow and based on an operator set dosing rate.

Each dosing system shall be provided with a static mixer of stainless-steel construction, with motive water provided by the motive water pumps. Water supply to each static mixer shall be regulated by control valve station. The gas supply to the static mixer shall also be provided with non-return and isolating valves.

All the pipework complete with valves, fittings, supports etc. for the total carbon dioxide plant shall be provided under this Contract. This shall include all the pipework from the storage tanks to the dosing point.

All the pipework, valves and fittings shall be in carbon steel. Internals of the valves shall be in stainless steel. Pipe connections of 2 inches and below shall be socket welded. However, the Pipe connection above 2 inches shall be flanged.

3.4.8.1 *Limestone Filter*

The remineralisation plant shall be capable of converting 100% of the permeate from the RO Plant into product water to the required Drinking Water standard. The potabilization shall be done using CO_2 gas injection and limestone filters. In case of partial remineralization and then mixing of two streams, about 50% of the permeate flow should pass through the limestone filter for remineralization. The bypass stream must mix with remineralized stream thoroughly before transfer to the Product Water Tanks. The composition of the product water following remineralisation shall meet the requirements stated in IS 10500.

The required alkalinity and hardness shall be maintained in the product water during remineralization. Finally, the pH correction shall be done through caustic injection to ensure the positive LSI of the product water. The process design of the remineralization plant is given in table below.

Table 3-13: Indicative Process Design Criteria for Remineralization System

Item	**Requirement**
Limestone Filter Plant	2 plants – 1 for each plant stream
Remineralization Process	Limestone filtration /Carbon dioxide Dosing – 2
Target filter surface loading	10 $m^3/m^2.h$
No. of filter modules per stream	14
Media Contact time	25-30 min
Hardness in the product water	≥ 60 mg/l as $CaCO_3$
Target pH range	7.5 to 8.5
Target Langelier Index	Positive
Max. TDS in product water	450 mg/l at battery limit.

Limestone Filter Beds

Limestone filters should include an automatic backwash system and loading system. Backwash should include air and water step for proper cleaning of the filters.

Proper corrosion protection should be implemented depending on filter material to ensure that corrosion will not impact post-treatment availability and operability.

Limestone grain size should be 2 – 4 mm.

The limestone used should be compatible with product water application; this should be validated by a certificate from a reputable international lab.

Storage capacity should be at least one month at full capacity.

The Contractor shall be responsible for ensuring purity and local availability of the limestone for design; however, the design should not consider purity above 96%.

Care must be taken that volatile organic and inorganic constituents (THM etc.) cannot be passed to the drinking water. Adequate adsorption and cleaning facilities (absorbers etc.) shall be installed in the CO_2 feed lines to the alkalinisation stage. The use of seawater for remineralisation is not permitted.

The excess CO_2 from the process after the treatment shall be vented out through the degassers or alternatively neutralised by the addition of chemical (NaOH). The degasser tower and the water storage tank shall be fabricated in GRP. In order to control the remineralisation process and to guarantee the quality control of the water the following measurements and control are required;

- Calcium monitoring and control;
- Conductivity measurement;
- Turbidity measurement;
- Residual chlorine detection and control system.

Carbon dioxide flow for re-injection shall be automatically adjusted pro-rata to permeate flow with the remote manual trimming to compensate for variations arising from product water temperature and chemical composition. The calcium alkalinity adjustment system shall be automatically controlled to maintain a positive Saturation Index to DIN 38404-10 and calcium concentration.

The piping material for the entire remineralization Plant shall be in GRP. The GRP pipes shall be designed for the maximum pressure that is likely to occur in the piping system (pressure surge phenomena shall also be considered for this purpose). However, the minimum stiffness class of the piping shall be 5000 PSI.

All the valves used for this plant shall be suitable for product water application. The Valve casings shall be in Ductile Iron or Cast Steel material. Valve internals shall be lined with fusion bonded epoxy coating. Valve discs shall either be fusion bonded epoxy coated or encapsulated with EPDM. Stainless steel shafts shall be provided for the valves.

All the pumps in the system shall be in stainless steel SS316L construction, i.e. casing, impeller, shaft, shaft sleeve, wear rings and other wetted parts. The pumps shall be designed, manufactured and tested according to the latest ISO, BS or DIN or equivalent International codes. Adequate stand by equipment shall be provided in the process. All the standby pumps shall be capable of operating automatically in case of failure of the main pump.

3.4.9 Product Water Disinfection

Bidders shall consider the use of sodium hypochlorite for disinfection of product water. Suitable number of N+2 dosing pumps with solution tanks shall be kept to dose in the product water feed to Product Water Tank. The specification for sodium hypochlorite shall be as per the above chlorination description.

3.4.9.1 *Chlorine Residual Monitors*

One chlorine residual monitor shall be provided in each pipeline from Product Water Tanks to Clear Water Tank for monitoring the final water downstream of the chlorine injection points. The Contractor needs to maintain 0.5 ppm residual chlorine at the outlet of the plant.

The monitor installation shall be located in a covered location easily accessible for viewing and maintenance and shall be provided complete with sample pumps as necessary to ensure the continuity of the sample.

The sampling pipework complete with isolation valves etc. shall be designed to ensure the sample reaches the monitor in a time not greater than 1 minute. The monitor drainage pipework shall permit the visual checking of the presence of flow and shall discharge to the plant drain. Sample water not passed through the monitor shall be returned to the process. The residual signals shall be displayed at the local control panel and the central HMI. High and low chlorine residual levels shall raise alarms at the local control panel and the central HMI.

3.4.9.2 *Ventilation System*

Each area where hypo is stored or used liquid shall be provided with a forced ventilation system. Air intakes shall be sized to allow uniform ventilation and positioned to prevent possible recirculation.

3.4.10 **pH Adjustment of Product Water**

Sodium hydroxide shall be used for the pH adjustment of the product water before product water tank. Sodium hydroxide storage and dosing system shall be provided for the purpose. The chemical shall be dose to maintain the pH of the permeate within 7 - 8.5. The chemical shall be delivered in liquid form and stored in dedicated storage tanks from where it shall be transferred to the dosing tanks in the chemical building.

The liquid chemical shall be dosed to the upstream of chlorine dosing point, in a controlled manner, by dedicated, duty/standby dosing pumps.

3.4.11 **Product Water Tank (PWT)**

Product water tanks shall be provided by the Contractor with 2-hour storage capacity (at least 30 ML). Total capacity of two product water tanks for each stream shall not be less than 15ML. The tank shall be subdivided into two compartments so that one compartment can be taken out of service for maintenance or cleaning without disrupting the operation, i.e. water production and distribution. All valves, gates, pipes and instrumentation shall be provided to make a complete water storage tank. The tank will have level sensors and overflow pipeline to the Outfall tank.

The water from the product water tanks of both the streams shall be fed to a Clear Water Reservoir (CWR) for pumping water to Porur for distribution.

The main outlet pipe from the product water tanks of each stream to CWR will have two metering system, online turbidity, conductivity meters and sampling points to demonstrate the product water quality/quantity and to meet the product water guarantee conditions.

There will be provisions for pumping of the product water from PWTs to meet the plant captive water requirements for administrative building, toilets, safety showers etc. and also for a fire system (pumps, diesel generator set, network).

These two-compartment tanks will be constructed of concrete or metal panels with provision of corrosion protection. The remineralised water from the limestone filter will gravitate to the product water tank.

3.4.12 Clear Water Reservoir (CWR)

A clear water reservoir shall be provided by the Contractor with a minimum of 30 minutes of storage capacity. The reservoir capacity shall be at least 9000 m3 and made of reinforced concrete. The tank shall be subdivided into two compartments so that one compartment can be taken out of service for maintenance or cleaning without disrupting the water production and distribution. There will be an overflow line from the CWR to the outfall tank. The CWR will be the battery limit of the contract. The Contractor is to provide all sensors, instruments, gates, inlet pipes, valves, dismantling joints, puddles in the CWR up to 5m length of flanged pipes of required specification on the discharge side. The pipes, centrifugal pumps and all valves, sensors and instrumentations at the CWR discharge line are not in the scope of the Contractor .

3.4.13 Plant Sludge Treatment System

A sludge treatment facility shall be constructed to treat sludge from the proposed 400 MLD SWRO desalination plant.

The selected sludge treatment units are sludge balance tank (SBT), thickeners and belt filter press (BFP) units. All the sludge will be collected in the sludge balance tank and mixed for a homogeneous sludge solution. From SBT, the sludge will be pumped to the thickeners where it will be thickened up to 5% solid consistency. The thickened sludge will be transferred to the sludge holding tank under gravity which will then be pumped to BFP units for dewatering. The polymer will be used before thickener and BFP to promote solid separation. The filter backwash water, supernatant from thickener and wash water/ filtrate from BFP shall be directed under gravity to the Outfall tank. Rodding points or other provisions shall be provided throughout the installation to clear sludge blockage without dismantling any pipe section.

Sludge disposal shall be as per the norms of the local and state regulations.

3.4.13.1 *Design Basis*

The pre-treatment process for 400 MLD Perur Desalination Plant includes Lamella Clarifier (LC) and Dissolved Air Flotation (DAF) followed by Gravity Dual Media Filter (GDMF). Most of the solids in raw seawater will be eliminated in the Lamella filter, and some lighter particles will be removed in DAF. The concentration of suspended solids in the seawater to GDMF is expected to be less than 5 mg/L most of the time, which will be removed in filter beds. The sludge generation in LC, DAF and GDMF at a peak feed flow rate (42% recovery) and high/average turbidity are given below.

Table 3-14: Indicative Sludge Flow and Dry Solids at Sludge Treatment System

		Lamella	DAF	DMGF	Total
Sludge Flow	MLD	21	10	40	71
Dry Solids (Ton /day)	Peak	276	51	5	332
	Normal	70	17	2	89

The generation of sludge streams from LC, DAF and DMGF will be about 21, 10 and 40 MLD. The primary solid loads will be in the Lamella clarifier and DAF waste streams. The design will be based on the normal condition with average seawater quality having TSS 75 mg/l. The solid load from the DMGF waste stream is expected within 2 tons/day, which is very low compared to LC and DAF. Therefore, only LC and DAF sludge have been considered for treatment.

3.4.13.2 *Sludge Balance Tank*

The sludge from the Lamella Settler and DAF will be collected in a sludge balancing tank before pumping to the sludge thickener. The sludge balancing tank shall be of reinforced concrete construction.

The Contractor shall provide at least three submersible mixers installed and one mixer in store (3 duty/1 standby). The mixers shall be of the wall-mounted type with coupling devices, guide rails and support brackets. The mixers shall be provided with adjustment for depth and mixing directions.

An overflow line for discharging of excess sludge to the Outfall tank shall be provided. The system shall be complete with all necessary controls and a set of level elements to provide the required controls and alarms. An indicative design criterion for the sludge balancing tank is listed below.

Table 3-15: Indicative Design Criteria for Sludge Balancing Tank

Parameters	Unit	Value
Required tank volume	cu m	2592
Number of RCC tanks		1
Tank sludge depth	m	3.5
Tank area	sq m	741
Tank diameter	m	31
Flow Meter		Electromagnetic
No. of submersible mixers		4 (3 duty/1standby in-store)

3.4.13.3 *Thickener Feed Pumps*

Three thickener feed pumps (2 duty/1 standby) shall be provided. The pumps shall be of the submersible non- clog type and be mounted in a wet well within the tank. The pumps shall be automatically controlled by the water level in the sludge balancing tank.

A static mixer or equivalent device shall be mounted on the pump delivery line inside the pumping vault to ensure adequate mixing of the injected polymer within the bulk of the sludge. A manually operated chain pulley block and running beam shall be supplied for removal of the pumps. The indicative design criteria for the thickener feed pumps are listed in in the table below.

Table 3-16: Indicative Design Criteria for Thickener Feed Pumps

Thickener Feed Pumps	**Unit**	**Value**
Design flow	cu m/hr	650
Maximum flow	cu m/hr	800
Minimum flow	cu m/hr	400
Pump type		Submersible non-clog
Discharge head	m	15

3.4.13.4 *Polymer Dosing System*

Two metering pumps (1 duty/1 standby) and all associated polymer make facilities, pipework and valves etc. shall be provided to dose polymer from a polymer storage tank into the thickener feed line at a rate of up to 5 kg per ton of dry solids.

The metering pumps shall be of the diaphragm type driven by a fixed speed motor with manual stroke adjustment, with a 10 to 1 turndown and an accuracy of ±3% over the operating range. An indicative design criterion for the thickener polymer dosing system is listed in the table below.

Table 3-17: Indicative Design Criteria for Thickener Polymer Dosing System

Thickener Polymer	**Unit**	**Value**
Polymer Type		Food grade
Polymer dosing concentration	%	0.5
Operating hrs	hrs	24
Polymer dosing rate	kg/SS-T	5
Polymer Dosing System		
Type		Metering pump
Number, duty		1
Number, standby		1
Pump capacity	m3/hr	0-15

3.4.13.5 *Sludge Thickeners*

The sludge in the sludge balancing tank will be pumped to sludge thickener. The sludge thickener shall have two functions:

- to clarify the supernatant to turbidity below 10 NTU prior to the return of the supernatant to mixing and distribution chamber.
- to thicken the sludge to a concentration of up to 5% solids prior to dewatering using belt filter presses (BFPs)

The sludge thickener shall have a sloping bottom and shall be fitted with a rotating sludge scraper to transfer thickened sludge to a central removal hopper. The scraping gear shall be supported from the tank base and a fixed bridge carrying the central electric drive for the rotating gear. The equipment, including driving motor, gears, shafting and scrapers shall be designed for continuous operation and sized for the most arduous operating conditions. Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and overload protection to alarm in the event of a failure.

The supernatant shall overflow a peripheral v-notch weir into a collecting channel and then flow by gravity to the Outfall tank. The supernatant may be directed to the Intake well. In that case, the polymer should be food grade.

The thickener shall have a full diameter fixed bridge complete with a walkway for personnel access to the centre, access stairs to ground level and handrailing, a motor-driven sludge scraper complete with tie bars and tensioning members, all necessary controls, delivery pipework, a stilling well and overflow steel weir plates. Walkways, access steps etc. shall be galvanised. Handrailing shall be of Type 316 stainless steel material. Underwater fasteners shall be Type 316L stainless steel material.

The electric motor, gearbox, etc., shall be provided with a sunshade. The fixed bridge and the stilling chamber shall be steel coated with polyurethane, including the scraper mechanism. Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and over-torque protection to alarm in the event of a failure.

An electromagnetic flow meter shall be provided in the supernatant return pipe to the mixing and distribution chamber. The supernatant pipework shall be arranged to ensure that the pipework in the region of the flow meter always remains full. Flows shall be indicated, totalised and recorded at the local control panel and at the central SCADA system HMI. An online turbidity sensor shall be provided in the return pipeline to assess and record the performance of thickener. An indicative design criterion for the sludge thickener is listed in in the table below.

Table 3-18: Indicative Design Criteria for Sludge Thickener

Sludge Thickener	**Unit**	**Value**
Type		Continuous Circular Thickener

Sludge Thickener	Unit	Value
Design flow	cu m/hr	1500
Design inlet solid	kg/hr	13721
Solid loading rate	kg/day/sq m	86
Thickener surface area required	sq m	3830
Number, duty		2
Diameter of thickener	m	35
Hydraulic loading rate	cu m/sq m/hr	0.7
Depth of thickener	m	4
Thickener removal efficiency	%	90
Flow meter on supernatant return pipe		electromagnetic

3.4.13.6 *Thickened Sludge Holding Tank*

A tank shall be provided to store thickened sludge and to act as a sump for the BFP feed pumps. The tank overflow shall pass to the Outfall tank. The tank shall be fitted with continuous level measurement equipment.

The Contractor shall provide two agitators. The agitators shall be mounted on platforms that extend across the tank. The indicative design criteria for the thickened sludge holding tank are listed in the table below.

Table 3-19: Indicative Design Criteria for Thickened Sludge Holding Tank

Thickened Sludge Holding Tank	Unit	Value
Total sludge flow	cu m/hr	240
HRT	hr	4
Required tank volume	cu m	960
Number, duty		1
Depth of tank	m	4
No. of agitators		2

3.4.13.7 *Sludge Dewatering Process*

a) General

Continuous-feed belt filter presses (BFPs) that use the principles of chemical conditioning, gravity draining and mechanically applied pressure shall be used for the sludge dewatering operations. Sludge shall be first conditioned using polymer prior to dewatering on the belt filter press. Polymer (non-food grade) shall be dosed to the sludge via a static mixer. The conditioned sludge shall be introduced on a gravity drainage section where it is allowed to thicken. Following gravity drainage, the pressure shall be applied on the opposing porous belts where sludge is squeezed and dewatered. Each belt press shall be designed and sufficiently automated to involve minimal operator attention.

b) BFP Feed Pumps

The BFP feed pumps shall be progressive cavity pumps.

c) BFP Requirements

The indicative design criteria for the BFP dewatering system are listed in the table below.

Table 3-20: Indicative Design Criteria - BFP Dewatering System

System	**Unit**	**Value**
BFP Feed Pumps		
Type		Progressive cavity pump with VFDs
Minimum capacity	cu m/hr	24
Maximum capacity	cu m/hr	30
Number, duty		
Number, standby		
Belt Press Filter		
Design flow	cu m/hr	240
Design flow	cu m/day	5760
Operation times (minimum)	hr/day	16
Required BFP capacity	cu m/hr	360
Number, duty		
Number, standby		

d) Polymer Dosing System

All associated polymer makeup facilities, calibrator, pipework, flowmeter and valves etc. shall be provided to dose polymer from a polymer tank into a static mixer on the BFP feed lines. The metering pumps shall be of the diaphragm type driven by a fixed speed motor with manual stroke adjustment, with a 10 to 1 turndown and an accuracy of ±3% over the operating range. The metering pump shall start and stop simultaneously with the associated BFP feed pump. The indicative design criteria for the BFP polymer dosing system are listed in the table below.

Table 3-21: Indicative Design Criteria for BFP Polymer Dosing System

BFP Polymer Dosing System	Unit	Value
BFP Polymer		
Polymer Type		Non-food grade
Polymer dosing concentration	%	0.5
Operating hrs	hr	16
Polymer dosing rate	kg/SS-T	5
Polymer Tanks		
Type		Circular tank
Number, duty Tank		2
Polymer Dosing Pumps		
Type		Metering pump
Number, duty		
Number, standby		

3.4.14 Functional Design Specification

3.4.14.1 *General*

Before commencement of software development for the PLC/DCS/SCADA system, the Contractor shall prepare the Functional Design Specifications (FDS) for the plant processes. The Contractor shall be fully responsible for collecting all relevant data and information such as process parameters, alarm setpoints, interlocks etc. required to develop the FDS. Information collection by way of posting a Request for Information is not acceptable.

3.4.14.2 *Plant Interlocks*

The FDS shall comprise a listing of all plant interlocks. The plant interlocks shall include but not be limited to

- interlocks between various process units
- interlocks within a processing unit
- interlocks between equipment
- interlocks within a piece of equipment
- interlocks between the plant and external system

It is also the responsibility of the Contractor to identify any new equipment type interlock that may not be shown on the Standard Starter Templates. All these interlocks shall be presented in the form of a table and may also be presented in the form of a spider diagram or any other means subject to approval by the Engineer.

3.4.15 Hydraulic Profile

The Contractor shall provide the hydraulic profile of the complete seawater desalination plant including the intake pumping station, inlet chamber, flash mixing, flocculation and Lamella clarification, DAF, media filtration, RO system, Remineralization, disinfection, product water storage, sludge treatment and any other water treatment plant process.

3.5 Material Selection and Corrosion Control

The material selected for each equipment item shall have a proven track record for that same equipment item in an equivalent operating environment. The selected material shall be clearly indicated in the Contractor's Proposal Attached to the Contract. The material selection for all major equipment including pipes, pumps, valves, gates, joints, meters, tanks etc. shall be submitted to the Employer for approval during the design phase.

The quality of all materials, prefabricated parts and instruments as well as the quality of workmanship during assembly and erection shall be such that the plant shall have its operational life as defined in bid document elsewhere. The equipment shall be of a well-proven design and renowned manufacturer. The latter shall demonstrate that the proposed equipment has been installed in other plants running successfully under similar conditions. Moreover, in the selection of equipment, the Contractor shall take into account that workshops and offices of the vendors exist in the region.

The Contractor shall indicate the corrosion/erosion allowances intended to be applied based on the operational life for the whole installation.

At locations where the contact between different metals cannot be avoided, protection against corrosion due to galvanic potential difference shall be provided. Where necessary, bolted connections of dissimilar materials shall be insulated from the surrounding metals by means of insulating washers and sleeves to prevent electric current to circulate and establish a galvanic element.

All external stainless-steel components shall be protected against salt deposits

The design and the construction shall be performed so as to avoid crevice corrosion.

External bolts, nuts and washers shall be of corrosion-resistant material.

Any rubber or plastic parts, coatings etc. shall be provided with suitable protection against the ultraviolet radiation of the sun.

Fittings like valves, filters, pumps etc. shall be standardised as much as possible (made by the same manufacturer) to minimise spare parts inventory. The spare parts shall be fully documented, and clearly identified in related drawings.

Workmanship and general finish shall be of first-class commercial quality and in accordance with the best workshop practices and shall provide what is generally recognised as waterworks finish as defined elsewhere.

All similar items of plant and their component parts shall be completely interchangeable. Spare parts shall be manufactured from the same materials as the originals and shall fit all similar items of plant. Machining fits on renewable parts shall be accurate and to specified tolerances so that replacements made to manufacturer's drawings may be readily installed.

All equipment shall operate without excessive vibration and with a minimum of noise as defined in the bid document elsewhere. All revolving parts shall be dynamically balanced so that when running at all operating speeds and any load up to the maximum, there shall be no vibration due to lack of balance.

All parts which can be worn or damaged by dust shall be totally enclosed in dust-proof housings.

Dynamic balancing of rotary components shall be to the relevant standards. All bearings shall have L-10 rating life of minimum 16,000 hours.

3.5.1 Requirements for Materials

Materials selected by the Contractor shall be proven to be eligible and sufficient for the RO Plant design life. All materials and equipment shall be designed for long life and shall be suitable for continuous 24 hours per day operation for prolonged periods with a minimum of maintenance. The Contractor may be called upon to demonstrate this for any component either by the service record of similar equipment elsewhere or by records of extensive type tests.

All materials incorporated in the Works shall be the most suitable for the duty concerned and shall be new and of first-class commercial quality, free from imperfections and selected for long life and minimum maintenance. The selection of the material of all the equipment and pipelines shall be done with consent of the Engineer.

All parts in direct contact with various chemicals shall be completely resistant to corrosion, or abrasion by these chemicals, and shall also maintain their properties without aging due to the passage of time, exposure to light or any other cause.

Seawater pumping pipes and all pipes and fittings in Pre-Treatment area shall be manufactured in GRP in accordance with AWWA C 950.

Pipe and fitting for low-pressure system and reject (low pressure) shall be GRP of minimum pressure rating of PN10. The piping material for permeate/ product water shall be GRP of pressure rating PN25 as a minimum.

The pipes shall have a minimum stiffness of 2500 N/m^2 in accordance with AWWA C 950 and shall include an internal and external corrosion barrier. These pipes shall also be designed for the full vacuum conditions that may occur in the piping system and shall be designed to withstand the pressure scenarios that occur during the surge condition.

Components of the RO Plant which are in contact with Seawater or are subject to abrasion or potential high rates of wear shall be selected from proven grades of high corrosion/erosion-resistant materials.

All stainless-steel material in contact with seawater and concentrate (brine) in minimum shall have a Pitting Resistance Equivalent Number (PREN) and Crevice Factor (CF) as follows:

PREN = Cr(%) + 3.3 x Mo (%) + 16 x N (%) for austenitic material or

PREN = Cr (%)+3.3 x Mo (%)+30 x N (%) for Duplex material ≥43

CF = Cr (%) + 3 x Mo(%) + 15 x N (%) of not less than 35.

Material for desalination major process pumps (Seawater supply, Seawater booster and high-pressure pumps) shall be super-duplex stainless steel with a PREN ≥ 43. The materials of the other balance of plant equipment and systems shall be suitable for the services intended.

Cathodic protection system as applicable shall be provided to mitigate the corrosion that may occur due to a combination of different materials.

Particular attention shall be paid to the prevention of corrosion due to the close proximity of dissimilar metals. Where it is necessary to use dissimilar metals in contact, these shall be selected so that the bimetallic corrosion is as low as possible and the dissimilar metals shall be isolated by barriers or isolating material. The publication by H. M. Stationery Office (in the U.K.) entitled "Corrosion and its Prevention at bimetallic Contacts" shall be used as a guide.

All outdoor instruments shall be provided within FRP/GRP enclosures, or of any other equivalent suitable material which shall withstand the corrosive sea environment.

Butterfly valves for On-Off service and non-return valves that are in contact with seawater shall have a Ductile Iron body with hard rubber lining. Control valves for modulating service which is in contact with seawater and subject to abrasion and high rates of wear shall be of highly resistant materials such as Ni-Al Bronze.

The staircase and platform shall have SS316 handrails for safe climbing and access. All platforms and stairways shall have a minimum clear width of 1000 mm. All platforms, stairways, landings etc shall have SS316 railings and guards.

3.5.2 Materials for Pipelines

Each pipeline shall be constructed in a material compatible with the fluid conveyed through that pipeline, i.e. the materials used in the pipes which are or can be in contact with the untreated or treated water, shall not contain any matter which could impart taste or odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed. Nor shall any pipe be adversely affected by the fluid being conveyed through that pipe.

The Contractor shall provide a table for the components of all process units and the ancillaries with their required materials of construction and recommended coating.

Pipework and valve materials for the following duties shall be as follows or to the approval of the Engineer:

Table 3-22: Materials for Pipes and Valves

Application / Location	Material
Coagulation solution	GRP, HDPE or cPVC

Hypo-chloride dosing line	GRP, HDPE or cPVC
Raw Sea Water, brine discharge, Intake Pumping, Piping in Pre-Treatment	GRP AWWA C950/HDPE Pipe and fitting for low pressure system and reject (low pressure) shall be GRP of minimum pressure rating PN10. The piping material for permeate water shall be GRP of minimum pressure rating PN25.
RO High Pressure and all high-pressure piping, valves and equipment in the RO system	Super Duplex with PREN ≥43 and Crevice Corrosion Factor ≥35
Instrument air, all materials (pipe, Flange, fittings, valves) for air	SS-316 L
Wastewater drain line – drain network inside a building	HDPE or uPVC
All nuts, bolts, screws and studs for gland joints, couplings joints,flanges and any other fittings. Prior to assembly, all threads of stainless fasteners shall be coated with a nickel-based anti-seize compound. Where anchors, threaded rods, nuts, washers and fasteners etc. to be embedded in concrete shall be manufactured in Type 316 stainless steel. Wherever possible, chemical set fasteners shall be used.	Type 316L stainless steel
All structural components, not exposed to a corrosive environment, (e.g. walkways, fasteners)	hot-dip galvanised iron / GRP

3.5.3 Welding

In all cases where welds are liable to be highly stressed, the Contractor shall supply to the Engineer before fabrication commences detailed drawings of all welds and weld preparations proposed. No such welding shall be carried out before the Engineer has signified his approval of the details proposed. No alteration shall be made to any previously approved detail of weld preparation without prior approval of the Employer.

Welding shall comply with B.S. 5135.

Approval of welding procedures shall be as per International / B.S. EN 288-3:1992 standards. Welders shall be qualified to ASME / B.S. EN 287-1:1992. All aspects of fabrication and examination procedures, including pre/post-heating treatment, electrodes, non-destructive Tests

(NDT) shall be subject to the approval of the Engineer.

Following codes shall apply for the NDTs:

- B.S. 2600: Radiography;
- B.S. 3923/IS 13311: Ultrasonic Test;
- B.S. 6072: Magnetic Particle Test;
- B.S., 6443: Penetrant Test.

3.6 Instrumentation and Control Works

The entire desalination plant shall be designed for automatic operation to minimize the requirement for manual intervention. Flow rates of main streams, seawater to the pre-treatment section, RO trains' feed water, permeate product water, and so on shall be controlled as per the flow rates and shall be continuously monitored by the flow meters.

The plant's information and operation control system proposed shall be based on the network control system. The Distributed Control System (DCS) shall be configured in redundant control mode deployed and distributed in the field areas of the plant by process locations. The DCS shall function independently and autonomously, such that failure of any one element will not affect the operations of the other elements in the entire system. As a result, the system provides maximum availability and reliability for the operation.

The specifications under this section shall be read in conjunction with the specifications provided for specific discipline of the works elsewhere in the contract. In the event of any conflict between this and requirements elsewhere in the contract, the most stringent specifications for all the parts, equipment and works shall apply or as per the consent of the Engineer.

The Proposed DCS system at Desalination Plant with the following features:

- Automation, Monitoring, Process Control, Management & Engineering or machine interface
- Reliable User Guidance
- Redundancy Levels in terms of Controller, Power Supplies, Communication & Operator Work Station except for IO channel Redundancy.
- Uniform operation
- Modern Object-Oriented Software Structure
- Communication with external system and intelligent field equipment
- Integrated diagnosis & documentation system
- Communication support

The DCS will have the following sub-systems/functions.

- Measurement system

- Control system including closed-loop controls, interlock, protection and sequential control system
- Data bus system for control and communication with the process
- Shall be self-diagnostic both module level and channel level diagnostic
- Man-Machine interfacing system
- Maintenance Engineer's station
- Historical data & retrieval facility
- Alarm management system & Sequence of event recording
- Interfacing with other 3rd party control systems and equipment
- External interfaces to stake holders
- External network interfaces shall be through an industrial firewall
- Dynamic mimic display, alarm monitoring, report trending, logs calculation and printing outs logs, reports and trends.
- All Peripheral hardware failures are hardwired & system status changes through the soft link as per OEM standard for Alarm logging in DCS.
- Time Synchronization with DCS and all other package PLCs.
- The required instrumentation shall be provided for the Units/Facilities to facilitate the smooth plant automation, alarm, monitoring and recording.
- The automation shall be provided to all the processes at the plant such as for but not limited to the following units/facilities of the plant.
    - Seawater intake system
    - All chemical dosing systems
    - Lamella and DAF sludge discharge system
    - DMF backwash systems
    - Pre and Post-chlorination - dose rate shall be controlled based on the level of residual chlorine
    - RO with CIP system
    - Remineralization system and pH adjustment
    - Sludge treatment and waste disposal system
- Alarms and Report Generations - Apart from the above, DCS system shall receive a signal from all instrumentation, units and processes on a real-time basis at the interval selected by the operator, and it shall generate alarms & various Plant Operation Reports.
- Contractor shall provide the functional specification detailing the operation of equipment in manual and automatic mode, description of interlocks and alarms, and description of inputs and outputs signals.

- The system shall provide an orderly shutdown in the event of the operation of a protective device or an equipment failure. There shall be a means of capturing the sequence of the failures and transmitting them to the Central Station for Root Cause Analysis.
- A list of alarms and other important I/O signal (for determining the root cause of failures) shall be provided for review/modification by the Employer and PMC.
- A written process control narrative describing the local and remote operation, interlocking, sequencing, and trip logic shall be provided.
- A list of both hardwired and interface I/O signals shall be provided in electronic format (MS Access or Excel)
- Electronic copies of the PLC program, HMI configuration files (if applicable), and a sample of local HMI display screens (if applicable) shall be provided.
- In the event of operating air or electric power failure, design controls, components shall go into fail-safe condition.
- All alarms shall be configured for "closed" under normal operating conditions and "open" to alarm. Alarm contacts provided for the Employer's use shall be wired to easily accessible terminal blocks for field connection.
- Separate Routing: Provide separation for each of the following systems:
- 240 VAC power and control wiring.
- Low voltage DC signal wiring, including milliamp, voltage, thermocouple, and Resistance Temperature Detector (RTD) signals.
- Data communications cables such as coaxial, Ethernet Category 6, two or four-wire RS-232/RS-485.
- Prior to shipment from the manufacturer's facility, the Programmable Logic Controller/Operator-Interface Terminal (PLC/OIT) control systems, I/O modules, panels and other peripheral devices shall be staged and energized for operational testing and demonstration. The Contractor's testing procedures shall be submitted for Employer's review and comment.

3.6.1 Redundancy Levels of DCS system:

a. Controller Level : Required set of Redundant Controllers have been considered as a minimum.

b. Communication Level:- The communication redundancy for DCS shall be applied as follows,

    i. Controller to IO Modules -Redundant (communication protocol shall be as per OEM standard)

    ii. Controller to Operator/Engineering Stations - Redundant Ethernet

iii. DCS to third party control system - Redundant OPC/ MODBUS TCP-IP/ RS 485

iv. Time Synchronization with GPS Master clock - Redundant through NTP

v. DCS to MOV's - Simplex Profibus/Profinet

vi. DCS to Intelligent Master Control Centers (I-MCC's) - Redundant Profibus/Profinet

c. Power Supply Level

The Redundancy shall be applicable on Power Supply modules which are located at main Controller. Bulk power supply shall be redundant. The system power supply is isolated from field device power/ interrogation supplies.

3.6.2 Central Control Room (CCR) System

The Central control room of Desalination plant shall be facilitated with below,

i. Operator Work Stations (OWS's)

The Redundant Operator Workstations shall be interfaced with DCS controllers by using Redundant Data Bus, and the same will be proposed in Central Control Room of Desalination plant.

ii. Historical Storage and Retrieval system (HSR)

The Redundant Historical Storage stations shall be proposed for storage and retrieval facility will collect and store data and parameters including trends, alarms and events from plant unit DCS database periodically and automatically to removable data storage devices once every 24 hours.

iii. Engineering Station & Laptop

The Engineering station and Laptop shall be proposed in Central Control Room for the operator's immediate updation on Logic & Graphics without affecting Real-time Process monitoring & control.

iv. Printers

The Printers shall be proposed in Central Control Room for Printing of Reports, Trends etc. and those are to be interfaced with Hot Redundant LAN so that operators can take prints from multiple stations as and when required with credentials of Administrator.

- One Number of A3- Colour LaserJet Printer
- A-3 / A-4 Black & White LaserJet Printer
- All in One LaserJet Printer

v. Large Video Screen

Two numbers of Large Video Screens shall be proposed inside the Central Control Room for operator monitoring of entire plant screen systems.

3.6.3 Critical Operation Points

The below table shows the Critical Operation points for the Proposed Perur DSP.

Table 3-23: Critical Control Points

Control Points	Location	Parameter
CCP -0	Filtrate from DMF	Turbidity < 0.5 NTU, TOC < 2 mg/L, SDI < 3 (95% of time), SDI < 4 (100 % of time)
CCP -1	RO feed pump discharge (Cartridge Filter outlet)	Turbidity < 0.2 NTU, ORP -300 mV, TOC < 2 mg/L, SDI < 3 (95% of time), SDI < 4 (100 % of time)
CCP – 2	SWRO permeate	TDS < 350 mg/L (derived value from Conductivity), Boron < 1.0 mg/L
CCP - 3	Product water storage tanks discharge line for both the streams	TDS ≤ 450 mg/L, Residual Chlorine < 1.0 mg/L, Boron < 1.0 mg/L, Turbidity < 1.0 mg/L
CCP - 4	Outfall tank discharge line to sea*	TSS < 100 mg/L Iron < 3 mg/L Residual Chlorine < 1 mg/L Temperature – Shall not exceed 5°C above receiving water temperature

Note : * - The values are discharged are based on General discharge standards of CPCB. TNPCB.

3.6.4 Online Monitoring Locations

The Table below indicates the minimum envisaged online monitoring locations of water quality for the proposed Perur DSP.

Table 3-24: Major Sampling and Monitoring Locations of Water Quality

S. No.	Parameter	Raw seawater	Filtered water	Potable water	Marine Outfall
1	Silt Density Index	✓	✓	--	--
2	pH	✓	✓	✓	✓
3	Total Dissolved Solids	✓	✓	✓	✓

S. No.	Parameter	Raw seawater	Filtered water	Potable water	Marine Outfall
4	Temperature	✓	✓	✓	✓
5	Electrical conductivity	✓	✓	✓	✓
6	Turbidity	✓	✓	✓	✓
7	Residual chlorine	✓	✓	✓	✓
8	Boron content	✓	✓	✓	--
9	Langelier Saturation index	--	--	✓	--
10	Oxidation-reduction potential	--	✓	--	--
11	Alkalinity	--	--	✓	--

Monitoring through Online Analysers of all the above parameters and any other important parameter as needed, shall be provided, and the real-time readings will be obtained.

Auto Samplers shall be provided at all sampling locations to collect 24 hourly composite samples for analysis in the plant laboratory.

3.7 General Requirements

The Contractor shall provide all necessary services to complete the plant construction Works and to make a fully working plant as per the Employer's Requirements; these services may include:

- All necessary design as well as all necessary inclusions/accessories to provide a complete and operating system irrespective of whether or not all items are specifically mentioned in the specifications or drawings. All materials offered must be suitable for the environment at the plant site in Perur, Chennai and suited to their duties.
- Equipment identification and pipe markings to clearly identify all components for installation, operation and maintenance purposes.
- Platforms, stairs, handrails, and supports to allow safe access to all equipment, tanks and instrumentation requiring inspection, maintenance or calibration.
- The equipment shall be sited in an indoor environment and will not be subject to exposure. Manufacturer's standard painting systems shall be considered suitable if approved by the Employer.
- Erection of all the items, equipment, instruments and other accessories to form a complete functional water treatment plant system capable of performing all the duties required by these specifications and any additions that Contractor needs to provide for a complete functional seawater desalination plant with sludge treatment facilities.
- Contractor shall provide easily accessible water quality sampling points, on each process tank inlet line and/or outlet line, as required by the Employer. Convenient means shall be provided including all interconnecting pipework, sampling pumps and taps, adequate sink and drainage as required to obtain samples manually and locally from all

tanks and inlet/outlet lines. Each sampling point shall be provided with an outlet convenient for the collection of samples for laboratory testing and the connection of a portable quality measuring meters.

- Noise levels shall be contained by the appropriate equipment design. Acoustic enclosures should be used only if other appropriate engineering measures are not practical. Noise at the steady-state operation at peak capacity, start up, and shutdown shall not exceed 85 dB (A) for the blowers and compressors and 65 dB(A) for the pumps.
- Freeboard in new units shall generally be not less than 500 mm. Freeboard if necessary, shall be higher such that in the event of excess flow (flow up to +25%) no overflow takes place and marginal freeboard up to 25 mm shall remain. Freefall shall be kept adequate and meet criteria that in the event of excess flow up to +25%, marginal free fall up to 10 mm shall remain.

The specifications under General Requirements shall be read in conjunction with the specifications provided for specific discipline of the works elsewhere in the contract. In the event of any conflict between this and requirements elsewhere in the contract, the most stringent specifications for the parts, equipment and works shall apply or as per the consent of the Engineer.

3.7.1 Service Water System

The Contractor shall construct a plant service water system. The service water storage tanks shall be provided over chemical buildings and sludge treatment buildings for chemical makeup/preparation, inline chemical dilution and chemical laboratory. The service water shall be fed by duty/standby service water pumps located at RO permeate tank. The storage tanks shall provide at least one-hour storage of service water at average usage rates.

The product water shall be used from the product water tank for the following services:

- housekeeping
- emergency showers and eyebaths in the chemical building, sludge dewatering building, laboratory, chlorination buildings and any other locations
- fire-extinguishing system
- cleaning and flushing
- domestic water system – administrative and all other area/buildings at the plant premises.

Product water storage tanks of RCC shall be provided at all the buildings where there is the frequent use of service/product water. All service connections shall be provided with isolation facilities to permit work to be carried out at one point of supply without affecting other users. Independent power and control panels shall be provided for the service water systems. Status annunciation shall be carried out using discrete indicator lights located on the pump starter enclosures.

The following alarms shall be provided at the control panel and the central HMI.

- duty pump failure
- system failure (i.e. both pumps failed or a similar occurrence which prevents the system from working)
- storage tank high level

3.7.2 Piping, Pipe Fittings and Valves

The pipes, fittings and valves shall meet the following:

- All process pipework including valves, fittings, and accessories shall be fabricated of and jointed by materials unaffected by and compatible with the conditions of service anticipated.
- All piping shall be designed based on the maximum anticipated flow rates. In general, the pump suction line shall be designed for the maximum velocity at 0.9 m/s and the discharge line at 1.5 m/s. The velocity in other pipes shall be about 1 m/s.
- Pipe, fittings, and valves shall be made of suitable corrosion-resistant material for the purpose of use. Control valves shall be Type 316L stainless steel or other comparable corrosion-resistant material and be tight shutoff and flanged with pneumatic actuators. Actuators shall fail to a safe position.
- All pipe spools shall be factory tested per current requirements. Piping larger than two inches in diameter shall be flanged.
- Instrument lines shall be Type 316L stainless steel unless the fluid requires a more resistant material.

3.7.3 Dismantling Joints

Dismantling joint shall be provided for ease of erection and dismantling of pump/valves/ flowmeters. The body, counter flanges shall be of Ductile Iron / Cast Iron. Bolts and Nuts of the joint shall be of stainless steel. The joint must allow the dismantling of the valve, pumps, meters, etc., without causing stress to the joints of the attached pipes. The pressure class of the dismantling joint shall be the same as that of the pipe and valve. The seal of rubber shall be NBR. The axial flexibility of not less than 25 mm, and the radial flexibility of minimum 2mm shall be provided. It shall be double flanged with a collapsible arrangement. Flanges shall conform to the flanges of connecting pipe/valve. Dismantling joints on pump delivery and pumping mains shall be subjected to a hydrostatic test pressure of 1.5 times the delivery pressure. Detailed drawings of the dismantling joint shall be submitted to the Engineer for approval. The joints shall be painted with corrosion-resistant coating as per specification given for exposed pipes.

3.7.4 Conveyance Channels/Overflows

The arrangement of all conveyance channels and drain piping inter-connecting the units shall ensure that the units will be capable of taking maximum flow. During emergency conditions, excess flow shall be directed to drain until control is regained in order to avoid flooding and protect the various structures. Based on the same, overflow arrangements shall be made at all units and structures where required.

All overflows will be sized for the maximum flow. Overflows will be discharged by gravity to Plant Outfall tank.

3.7.5 Intercom System

An intercom system shall be provided between the following points within the treatment plant:

- control room
- pump and compressor room with the adjacent main distribution panel room
- laboratory
- chemical buildings
- chlorine buildings
- sludge treatment building
- electrical/ MCC rooms
- Seawater intake facility
- RO building
- Pump stations including backwash pump rooms
- Security Guard House
- Administrative building
- Central Control and Laboratory Building

3.7.6 Chemical Laboratory

The Contractor shall provide a well-equipped chemical laboratory with new meters/equipment to analyse all the required water quality parameters, including the following chemical and bacteriological routine analyses:

- temperature
- pH
- conductivity
- alkalinity
- turbidity
- suspended solids
- total dissolved solids
- residual chlorine
- ammonia
- nitrate and nitrite
- phosphate
- e-coli counts
- BOD/COD
- Oil and grease
- TOC Analysis – based on combustion method
- All relevant cations and anions

The Contractor shall supply an advanced multi-analysis kit with chemical reagents and equipment for batch tests on coagulation and flocculation (Jar test simulator). In addition, the Contractor shall provide the laboratory test glassware such as burette, auto-pipette, flask, beakers (of 25 to 500 ml capacity), graduated cylinders of varying sizes and other equipment and reagents for above chemical analyses. The testing methods shall be as simple as possible and the equipment as robust as possible. The Standard methods shall be described in a Test Manual.

3.7.7 Integrated Security System

3.7.7.1 *General*

This specification describes the technical requirements for the Security System at 400 MLD SWRO desalination plant and covers the minimum requirements for design, engineering, manufacture, erection, inspection and testing. The specification shall be read in conjunction with the specifications provided in Chapter 9, ICA Requirements and elsewhere in the contract. In the event of any conflict with the requirements elsewhere in the contract, the most stringent specification shall apply or as per the consent of the Engineer shall be obtained.

The Integrated Security System (ISS) and related equipment shall be complete in every respect and suitable for safe and reliable operation.

Preferably, the whole integrated security system of the entire plant would be one unified system of the same make and type, which would ideally be sub-contracted as a whole to a single reputable company subject to Employer's approval.

This specification does not enumerate or describe all the materials and equipment to be supplied and all the services to be performed. All materials and equipment shall be provided as are required to make a complete, properly functioning installation and shall conform to the highest standards of engineering design and workmanship.

The Integrated Security system shall cover the whole area of the Plant site and shall cater for all potential risks and provide the correct response to any if detected. The Integrated Security System (ISS) shall comprise following discrete systems:

1) CCTV Surveillance System
2) Access Control System
3) Identity Management system
4) Security Control Point
5) Public Addressing System
6) Communication System

The above systems are required to safeguard the assets by various collusion threats from insider or outsider and to improve the overall security & surveillance.

The scope of work includes as a package: designing, obtaining authorities approval, manufacturing, construction, factory testing, packing for transport, transport and delivery to site, unloading at site, storing, complete erection, testing at site, painting, commissioning, acceptance tests, preparation of test reports and handing over a fully Integrated Security

System.

3.7.7.2 Scope

The scope of supply includes but is not limited to : a computer-based central security system, CCTV cameras, TV monitors, video recorders, intrusion detectors, work stations, card readers, door switches, uninterruptible power supply, any special tools or test equipment and software for the purpose of installation, maintenance, administration and operation of the system.

A functional design specification (FDS) shall be prepared for approval of the Engineer.

The factory acceptance test procedure (FAT) for the ISS shall be approved prior to the execution of the tests.

The proposed system should provide a fully functional and integrated command and control security system. This system shall assist the security managers and security staff in maintaining the maximum level of security at the site. The main control of the system will be from a dedicated security control room.

The ISS shall include:

- CCTV Surveillance system with recording and playback facility with LCD screen technology display showing a sitemap and lower-level maps of buildings of various zones. The details are given in Chapter 9.
- Intrusion Detection & Assessment System (IDAS) based on CCTV system, other trending and proven technologies if any shall be proposed by the contractor.
- Access Control System (ACS) with door monitoring system, access control, metal detectors, raising arm barrier, turnstiles, barriers, under- vehicles surveillance system. The details are given in Chapter 9.
- Identity Management System (IDMS) in line with the Access Control System with computer-based security system for ID badge, security administration, event/alarm management, recording of all the information, etc.
- Integration with public address and telephone.
- Security Control Centre (SCC) including all security equipment.
- All programmable equipment must be supplied with software, hardware communication protocol and documentation and necessary licenses.
- Cable, cable trays, conduits, channels and related accessories as required.
- Power supplied for all the system components, including cameras, sensors and recording system, should be powered by a centralized uninterruptible power source/ solar power fully compliant with project specifications.
- Complete design and installation
- The Contractor shall submit welding procedure specifications (WPS) and procedure qualification records (PQR) and Quality Assurance Plan (QAP) for approval before

starting any welding work.

- Training for the operation and maintenance of the system
- Commissioning of the system
- Preparation of the complete project documents such as wiring diagram, as built drawing and factory acceptance test reports.

3.7.8 Machine, Equipment & Tools for Workshops

The Contractor shall construct one workshop and one warehouse of metallic structures– and supply the minimum equipment and tools listed in the table below for the workshop. The machine, equipment and tools supplied shall be used for the maintenance of the plant. The Contractor shall arrange for any machine, equipment and tool required for his use in the operation and maintenance of the plant during the O&M Contract. At the end of the contract, all machines, equipment and tools shall be handed over to the Employer in good working condition. In case the machines, equipment and tools are worn out and not in its original operating/ performing condition, new machine, equipment, or tool shall be provided by the contractor.

Table 3-25: Heavy Duty Machines for Workshop

S. No.	Description	Quantity
1.	**Heavy duty high speed lathes, 250 mm centre height, 1500 mm** between centres including main spindle with taper roller bearings, bed with gap, hardened bed ways, complete with electrical equipment, including motor, motor protection switch, lead screw with metric pitch, longitudinal feeds and cross feeds, screw cutting without gear change, metric threads, inch threads, module threads, change gear with accessories, universal faceplate, stationary and travelling steady, coolant supply equipment, complete with electric pump, contactor and switch and machine lamp attachment.	1
2.	**Heavy duty high speed lathes, 200 mm centre height, 1500 mm** between centres including main spindle with taper roller bearings, bed with gap, hardened bed ways, complete with electrical equipment, including motor, motor protection switch, lead screw with metric pitch, longitudinal feeds and cross feeds, screw cutting without gear change, metric threads, inch threads, module threads, change gear with accessories, universal faceplate, stationary and travelling steady, coolant supply equipment, complete with electric pump, contactor and switch and machine lamp attachment.	1
3.	**Heavy duty high speed vertical lathes**, 2000 mm table diameter, working piece diameter 2300 mm, working piece height 1400 mm, working piece weight 20000 kg, with accessories	1
4.	**Horizontal boring, drilling and milling machine**, work spindle dia.100	1

S. No.	Description	Quantity
	mm, self-acting traverse of spindle at one setting 700 mm, with standard morse taper, clamping surface of table 1000 x 1200 mm, maximum distance between faceplate and steady 2800 mm, speed step less adjustable, table feeds endwise and crosswise, spindle head feeds up and down, with rapid travel, for metric threads, inch threads, including motor and motor protection switch, and standard accessories	
5.	**Surface grinding machine wet grinding**, grinding wheel diameter/ width 250/25 mm, distance table to centre of spindle approx. 500 mm, table clamping area 900 x 250 mm, steeples adjustable including electrical equipment with motor and standard accessories	3
6.	**Column grinder**, with 2 wheels 300 x 40 x 76 mm for wet grinding, left hand side with normal rest, right hand side with adjustable workpiece support table and angle stop, with graduation in degrees for grinding tools, articulated machine lamp, 2 eye protection shields with mountings, complete with electric motor, motor protection switch and standard accessories.	2
7.	**Universal milling machine**, table size 1300 x 400 mm, steeples feed drive in all three table directions, longitudinal travel of table 1000 mm, cross travel of table 340 mm, chip tray, second counter support head, centralized lubrication for all three movements, main spindle drive, motor protection switch , accessories, vertical milling head with stepless V-belt drive and separate motor, including overarm adjustment, universal dividing head, machine lamp, milling arbors, cutter arbors, taper sleeves, cutter chuck, collets for above.	2
8.	**Vertical milling machine**, table size 1900 x 400 mm, steeples feed drive in all three table directions, integrated automatic lubricating system, cooling system, main spindle drive, motor protection switch , controls integrated on panel, accessories.	1
9.	**Heavy duty high speed shaping machine**, 725 mm ram stroke, 725 x 340 mm table size, shaping width 600 mm, complete with electric motor equipment, automatic vertical feed of the tool holder, main switch, motor protection switch, rotary concentric machine vice, with standard accessories.	1
10.	**Screw threading machine**, with solid steel frame, including pole-changing 3-phase motor for pipe and whitworth thread from 1/4 to 2", metric threads M6 to M52, with motor protection switch and standard accessories.	1
11.	Heavy duty power hacksaw, fully hydraulic 4 stroke, cutting range in round material 225 mm, for mitring from 450 mm, complete with electric motor equipment, stock support 500 mm high with heavy material Toller, accessories.	2
12.	**Heavy duty circular column drilling machine**, drilling capacity in steel up to 35 mm, in cast iron up to 45 mm, 350 mm column-spindle distance,	1

S. No.	Description	Quantity
	column diameter approx. 160 mm, stepless, with at least.3 kW electric motor, motor protection switch, coolant supply pump, accessories.	
13.	**Bench drilling machine**, drilling capacity in steel up to 10 mm, radius 200 mm, with high-capacity high-speed chuck to 10 mm, adjustable rectangular table, drilling depth 60 mm, column diameter 70 mm, base plate 170 x 170 mm, complete with electrical equipment and motor, motor protection switch and standard accessories.	2
14.	**Electric pipe bender**, complete with all necessary tooling required for cold bending heavy gauge steel pipe of up to 100 mm inside diameter to the smallest radic possible, limited only by the pipe bore and wall thickness, without flattening.	2
15.	**Universal folding press**, for hand operation, including base frame, for 3 mm plate thickness, 2000 mm working width, 45° angle bar, 3 mm rad. round bar, steel rail for the bending beams, accessory holders with standard accessories.	2
16.	**Combined plasma welding and metal cutting set**, cutting range from 2 to 25 mm in steel, provisions for connecting to argon, nitrogen or hydrogen gas bottles complete with welding and manual cutting torches, pressure regulators and one year's supply of welding rods and gas bottles.	2
17.	**Mobile work benches 1500 x 700 mm surface area**, suitable for containing one set of mobile work bench tools each.	2
18.	**Steel tool cupboards 500 x 500 x 1000 mm high**, including 125 mm leg height, with upper steel drawer and two removable trays, door latch for padlock, including lock.	4
19.	**Steel tool cupboards with double doors, 1000 x 500 x 1000 mm high** including 125 mm leg height, with centre partition, each side separately lockable with two steel drawers and two removable trays, door latches for padlocks, including padlocks.	6
20.	**Work benches with 1500 x 700 x 50 mm** plywood top, backboard, angle iron supporting frame, one steel plate drawer, with safety lock and two keys, one shelf underneath of extra strong construction, with six (6) all-steel parallel vices, 150 mm jaw width with bolts for through attachment to the benches.	10

Table 3-26: General Equipment and Tools for Mechanical and Electrical Workshop

S. No.	Description	Unit	Qty
1.	Vertical drilling machine	Nos.	2
2.	Hacksaw machine	Nos.	2
3.	Bench Grinder	Nos.	2
4.	Miscellaneous items and hand tools with safety equipment	Nos.	Lot
5.	Toolboxes	Nos.	10

S. No.	Description	Unit	Qty
6.	Portable Noise level tester	Nos.	4
7.	Portable vibration tester	Nos.	4
8.	Magnetic base dial gauge	Nos.	4
9.	Portable temperature meter	Nos.	4
10.	Filler gauge	Nos.	4
11.	Precision spirit level	Nos.	4
12.	415V, 3 phase, 50hz, 40kVA portable DG set (trolley mounted) including all necessary metering & protection unit, battery, manual control panel, plug & socket, etc., with cable and accessories. Acoustic enclosure which complies with all environmental regulations shall be included as a part of the supply.	Nos.	2
13.	Toolbox with all necessary tools fixed spanner, ring spanners, screwdrivers, adjustable jaw spanners, etc.	Sets	5
14.	Hand trolley (500kg capacity)	Nos.	4
15.	Tripod with chain pulley blocks of 1 Ton capacity (6.0m legs)	Nos.	4
16.	Welding set, 400 amp, three-phase regulator type, air-cooled, wheel mounted with 15 m welding cable, 2 m. welding cable for earthing, one welding holder, one welding screen with glass and 3 cable lugs, one pair hand gloves and one wire brush	Nos.	2
17.	Portable hand drill (heavy duty) of capacity 13 mm to 23 mm with ½" drill chuck but with drill bits and drill stand	Nos.	4
18.	Tong tester, 1000 Amp	Nos.	4
19.	Hand crimping tool with dies suitable for cable joining up to 95 sq. mm.	Nos.	2
20.	Hydraulic crimping tool, suitable for cable joining from 25 to 400 sq. mm.	Nos.	4
21.	Hydraulic jack, 5 Ton capacity	Nos.	4
22.	De-watering pump sets of 5 kW with 50 meters hose pipe	Nos.	4
23.	Motorized and handle operated insulation resistor tester, 5 kV (multi-range setting), with battery pack	Nos.	4
24.	Handle-operated insulation resistor tester - 1000 Volts	Nos.	4
25.	Megger, 1000 volt	Nos.	2
26.	Megger, 5000 volts (motorized)	Nos.	2
27.	Insulating oil tester and filter	Nos.	2
28.	Hand grinder (Angle 7")	Nos.	2
29.	Clamp-on Digital Meter (0 - 1000 Amperes)	Nos.	2
30.	Multi-meter (Digital)	Nos.	2
31.	Micro-Ohm meter	Nos.	2
32.	Portable vacuum cleaner/blower (industrial type)	Nos.	4

S. No.	Description	Unit	Qty
33.	Aluminium folding ladder - 8 meters	Nos.	4
34.	4 terminal Earth Tester (digital)	Nos.	4
35.	Rubber gloves (110 kV rating)	Sets	12

The contractor may use all the above machine, equipment and tools for the maintenance of the plant. He may employ other tools and equipment for fitting, welding or blacksmith workshop and also for tin smithing, carpentry, mobile tools/equipment, any other mechanical/ electrical/ I&C tools or painting and gardening tools/equipment. At the end of the operation and maintenance period, the Contractor shall turn over all such machine, equipment and tools in good serviceable condition to the Employer.

3.7.9 Heating, Ventilation and Air Conditioning

3.7.9.1 *General*

The works described in the following section shall include for the heating, ventilation and air-conditioning (HVAC) systems, including all details, accessories, electrical and other associated services, etc. required for the complete installation and satisfactory operation of the whole systems, whether these details are specifically mentioned in the specifications or not. The Contractor shall supply all necessary HVAC equipment with the consent of the Engineer that may be required at the buildings under the Specification of this Contract. The specification shall be read in conjunction with the specifications provided in Chapter 7, Mechanical Requirements and elsewhere in the contract. In the event of any conflict with the requirements elsewhere in the contract, the most stringent specification shall apply or as per the consent of the Engineer.

The performance shall be in strict accordance to the latest standards recommended by American Society of heating, refrigerating and Air-conditioning engineers, Inc. (ASHRAE) and to the best engineering Code of Practice and to the relevant requirements of the CMWSSB.

The supply shall include – but not be limited to – all auxiliary work and material necessary for the complete plant ready for satisfactory operation, including:

- AC and refrigeration equipment
- Air Handling Unit
- Packaged Air Conditioner
- Split AC unit
- Pipe work
- Paint work and surface treatment
- Electric/electronic installation
- Electric cabling to motors, heaters, control equipment, distribution and control boards and the connection thereof
- Insulation work
- Commissioning and hand-over to Employer

3.7.9.2 *Specific Impositions*

i) All equipment shall be designed for marine environment.

ii) The supply air temperature into occupied rooms and other air-conditioned areas shall not be more than 10º C below the design room temperature.

iii) No return air shall be taken back into the system from battery rooms, or from any other polluted rooms.

iv) Battery rooms shall be provided with a 100% run / standby forced air ventilation system, as a back-up to the main air-conditioning system in order to maintain a negative pressure at all time. If lead batteries are used, then all ventilation equipment shall be explosion proof.

v) Adequate spare capacity and standby plant (chillers, Air handling Units (AHU's), pumps etc.) shall be provided for systems serving control rooms, computer rooms, electronic rooms, relay rooms, communication room, switchgear rooms and any other areas where failure of any air- conditioning plant will affect the performance (≤50 TR) shall be 100%, i.e. 1 run + 1 standby.

vi) For "larger" systems (>50TR) a partial standby capacity shall be provided, i.e. 2 or 3 run + 1 standby, etc.

vii) Above standby criteria applies to air conditioning units, fans, blowers, pumps, drives, etc.

viii) Bidder should ensure that HVAC loads are optimized and included in power source.

ix) Additional extract fan shall be provided for toilets of air-conditioned buildings and a minimum of 10 air changes per hour shall be provided.

x) All cable basements shall be ventilated via a forced air ventilation system with 50% spare capacity standby plant.

Each air conditioning, ventilation and heating plant shall be a self- contained, functionally reliable unit, which shall be suitable for the appropriate building, with respect to performance and choice of system and also with respect to the spatial arrangement, the dimensions and the weights, as specified to suit the building and its purpose. It is therefore expressly required that reference shall be made to the appropriate building drawings in addition to this specification.

Furthermore, all the information regarding the nature of the building, the size of the windows, geographical directions etc., necessary for determining the external cooling loads, shall be taken from the building drawings.

The internal cooling and heating load shall be determined by the anticipated number of occupants, as well as the equipment to be installed.

For the refrigeration only air-cooled chillers or air-cooled condensing units shall be provided. Pipework from the chillers or condensing units to the air handling units shall be regarded as part of the refrigeration system.

For the purpose of providing the "basic cooling load" for the project, air-cooled chillers including stand-by units shall be positioned in the "central chilled water plant", together with the required chilled water pumps, chilled water pressurization & make- up unit, as well as "automatic chemical dosing equipment for maintaining the necessary chilled water quality.

Separate plant rooms/areas shall be provided for the air handling and ventilation equipment. Alternatively, this equipment may be placed on the roof, or at ground level next to the respective building. In this case, the equipment shall be fitted out for "tropical outdoor installation".

All equipment shall be placed in such a manner that sufficient space (as recommended by the manufacturer) is available for servicing and maintenance.

Isolated or geographically remote guard houses, etc., may be served via independent DX-systems.

Control rooms shall be served via precision systems for full control of temperature and humidity.

The Contractor is fully responsible for the exact calculation and the dimensioning of the air conditioning and ventilation systems as well as for the installation works at all buildings in the plant and getting approval for the requirements from the Engineer.

All ventilated or air-conditioned buildings shall be pressurized by supplying more air (approx. 15%) into the building than extracting from it.

Air conditioning shall be provided for:

- All buildings or rooms in which waste heat occurs which is not removed by other means and where, due to the installed equipment, temperature limitations exist, for example switchgear, control gear rooms, battery rooms, control rooms, etc.
- All the buildings or rooms intended for human occupation whether for working, living or assembly purpose. Offices, assembly hall, etc. are examples of this type of buildings such as administrative, computer laboratory etc.

For the above, the air conditioning includes filtering, cooling, heating, humidification and de-humidification of the supply air and the supply of fresh air.

Ventilation shall be provided for:

- All the buildings or rooms in which waste heat occurs which has to be removed but where temperature ranges do not necessitate air conditioning, for example Workshop, machine hall, pump rooms etc. Air washers using the principle of evaporative cooling shall be provided for ventilation of these rooms.
- All washing and changing rooms (if existing) which are occupied only for a short period of time, where air conditioning is not necessary and the like, to the extent necessary with regard to the nature of the work or of the materials stored.

Suitable facilities for smoke release (in case of fire) shall be provided for all control, relay, electrical, cable rooms, cable ducts, etc.

No window or mini-split units shall be installed in buildings where central air conditioning units supply other parts of that building.

3.7.10 Fire Fighting System, Detection & Alarm System

3.7.10.1 *General*

This section of the specification describes the technical requirements for the Fire Fighting System for 400 MLD SWRO Desalination Plant and covers the minimum requirements for design, engineering, manufacture, erection and inspection and testing. The specifications in this section shall be read along with the specifications in Part-2 Chapter 7 & 9 and elsewhere in the contract. In the event of any conflict between the requirements in the contract, the most stringent specification shall apply or as per the consent of the Engineer.

The Fire Fighting System consists of Fire Protection System and Fire Detection System.

The Fire Protection System equipment shall be complete in every respect and suitable for safe and reliable operation.

Preferably, the whole firefighting system of the entire plant would be one unified system of the same make and type, which would ideally be sub-contracted as a whole to a single reputable company subject to Employer's approval.

However, installation and testing of equipment shall remain under the scope of the individual packages.

This specification does not enumerate or describe all the materials and equipment to be supplied and all the services to be performed. All materials and equipment shall be provided as are required to make a complete, properly functioning installation and shall conform to the highest standards of engineering design and workmanship.

Firefighting system covers the whole area of 400 MLD SWRO Desalination Plant site, where required duty has to be performed.

Fire protection system shall cater for all potential risks from fire and provide correct response to any fire detected.

Automatic and manual extinguishing systems operation is anticipated.

3.7.10.2 *Fire Fighting and Detection System Description*

The SWRO Desalination Plant shall be designed and built with provision of a safe operating environment for equipment and personnel. This shall be achieved by separation and segregation of equipment with sufficient distances and by selection of suitable equipment and materials.

Hazardous areas shall be identified, and suitable equipment shall be selected for use in such areas. Different firefighting systems shall be adopted according to the operational characteristics of the particular plant areas and buildings to be protected.

The firefighting protection and detection systems for the Desalination Plant, including the diesel storage tank and buildings shall be designed in accordance with NFPA codes, International Building Code (IBC) and International Fire Code (IFC).

Table 3-27: Main Areas for Fire Fighting Protection

S. No.	Building/Area/ Equipment	Fire Fighting Installations	Detection Systems
1.	Intake pump station	Indoor hydrants. Portable extinguishers.	Smoke detectors. Automatic fire alarm system and manual fire alarm stations
2.	Potable/permeate Water Pump Station	Indoor hydrants. Portable extinguishers.	Smoke detectors. Automatic fire alarm system and manual fire alarm stations
3.	Chemical Buildings	Manual water spray system and indoor hydrants. Portable extinguishers.	Smoke detectors. Linear heat detectors. Automatic fire alarm system and manual fire alarm. Gas detector.
4.	Chemical Stores	Automatic water spray fixed system and indoor hydrants	Smoke detectors. Linear heat detectors. Automatic fire alarm system and manual fire alarm
5.	HV, MV, LV Switchgear Buildings housing switchgear. Electrical Buildings- RO building	NOVEC systems designed as per NFPA 2001 or a comparable and suitable system	Smoke detectors. Automatic fire alarm system and manual fire alarm stations
6.	All Oil Filled Transformers	Automatic water spray fixed systems, Portable extinguishers and CO2 extinguisher.	Fusible bulb/quartzoid bulb as well as sprinkler head heat detectors. Automatic fire
7.	Diesel Generator	Automatic foam/water spray fixed system and mobile 50 kg dry-powder extinguisher	UV/IR detectors. Smoke detectors. Automatic fire alarm system and manual fire alarm stations.
8.	RO Buildings DAF/DMF buildings	Automatic water spray fixed systems, Portable extinguishers	Automatic fire alarm system and manual fire alarm stations. Smoke detectors.
9.	Workshop/ warehouse	Indoor hose reel. Portable extinguisher and CO2 extinguisher	Automatic fire alarm system and manual fire alarm stations. Smoke detectors.

10.	Storage buildings (RO membranes, mechanical, etc.)	Automatic water spray fixed systems, Portable extinguishers	Automatic fire alarm system and manual fire alarm stations
11.	Local Control, Computer, Electronic and Switchgear Rooms	NOVEC systems designed as per NFPA 2001. Portable extinguishers and CO2 extinguishers.	Smoke detectors. Automatic fire alarm system.
12.	Cable Floors, Shafts and Tunnels, including 110 kV cable tunnels	Automatic water spray fixed systems	Smoke detectors for ventilated cable floors and tunnels. Linear heat detectors for non- ventilated cable floors and tunnels. Automatic fire
13.	Battery rooms	Portable extinguisher and CO2 extinguisher	Automatic fire alarm system and manual fire alarm stations. Smoke detectors.
14.	Administration Building / Engineering – Operation building / Laboratory/ computer building	Indoor hose reel. Portable extinguishers, sprinklers system	Smoke and heat detectors. Automatic fire alarm system
15.	All other buildings and areas	Outdoor hydrants and indoor hose cabinets	Manual fire alarm stations

Any building or area which is protected by a "wet" firef ighting installation must in addition be provided with an "external fire brigade connection".

The "Siamese Breaching inlets" shall be housed in stainless steel cabinets with "wire glass" doors, located around the perimeter of the protected area.

They must be so placed as to allow ready access by the fire brigade tanker. Upstream of the above fire brigade connection, suitable non-return valves in the main and branch line must be provided, in order to facilitate pressurization of the "installation" from the 2 different sources.

Extinguishers shall be sized, rated and spaced in accordance with NFPA 10 and or equivalent IS code. Local buildings fire alarms, automatic fire detectors and the fire signalling panel shall be in accordance with NFPA 72 or equivalent IS code.

It shall be assured that a dedicated two (2) hour fire water supply to cover the system design flow rate is available for the facility in accordance with NFPA or equivalent IS code.

A dedicated Fire Water Tank drawing water from the Product Water Tanks shall be provided and the Fire water pumps shall draw water for fire hydrant system from this tank. Requisite fire protection pumps shall be provided for the purpose.

Fire hydrant system shall be sized and the relevant calculations shall be submitted for approval.

3.7.11 Crane and Lifting Equipment

3.7.11.1 *General*

This section covers the minimum requirements for the design, engineering, manufacture, erection and inspection and testing of cranes and lifting systems. This should be read in conjunction with the requirements provided in Part-2 Chapter 7 & 8, and elsewhere in the contract. In the event of any conflict between the requirements elsewhere in the contract, the most stringent specification may apply or as per the consent of the Engineer.

Cranes and lifting equipment shall be complete in every respect and suitable for safe reliable and continuous operation.

This specification does not enumerate or describe all the materials and equipment to be supplied and all the services to be performed. All materials and equipment shall be provided as are required to make a complete, properly functioning installation and shall conform to the highest standards of engineering design and workmanship.

In addition, motor operated hoists and manual hoists shall be provided with runway girder where necessary for lifting purposes during maintenance works and where the equipment are not in the reach of mobile crane.

Cranes and lifting equipment are to be located all over in the buildings, structures and areas of the project site, where hoisting during maintenance and repair is required.

3.7.11.2 *Scope of Works*

This section sets out the scope of the equipment and services as well as specially requested supplies and services but it in no way excludes other necessary components and services not specifically mentioned herein.

The Contractor shall provide and supply the cranes and lifting equipment complete, including all necessary components, spare parts and services.

Table 3-28: Details of Cranes and Lifting Equipment

S. No.	Location	Type of cranes	Manual/ Electrically operated; controlled
1.	Low pressure pumping station	EOT	Electrical; pendant switch
2.	Filters backwash pumping station	Underslung Crane	Electrical; pendant switch

3.	RO Building	Double girder EOT(Two sides)	Electrical; pendant switch
4.	RO Building (cartridge filters)	Monorail Hoist	Electrical; pendant switch
5.	RO Feed pumping station	Underslung	Electrical; pendant switch
6.	Chemical Handling	Monorail Hoist	Electrical; pendant switch
7.	Service water and pumping station	Underslung	Electrical; pendant switch
8.	Store buildings and workshop	Motor hoists	Electrical; pendant switch
9.	Mechanical Workshop	EOT	Electrical; pendant switch
10.	Submerged pumps with weight < 20 kg	Lift hoist	Electrical; pendant switch
11.	Any other as needed	Bridge Crane/Motor hoist/Lift hoist	Electrical; pendant switch

Scope of supply and services shall include the design, manufacture, construction, factory testing, packing for transport, transport and delivery to site, unloading at site, storing, complete erection, testing at site, painting, commissioning, putting into normal operation, reliability and performance testing of cranes and hoists and associated equipment including but not limited to:

- overhead travelling cranes
- motor hoist with trolley
- manual hoist
- runway rails and beams
- control, monitoring and electrical supply
- complete detail labelling of all installation
- consumables such as first fill of lubricants and greases
- set of special tools and equipment for maintenance, inspection and repair
- all standard equipment and accessories which are normally included in the supply schedule but which are not separately listed.
- detail design and calculation
- compiling and local collection of required data
- training, inspection and supervision services by the Manufacturer

- spare parts and wear-and tear parts
- complete documentation as specified
- numbering of all equipment
- test loads as required
- testing of all equipment as required by the regulation.

3.7.12 Package Sewage Treatment Plant

Bidder shall provide a Package Sewage treatment plant for treatment of domestic sewage from toilets and Canteens at the plant premises building.

The minimum capacity of the plant shall be 13.5 KLD. The reclaimed water from the package sewage treatment plant shall be used for Landscaping and toilet flushing.

The required reclaimed water quality for reuse shall be as indicated below:

Table 3-29: Quality of the Treated Domestic Sewage

Parameter	Units	Minimum Outlet Parameter
BOD	mg/l	<50
COD	mg/l	<250
Total suspended solids	mg/l	<100
Total coliform bacteria	MPN / 100 ml	<100 (desirable)
Residual Chlorine	mg/l	1

Bidder shall select a suitable treatment technology to treat the domestic sewage to meet the above-reclaimed water quality. All system shall be designed with equipment and materials suitable to withstand the saline environment. Bidder shall provide inlet and outlet Electromagnetic flowmeters for measurement of wastewater entering Package treatment facility and reclaimed water respectively.

Contractor to submit basic engineering documents of the packaged sewage treatment facility to the Employer for review and approval before execution.

3.8 Quality Assurance

All equipment, materials and Works shall comply with the relevant Indian Standards. Where suitable updated Indian Standards are not applicable or appropriate as per the understanding of the Engineer, approved International standards such as BS 5750 or an equivalent shall be used.

3.8.1 Policy

As per the Conditions of Contract of Part-3, the Contractor shall apply the formal requirements of Quality Assurance to the design, supply, construction and maintenance of the Works. This shall be achieved through the implementation of a Quality System compliant with the requirements of BS 5750 or an equivalent International Standard. A positive commitment to Quality Assurance shall be expressed in a formal policy statement given in the Contractor's Quality Manual and to be certified by an external certificate.

It shall be the stated aim of the Contractor to achieve and demonstrate the achievement of quality as expressed by `due care and diligence' of the design, supply, construction and maintenance of the Works as defined by the Employer's Requirements. The criteria to define `due care and diligence' shall be explained in the Contractor's Quality Plan and shall embody all of the design, supply, construction and maintenance requirements of the Works.

3.8.2 Quality System

The Quality System shall be fully integrated for all of the Works. This system will be defined by the organisational structure, responsibilities, activities, resources, and events that together demonstrate the capability of the Contractor to meet the stated quality requirements. The Contractor shall ensure that all sub-contractors and sub-consultants establish quality systems and shall supply to the Employer such evidence as is necessary to demonstrate the effective implementation of a quality system in each subcontractor or sub-consultant organisation.

The Quality System of the Contractor and of his sub-contractors and sub-consultants will be subject to periodic audits undertaken by the Employer's Representative. The Employer's Representative will give one weeks' notice of such audits that will involve a full assessment of the performance and efficiency of the Quality System and will include review of the feedback and records derived from the Contractor's monitoring and internal reviews. On a day-to-day basis the Contractor shall afford reasonable availability of staff and documentation for the Employers Representative to assess the implementation of the Quality System. The Contractor shall ensure that all relevant personnel and documentation are available for such audits.

3.8.3 Quality Assurance Plan

All materials and equipment supplied to the plant shall be inspected and approved for supply. Suitable quality assurance plans shall be submitted for each item for review and approval by the Employer. The implementation of the Quality System shall be through the establishment of a comprehensive Quality Plan issued to and approved by the Employer's Representative. The documented procedures shall include but not be limited to:

- Management Procedures;
- Design;
- Manufacturing;
- Supply/Procurement;
- Construction;
- Putting to work/Commissioning/Reliability Trial/Performance Test;
- Operator Training and Maintenance;
- Interface Control;
- Quality Performance, Monitoring and Review.

There shall be procedures to control transmission of information across all interfaces both internally (that is, within the Contractor's Quality System) and externally. Those of the latter shall include all Statutory Bodies, Authorities and the Employer's Representative. Formal assessment of any non-compliance with the Quality Plan shall be achieved through periodic reviews undertaken by a team appointed by the Contractor. All deficiencies shall be recorded and appropriate corrective measures shall be assessed, within an appropriate timescale, through subsequent formal reviews undertaken by the Contractor.

3.8.4 Quality Feedback

The system shall include for the reporting back, recording and incorporation into the system of deficiencies noted during the control of the project.

3.9 Environmental Protection

The Contractor shall minimize, as far as is practically possible, the effects of all his and his Subcontractors' activities upon the environment and shall implement and monitor measures to prevent:

(a) Contamination of surfaces, ground, groundwater, surface water and rivers,
(b) Emissions to air, including smells, gases, smoke, and dust.
(c) Unsanitary or unsafe storage or discharge to drain, sewer and surface waters,
(d) Unsanitary or unsafe storage or discharge of solid wastes,
(e) Noise,
(f) Visual intrusion, and
(g) Excessive energy and water consumption.

These requirements shall be met through the constant and careful attention of the Contractor's management of all Site and off-site activities, and by instruction to all staff and labour in these matters.

The Contractor shall appoint an Environmental Control Manager for the Works, who shall be responsible for preparing an Environmental Management Plan and ensuring its implementation by the Contractor after obtaining approval of the Engineer.

Implementation shall include for monitoring and reporting on the results of the above measures. Monitoring reports shall be in writing and submitted on a monthly basis as part of the monthly report referred to above. The report shall include a listing and summary of daily monitoring results on all aspects listed above.

All potentially affected areas of the Site, other areas used for or affected by the works and all adjacent or affected waterways shall be monitored and, where instructed by the Engineer, tested.

The Environmental Management Plan (EMP) shall identify the potential environmental impacts from the various construction and operations and maintenance activities to be undertaken in the Contract and set out in detail the approach be adopted in mitigating these environmental impacts to ensure that the residual impacts are minor and confined to a short period. The details of the EMP is provided in Chapter-15, Part-2.

The EMP shall consider but not be limited to the following:

- The methods of materials delivery, storage, usage and disposal; equipment usage; and site activities to ensure they have minimal impact on the environment,
- Only environmentally safe products and practices shall be adopted in performing his works, and
- The Contractor shall comply with all of the statutes regarding environmental effects.

The EMP shall provide separate descriptions of its proposals for minimizing any adverse environmental impacts/effects during the construction phase and the subsequent operations and maintenance phase. The contractor to prepare a comprehensive Environmental Monitoring plan (EMoP) during construction and operation phase.

The EMP and EMoP shall be provided in draft form within 28 days from the Notice to Commence and shall be updated from time to time by the Contractor as agreed or required by the Engineer to ensure the objectives of environmental protection are fully met.

3.10 Safety at Site

The Contractor shall prepare a Safety Plan and submit the same to the Employer's Representative for review within 28 days of signing of Contract Agreement. The Safety Plan shall be followed at all times by the Contractor and shall contain adequate control measures, in accordance with the relevant protection of property and local laws and regulations as well as internationally accepted good practice, for the prevention of accidents, fires and public nuisance. The Safety Plan shall be implemented properly and diligently throughout the execution of the Works and during the operations and maintenance period.

Contractor's Safety Plan shall make safety provision for, among other things:

(a) Offshore works.

(b) The deep excavations and collapsing sides in trench excavations,

(c) Scaffolds and overhead working,

(d) Working in confined spaces,

(e) Working in seawater/water,

(f) Contractor's Equipment, especially cranes,

(g) Handheld power tools,

(h) Electrical equipment,

(i) Hazardous chemicals, gases and fuels,

(j) The use of protective clothing, and noise protection

(k) The provision of first aid facilities

The Safety Plan shall be developed to ensure zero fatal accidents and zero hazardous incidents/occurrences in all construction works. The Safety Plan shall include descriptions of the company's standard policies and procedures regarding its site organization and procedures, methods and frequency of conducting safety audits at the Site(s), record keeping and reporting, providing safety training for its personnel (including subcontractors), issue and mandatory use of safety equipment, and details of the qualifications and experience of the Bidder's proposed Health & Safety Engineer to be deployed at the Site(s). The Contractor shall provide separate descriptions in its Safety Plan covering the construction phase and the subsequent operations and maintenance phase.

The Contractor shall appoint a Full-Time English-speaking Health & Safety Engineer for the Works having experience in this field, who shall be responsible for implementing the Safety Plan. He shall be supported by at least two safety officers who are qualified for such safety works, out of which at least one should be well versed/ have complete knowledge of Hindi and Tamil. The Contractor shall ensure that his staff and labour and his Subcontractors are all fully trained in and aware of good and safe working practices. The Contractor shall ensure that all precautions are taken to safeguard the general public and construction/operating staff from any danger.

All temporary and partially completed works shall be protected by way of barricading, lights, notices and the like. Proper lighting shall be placed for offshore works while jacking through the shore. All excavations and the like are to be protected by barricades at all times and adequately illuminated at night. Warning and diversion signs concerning roadwork shall be suitably placed to give motorists ample warning. During the movement of heavy vehicles across roads or onto roads, men, bearing red flags, shall be in attendance to warn other road users and to generally control traffic safely.

The Safety Plan shall also consider requirements for warning and protection for other risks including overhead and underground cables, pipes or obstructions, or voids, openings, pits and trenches. The Contractor shall ensure that all appropriate measures are implemented. The Safety Plan shall include a policy statement signed by the CEO or equivalent authority of the Contractor declaring that safety and loss prevention shall be given the highest practicable priority in all aspects of the Contract. The Safety Plan shall be updated as necessary to cover the activities to be undertaken for operations and maintenance.

3.11 Risks or Hazards

The major risks anticipated in the desalination facility are Fire, explosion, toxic release and natural calamities like Cyclone, Flood, Earthquake and Tsunami. Fire would result from Storage vessels which stores chemicals. Explosion is another risk which primarily depends on the rate of which the energy is released. It could result in thermal effects, missile effects and injury to personnel. Toxic release of chemicals is another major risk where the release in form of gas or vapour can pose a major hazard if proper care is not taken into consideration. The risk due to toxic release primary depends on the duration of exposure which ranges from sudden exposure at high concentration to a prolonged exposure at lower concentration.

Natural disasters viz. cyclones striking the project area could not be ruled out. All equipment and buildings in the desalination facility are to be designed in such a way that withstands to maximum wind speed during cyclones. The storm surge of 1.3 m height has been predicted for a cyclonic wind speed of 180 kmph for this region. As the project area is required to be elevated and the impact may not be severe.

Although earthquake is not a regular phenomenon, the possibility of its occurrence cannot be ruled out. Earthquakes will pose a major risk to the equipment/ buildings and pipelines, life of personnel and environment. The effect of earthquake includes ground lateral displacement, ground shaking and ground uplift, ground uplift, ground settlement, soil liquefaction and fires.

The risk associated with flood are water entering the desalination facility/ process units, danger to life of operating personnel and outbreak of epidemic and other contagious diseases. Flood warning systems from the local meteorological department on flood warning and specific actions to be taken during those occasions are to be considered in the Disaster control preparedness plan.

The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. One worst Tsunami occurred on 26th December 2004 along the Tamil Nadu coast and the destruction was more near the project region. The project region is located on the notified area of Tsunami impact, as the offshore tectonic plates are alive in Andaman Island. The presence of sand dunes (> 3 m) on the coast may to some extent, dissipate the strength of tsunami but cannot totally protect from tsunami run-up.

A detailed Disaster Control Preparedness Plan to be prepared by Contractor considering multidisciplinary approach by involving government agencies at Central and State level, Fire services, Civil defence, Medical, Police, Army, Voluntary organisations etc. This plan is required to provide guidance to stakeholders to take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur. This plan should cover both Onsite Disaster management plan as well as Offsite Disaster management plan.

3.12 Standards

All work performed and equipment supplied shall comply with the appropriate standards, codes and legislative requirements.

Where there is an apparent ambiguity or conflict between any of the applicable Standards and this Specification, the Engineer shall be notified in writing whose decision shall be binding.Regulations, Laws and Permitting

The details of regulatory compliance requirements for the proposed Perur DSP project are furnished in the table below. The table below shall be considered minimum and not limited to:

Table 3-30: Regulations, Laws and Permitting

S. No.	Construction activity	Statutory authority	Regulatory requirement	Implementation responsibility	Supervision
1.	Intake and Outfall pipe laying, Pumping station and Desalination plant	Ministry of Environment and Forests and Climate Change (MoEF & CC)	Coastal zone regulations, 2011	CMWSSB	---
2.	Construction of Desalination facility	Tamil Nadu Pollution Control Board (TNPCB)	Consent to Establish from State Pollution Control Board under Water Act 1974 & Air Act 1981	CMWSSB	---
3.	Generation of Brine and Sewage, potential to emit air pollution (including but not limited to diesel generators and vehicles)	Tamil Nadu Pollution Control Board (TNPCB)	Consent to Operate from the State Pollution Control Board under the Water Act 1974 & Air Act 1981	Contractor	PIU - CMWSSB
4.	Generation of Municipal solid waste	Tamil Nadu Pollution Control Board (TNPCB)	Authorization under MSW (M&H) Rules 2016	Contractor	PIU-CMWSSB
5.	Noise generation	Tamil Nadu Pollution Control Board (TNPCB)	Noise pollution (Regulation and Control) rules, 2000 and its amendments, 2010	Contractor	PIU-CMWSSB
6.	Generation of Hazardous waste	Tamil Nadu Pollution Control Board (TNPCB)	Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016	Contractor	PIU-CMWSSB
7.	Construction of Desalination facility	Divisional Fire Officer, Kancheepuram	NOC from Fire dept., Tamil Nadu Fire Service Act, 1985	Contractor	PIU-CMWSSB
8.	Intake and Outfall pipe laying, Pumping station construction	Tamil Nadu Maritime Board	Consent for the erection of offshore structure to be obtained Tamil Nadu Maritime Board as per Tamil	Contractor	PIU-CMWSSB

S. No.	Construction activity	Statutory authority	Regulatory requirement	Implementation responsibility	Supervision
			Nadu Maritime Board Act, 1995		
9.	Engagement of Labour	Office of the Labour Commissioner	- Labour license from labour commissioner office as per The Contract Labour (Regulation and Abolition) Act, 1970. The Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Act, 1979	Principal Employer – labour license	PIU-CMWSSB

3.12.1 Discharge Permit

The regulatory compliance requirements for proposed DSP are identified for the proposed Perur project, and they are related to waste management and disposal, and ambient noise pollution regulation and control is furnished in the table below. The Contractor is required to adhere to the condition of the discharge limit. It is in the scope of the Contractor to achieve the required permits with the help of the Employer.

Table 3-31: Discharge Permit

S. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
1.	Construction/ Operational Phase	Consent to Operate from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	TNPCB
2.	Construction/ Operational phase	Authorization under MSW (M&H) Rules 2016 (State Pollution Control Board)	Statutory	TNPCB
3.	Construction/ Operation phase	Noise pollution (Regulation and Control) rules, 2000 and its amendments, 2010	Statutory	TNPCB

3.13 Plant Commissioning

3.13.1 Commissioning Plan

The Commissioning Plan shall include:

- The sequence of commissioning activities, including interdependencies, durations and undertakings to verify the Completion of the Contract has been achieved
- Appropriate Risk Assessments for the proposed undertakings
- Inspection and Test Plans (ITPs) shall be submitted 30 days prior to conducting the tests/checks.
- Lists of equipment, plant, and systems to be commissioned, including the asset numbers allocated to them, and a schedule for commissioning them. These lists must be prepared at least two weeks before the proposed date of commissioning.
- Non-conformance and corrective action procedures
- Emergency and contingency procedures during commissioning activities
- A list of names of the members of the Contractor constituting the commissioning team formed to implement the Plan and their CVs and qualifications.

3.13.2 Commissioning Team

The Contractor, along with the Employer's Representative, shall form a commissioning team. The members of the Contractor constituting the commissioning team shall include, but not necessarily be limited to, the following:

- Contractor's Representative(s) including the Commissioning Manager; Commissioning Engineer, Commissioning Specialists and equipment suppliers (if required).
- Nominated representative(s) of the Employer's representative and PMC.

During commissioning, the Contractor shall coordinate the activities of the Commissioning Team. The Contractor shall provide the expertise necessary to commission the equipment, plant, systems and take measures, within the scope of this Contract, to complete the commissioning successfully.

3.13.3 Stages of Commissioning

The plant commissioning and testings shall be read along with the Part-2, Section VI, Chapter-10 Inspection and Testing Requirements and the provisions in particular conditions of the Contract. The Contractor shall submit a detailed commissioning procedure for review and approval of the Employer's Representatives. Typically, the commissioning shall be completed in four stages, followed by the Process Proving Test. These stages are:

(i) pre-commissioning checks
(ii) dry commissioning
(iii) wet commissioning
(iv) initial performance tests
(v) process proving

Total estimated period for commissioning and process proving is 6 consecutive months (180 days). The first three phases (i.e., pre-commissioning checks, dry commissioning and wet commissioning) shall be carried out in two and half months (75 days) and then initial performance testing shall be conducted in 15 (fifteen) days. After a successful initial performance test, the process proving shall be carried out for the consecutive 3 (three) months duration. During this period, the performance of all the process units, particularly the RO system, shall be evaluated. The propensity of the membrane fouling and the effectiveness of the CIP cleaning shall also be evaluated during the process proving test.

Tests and inspections, unless otherwise specified or accepted, shall be in accordance with the accepted ITPs, Inspection & Testing requirements (Chapter-10, Part-2) and relevant Indian standards.

All necessary resources to enable effective testing, including but not limited to all necessary labour, materials, equipment, and instruments, shall be arranged prior to the tests. Where equipment items or systems are duplicated in the design to provide 'Duty' and 'Standby' facilities, all items of equipment and/or systems of both the 'Duty' and 'Standby' facilities shall be fully tested in accordance with the suppliers' requirements.

All relevant information and experience gained during these tests, including readings such as flow, noise, odour, vibration, power draw, etc. shall be integrated into the Installation Instruction and Operation & Maintenance Manuals, Standard Operating Procedures (SOPs), Unit Process Guidelines (UPGs) and work-as-executed drawings, including P&I diagrams.

The procedures within the Commissioning Plan shall define how non-conformances shall be managed and rectified. Should the equipment not perform the required function to the level of performance required by design during any test, such failure shall be deemed a defect, and the Contractor shall promptly initiate the non-conformance and corrective action procedures required by the Contractor's Quality Assurance System.

A Commissioning Report shall be prepared at each phase of commissioning to demonstrate the assurance that all the activities associated with the commissioning phases have been successfully completed according to the relevant Standards as stated above and to the satisfaction of the Employer's representatives. All Commissioning Reports shall be prepared within seven days after completion of each phase and submitted to the Engineer for approval.

All costs of the commissioning with the initial performance test and process proving tests including chemicals, power, equipment, spare parts, manpower and all consumables shall be borne by the Contractor. The bidders should include these costs in their price bids for the Works (Design & Build) Contract.

3.13.3.1 *Pre-commissioning Checks*

After completion of all mechanical and electrical installation, all equipment and instrumentation shall be inspected to verify that they are ready to operate. This includes checking that all bolts are properly tightened, safety guards fitted, no signs of damage are visible, lubrication has been completed, electrical point-to-point testing is successfully completed, operation certificates from statutory authorities are obtained, and generally everything has been checked in readiness for operation.

3.13.3.2 *Dry Commissioning (offline)*

After successful installation and pre-commissioning checks, all instruments where possible, including pressure differential transmitters, process analysers, and flow meters shall be field calibrated. Instruments which cannot be field calibrated shall be checked for accuracy in the field.

Once a written certification of proper installation has been issued by the Contractor, dry commissioning (functional testing) shall be initiated for all equipment. To perform the Functional Test, all valves, controls, and other devices shall be operated to ensure they are functional and ready for wet commissioning and performance testing. All control sequences shall be fully tested unless there is potential for damage to the equipment. All safety and protection devices (e.g. flow switches) shall be tested to ensure that they operate correctly.

The purpose of the Dry Commissioning tests shall be to demonstrate, as a minimum, the effectiveness of the following system components and features:

a) Automatic and Manual START/STOP of all equipment using local panel and SCADA

b) Automatic backwashing at various time intervals

c) Automatic shutoff and alarm for various failure modes

d) Monitoring and recovery of operating data

e) Proper operation of the equipment and instrumentation systems

f) Monitoring and control from a remote workstation

g) Automatic switchover from normal power to emergency power, and emergency power to normal power

h) All control functions, both at local system and remote workstation

i) Operation of all monitoring instruments

3.13.3.3 *Wet Commissioning (on-line)*

Commissioning on-line shall commence with the approval of the Employer. Where practical, the process tanks shall be filled with water, and the control sequences shall be re-tested. A continuous operation of the component for a period of two days to the satisfaction of the Engineer will be deemed to demonstrate satisfactory completion of the wet commissioning of that component. The pre-commissioning checks, dry commissioning and wet commissioning period shall proceed for at least 75 consecutive days or as long as is required to establish the process and meet the required plant performance. As a minimum, the following shall be verified during on-line commissioning:

- Local and automatic operation of all equipment and protection systems
- Operator adjustable set-points
- Alarm initiation
- Demonstration of the system under equipment failure scenarios
- Verification of conformance to specified or guaranteed performance as far as is practical

at the initial loading.

All the necessary adjustments and tuning shall be conducted until the water treatment plant functions as specified under operating conditions. Tests shall be carried out to verify that the water treatment plant shall operate under the full range of operating conditions, meet the performance requirements of the Contract and the design.

Start-up tests shall be conducted as part of the wet commissioning. The start-up test shall be carried out for each process areas across the plant, which verifies the completeness of the Plant and to all ancillary equipment, and of no known defects or outstanding works.

Upon successful completion of the start-up tests on the plant, trial run of the full plant shall be carried out for a period not less than 24 hours or as long required to confirm the operability of the plant with successful testing on the plant start, stop, switchovers, recovery change and varying production loads.

3.13.3.4 *Initial Performance Testing*

After the wet operation has been successfully proven and satisfactorily documented, and all necessary approvals are in place, the initial performance of the plant shall be tested. Successful completion of the Initial Performance Test shall be defined as 15 days of operation without a significant failure in the system and demonstration that system meets all performance requirements established herein. The Contractor shall operate the plant and collect and summarize data to demonstrate that the system meets the performance test requirements for production quality and quantity, pressure limitations, membrane permeate quality, and chemical and power usage.

A major failure in the system is one that fails to produce product water of the required quality or decreases production capacity below 97 percent of design capacity for more than 24 hours due to equipment failure or any other reason, even though the quality of the product water is maintained as required during the failure. If the inlet system/Lamella/DAF/DMF/RO system/ Limestone filter or any other system fails to perform successfully during the Initial Performance Test, the Contractor shall have the option to fix the problem and repeat the test for additional 15 consecutive days. If the system fails to successfully complete the Initial Performance Test during the second test period, the Contractor shall prepare a written plan within seven days for modifying the system to meet all test requirements. All the cost of this test and fixing the problem shall be borne by the Contractor.The penalty for delay damage shall be levied as per the conditions of the Contract (Part-3).

Reports on the performance of the plant shall be provided every week to the Employer to demonstrate that the system meets the performance test requirements. The reports shall contain the following as a minimum:

- Automatic operation of the system
- Raw seawater quantities and qualities
- Water quantity and quality monitoring at Lamella Settler, DAF, DMF, RO, Limestone filters and Product water tank

- Sludge quality and quantity at thickener and BFP
- Other qualities of process importance
- Chemical usage
- Power usage
- Product water production
- All maintenance work log record
- Any "failures" and rectification log
- Any other relevant information

3.13.3.5 *Process Proving*

Process Proving shall be carried out as soon as is reasonably practical after the successful Initial Performance Testing of the plant. The product water produced during process proving shall be distributed to the household consumers after certifying the product water quality meets the required drinking water guidelines. The Contractor shall give to the Engineer not less than 7 days' notice of the date after which the process proving test will be carried out.

The Process Proving Period is a continuous operation of a desalination plant for 90 days. During this period, the plant should run without any deterioration of the product water quality and quantity, and other performance requirements. In the event of a failure when the System or any of the facilities does not satisfactorily achieve the required performance standards during this period, the proving period shall be extended until the Contractor has satisfactorily rectified any deficiency as may be necessary to satisfy the performance requirements and completed the rest of the proving period, at the risk and cost of the Contractor. A failure in the system is one that fails to produce product water of the required quality any time; decreases system overall production capacity below 97 per cent of the design capacity in 72 hours due to any reason including equipment/unit failure. In the case of more than two events of failure or performance deterioration (deviation from the Contractor's performance guarantees), the proving test shall be deemed as failed, and the test shall be terminated. The Contractor shall fix the problem first and then repeat the process proving test with the consent of the Engineer for 90 days at their own risk and cost. The event of failure is defined as more than 3% reduction in production with no deterioration of product water quality in terms of TDS, Boron and other vital parameters as per BIS10500-2012 in a consecutive 72 hours. The penalty for the delay damage shall be levied as per the Contract provisions.

During the Process Proving Test, the Employer's representatives will observe the operation of the desalination plant, but the Contractor shall hold the responsibilities for the complete operation and maintenance of the desalination plant with waste disposal. All costs of operation and maintenance, including power, chemicals, spare parts, component replacement and waste disposal as required during the process proving period shall be borne by the Contractor. In case of excess consumption of the power and chemicals beyond the guaranteed values given by the Contractor in his technical proposal, the Contractor shall be required to change the concerned equipment/units with more efficient system. The penalty for excess power consumption shall be paid by the Contractor during O&M period as per the contract provisions.

The Process Proving Test shall verify the complete operation and functionality of the system when automatically controlled and achieving the guaranteed performance. As a minimum, the following shall be verified:

- Automatic operation of the system (including changeover between duty and standby equipment items)
- Recording and trending of all data
- Demonstration of all equipment at full design capacity
- Recorded flow rates
- Differential pressure at RO membrane
- Projected consumption of chemicals and power
- Verification of conformance to the specified or guaranteed performance
- Guaranteed product water quality: If the system fails to comply with requirements for product water quality, the Contractor shall provide a written plan of modifications in plant or operation to achieve compliance with the requirements. Upon implementation of a plan of modifications, Process Proving test shall re-commence in its entirety.

The Contractor shall be issued the Commissioning Certificate only after the successful completion of the Process Proving Test. The successful completion of Design-Build Period is a pre-requisite for the Issue of the Commissioning Certificate and subsequently marks the commencement of the O&M Period.

3.13.4 Plant Operation & Maintenance

After successful completion of the Process Proving and submission of all the required documents by the Contractor, the first phase of the contract for construction of the plant (Design- Build) will be completed and the O&M phase for 20 years will commence. During the O&M period, the cost of the power will be given by the Employer within the guaranteed limit provided by the Contractor in its functional guarantees. Any extra consumption of power above the guaranteed limit that is required to meet the quality and quantity of the product water, shall be borne by the Contractor as per the provisions specified in the conditions of contract. The consumption of chemicals shall be monitored to ensure the smooth operation of the plant and extended asset life. The details of the plant Operation and Maintenance are provided in the Part-2, Section VI, Chapter-13.

3.14 Documentation

The Contractor shall finalise documentation (such as FDS, SOPs, UPGs, O&M Manuals, control philosophy, P&IDs, etc.) as soon as practicable at the start of the Process Proving Test. The documentation shall apply to all processes, facilities and equipment supplied under the Contract. The documentation shall include the following as a minimum:

a) Functional Design Specification describing the functionality of the PLC, including the process control philosophy.

b) Unit Process Guidelines (UPGs): One for each unit process, giving the underlying principles of the unit operation and troubleshooting guidelines for bringing the operating parameters within the specified limits.

c) Standard Operating Procedures (SOPs): One for each unit process covering the start-up and shutdown procedures for each piece of equipment, including all steps and actions, both at the HMI screen and in the field. Problem-solving guidelines for tracing equipment faults must be included.

d) Installation Instructions and Maintenance Manuals, including data sheets to clearly identify the particular model and optional fittings and features of the equipment provided.

e) PLC Program

f) System Control and Data Acquisition Manual

g) A combined maintenance schedule for all equipment showing all activities required daily, weekly, monthly, quarterly, biannually, annually or at other intervals as specified by the manufacturers. All details of lubricants and other consumables must be included. The activities in the schedule are to be completed and documented by the contractor during the operations period to ensure full compliance with the manufacturers’ warranty conditions.

h) As-built Drawings (both in AutoCAD, PDF and .SHP files) along with hard copies

i) The list of assets commissioned, including the asset numbers and description of the assets and commissioning dates.

j) Commissioning Report

k) Process Proving Report

l) Training of the Employer's Operations and Service Provider personnel

The Process Proving Report shall be a compilation and summary of the previous reports required for Contract Completion. It shall follow the history of the commissioning, i.e. chronological diary log of findings, incidents and activities completed and checked including:

a) Plant operating peculiarities and observations

b) Any measurement, checks and settings which may be required by operating and maintenance personnel.

c) Results of any testing and inspection

d) Copies and a listing of all electronic media files such as photos, DVDs and the like

e) A comparison between the actual performance measured during the Process Proving Test with the Contract requirements

f) All non-complying points and limitations arising from the commissioning.

g) All formal commitments from the suppliers or subcontractor(s) to rectify faults uncovered during commissioning.

h) Certification by the Contractor's Designers that the equipment meets its design performance and is ready for the ongoing operation.

i) All changes to the operating and maintenance requirements found essential after process proving, shall be reflected in the appropriate sections of the O&M Manuals, UPGs and SOPs which shall be updated at the end of the Process Proving Test.

Delivery of the documentation shall be as follows:

- All Commissioning, Performance Testing and Process Proving Reports shall be prepared by the Contractor within 7 days after completion of each task.
- Seven complete sets of the final documents and one complete set in the latest MS Office and AutoCAD format and in Adobe Acrobat Reader format on USB drive shall be provided to the Employer within 15 days after the end date of the Process Proving Period. This final version shall incorporate all information updated as a consequence of operation during the proving and operations periods.

CHAPTER-4

4. GENERAL REQUIREMENTS

4.1 Introduction

This part of the Specification sets out the general requirements/ standards of plant design /materials to be supplied and the workmanship required to be ensured by the Contractor. All component parts of the Works shall, unless otherwise specified in the particular documents, comply with the provisions of this part or be subject to the approval of the Employer's Representative. Particular attentions shall be paid to a neat, orderly and well-arranged installation carried out in a methodical competent manner.

All information pertaining to the Works to be executed including the information about suppliers, procedures, performances, capabilities, factory acceptance test (FAT) reports and other significant data shall be furnished for review and acceptance by the Employer's Representative, who shall have discretion to reject any parts which in his opinion are unsatisfactory or not in compliance with the specifications and such parts shall be replaced by the Contractor at no extra cost to the Employer.

4.2 Scope of Work

The detailed scope of work for the Contract has been described in Part-2, Section VI, Chapter-1 and Chapter-3 of Employer's Requirements along with technical details of the different components, and the Drawings in Part 2.

4.3 Technical Standards and Regulations

Except where otherwise specified, Plant materials and workmanship shall comply with the requirements of the relevant Indian Standards (hereinafter referred to as IS) issued by the Bureau of Indian Standards, other equivalent International Standards such as those issued by the International Organisation for Standardisation (ISO) may be substituted by the Contractor (so long as they are more stringent than the equivalent IS) at the sole discretion of the Engineer or as may have been agreed in the Contract. If relevant IS standards are not available then at the discretion of the Employer, Contractor shall be allowed to use international standards such as ASTM/ANSI/AWWA/DIN/JIS/BS. All standards used shall be the current version and most safe and subject to the acceptance of the Engineer.

All materials and workmanship not fully specified herein or covered by an approved standard shall be of such kind as is used in first class work and suitable to the climate and conditions in the project area.

Where the requirements of any such standard specification or regulation conflict with the requirements of the Employer's Requirements or any item on the Drawings, the Contractor shall refer to the Engineer for clarification before proceeding with that portion of the Works.

4.4 Plant Commissioning

After execution of all mechanical and electrical installations, the Contractor shall execute the commissioning as per the procedures indicated below and in Part 2 Section VI Chapter-3. The total period for commissioning shall be 90 consecutive days including Initial Performance Test. In the first 75 days, pre-commissioning checks, dry commissioning and wet commissioning shall be conducted. In the final 15 days, initial performance of the plant operation shall be tested. A commissioning team shall be formed which will include the representatives of the Contractor and the Employer. The details of the commissioning and the process proving are provided in Chapter-3 and Chapter 10 of the Part-2 document.

4.5 Details and Data by the Employer

The Employer has the following data available and used these in formulation of the Tender Documents. They are listed below and shall be used only as guidelines. The Employer does not, however, guarantee either the sufficiency or accuracy of the data provided. The Contractor has to undertake all investigations needed to finalize the process, civil, electrical and mechanical design.

1. Topographical Survey Data
2. Environmental and Social Baseline Data
3. Meteorological Data and Tidal Data
4. Ground Investigation and Ground Condition Data (i.e. Geotechnical Data, Geological Data)
5. Land Ownership Data

Contractor shall carry out a fresh survey, investigation and testing/and all other details necessary for proper planning and work execution. The Contractor shall be required to provide full details of the investigations and analysis for approval of the Engineer.

4.6 Precedence of Works' Requirements

The requirements specified in the respective Particular Requirements, shall be in addition to those specified in the General Requirements. In case of conflict between the parts, the requirements of the respective Particular Requirements parts shall take precedence.

4.7 Units of Measurement

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

4.8 Programme

In accordance with Clause 8.3 of the Conditions of Contract, the Contractor shall within a time specified in the Contract Data, submit a detailed programme for the review by the Employer's Representative and Project Management Consultant (PMC) and the approval by the Engineer which shall include details of all temporary and permanent works, construction procedures and methodologies.

In addition to the requirements set down in the Conditions of Contract, the programme shall include the following details, but not limited to:

(a) Contractor's project organisation structure for the including details of all site supervisors and their responsibilities.

(b) A statement giving the numbers and categories of supervisory and technical staff and skilled and unskilled labour to be employed on the Works.

(c) A list and type details of major constructional plant (including vehicles) which the Contractor proposes to employ on the Works, including programmed dates for order and delivery.

(d) Details of the Contractor's methods of working for all operations.

(e) A statement giving the proposals for location or locations and sizes of offices, workshops and stores at the Site.

(f) A complete resource allocation showing the number of units and allotted times for each unit of constructional plant, materials and labour allocated to each part of the Works.

The programme shall be co-ordinated to consider the requirements of climatic, groundwater and other conditions to provide for the completion of the Works in accordance with the Contract. The programme shall be prepared using MS Project or Primavera software and shall be submitted in both soft and hard copies (editable copy).

4.9 Important Inputs Required from the Contractor

4.9.1 Topographical Survey and Soil Investigation Agency

The Contractor shall reconfirm the topographical surveys, soil investigations, environmental conditions and all other site conditions available with the Tender Documents. The Contractor shall ensure that the work starts within 14 days of the Commencement Date with the qualified agencies whom the Contractor will use for the purpose.

The Contractor shall also conduct additional investigations and land development as are normally necessary to ensure full and satisfactory designs and safety. The surveys shall be carried out with Total Stations and necessary software shall be used for creating the required drawings.

4.9.2 Field Laboratories

The Contractor shall be required to establish a field laboratory as approved by Engineer, suitably equipped to carry out tests as stipulated in the QA/QC Manual, including all specialized equipment which will be required for testing the material and equipment being supplied under the Contract. Suitable trained laboratory staff shall be posted with full facility of computerized record keeping. The minimum equipment to be provided in the laboratory shall be as listed below. Additional equipment as may be deemed necessary may be added to the same in due course on requirement of the Employer/Contractor.

In addition to the equipment in the laboratory, the Contractor shall also provide field testing equipment as directed by the Engineer on the various sites where work is in progress.

The Contractor shall provide a laboratory at a suitable site as approved by Engineer for the testing of materials. The laboratory shall have the following facilities required for sampling and testing materials and concrete in the field.

The following equipment with operators shall be made available at Engineer's request (all must be in serviceable condition).

Table 4-1: List of Equipment to be provided for Civil Laboratory by the Contractor

S. No.	Description	Quantity
1.	Concrete cube testing machine suitable for 15 cm cubes of 100 tonnes capacity with proving calibration ring	1 No.
2.	Cast iron cube moulds 15 cm size	50 Nos. (Min)
3.	Slump cone complete with tamping rod (as required to suit concrete plan)	2 sets
4.	Laboratory balance to weigh up to 5 kg with sensitivity of 10 gm	1 No.
5.	Laboratory balance of 2 kg capacity and sensitivity of 1 gm	1 No.
6.	IS Sieves for coarse and fine aggregates	2 Set
7.	Set of measures from 5 litres to 0.1 litre	2 Set
8.	Electric oven with thermostat up to 120^{o}C	2 No.
9.	Flakiness gauge	2 No.
10.	Schmidt Hammer	2 Nos.
11.	Elongation index gauge	2 No.
12.	Sedimentation pipette	2 No.
13.	Pycnometer	2 No.
14.	Calibrated glass jar (1 litre capacity)	4 Nos.
15.	Glass flasks and metal containers	As required
16.	Chemical reagents like sodium hydroxide, tannic acid, litmus papers, etc. as required	As required

Arrangement can be made by the Contractor to have the cubes tested in an approved laboratory in lieu of a testing machine at site at his expense, with the prior consent of the Engineer. The outside laboratory shall also be used for routine testing of cement, reinforcement, coarse and fine aggregate and other items.

4.9.3 Supervisory Staff for Contractor

The Employer places great importance on the quality and authority delegated to the Contractor's key staff deployed in the field to execute and supervise the works. The Contractor is required to ensure deployment of qualified and experienced staff in sufficient numbers on site to ensure quality. There shall be supervisory staff deployed at the Site in sufficient numbers to ensure day to day quality supervision of the work.

The minimum number of supervisory staff to be deployed at each plant stream is shown in the table below.

Table 4-2: Minimum Supervisory Staff

Works	Minimum Supervisory Staff
Civil	4
Electrical	2
Mechanical	2
Instrumentation	2
Safety Engineer	2
QA/QC Engineer	2

The staff as mentioned above and the key personnel shall be maintained at the Site when the works on the relevant field are being actively carried out. The Contractor shall arrange and maintain sufficient experienced workers and foremen and other support staff as required on sites in sufficient numbers.

Contractor shall appoint a Planning Engineer at Project Site with computer having MS Project / Primavera and AutoCAD facility. The role and purpose of the Planning Engineer shall be mainly to maintain weekly reporting to the Employer (besides Monthly Progress Reports) on an approved format of the Employer through e-mail facility kept by the Contractor at site. Also, CAD drafting facility is required to incorporate necessary details/variation on drawings or the As-Built Drawings time-to-time during construction process and to avoid any discrepancies therein.

4.9.4 Minimum Construction Equipment to be brought by Contractor on Site

The Contractor shall assign the minimum equipment on site for ensuring quality and timely progress of works. The minimum equipment, including but not limited to the equipment described in this Subsection, and shown in the table below, shall be mobilized by the Contractor at the Site for each plant stream of 200 MLD SWRO desalination plant in working condition. The Contractor should submit the equipment mobilization program in the Tender schedules.

Table 4-3: Minimum Equipment to be mobilized by the Contractor at the Site

Sl. No.	Description of Equipment	Capacity/ Type	Minimum Number to be Mobilized
A	**Excavation, Transportation, Handling and Erection**		
1.	Dozer/JCB/ Excavators	250 HP	4
2.	Crawler crane		2
3.	Crane – 10 T Hydra		4
4.	Tipping Trucks		4
5.	Ripper		2
6.	Tripods and Chain Pulley Blocks		4
7.	Dewatering Pumps		20
B	**Concreting**		
1	Concrete Batching Plant (Semi-Automatic)	20 cu m	2
2	Concrete Batching Plant (Automatic)	20 cu m	2
3	Concrete Mixers	10/7 and 14/10 cu ft	10
4	Needle Vibrators		20
5	Plate Vibrators for Bedding		10

4.10 Completeness of the Offer

The Contractor shall be fully responsible to ensure that the whole of the Works, including each individual component, is designed and constructed in a manner so that the system as a whole operates as a fully integrated system which is capable of achieving the required output in an efficient and economical manner, and to include all plant, equipment and accessories required for the safe and satisfactory operation of the facilities. To achieve this, the Contractor shall ensure that each individual component performs in a manner which is complimentary to that of all other components.

Any accessories which are not specifically mentioned in the specifications, but which are usual or necessary for completion of the Works and successful performance of the System and facilities shall be provided by the successful Tenderer within the tendered cost.

The Contractor shall, to the maximum extent practical and feasible, endeavour to standardize on the manufacture and supply of plant and equipment so as to minimize the operation and maintenance requirements. The Contractor shall ensure that his designs are "maintenance-friendly" and that all items of plant and equipment are designed and installed in a manner which will facilitate routine and periodic maintenance operations.

4.11 Time for Completion

The whole of the Works, including mobilization, reconnaissance, survey, sub-soil investigations, design, manufacturing, transportation, construction, installation, commissioning, testing and process proving shall be completed within the scheduled Time for Completion as set out in the Tender Documents Part 2, Section VI, Chapter-1. The physical completion of the system and facilities shall be achieved before commissioning.

4.12 Milestones

The Contractor is to ensure consistent pro-rata progress on all Milestones of the Contract during the entire Contract Period. The Contractor to prepare the Programme based on the key Milestones set out in Table 1-6 and submit the same during the bidding stage. This Programme shall be reviewed after the award of contract duly considering the actual site conditions and approved by the Employer. This approved Programme will be adopted for periodic review of the progress of various Milestones and assessment of any delay in the implementation of the works. Accordingly, this approved Programme is the basis for making decisions of delay damage as per the provisions of Clause 9.6 of the Particular Conditions of Contract – Part 3, Section VIII.

4.13 Contract Management

The Contractor shall be responsible for administration of the Contract from award of Contract through design, manufacture, manufacturer's works testing, and delivery of Plant to the Site, installation, commissioning, testing and performance proving. For this purpose, the Contractor shall nominate a Contractor's Representative in accordance with Sub-clause 4.3 of the General Conditions of Contract who shall be fully responsible for and undertake this administration.

Specific responsibilities of the Contractor's Representative shall be:

(a) The sole representation on behalf of the Contractor in all discussion, correspondence and matters relating to the Works.

(b) The co-ordination and monitoring of Contract progress, which shall include the preparation of the Contract programme, monitoring of progress and submission of monthly progress reports. At the discretion of the Engineer, regular meetings shall be called at which the Contractor's Representative shall give a full account of the Contract progress and programme.

(c) The co-ordination and checking of designs, drawings and submissions. The Contractor's Representative shall be responsible for co-ordinating the design, technical information and data between sub-contractors. All calculations, drawings and information submitted to the Engineer shall be checked by the Contractor's Representative and certified as having been checked before submission.

(d) Contract communication between the Engineer and the Contractor. The Contractor's Representative shall attend all meetings involving the Contractor and the Engineer.

(e) The co-ordination and programming of manufacturer's works tests and the submission of test certificates.

(f) The co-ordination and programming of Plant delivery.

(g) The co-ordination and programming of the installation of Plant at the Site, site tests and take over trials. The Contractor's Representative, although not necessarily based at the Site, shall be responsible for the various sub-contractors. At the discretion of the Engineer regular site meetings will be held during which the Contractor's Representative shall give full account of site progress and programme.

(h) The Contractor's Representative shall also be responsible for producing in advance of the work being undertaken, detailed method statements of any work, which involves or affects the performance of existing equipment, processes, or disruption to existing water supplies.

(i) The co-ordination and preparation of As-Built Drawings and operating and maintenance manuals.

(j) Soft copies of all submissions should be in editable form.

(k) The preparation and co-ordination of training.

(l) The submission of applications for payment.

4.14 Meetings

From time to time, the Engineer will call meetings in his office or at the Contractor's office, or at the Site, as he deems necessary, to discuss progress and any technical points requiring settlement. The Contractor's Representative or responsible representative shall attend such meetings. The Contractor shall prepare and submit to the Engineer a daily activity report summarising the main activities undertaken each day.

4.15 Photographs

In accordance with the requirements of Clause 4.21 of the Conditions of Contract the Contractor shall supply digital photographs of such portions of the Works, in progress and completed, as may be directed by the Engineer and specified herein. The photographs shall be the property of the Employer and JPEG files shall be delivered to the Engineer with the prints. No prints of these photographs shall be supplied to any other person without the written permission of the Engineer.

The photographs shall be of the following categories:

- progress photographs
- record photographs
- digital video recording

Photographs shall be properly referenced to the approval of the Engineer, and on the back of each print shall be recorded the date and time of the photograph, the direction in which the camera was facing, an identifying description of the subject and the reference. Similarly, the titles of JPEG files shall include the date and time, and an identifying description of the subject.

Photographs taken for record purposes as ordered by the Engineer or as specified herein shall be supplied with MPEG files, JPEG files and three (3) prints, with one print having the signatures of the Contractor and the Engineer (or their authorised representatives) on the reverse side for the purpose of attestation. If required, the Contractor may at his own expense have an additional print similarly attested for his retention. Digital video files shall be supplied to the Engineer in a format approved by the Engineer.

Photographs of the Works by the Contractor for any other purpose whether for use in India or in any other country shall not be carried out without written approval from the Engineer.

4.16 Erection of Plant

Erection of Plant equipment shall be phased in such a manner so as not to obstruct the work being done by other contractors. Before commencing any erection work, the Contractor shall check the dimensions of structures where the various items of Plant are to be installed and shall bring any deviations from the required positions, lines or dimensions to the notice of the Engineer.

Plant shall be erected in a neat and workmanlike manner on the foundations and at the locations shown on the Approved Drawings. Unless otherwise directed by the Engineer, the Contractor shall adhere strictly to the aforesaid drawings.

The Contractor shall be responsible for setting up and erecting the Plant to the line and level required and shall ensure that all Plant is securely held and remains in correct alignment before, during and after grouting-in. This responsibility shall not be passed to any other contractor.

Any damage caused by the Contractor during the course of erection to new or existing plant or building or any part thereto, the Contractor shall at his own cost, make good, repair or replace the damage, promptly and effectively as approved by the Engineer and to the Engineer's satisfaction.

4.17 Site Labour and Supervision

The Contractor shall provide all the skilled and unskilled labour required, and all necessary tools and equipment, to erect, test and commission the Works within the period agreed in the programme. The Contractor shall not remove any supervisory staff from the Site without the Engineer's prior approval.

4.18 Sub-letting

The Contractor shall not sub-let the whole of the Works. Where, any design or manufacture is sub-let, the Contractor shall not be relieved of his obligation under the Contract. The Contractor shall be responsible for the acts, defaults and neglect acts in manufacture or design of any sub-contractor, as if they were his own.

Where the Engineer has consented to supply of Plant or execution of work by manufacturers or sub-contractors proposed by the Contractor, such manufacturers or sub-contractors shall not be changed without the prior approval in writing of the Engineer.

A copy of every sub-order shall be sent to the Engineer at the time the order is placed each clearly marked with the title of the Contract and the Contract Number.

4.19 Temporary Works

Not less than 14 days before commencing any portion of the Works, the Contractor shall submit to the Engineer for his approval comprehensive drawings and calculations for all Temporary Works which the Contractor proposes for the construction of that part of the Works.

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

4.20 Languages

All design and drawings (including patented), instructions, signs, notices, name-plates, etc. for use in the design, construction, operation and maintenance of the Works shall be in English. All site sign boards and warning signs shall be in Tamil, Hindi and English.

4.21 Drawings and Information

4.21.1 General

The drawings that are prepared and issued for this Contract shall be classified as follows and where relevant shall be to a scale which is suitable for the representation of those details illustrated.

The term Drawing shall be deemed to include all drawings, schedules, lists, software documentation, descriptive text and calculations necessary for the design, construction, operation and maintenance of the Works and referred to in this clause. The Contractor shall submit all the drawings (A1 size) and documents on (A4 size) in hard as well as soft (editable) format.

4.21.2 Pre-Contract Drawings

The Pre-contract Drawings are those issued to Tenderers either with the Tender Documents for the purpose of illustrating and clarifying the Works described in the Employer's Requirements or later during the tender period as part of an Addendum to the Contract Documents.

Such drawings shall be deemed to have been issued for the guidance of Tenderers and shall, for the purpose of executing the Works, be superseded by the Construction Documents.

4.21.3 Tender Drawings and Documents

The Tender Drawings and Documents are those furnished by a Bidder with his Bid for the purpose of illustrating, detailing, and clarifying his proposals which will be used in the bid evaluation. These shall include:

- Construction program with milestone
- General plant layout plan

  - Process flow diagram with flow data
  - Hydraulic profile
  - Building preliminary GA
  - Description of the proposed Intake/Outfall system, Pre-treatment, SWRO Desalination, Post-treatment Processes, Waste Treatment and Disposal system, Building, Tanks and all allied works
  - Process and Instrumentation Diagram (P&IDs)
- DCS overall System Architecture
- Overall Single Line Diagram and Electrical Load List
- Chemical Usage
- Major Equipment Make/ Type / Origin List
- Generic testing Plan

The above information is important and shall be mandatorily submitted along with the bids by the bidders.

4.21.4 Construction Documents

The Construction Documents are certified Drawings submitted by the Contractor to the Employer's Representative during the course of the Contract for approval. The Contractor shall supply five (5) hard copies each and soft copy of the initial design calculations for the process and sizing of all components of the System including architectural, structural, process, mechanical, electrical and instrumentation equipment, supported by design calculation (excel spreadsheets), flow diagrams and general arrangement drawings for approval to the Engineer. It is a matter of high priority that the Contractor ensures the submission and finalization of such designs and drawings in the stipulated time schedules as elaborated.

It is the intention of the Employer to ensure that the approval of such submissions is made expeditiously and in time. The Contractor is therefore required to setup his project office in Chennai (fully equipped and staffed) to enable continuous submission, interaction and timely clearances.

The Employer shall arrange to send observations if necessary, within twenty-one (21) days of receipt of the design and drawings for modifications to the Contractor. The Contractor shall incorporate all necessary comments of the Engineer in the above design and drawings, if any, and shall re-submit further five (5) hard copies each and soft copy of the revised design and drawings within ten (10) days for final approval of the Engineer.

The Contractor shall thereafter submit seven (7) copies each of the approved design and seven (7) hard copies and soft copy each of the approved drawings together with one copy each of the reproducible tracings. The Engineer will return two (2) approved copies to the Contractor and retain five (5) for the Engineer's office and field use.

If the submissions require more than one round of revision on account of incomplete compliance from Contractor, the delay shall be on account of the Contractor. If new observations are given by the Engineer based on the earlier submission, the Contractor shall be entitled to take an additional ten (10) days period for compliance. Further design calculations and drawings shall be submitted in sequence as per a schedule to be drawn and agreed upon mutually, immediately after submission of the general arrangement drawings.

A blank space 90 x 50 mm shall be provided immediately above the title block for the approval stamp. If required, the detailed design and the execution drawings shall be submitted only after verification by an Institute approved by the Employer. The Contractor shall be responsible for the preparation of working drawings and the construction documents for Works, as specified in the Contract. All costs for the verification shall be borne by the contractor.

The Engineer may require the Contractor to submit for approval additional drawings if they are necessary to enable him to satisfy himself that the items are well designed, that they comply with the Employer's Requirements and that they are suitable for their intended purpose. These drawings shall form the agreed basis for the execution of the Works. If an approved drawing is revised, revised copies shall be submitted for approval as above and no such revised drawing shall be used for the purposes of the Contract until it has been approved in place of the earlier issue of the drawing.

Approval of drawings by the Engineer shall not be held to relieve the Contractor of his responsibilities under the Contract. The Engineer will not permit construction to start on a part or section of the Works unless Construction Documents for that part or section have been approved.

4.21.5 Drawings for Approval

Drawings for approval shall be submitted in two (2) phases both in hard as well as in soft (editable) formats. The first phase shall be the Preliminary Drawings. Drawings submitted during this phase shall be of sufficient details for the Employer's Representative and PMC to understand in outline the Contractor's proposals for the design and construction of the Works.

The Preliminary Drawings shall inter alia comprise:

- comprehensive description of the process, the plant offered, its operation
- Operational and control philosophy
- treatment works hydraulic profile including hydraulic calculations
- chemical process and mass balance & flow calculations
- treatment works flow diagram including details of flows in each area of the plant
- preliminary process and instrumentation diagrams (P&ID); the diagrams shall indicate in symbolic form (to BS 1646 and BS 1553) the process, plant and systems of measurement, control and automation
- site layouts including information on levels detailing the location of:
    - buildings
    - process plant

  - storage tanks
  - transformer enclosures
  - roadways
  - buried pipelines
  - main cable routes
- civil works plans, elevations and main sections of all buildings
- site drainage details
- contract interface details
- general arrangements and main sections of all plant areas
- electrical single line diagram based on approved mechanical and process load list showing CT & PT details, starter details, cable sizes, feeder metering and protection details, equipment capacity and sizes, feeder Interlock operation logic, DG set starting and stopping operation logic, panel cable entry details, panel busbar capacity and sizes etc.
- a description of building services provisions proposed for the Works
  - control system architecture
  - load schedule
  - instrument schedule
  - I/O schedule for each PLC

The Preliminary Drawings shall be submitted by the Contractor for approval as a single submission. The second phase shall be the detailed design phase and shall comprise the submission of the Construction Documents. These shall be submitted after approval of the Preliminary Drawings by the Engineer. The Construction Documents shall be used for the construction of the Works and shall inter alia comprise.

4.21.5.1 *Materials, Plant and Equipment*

The Contractor shall place orders for the material and the equipment only after approval of the Engineer. The Contractor shall submit the detailed drawings from the approved manufacturers, and the procedure of submission, review and revision shall be as specified herein below.

The Contractor shall inform the Engineer about the likely dates of manufacturing, testing, and dispatching of any material and equipment to be incorporated into the Permanent Works. The Contractor shall notify the Engineer for inspection and testing, at least twenty-eight (28) days prior to packing and shipping and shall supply the manufacturer's test results and quality control certificates. The Engineer will decide whether he or his representative will inspect and test the material/equipment or whether he will approve it on the basis of the manufacture’s certificate.

The following inspection and test categories shall be applied prior to delivery of the equipment, of various categories as indicated in the technical specifications for each type of the equipment:

Category A: -The drawing has to be approved by the Employer's Representative before manufacture and testing. The material has to be inspected by the Engineer and PMC at the manufacturer's premise before packing and dispatching. The Contractor shall provide the necessary equipment and facilities for tests and all the related costs for the inspection thereof shall be borne by the Contractor.

The Equipment covered under this category includes all pumps, motors, chemical injection system, chlorination systems, RO system, safety equipment, electric hoists and cranes, screens, strainers, manual hoists of capacity 1 ton and above, valves, gates, nozzles, mixers, agitators, pipes and fittings, meters, actuators, belt conveyor, thickener drives and sludge scraping mechanisms, belt filter presses, DCS, metering instruments, Analyzers, all switchgears, 230kV/110kV/11kV/415V transformer, LT panels, distribution boards, MCC, capacitor bank with APFCR, diesel generator set, VFD, battery, battery charger with DCDB and cables.

Category B: - The drawings of the equipment shall be submitted and approved by the Engineer prior to manufacture. The material shall be tested by the manufacturer and the manufacturer's test certificates shall be submitted for approved by the Engineer before dispatching of the equipment. Notwithstanding the above, the Engineer, after examination of the test certificates, reserves the right to inspect the testing or instruct the Contractor for retesting, if required, in the presence of the Contractor's representative

The Equipment covered under this category includes sampling pumps, drain pumps, manual hoists less than 1-ton capacity, ventilation system, exhaust fans, instrument air compressor, filter media, dismantling joints, air-conditioner and lighting fixtures.

Category C: - Samples of the materials and/or equipment shall be submitted to the Engineer for pre-construction review and approval in accordance with the provisions of Sub-Clause 7.2 of General Conditions of Contract. Following approval by the Engineer, the material shall be manufactured as per the approved standards and delivered to the Site.

For material/equipment under Category "A" and "B", the Engineer will provide an authorization for packing and shipping after inspection.

The testing and approval for dispatching of the equipment/plant shall not absolve the Contractor from his obligations for satisfactory performance of the plant.

4.21.5.2 *Civil*

The Contractor shall comply with the provisions of the requirement of the Specifications for Civil Works, as applicable.

The civil construction drawings shall comprise but not limited to the following:

- site layouts providing information on levels and detailing the location of

  - buildings, architectural drawings/renderings
  - storage tanks
  - process plant
  - transformer enclosures
  - roadways
  - drainage
  - buried pipelines
  - cable routes for direct in ground and ducted systems
- plans, elevations and main sections of all structures, foundations and buildings
- general arrangements and main sections of all plant areas
- drainage provisions
- general arrangement drawings showing the location of each Plant item
- detail drawings of:
  - cable and pipework chambers
  - buried pipework
  - pipework connections
  - contract interface
- reinforcement drawings
- bar bending schedules
- The structural design calculation with computer input & output files for the design package program such as STAAD etc.

4.21.5.3 *Hydraulic*

- hydraulic profile
- hydraulic calculations

4.21.5.4 *Process*

<u>Drawings:</u>

- process flow diagram
- comprehensive P&ID s including details of:
- pipeline sizes and materials;
- valve size and type;

- instrumentation & critical interlocks;
- identification of controlling PLC.

Calculations for:

- process mass flow;
- process calculations for all processes
- RO projections
- plant load calculations
- Room ventilation
- chemical processes
- process drains
- plant service water
- Pump sump design calculations

4.21.5.5 *Electrical*

Drawings

- All Switchgears
  - (a) Dimensional Layout Drawing.
  - (b) Complete assembly drawings of the Switchgear showing plan, elevation and typical sectional views and location of cable boxes and control cable terminal blocks for external wiring connections, etc.
  - (c) Foundation plan showing the location of channel sills, foundation, anchor bolts and anchors, floor plans and openings.
  - (d) Schematic power and control wiring diagrams with control, interlocks, relays, instruments, space heaters, bus bar rating with material, Current transformers, potential transformers etc.
- 230kV/110kV/11kV/415V Main Transformer
  - (a) General arrangement drawing shall indicate the overall dimensions, net weights, quantity of oil, crane requirements for assembly and dismantling of transformers and the general constructional features.
  - (b) General arrangement drawing of the transformer, showing plan, front elevation and side elevation complete with all accessories and fittings, detailed dimensions, net weights, quantity of, crane lift for un-tanking, size of lifting lugs and eyes, clearances between EHV terminals, between LV terminals,

between EHV and LV terminals, between EHV & LV terminals and ground etc.

(c) Rating, diagram and terminal marking plates, complete with polarity and vector group

(d) Control wiring diagram for marshalling box

(e) Foundation drawing with position of foundation bolts and depth

- RTCC Panel for Main Transformer

  (a) General arrangement drawing shall indicate the overall dimensions, net weights, and the general constructional features.

  (b) Wiring diagram with tap position details and logic for on line operation

- L.T Panels, Distribution Boards, Power Control Centres, Power Motor Control Centres, Motor Control Centres etc

  (a) Dimensional layout drawing

  (b) Complete assembly drawings of the switchboard/distribution board / MCC showing plan, elevation and typical sectional views and location of cable boxes and control cable terminal blocks for external wiring connections, etc.

  (c) Foundation plan showing the location of channel sills, foundation, anchor bolts and anchors, floor plans and openings.

  (d) Schematic power and control wiring diagrams with control, interlocks, relays, instruments, space heaters, starter details Bi-metallic relay ratings and contactor ratings, bus bar rating with material, current Transformer, potential transformer etc.

- L.T Capacitor bank with Automatic Power Factor Correction Relay

  (a) Dimensioned general arrangement drawings of capacitor and capacitor control panel

  (b) Justification for number of steps for switching.

  (c) Fully dimensioned general arrangement drawings of capacitor and capacitor control panel with elevation, side view, sectional view and foundation details

  (d) Complete schematic and wiring diagrams for capacitor control panel

- Battery and Battery Charger with D.C. Distribution board

  (a) Dimensioned general arrangement drawings

  (b) Fully dimensioned general arrangement drawings of battery and battery charger with elevation, side view, sectional view and foundation details

  (c) Complete schematic and wiring diagrams

- Cabling System
  (a) Details of Installation of Cables in Trenches, on cable trays, directly buried etc at all locations inside the treatment plant.
  (b) Cable routing lay out inside and outside the plant.
  (c) Bill of quantities of cables, lugs and glands.
  (d) Cable termination and mounting Kit Layout drawing as required.

- Lighting system
  (a) Detailed Room wise Lighting Layout with Type of fixture details and Circuit diagram showing phase wise load distribution and interconnection between switches, fixtures, Lighting panel, receptacles etc.
  (b) Conduit layout showing room wise routing of wires from lighting panel to lighting fixtures, receptacles etc.
  (c) Internal road Lighting and Area lighting layout with type of mounting details and fixture details.
  (d) Street Light pole details with Foundation details

- Earthing System
  (a) Details such as material, sizes, etc. of the earth conductor and electrode pits
  (b) Earthing layout drawing showing routing of main grid inside and outside the plant with interconnection of equipment earthing to the grid and earth pits

- Substation Building Layout showing Panel locations, Transformer locations and Trench Layout
- Electrical Equipment and Panel Layout inside and outside the plant

<u>Schedules</u>

- cable schedules
- load and power consumption schedule
- junction box schedule
- protection relay setting schedule
- panel/MCC schedule

<u>Calculations for:</u>

- Cable sizing
- Fault level and Voltage Dip Calculations
- Co-ordinated protection study
- Standby generator sizing based on equipment finalized by Mechanical and Process

- Transformer Sizing Based on equipment finalized by Mechanical and Process
- Room wise Lighting Calculation as per Lux level given in the specification
- Earthing Sizing Calculation
- Panel Busbar Sizing Calculation
- light/lux calculation

4.21.5.6 *Control, Instrumentation and Monitoring System*

Drawings:

- power supply distribution single line and schematics diagrams (see note 1) for each control panel
- internal and external (see note 2) general arrangement for each control panel (dimensional)
- control and instrumentation loop drawings (see note 3)
- instrument installation detail drawing (hook up, see note 4)
- cable block diagrams
- cable routing/installation drawings
- foundation and fixing details and trenches drawings
- schematic diagram for system configuration of PLCs, operator stations, engineering stations, large screen, training station, report station, printers etc.
- HMI dynamic screens of process flows, diesel generator set and EHV power incoming panels etc.
- format of reports, alarms etc.

Schedules:

- cable schedule
- cable interconnection schedule
- control and instrumentation load schedule for each control panel
- I/O schedule for each PLC
- control and monitoring item schedule for each PLC and operator station
- alarm schedule
- junction box schedule
- instrument schedule
- instrumentation, process control set point schedule
- instrument data sheets

Documentation:

- functional design specification (FDS) (see note 5)
- factory acceptance test document (FAT)

- site acceptance document (SAT)

Notes:

1. Schematic drawings shall include a comprehensive schedule of the components used in each switchboard, MCC and control panel including details of the type, manufacturer and rating of each component
2. The external arrangement of each switchboard, MCC and control panel shall show the arrangement of all components including details of panel section, switch and instrument labels
3. Control and instrumentation loop drawings shall show on a single drawing of the complete circuit associated with an instrument or device, including details and location of power supplies, cabling and terminations
4. Hook up drawings shall detail how an instrument or device is installed
5. See details later for requirements of the FDS
6. Electrical control schematics, loop diagrams and schedules shall where practical be A3 size drawings; all other drawings shall be A1 size

4.21.5.7 *Mechanical*

Drawings:

- general arrangement of plant and pipework including sections
- isometric views of pipework systems
- detail drawings of proprietary and fabricated plant items

Schedules:

- pump curves
- plant performance details
- pipeline schedules
- Valve schedules

Calculations for:

- pump sizing
- pipeline sizing
- compressor sizing
- torque calculations
- Ventilation system
- Actuator sizing

4.21.5.8 *Mechanical Building Services*

Drawings:

- single line schematics for water and sludge handling system and drainage systems
- general drawings showing the location of each mechanical building service plant item
- general arrangement of ventilation systems
- fixing details

Schedule:

- plant data sheets
- pipeline schedules
- valve schedules

Calculations for:

- system sizing
- plant/equipment

4.21.6 **Drawing Format and Numbering**

All drawings shall be prepared using an identical title block format. This shall be approved by the Engineer and shall identify the project, drawing title, the Employer, the Contractor, Sub-contractor, if applicable, and the Engineer.

A formalised drawing numbering system shall be adopted with digits of each number, referencing location, revision, drawing type and size. The numbering format and allocation of drawing number blocks shall be approved by the Engineer. The Contractor shall provide a sequential numbering system for all Construction Documents.

All drawings shall be submitted to a formalised checking procedure prior to submission to the Contractor. Drawings not so checked will not be approved.

4.21.7 **Information required on As-Built Drawings**

The As-Built Drawings shall consist of the fully up-dated versions of the approved Construction Documents incorporating any additional information which will assist the Employer in operating, maintaining and if necessary, modifying or extending the Works at a later date. These drawings should extend and supplement the information given in the Operating and Maintenance Manuals.

4.21.8 **As-Built Drawings**

These drawings shall be compiled by the Contractor and shall constitute a permanent record of the Works as executed. These shall include all such drawings, schedules, documentation and calculations as necessary for a complete understanding of the Works design, operation and maintenance.

Draft As-Built Drawings shall be submitted sixty (60) days prior to the commencement of Tests on completion. The Engineer will signify his approval or disapproval of the As-Built Drawings within twenty-eight (28) days of submission.

The Contractor shall supply to the Engineer five (5) hard copies and soft copy of the As-Built drawings. The Contractor shall incorporate all necessary comments of the Engineer in the above drawings, if any, and shall re-submit further five (5) hard copies each and soft copy of the revised drawing within ten (10) days for final approval of the Engineer. The Contractor shall thereafter submit seven (7) hard copies each and soft copy of the approved As-built drawing with one copy each of the reproducible tracings. The Engineer will return two (2) approved copies to the contractor and retain five (5) for the Engineer's office.

A3 and smaller sized As-Built Drawings shall be provided on durable paper for reproduction by the photocopier. As-Built Drawings larger than A3 shall be provided as a paper copy and also produced in the form of black lines on a durable translucent film from which further paper prints can be taken by others as required. In addition, drawings shall be provided as an AutoCAD, SHP and PDF soft copy. Text shall be provided in an industry standard word processing, spreadsheet or database format as appropriate (Editable copy).

4.21.9 Control System Development

Within the time scale detailed in the Contract Programme, the Contractor shall submit a control system Functional Design Specification (FDS) for approval by the Engineer. FDS shall be the basis for automation of the total system, process control, and alarms. The FDS shall include as a minimum the requirements described as follows:

- a comprehensive description of the functions to be performed by the control system
- an overview of the control system hardware configuration and indication of the functional responsibilities of all the major hardware components
- the control system functionality description
- hardware configuration (system architecture) block diagrams and software block flow diagrams to provide an understanding of the overall capability of the control system
- a functional description of each part of the control system
- description of the communications functionality
- description of the communication functionality checks
- schedule of all hardware components, including the manufacture's name, model number, weight, dimensions, etc.
- electrical power supply requirements of all hardware
- electrical power supply schematic

- general arrangement control panels, furniture etc.
- equipment rack layout drawings
- room layout drawings

The following schedules for the PLC's:

- I/O schedule
- database schedule

The following schedules for the HMI's:

- screens types and reference numbers
- screens navigational structure
- alarms
- alarms directory structure
- events
- set points
- PID parameters
- trended variables including grouping details (real time and historic)
- archived variables

The FDS shall be divided into separate sections. A typical structure would be as follows:

Section 1	General Description;
Section 2	Detailed System Architecture;
Section 3	Control Philosophy
Section 4	System Functionality PLCs;
Section 5	System Functionality HMI's;
Section 6	Communications;
Section 7	PLC and HMI Schedules.

The FDS shall comprise an overall description of the plant, its functions, control and a detailed description of each section of the control system covering modes of operation, manual over rides, set point and parameter selection & adjustments. FDS shall describe the "fail-safe" features incorporated into the design for the event of failure of a plant item or a system or loss of an input signal affecting a control loop or a process sequence. FDS shall describe the control actions taken and monitoring functions which remain available during a sequencing, which take place during system start-up & shut-down.

4.22 Pre-dispatch Inspections Inside and Outside the Employer's Country

In the event the Contractor proposes to procure material which requires pre-dispatch inspection of the Employer's representative (up to maximum 4 engineers) from inside and outside of the Employer's country, the Contractor shall arrange and provide for the cost of the travel to the Manufacturer's place, accommodation, local transport and other expenses for the engineers.

4.23 Hot Line

During the Contract Period the Contractor shall maintain a 'Hotline' for trouble shooting purposes through which the operators can be contacted in case of problems.

4.24 Operating and Maintenance Manuals

4.24.1 General

The Contractor shall compile, operating, maintenance and overhauling instructions for the whole of the Plant, and shall consist of separate volumes. The manual shall not be only the collection of the manufacturers' manual but it should include a tailored document for operation, maintenance and troubleshooting of the plant systematically and user friendly. The Contractor shall submit a minimum of seven copies of the Operation and Maintenance (O&M) manuals. The manuals shall consist of:

(a) general descriptive text (including drawings for illustration) of the Works described section by section.

(b) comprising the complete operational instructions for the treatment plant. This shall be termed the Operators Manual. It shall be aimed at the operational staff and shall be written in clear unambiguous text complete with drawings where necessary for clarification of any issues. The manual shall comprehensively detail what to do on a day to day basis and also what to do in the event faults developing. It shall in addition, provide a complete list of the process maintenance tasks the operator should carry out, including the intervals between these tasks.

(c) the essential instructions for mechanical and electrical maintenance of the Plant. These instructions shall be short and concise and set out in a consolidated schedule the inspection, lubrication, cleaning and any other type of servicing operations required. The Contractor shall prepare typical maintenance log sheets that the Employer can subsequently use for daily, weekly, monthly or other periodic maintenance and shall form record sheets of plant maintenance operations.

(d) instructions for use of skilled maintenance personnel in fault location, carrying out routine replacements, withdrawing, dismantling, overhauling, re-assembling and testing the various items of Plant.

(e) manufacturer's Technical Documentation subdivided into categories for:

- civil
- process

- electrical
- electrical building services
- mechanical building services
- instrumentation and control

(f) Civil As-Built Drawings.

(g) comprising the FDS and PLC code.

(h) electrical As-Built Drawings. The electrical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(i) control and instrumentation As-Built Drawings. The electrical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(j) mechanical As-Built Drawings. The mechanical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(k) electrical and mechanical building services As-Built Drawings. The drawings shall be complete sets including all information including performance curves necessary for maintenance and spares replacement.

(l) FAT records for the Works.

(m) SAT records for the Works

Each volume shall be subdivided (relating to areas of plant) into sub sections or sub-volumes in order to ease the location of plant details. Each volume or sub-volume shall be provided with a comprehensive index for the volume or sub-volume concerned and the O & M manual as a whole.

Draft copies of the O&M manuals shall be submitted to the Engineer for his approval at least sixty (60) days prior to the commencement of Tests on Completion.

The Contractor shall supply to the Engineer 5 (five) hard copies and soft copy of the O & M manuals. The Contractor shall incorporate all necessary comments of the Engineer in the above manuals, if any, and shall resubmit further 5 (five) hard copies each and soft copy of the revised manuals within 10 (ten) days for final approval of the Engineer. The Contractor shall thereafter submit 7 (seven) hard copies each and soft copy of the approved manual together with one copy each of the reproducible tracings. The Engineer will return 2 (two) approved copies to the Contractor and retain 5 (five) for the Engineer's office.

Each volume shall be enclosed within A4 and A3 ring binders have tough grease resistant covers suitable for use on site and designed to permit the easy removal and insertion of the contents. The front cover and spine of each volume shall show details of the project, Employer, Engineer and a volume title.

Text shall generally be enclosed in A4 ring binders, A3 drawings shall be enclosed within A3 ring binders except where it accompanies A4 text in which case it shall be folded. A1 drawings shall generally be folded and enclose an A4 box files. Where A1 drawings accompany text they shall be folded and enclosed in an A4 plastic wallet, one wallet per drawing.

4.25 Notice of Operations

The Contractor shall give full and complete written notice of all-important operations to the Engineer sufficiently in advance to enable the Engineer to make such arrangements as the Engineer may consider necessary for inspection and for any other purpose. The Contractor shall not start any important operation without the written approval of the Engineer.

4.26 Reinstatement and Compensation for Damage to Persons or Property

The Contractor shall reinstate all properties whether public or private which are damaged in consequence of the construction and maintenance of the Works to a condition as specified and at least equal to that obtained before his first entry on them.

If in the opinion of the Engineer, the Contractor shall have failed to take reasonable and prompt action to discharge his obligations in the matter of reinstatement, the Engineer will inform the Contractor in writing of his opinion, in which circumstances the Employer reserves the right to employ others to do the necessary work of reinstatement and to deduct the cost thereof as certified by the Engineer from any money due or which shall become due from the Employer to the Contractor.

The Contractor shall refer to the Employer without delay all claims, which may be considered to fall within the exceptions listed in the Conditions of Contract.

4.27 Protection of Existing Installations

The Contractor shall apply to the Engineer in writing at least 28 days before starting any work that involves interference with existing structures, equipment, etc at and around the site. The Contractor shall not execute such work until he has received permission to proceed, in writing from the Engineer.

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

4.28 Protection of Existing Public and Private Services

The Contractor shall notify all public authorities, utility companies and private owners of proposed works that will affect them not less than two weeks before commencing the works.

The Contractor shall adequately protect, uphold, maintain and prevent damage to all services and shall not interfere with their operation without the prior consent of the public authorities, utility companies, private owners, or the Engineer as appropriate.

If any damage to services results from the execution of the Works, the Contractor shall immediately:

(a) Notify the Engineer and appropriate public authority, utility company or private owner.

(b) Make arrangements for the damage to be made good without delay to the satisfaction of the public authorities, utility company, private owner or Engineer as appropriate. The Contractor shall be liable for all costs for making good such damage.

The Engineer may issue instructions or make other such arrangements as he deems necessary, to repair rapidly any essential services damaged during the execution of the contract at the cost of the Contractor.

4.29 Spare Parts

The spares shall comprise an adequate stock of the parts likely to be needed as routine replacements together with any major items or components which it may be desirable to hold in order to facilitate or expedite repair for a period of 24 months. The Contractor shall supply spare parts required for the continuous operation of the works during the O&M period. The Contractor shall supply the details of spare parts and quantity required for the continuous operation of the plant for 2 years before 1 year of the end of the O&M period. The Contractor shall support the Employer in the procurement of the spare parts .

All spare parts available at the plant shall be packed separately from the main Plant in packages or containers designed to preserve the spares from the effects of long-term storage under the ambient conditions specified. Any items that cannot be packed in this way must be protected from corrosion by applying temporary protective coatings and shielded from mechanical damage. All items shall be clearly labelled with brief descriptions and part numbers.

4.30 Diesel Generator

Emergency diesel generators (DG) shall be provided, for the power supply of electrical loads to take the plant to shutdown without suffering damage. Two DG sets (1 duty + 1 standby) shall be provided for each stream and also one DG set for minimum lighting and illumination of the buildings and streets within the site boundary to the satisfaction of the Engineer. The capacity of the DC and safe AC system shall cover loads for the safe shut down of the plant. Automatic starting of the diesel generators during power failure shall be programmed and tested.

Also, the DG capacity should be sufficient to provide charging the voltage for the UPS chargers, minimum lighting to all buildings and the streets in case of power failure. The complete diesel generator system shall be remotely controlled and monitored by the DCS system. The DG set shall be housed in a DG room of the Electrical building.

4.31 Spillage and Leakage

Chemical preparing, dosing and transfer equipment shall be designed and arranged so that any leakage and spilling can be controlled and cannot enter ducts, channels, etc. and have a corrosive impact on pipes, cables or other equipment of the plant.

At all lubrication or greasing points grease trays or pans shall be provided to collect excessive lubricant or spillage onto the equipment or into water.

4.32 Special Tools and Appliances

The Contractor shall supply two complete sets of the special tools, lifting tackle, access equipment (ladders, scaffolding etc.) and greasing equipment necessary for the maintenance, repair, testing and overhaul of the Plant. The cost of all tools and test equipment shall deemed be covered under the O&M cost in the price schedule. All tools and tackles shall be handed over in fully working condition to the Employer after completion of the O&M period.

The Contractor will be permitted to utilise the overhead gantry cranes, supplied under this Contract for the purposes of installing the equipment in his supply. The Contractor shall be responsible for making all arrangements for the electricity supply to operate the cranes and for their service, maintenance and repairs. On completion of the installation, the Contractor shall restore the cranes to as new condition by the replacement of all worn or defective components.

All special tools and test equipment necessary for overhauling the Plant and testing its performance shall be included and mounted in the warehouse at site with lockable doors. Racks and clips shall be provided for individual items with outline markings and labels to show where any equipment is missing.

4.33 Packing and Protection

Before any Plant is despatched from a manufacturer's factory it shall be adequately protected and packed to ensure that it will arrive on the Site in an undamaged condition. The methods employed for protection and packing must be suitable for withstanding the conditions which may be experienced during shipment, delivery to the Site and prolonged periods of storage, whether the items are shipped in packing cases, crates or only partially protected according to their nature.

Bright parts and bearing surfaces shall be protected from corrosion by applying a rust preventive lacquer, high melting point grease or similar temporary protection. A sufficient quantity of solvent shall be supplied with the plant to enable this coating to be removed on the Site. All machined flanges and other mating surfaces shall be protected by means of wood templates. The bolts for securing these templates shall not be reused in the final installation.

No one crate or package shall contain items of Plant intended for incorporation in more than one part of the Works. All items of Plant shall be clearly marked for identification against the packing list, which shall be placed in a waterproof envelope inside every packing case or crate. Every packing case and crate shall be indelibly marked to show its weight, serial number, top and bottom, shipping marks and handling instructions or sling marks.

Electrical Plant shall be enclosed in sealed airtight packages with dehydrating material, before being placed in packing cases on shock-absorbent material and secured by means of battens.

The RO membrane shall be packed, transported and stored at site as per the instruction of the manufacturer. The RO membrane should not be brought at the site and stored for long period of time. The membrane shall be dispatched to site with the approval of the Engineer and in accordance with the recommendations of the manufacturer. The RO membrane shall be kept at the site in the control environment as per the manufacturer's instruction so that the warranty remains intact.

CHAPTER - 5

5. PARTICULAR CIVIL REQUIREMENTS

5.1 Introduction

The Standard Basic Specifications (SWRO Desalination Works Contract) issued by CMWSSB, set out the specifications that shall be followed for construction of general Works under the 400 MLD Chennai SWRO Desalination Project. In the event of any discrepancy between the provisions of the General Specifications and the Particular Specifications, the provisions of the Particular Specifications shall prevail over general specifications.

Contractor is responsible for the supply of all civil materials, machinery, marine equipment, supervision, labour, safety personnel and all expenses necessary for the installation of the structures that are part of the Contract. Nothing contained herein or missing shall be construed as relieving the Contractor of his obligation to provide a structure capable of performing its intended service for a submerged life as defined in the Contract. The Contractor shall provide necessary method of statement and procedures that will be followed for execution of the work in sequential step by step activities, and he will use the necessary float days for proactive work of critical works in the Planning program. The Employer or its representatives reserve the right to inspect and reject at all stages of the Works when the Contractor is found not in compliance with the specification. Contractor shall give the Engineer and Employer's Representative full and unrestricted access to all areas of the work. The Contractor shall invite the Engineer and Employer's representatives for inspection after completion of the tasks prior to covering, coating/painting operations. They reserve the right to use still photography or video cameras to document visual inspection at any stage of work by the Contractor.

If any inspection or testing defined by or referenced in this Specification reveals that the work is non-compliant, then the entire preparation and application procedure shall be redone from the point where the Contractor can demonstrate compliance to the satisfaction of the Engineer. All remedial work shall be at the Contractor's expense to the satisfaction of the Engineer. In general all the works shall be carried out by the Contractor to the satisfaction of the Engineer abiding along with the satisfaction of the Quality Control Engineer apart from IS codes of minimum requirements and also abide OSHAS standards to the utmost satisfaction of the Safety Engineer at project site.

The Contractor shall be in possession of the current revisions and addenda of all codes, standards and specifications required for the Works. All such documents shall be made readily available to the Engineer or the Employer's Representatives upon request. Contractor shall employ only qualified and experienced personnel for the work. The Engineer/ Employer's Representatives shall determine the competence of personnel and shall retain the right to seek replacement of any Contractor's personnel if in their opinion, the proposed personnel are not working in accordance with Contract, approved procedures or plans.

The Contractor shall maintain all equipment in good conditions at all times and where necessary fully calibrated. The Employer shall inspect equipment and all deficiencies shall be corrected by Contractor at his sole expense and to the satisfaction of the Employer. Contractor shall maintain the identification of every component and/or section of the pipe constituting the Intake and Outfall. These marks shall be recorded by the Contractor and the daily logs provided to the Engineer or Employer's site representative as requested.

All tests performed by the Contractor or his suppliers to prove materials characteristics shall be in accordance with the listed codes, standards and specifications or tests referenced herein and general civil requirements. In all cases, the Contractor is to get Engineer's written approval prior to the testing.

At the Employer's discretion, the Contractor shall be required to carry out tests to prove compliance of materials. All such tests shall be to Contractor's account. Contractor shall clearly state every exception to the requirements of this specification prior to Contract award, if no exceptions are stated full compliance should be confirmed.

After award of contract and before start of work, the Contractor shall submit a detailed written description of the procedures, materials, personnel, tests and safety measures for Engineer's approval. The description shall be accompanied by full details of the test results on similar works performed by the Contractor. The Contractor shall submit to the Engineer for review and approval of the following procedures:

- i) Construction and Project Management Plan
- ii) Site Organization Chart
- iii) Work Schedule and Progress Monitoring Plan
- iv) Quality Manual and Project Quality Plan
- v) Safety Execution Plan and Procedures
- vi) Installation Procedure and Manual
- vii) Utilization of Construction Equipment
- viii) Marine Operation Manual
- ix) Mooring Arrangements Procedure and Marine Spread Anchor Pattern
- x) Critical Lift study
- xi) Emergency and Medical Evacuation Plan

5.2 Scope of Civil Works

The scope under Civil Works includes complete structural designing, construction, procurement, installation, commissioning and 20 years of operation and maintenance of the 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis. The Works include all civil and all associated works required for construction of the plant.

The following buildings/structures are part of the Works in scope along with all other civil works required to construct the 400 MLD SWRO desalination plant fully functioning as per the contract specifications and guarantees.

(i) Construction of complete Intake and Outfall works including intake/outfall pipeline, intake heads, intake well, pumping station etc. The scope includes the supply of all material, machinery, plant site, supervision, labour, safety personnel and all expenses necessary for the installation, testing and commissioning of the Intake and the Outfall system with all onshore and offshore works.

(ii) RCC Clear Water Reservoir of 9ML capacity.

(iii) RCC Outfall Tank of about 4.5 ML capacity for wastewater discharge to the sea through diffusers.

(iv) Construction of RCC Sludge Balance Tank with pumping arrangement

(v) Construction of two Gravity Thickeners & Thickened Sludge Holding tanks with all associated structures.

(vi) Construction of Sludge treatment building (Belt Filter Press (BFP) building) with all associated structures.

(vii) Construction of Substation building including Switchyard & Transformer area

(viii) Construction of Administrative Building with all associated works.

(ix) Construction of Laboratory and Plant Central Control building with Record room

(x) Construction of large Workshop and Warehouse

(xi) Construction of all main and connecting roads and landscaping of the plant site area.

(xii) Construction of Retaining wall all around the site and filling of soil up to the required level.

(xiii) Construction of RR masonry Boundary wall all around the project site.

(xiv) Providing shore line protection works (Requisite clearances to be obtained from the relevant authorities) near the plant area to prevent soil erosion and disruption to "Nemmeli Kuppam" Boat landing centre.

(xv) The following units/items shall be constructed separately for each plant stream of 200 MLD.

a) Construction of inlet chambers and channel with baffles, flash mixing chamber, distribution chamber with weirs, walkway etc.

b) Construction of Flocculators & Tube Settlers tanks along with walkway etc.

c) Construction of Chemical Building with RCC solution preparation Tanks for coagulant and Polymer, Storage area, Bunds to collect splash chemicals, etc. and other features.

d) Construction of covered area for chlorination, acid and any other chemical storage tanks and dosing system.

e) Construction of DAF (Dissolved Air Flotation) tanks covered along with walkway etc.

f) Construction of Gravity Dual Media Filters (GDMF) under Filter Building along with pumps, blowers areas and walkway etc.

g) Construction of RO (Reverse Osmosis) Feed Tanks and other associated structures.

h) Construction of RO building along with CIP area, storage/maintenance areas and other allied structures etc.

i) Construction of Chemical Building for RO system to accommodate all chemical tanks and dosing system.

j) Construction of Permeate Tank and other associated structures.

k) Construction of Limestone Filters along with the Filtrate area, CO2 generation area, online Limestone makeup system and other associated structures.

l) Construction of Product water tank of capacity 4 x 7.5ML along with other associated structures and piping.

m) Construction of covered Chambers for all valves, dismantling joints and flowmeters along with laying of all yard piping.

n) Construction of all MCC buildings

o) Any other civil construction to fulfil the requirements for the proposed plant as per the Contract.

5.3 Intake and Outfall Works

The intake system will be designed to have a hydraulic capacity of 1040 MLD. The intake conduit shall be of two number 2500 mm OD @ >6.5 bar HDPE pipe (SDR≤26) and the outlet conduit shall be one number of 2500 mm OD 6.5 bar HDPE pipe (SDR≤26) to produce net 400 MLD product water capacity. The waste seawater with high salinity will be discharge to the sea through nozzles to allow fast dispersion and less environmental impact.

Conventional dredging/trenching method or as approved by the Engineer is proposed to be employed for laying of Intake and Outfall conduits in the sea with minimum 1.5m cover over the pipe. The backfilling of the trench shall be done with the same excavated earth/material. The Spoil would be removed and returned to shore. The pipe would be prefabricated and floated over the trench or dragged along the trench. A safety boat shall be deployed in the vicinity to warn other craft to keep clear of the working area. Pipe shall be handled with care so as not to cause any deformation or out-of-roundness of the pipe, damage to the ends, bending of the pipe etc. Excavation of the trench at the shoreline shall be executed in such a way to prevent damages to the shore structures. The trench shall be dredged to a depth from the sea bottom in order to give a vertical distance of 1.5 m (pipe top cover) between the top of the respective intake/ outfall pipelines and the surrounding natural undisturbed seabed level. The bottom of the trench shall be filled with a levelling fine sand bed having a minimum thickness of 200 mm to avoid any dent or puncture of the pipe due to hard pointed rock surface.

During excavation of the trench as per approved drawings, all efforts shall be made by providing supports to protect the lateral walls from collapsing. Walls shall have a slope with a minimum inclination of 1:3 to maintain safety and to avoid any mishap. The trench shall be graded such that the minimum vertical radius of curvature of the pipeline does not generate excessive stresses in the pipeline. Any trench transitions for the pipelines (at spool pieces) shall be smoothly profiled back to the undisturbed natural seabed level so as to ensure that the pipeline is not subjected to over-stress while exiting or entering the trench. The bottom of the trench in a transition zone shall be at a constant smooth gradient providing a gentle continuous surface to support the pipeline.

Before start of the sinking process, the route shall be marked properly by buoys floating at sea surface. The Sinking of the pipeline shall be mainly carried out by nature's own forces i.e. gravity, buoyancy and air pressure while sinking of the diffuser, involves use of cranes. The sinking shall be carried out in a continuous basis. The pipelines shall be equipped with blind flanges fully checked for tightness at each end. If for any reason, there is an interruption in the sinking operations, the reverse sinking process should start immediately.

The sand backfilling can start when pipelines are laid and it is ensured that the extremities of the line at the intake chamber and spool piece end respectively remains free for the future connection to the onshore equipment and to the offshore intake screen installation. Backfilling shall be carried out using the native sand, restoring to the original situation. The backfilling shall be carried out in subsequent stages in order to allow the sand to be deposited duly compacted and to give, as final result, the original sea bottom configuration and water depth. The intake head and outfall diffuser section shall be connected to the main HDPE pipelines by means of appropriate pipe expansion spool pieces to be installed after the final positioning of the intake to suite levels. The seabed characteristics of the area surrounding the Seawater Intake and the Outfall is generally constituted by loose sand with some areas of compact sand and some clay patches. The report comprising of the data & results w.r.t to offshore studies are enclosed with the Tender, Part-2 Site Data for reference. However, these studies are only indicative, and the detailed investigations shall be carried out by the selected bidder (Contractor), as required before execution of works to confirm the data and to meet the contractual requirements.

The scope of the Contractor for intake and outfall system includes but is not limited to:

- Contractor will be responsible of the supply of material, machinery, marine equipment, supervision, labour, safety personnel, video monitoring system and all expenses necessary for the installation of the structures and inspection by approved third party as part of the Contract.
- Carryout all the onshore and offshore studies and surveys of the area including bore logs to verify the nature of the sea bottom for construction of marine works. and get all works checked and inspected and approved by the Safety Engineer, Quality Control Engineer, and the Engineer.
- Excavation of the appropriate trench in the sea bottom with appropriate equipment and supply and receive the HDPE pipes along with associated accessories constituting the intake and the outfall.
- Backfilling of the trench, supply and installation of the various materials in the areas for

construction of sea water intake and outfall along with pipe conduits.

- Supply, welding, laying and connection of two PE 100 High Density Polyethylene (HDPE) intake pipes > 6.5 bar and one HDPE outfall pipe 6.5 bar in the submarine trench in accordance with the specifications.
- Prefabrication and installation of concrete/anchor blocks for the anchorage of the pipes. The blocks shall be manufactured with Portland Slag cement.
- Prefabrication and installation of the concrete blocks for the system towards protection against trawling fishing and other possible causes of damage.
- Fabrication and installation of the intake heads and GRP or Duplex Steel intake screens (as per the consent of the Engineer) at the extremity of the sea water intake pipeline and connection of the pipeline with special expansion spool piece joint as required.
- Provision for pigging to clean the pipelines and pig launching station and landing (collection) point suitable for the purpose shall be provided.
- Fabrication and installation of the HDPE reject outfall diffusers section and connection with special expansion spool piece joint as required.
- Supply and installation of the necessary Navigational Aids like buoy with red lantern marks to mark the position of the structures as per approved drawings.

The decoded and validated digital data shall be supplied by the Contractor to the Employer through email transfer and also on Compact disk/ pendrive. The information shall be on the Longitudinal profile and Event data. The Longitudinal profile shall include the key parameter (KP) along the theoretical design route, sea bottom depth along the pipe axis, Pipe depth, Easting and Northing coordinate and any other related information. The Event data shall include the KP along the theoretical design route, Event code and event description. These files shall be delivered before post trenching activities survey.

5.3.1 System Description

5.3.1.1 *Seawater Intake*

The sea water intake facilities cover two seawater intake heads with screen offshore and two intake pipes to bring water to intake well and pumping station onshore. Each of the offshore units of sea water intake system comprise of intake suction head, 100 mm c/c GRP/ Duplex steel screen along with ring provision of Hypo dosing, air bursting arrangement. A nylon net, around the periphery of each intake head is provided to prevent small fish entry. The net shall be properly anchored and shall have provision for easy replacement. The intake structure (Head) shall be prefabricated in one single piece and shall be installed using the preapproved procedure.

The seabed conditions are one of the primary factors in determining the location of seawater intake and outfall conduits. A 100 mm c/c opening screen in GRP/ Duplex steel construction shall be provided at the intake to exclude larger marine life. The said screen shall be designed with an approach velocity of ≤ 0.12 m/s to minimise the entrapment of marine species. The net will be required to be inspected and replaced from time to time, as the same is likely to be damaged by marine lives. The head loss through the intake system will also be monitored, and in any increase in system losses indicating fouling at the intake, or the growth of biomass within the intake conduit, the same shall be cleaned. The Hypo dosing lines and compressed air line shall be of HDPE material per IS 4984 with possibly GRP cover to protect the pipe and shall be laid along the intake pipe properly clipped at the crown of the pipe. The preliminary study proposed that the intake pipes should be laid up to the intake head located approximately 1150 m offshore, the depth at the intake would be >10 metres at low tide.. The two intake pipes shall be laid in a common trench along with the outfall pipe.

5.3.1.2 *Reject Outfall*

An outfall shall be one 2500 mm OD 6.5 bar HDPE pipe conduits. Coastal currents flow from south to north from August to October and from north to south from November to March each year. The currents from the South to the North are stronger than the currents from the North to the South. For this reason, the outfall will be located to the North of the intake, same as in the existing Nemmeli plants. Since the near shore currents in this region are predominantly directed towards North, it is preferred to locate the outfall on the Northern side, so that the plume spread would be mostly oriented towards North and there would not be any re-circuit to the intake. Sea water outfall pipe shall be High density polyethylene pipe (black). As per the study the outfall pipe should be laid at 750m offshore. However, a brine diffusion analysis can be carried out by the Contractor.

5.3.1.3 *HDPE Pipes*

Contractor shall supply the HDPE pipes (< SDR 26), shall keep them in custody in a safe and protected area, shall check all pipes for damage, dents, out of roundness, gouges and flat ends etc. All damage and other defects noted shall be recorded by the Contractor and witnessed by the Engineer/ Employer's representatives. Damage caused to pipe whilst in the custody of the Contractor shall be reported to the Engineer and replaced or repaired by the Contractor to the satisfaction of the Engineer. The cost of replacement or such repair work and the cost of any material lost shall be at the Contractor expense. The history and details of each pipe, including the pipe identification number shall be recorded by the Contractor before the commencement of installation and a unique cross reference number shall be painted by the Contractor on the inside and outside of the pipe on both the ends. All documents related to the pipes shall be preserved by the Contractor for inclusion into the final certification documents.

5.3.1.4 *Pipe Handling*

HDPE pipes shall be handled at all times in a manner, which avoids damages. All pipes shall be lifted clear and moved without being dragged over the ground or any obstructions. Alternate lifting equipment or specially manufactured lifting hooks may be permitted after approval has been given by the Engineer and under the supervision of the pipe manufacturer. Pipes shall not be rolled or dropped. Line pipe shall be positioned with care so as not to cause out-of-roundness of the pipe, damage to the ends, bending of the pipe etc. Any pipe suffering impact damage during handling shall be immediately quarantined and the Engineer/ Employer's representative be advised for their inspection and eventual subsequent acceptance and/or repairs. Excess damage beyond the repair will be assessed by the Engineer/ Employer's representative and shall be rejected. The rejected pipe shall be removed from the site by the Contractor immediately. Lifting equipment shall be approved by the Engineer. Wire ropes alone shall not be used to lift pipes. Where forklift trucks are to be used to transport the pipe, they shall be suitably padded to prevent damage. All pipe handling equipment and procedures shall be subject to the approval of the Engineer prior to their use.

5.3.1.5 *Pipe Stacking*

Bare pipe shall not be stacked more than two layers high. The pipe shall be stacked, either on properly constructed and maintained pipe racks, inspected and approved by the Employer, or on a minimum of two coal tar enamel covered loose graded sand windrows. The sand windrows shall at least be 15 cm deep and not less than 2 m wide (each), approximately 7 m apart, and shall not be separated by bearers. Contractor shall submit proposed stacking arrangement by detailed shop drawings, including stacking heights pipe end supports and stacking surface to the Employer for approval, prior to use and installation. If the Contractor requires to stack the pipes in a different number of layers, he shall submit to the Employer all relevant calculations certifying the new proposed configuration.

End supports need to be placed at either end of the stack to prevent to pipe joints from rolling. If pipes are to be stored for an extended period, precautions shall be taken to prevent damage of pipe ends and interiors. The pipe shall be carefully lowered to prevent impact damage and stacked in such a way that water and mud cannot accumulate within the pipe.

5.3.1.6 *Concrete*

Cement, sand, aggregate for concrete works shall be as per the enclosed General Civil specifications of the bid document and in case of conflict between the General Civil specifications and the guidelines mentioned in Particular Civil works, the Particular Civil specifications shall prevail. The concrete blocks to be installed for the support and ballast of the Outfall diffusers and Intake screen, for the cast in situ inside the prefabricated caisson at the elbow of the Intake pipeline and for the anti-trawl fishing protections, anti- buoyancy saddles for intake and outfall pipeline as per the span & load mentioned in the respective intake and outfall pipeline construction drawings shall be of the type for underwater marine seawater environment construction and shall be dense concrete not less than M40 / IS code shall be referred and approved by the Engineer based on Soil test report and trial mix design for the special case to Sea shore Structures. The concrete shall be suitable for marine installations and cement used shall be resistant to sulphate and chloride attack under submerged seawater conditions.

5.3.1.7 *Cement*

Sulphate resisting Portland cement conforming to BS-4027 or as per IS 12330:1988 specification for sulphate resisting Cement Portland cement or better shall be used. Cement shall be suitable for use for seawater and shall have a Tri-Calcium Aluminate (C3A) content of not more than 3.5% and an alkali content of less than 0.6%. Alternatively, Blast Furnace slag cement conforming to IS 455 shall be used. All cement batches shall be covered by manufacturer's test certificates which shall be submitted to the Engineer. These shall cover the physical and performance characteristics of the cement. Cement shall be stored in such a way that provides satisfactory protection from ambient elements. Cement that has hardened, become partially set or has become lumpy shall be rejected and removed from the site by the Contractor. A Special Consideration shall be considered for the Sea water Structures by the Contractor in choosing the type of cement, Quick setting, Sulphate resisting, etc. based on site soil condition and the pile foundations to be considered if required. However final recommendations will be followed with consent of the Engineer.

5.3.1.8 *Sand*

Sand used for concrete coating mix shall be silica type conforming to BS EN 12620 or IS 2116 - 1960 and shall be well graded from fine to coarse grains. As a part of general Instruction Contractor shall follow Indian code standard and any other code for reference shall be with compliance statement matching to the Indian standards and to the satisfaction of the Engineer. As an emergency scarcity option M-sand (manufactured Sand) from crushing Quarry stone to sand (in line with IS:383 – 1970 or latest version) shall be used with the consent of the Engineer and with Compliance statement to IS codes for Ordinary river Sand.

5.3.1.9 *Crushed Stone*

Crushed stone shall be clean and free from any chemicals or soils or organic material that could impair the concrete strength or as per IS 383 1970 or as specified by the Engineer's approval.

5.3.1.10 *Aggregate*

Mix Grading Aggregate mix shall be clean and free from injurious amount of clay, salt and alkali, organic or other deleterious material or as per IS 383 1970 or as specified. Alkali compatibility is essential for aggregate. The Contractor shall maintain a material traceability system to record properly the receipt, return or disposal of all materials supplied and their location within the coating yard on a real-time basis. The Contractor shall permit inspection of these records by the Engineer/ Employer's representatives at any time.

5.3.2 **Installation Specification**

5.3.2.1 *Shore Approach Preparation*

Contractor shall reclaim and prepare the Site where he intends to constitute the yard for the assembly and preparation of the structures. He is responsible for the construction of the required access roads and the installation of all services relevant to the Works. The start of the excavation of the trench at the shoreline shall be executed in such a way to prevent damages to the shore structures and appropriate sheet pile walls shall be installed (if necessary) to avoid that the action of the waves can cause difficulties to the works carried out by others onshore. The pipeline trench would be dredged using an air lift pump, dragline or clamshell, or excavated with a long armed back hoe from a jack up barge. If rock is present, underwater drilling / rock cutting may be required. Spoil would be removed and returned to shore. This activity would create significant stirred sediments and may require the use of temporary curtains to contain the turbidity plume. Stone bedding material would be imported and placed at the bottom of the trench. The pipe would be prefabricated and floated over the trench or dragged along the trench with neutral buoyancy before being sunk progressively into position by the release of air. Stone pipe surround would then be placed from a barge using chutes and divers and rock protection lowered and placed as trench backfill. The size of the rock protection shall be decided upon the wave climate and depth and the seabed to its original profile and allows longshore drift to remain unaffected in the long term.

5.3.2.2 *Pre-Work and Pre-Lay Site Survey*

The Contractor shall carry out a pre-works survey to confirm that the site conditions, including sea bottom profile, are the conditions described as per the bathymetry report and side scan supplied by the Employer. Contractor is responsible to highlight to the Engineer any eventual discrepancy with the original data and all eventual variations due to a lack in the execution of this survey and communication to the Employer shall not constitute origin for any claim whatsoever. Prior to trenching operations, Contractor shall ensure that the pipeline is not subjected to excessive spanning as per the requirements of specific Standards. For that purpose, Contractor shall conduct a post-lay survey using divers and/or ROV (Remote Operated Vehicle) depending on the work area. Accordingly, Contractor shall propose procedures with all supporting documents along with method of statement for the trenching equipment to negotiate areas of pipeline spanning (if any) such that the pipeline is not over-stressed. Prior to mobilizing for the trenching activities, the Contractor shall review soils data along the pipeline route to ensure the adequacy of the proposed trenching method and that no adverse conditions, which could affect the trenching operations efficiency.

5.3.2.3 *Trenching Method*

The Contractor shall propose its preferred method(s) for trenching the pipeline taking into consideration the involved soils and seabed features along the proposed offshore route. A preliminary study of the bathymetric survey has been included in the tender Part-2 D-Site Data. The proposed method shall include procedures for negotiating seabed features, the direction of trenching, trenching sequence and split and the entire trenching methodology shall be established by the Contractor in conjunction with the Engineer/ Employer's representative to guarantee the efficient operation of the trenching spread.

5.3.2.4 *Trenching Requirements*

The Contractor shall proceed with the excavation of the trench of the 2500 mm OD, subsea pipeline taking into consideration the following:

Contractor shall dredge the trench to the required depth from the sea bottom in order to give a vertical distance of 1.5 m (pipe top cover) between the top of the respective intake and outfall pipes and the surrounding natural undisturbed seabed level. The top shall be accounted from the crown of the pipe.

- Lateral walls of excavation shall have a minimum slope characteristic of the sea bed to prevent collapse of trench.
- Contractor shall maintain a maximum trench out-of-straightness "OOS" of 0.25 m all over the route in order to mitigate upheaval buckling in case of natural backfilling.

- Pipe should not be lowered until the trench is of the desired width. Any pipeline portions not satisfying the above mentioned "OOS" value shall be adequately corrected in accordance with Contractor procedures and at his sole expense.
- The bottom of the trench shall be compacted and filled with a levelling fine sand bed having a minimum thickness of 0.2 m. Eventual material protruding out of this layer shall be duly recorded and the Engineer shall be informed to agree with the Contractor for the necessary remedies.
- The shape of the trench shall be always in control of the Contractor and designed section shall be restored when and if necessary, at the sole expense of the Contractor.

If, during trenching operations, Contractor encounters obstacles (not likely), he shall at his own expense and to the satisfaction of the Engineer, immediately cease trenching operations on that portion of the pipeline and report to the Engineer the details of the obstructions along with his recommended solution. Any obstacles such as boulders or wrecks, preventing trenching the line shall be removed by the Contractor.

5.3.2.5 *Trench-Out of Straightness- Survey (OOS)*

As soon as possible after completion of trenching operations, Contractor shall conduct a post-trenching survey to determine the out-of-straightness of the pipeline and ensure that it does not exceed 0.25 m for the entire route. Contractor shall acquire, record and map all necessary data required to determine the "Astrenched" position. Contractor shall perform imperfection out of straightness "OOS" surveys, which shall constitute the basis for "OOS" Assessment, to ensure that the required cover depths for the two intake and one outfall pipelines are maintained along their route. The required "OOS" survey should accurately define the pipeline profile after completion of trenching operations. Prior to the "OOS" survey, repeatability trials should be undertaken to assess the accuracy of the OOS measurements.

5.3.2.6 *Trench Grading and Profile*

The trench shall be graded such that the minimum vertical radius of curvature of the pipeline does not generate excessive stresses in the pipeline. Any trench transitions for the pipelines (at spool pieces) shall be smoothly profiled back to the undisturbed natural seabed level so as to ensure that the pipeline is not subjected to over-stress while exiting or entering the trench. The bottom of the trench in a transition zone shall be at a constant smooth gradient providing a gentle continuous surface to support the pipeline. Unsupported pipe spans caused by trenching (despite being unlikely) shall not be in excess of the maximum allowable free span lengths given in the relevant standards. Unsupported pipeline spans greater than the allowable span lengths shall be corrected by the Contractor.

5.3.2.7 *Levelling Sand Bed*

The Contractor shall describe in detail the method he intends to use for the distribution of the fine sand in the bottom of the trench in order to have a perfectly levelled and smooth surface. Contractor shall provide, at his own expense, to the correction of any eventual differences in level of the fine sand bottom trench bed.

5.3.2.8 *Sinking of Submarine HDPE Pipeline*

The specifications below deals with the sinking process and necessary precautions to be taken to secure a safe installation of pipeline at the bottom. Sinking of the pipeline is mainly carried out by nature's own forces i.e. gravity, buoyancy and air pressure.

During sinking of the intake and outfall pipeline, the following factors shall be taken into consideration:

a) Detailed sinking procedure must be worked out including technical parameters, necessary resources, communication systems and emergency procedures.

b) Detailed calculations of the sinking curvatures must be carried out by computer programs.

c) The pulling force in the end shall be calculated and minimum shall be 40 tons. Necessary equipment should be arranged for the same.

d) The sinking speed shall not exceed 0.3m/s.

e) The compressor required for air filling in pipeline shall work up to 10 bar. Air pressure curve as a function of depth shall be calculated.

f) The critical radius of curvature is to be determined for outfall and intake pipeline.

g) The sinking shall be carried out in a continuous basis.

h) Concrete weights must be fixed securely.

i) The weather conditions must be satisfactory and favourable.

j) The diffuser and intake head must be installed as a beam system by use of cranes.

k) The static system during lowering of the intake head and diffuser must be calculated.

l) The intake screen head and diffuser must be 'mated'/ connected to the main pipeline at sea bottom (in the trench) with the special spool joint.

m) The sinking shall be carried out under assistance of well certified and experienced personnel in this field.

n) Use of divers shall be minimised and minimum possible work related to installation must be carried inside the sea.

o) The pipe string will be towed from the production area by tugboats to the installation site. The Contractor shall prepare a detailed sinking procedure before installation.

The concrete weights shall be fixed to the pipeline at the prescribed centre to centre distance. The weights can be installed onshore or offshore. The concrete weights shall be fixed properly to prevent sliding during installation. To increase the co-efficient of friction and to avoid scratches in the surface of pipe, an EPDM (ethylene propylene diene monomer) rubber gasket between the pipe and concrete weights shall be fixed. When all the pipe sections are fitted together, the pipeline is ready for sinking process. The pipeline is equipped with blind flanges in each end. At the outmost end, the blind flange is also equipped with pipes and valves for air evacuation and air filling.

Before start of the sinking process, the route shall be marked properly by buoys floating at sea surface. Particular care should be taken for the weather forecast as very little wind and waves should exist during the sinking process. The entire pipeline shall be positioned in the correct route by boats, barges and small boats.

The inmost blind end of the pipeline is also connected with valve and pipe for controlled water pumping inside the pipeline through pump during sinking The air pressure inside the pipe shall be adjusted depending on the depth through the air valve and compressor to prevent any "run way".

The calculated pulling force must be applied in the outmost end (end near shore) of the pipe before the sinking starts. This force can vary during the sinking operation and shall be specially calculated beforehand.

The sinking starts by opening of the air valve in the outmost end carefully and controlling the inside pressure by a manometer if required to charge the pipe with compressed air. The Contractor shall before starting the sinking operation will prepare the curve showing the necessary air pressure as it is the function of sinking depth. The sinking speed shall be a controlled speed and shall not exceed 0.3 m/s.

All precautions should be taken to avoid buckling of pipe section. The sinking operation shall be continuous process. If for any reason, there is an interruption in the sinking operations, the reverse sinking process should start immediately by starting the compressor and must be completed within 15 minutes.

When the sinking reaches the outmost end of the pipeline, the S- configuration will transform to J-configuration and at this position, very precise and correct pulling force and sinking speed shall be applied to prevent dynamic acceleration forces when the last volume of air leaves the pipe. 50% of the pipe length, without water should be able to sink during launching. Hence proper anchorage should be done.

5.3.2.9 *As-Lowered Survey (Post-Trench Survey)*

As-lowered survey shall be conducted in order to meet the following objectives:

- To provide all relevant documentation necessary to demonstrate and to prove that the pipelines have been lowered in accordance with the acceptance criteria.
- Video inspection of the physical condition of top and sides of the As-lowered pipeline for detection of possible damage, pipeline suspensions, etc.
- Determination of As-lowered pipeline position.

5.3.2.10 *Anti-Trawl Barriers for Intake and Outfall*

Within the Scope of Work of this project is the installation of about 50 nos. 2.50 x 2.50 x 1.50 m anti-trawling fishing concrete blocks in two concentric lanes having origin in the centre of the two Intake structures. Also, similar anti-trawl fishing protection zone shall be provided around diffusers. The installation of these concrete blocks shall be carried out at the real end of the construction, when the Intake/outfall structure is installed by using the crane of the installation barge with the assistance of the underwater equipment. Installation procedure proposed by Contractor shall be approved by Employer's representative.

5.3.3 Inspection

Contractor shall perform stage wise inspection and testing of all equipment/material used to carry out the survey work and the same shall be witnessed by Engineer/Employer's representative. Certified test reports of the instrument used shall be provided. Contractor shall carry out onshore pressure testing (hydro testing) of the intake and outfall pipeline at 1.5 times the rated pressure prior to marine installation of the pipelines. Hydrostatic testing of the system should be carried out as per IS-7634 – 1975/ equivalent European standard. Contractor shall provide a means of remotely monitoring the trenching operations. A full video record of trenching operations shall be obtained and submitted to the Employer. The operations observed will depend on the trenching equipment being used. Trenching shall proceed only when video monitoring is available. Contractor shall continuously monitor the status of trenching operations, the lowered depth of pipe and the position of the pipelines in the trench to ensure satisfactory performance of the equipment being used.

5.3.4 Diving or ROV Reporting

As part of the trenching spread, Contractor shall provide an experienced Diving team and/or the Remote Operating Vehicle (ROV) with all required facilities to perform the Scope of Work. Facilities for continuous video monitoring and recordings of trenching machine operations shall be provided. During the trenching operations, Contractor shall periodically report to Employer at least once every 24 hours on the operation of the trenching machine. This check shall be increased to every 8 hours after the initial start-up for the first 24 hours. The performance report for information about the condition of the pipe and joints, depth and profile of trench and video inspection back-up shall be provided every day.

5.3.5 Pipe Laying

Laying of the Intake and Outfall pipelines is expected to be with the "Bottom Pull" system carried out by an appropriate pulling barge equipped with a suitable pulling winch. The two accessories approx. 100 mm dia. hypochlorite and 100 mm dia. compressed air respectively submarine pipelines can be laid simultaneously with the main 2500 mm OD HDPE pipeline. In this case the intake line shall be firmly anchored to the sea bottom and natural backfilling so that the current and/or storm shall always be under control and not disturb the pipeline. With the utilization of the above system the Contractor shall be responsible to prepare a suitable area onshore for the transportation, storage and assembly of the pipeline strings. Contractor shall submit to the Employer, for approval, a detailed layout of the Site including the description of the sources of power, water, aggregates etc. he intends to utilize for the Project.

If Contractor intends to utilize a different system of laying, he may be allowed to do so but shall propose the alternative procedure to the employer for their approval. The proposed procedure for installation shall describe in details about the methodology and equipment required for Employer's review and approval. In any case, the Contractor shall deliver to the Employer the full description of the marine equipment proposed to be deputed for the execution of the marine operations clearly indicating whether the equipment is owned, hired or at a temporary disposal.

5.3.6 Backfilling

5.3.6.1 *Intake Pipeline*

Once the entire offshore length of intake pipeline has been laid and the final position controlled by positioning system is assured, the sand backfilling can start ensuring that the extremities of the line at the intake chamber and spool piece end respectively remains free for the future connection to the onshore equipment and to the offshore intake screen installation. Backfilling shall be carried out using the natural original as backfilling material sand, restoring to the original situation. Contractor shall take due care during backfilling that together with the fine sand, coarse material that can damage the Intake pipe is not used. Measurements of the backfilling shall be continuously under control of the Contractor and report and diagrams of the profile submitted daily to the Employer. The backfilling shall be carried out in subsequent stages in order to allow the sand to be deposited duly compacted and to give, as final result, the original sea bottom configuration and water depth.

5.3.6.2 *Intake Structure Area*

After the installation of the Intake structure and its connection to the HDPE submarine pipeline with special spool piece, the area surrounding the Intake structure shall be covered by a layer of approximate weight of stones of 5-100 Kg size up to minimum 2 m below the natural sea bed level. On top of this small size stones layer, another layer 1.0 m thick of 250-500 Kg stones shall be installed. The area covered by these two layers shall have a diameter of 50 m having origin in the centre of the Intake screen structure (Intake Head). Floating fence nylon net shall be installed all around with floating buoys.

The structure must be modelled in order to establish the structural dimensions, so that it is able to support the forces generated by the calculated force actions. The concrete structures, the piece shall be reinforced, and it is recommended to construct a finite elements model, this is because, very often, it is intended that the structure has a significant weight, and accordingly the concrete walls and base plates have significant thicknesses. The structure/tower/head should be anchored to the hard strata below the sea bed level and the area around that shall be filled with gravels. The vertical height in 1:3 from bottom of sea bed to the 300 mm level below the screen should be graded with gravels to prevent intake of sea bed turbulence sediments in the plant.

5.3.6.3 *Outfall Pipeline and Diffusers Area*

Similarly, the backfilling operations for the entire length of Outfall pipeline, shall be carried out by Contractor in order to return to the original configuration of the seabed. The area where the diffuser's manifold has to be installed, having approximate dimensions of 70 x 15.0 m and a thickness of 2.0 m average, shall be covered by a layer of 200-500 Kg stones. This may be changed after proper calculation to be carried out by the Contractor.

5.3.6.4 *Outfall Diffusers Installation*

The Outfall diffuser is constituted by a HDPE manifold 2500 mm OD of an approximate length of 150 m and having about 30 nos. internal dia 350 mm HDPE pipe diffusers inserted with an angle of 50° in respect of the upper tangent of the pipe. This is an indicative design information. Additional simulations for brine dispersion will be done by the Contractor to fine-tune the diffuser location and arrangement. Duckbill valves shall be installed in all diffusers.

5.3.7 **Contractor Equipment, Personnel & HSE Requirement**

5.3.7.1 *Equipment*

Contractor shall furnish complete details of the machineries to be deployed for the trenching spread capable of working in the involved water depths, seabed conditions and environmental conditions. Contractor trenching equipment and its operation shall be such that the pipelines and their joints do not sustain damage. Contractor shall present all design and operation calculations demonstrating that the machine is appropriate, safe and efficient for the trenching works. Documentation shall include results of all field trials, including description of location, soil types and trenching performance.

5.3.7.2 *Support Machinery*

All vessels/ support machineries required for carrying out of the Scope of Work shall be in full working order and in good conditions. Contractor shall provide to Client descriptions and technical information on all proposed trenching vessels. The vessel used for the works shall have the following characteristics:

- i) Ensure a good operating stability.
- ii) Have installed a suitable capacity for the job requirements crane.
- iii) Satisfy international safety rules applicable in the work area.
- iv) Have all the permits required to operate in the work area.
- v) Hold certificates issued by competent agency.
- vi)
- vii) Radio equipment with frequencies for establishing reliable links with local radio stations.
- viii) Allow suitable space with the necessary equipment and facilities for divers' activities.
- ix) Provide a workshop for instrument maintenance.
- x) Allow suitable space for the installation of the Data Acquisition System and Data Processing equipment.
- xi) Provide air-conditioned working areas.

The contractor shall be fully responsible to complete the contract as per requirements with at most safety and meeting the environmental regulations.

5.4 **Inlet Structure**

The Inlet system including feed channel, chemical dosing, pre-chlorination, and rapid mixing shall be of reinforced concrete construction in CC mix M35. The chamber shall have the concrete stairs and a minimum 1m wide walkway along the length and across the width to allow operation and maintenance of the system with hand railing of SS316 on all the peripheral length, and reinforced concrete staircase. The Structure shall be constructed as per approved detailed drawings to withstand the seawater contact for the design life time.

5.5 Chemical Buildings

Three Chemical buildings shall be provided for the pre-treatment, the RO system including CIP chemicals and for the post treatment.

The pre-treatment chemical building shall have 3 portions or fully separate structures. One portion of the building shall be assigned for Ferric Chloride and Polyelectrolyte preparation and storage. Other two portions shall be assigned for Chlorination and Acid storage and dosing system.

The RO Chemical building shall be built near RO building, which will house all chemical tanks and dosing system for RO trains and CIP system. The post-treatment chemical building shall house caustic and hypochlorite storage and dosing system.

Adequate space shall be provided for storage, preparation and dosing of the chemical solution. The building should also have 1-3 ton EOT (electrically operated overhead travelling crane) as needed to move the pumps, motors and agitators for installation and maintenance. The details of the tanks and dosing system are provided in the Part-2 Section VI, Chapter3 Particular Process Requirements.

Separate and adequate vehicle approaches shall be provided for each portion of the building. The chemical building shall have sufficient ventilation as per the requirements given elsewhere. Sufficient stairs and walkway with hand railing of SS316 shall be provided to inspect the agitators and inside the chemical tanks. A covered reinforced concrete service water storage tank (minimum 2 hours capacity at maximum consumption) shall be constructed on the roof of each chemical building for chemical preparation and chemical inline dilution and line flushing as needed. Adequate toilet and wash room attached to the chemical building shall be constructed as per the specifications in the tender document.

5.6 Flocculator & Clarifier with Tube Settlers

The Clarifier with Tube settler shall be of reinforced concrete with access from two ends and walkway facilities for maintenance and inspection. The structure shall be constructed in RCC mix M35 as per the requirements for structures in contact with seawater. Drainage of flocculation tanks and tube settlers shall be from each hopper including back flushing system for cleaning purposes with manual valves. There will be a magnetic flowmeter and an auto operated knife / plug valve with remote sensors in the common header of sludge from flocculators and also in the common header of sludge from tube settlers. The clarified water from tube settler will be fed to the DAF. There is a bypass line which circumvent the DAF unit and directly feeds to the Filter inlet channel.

5.7 DAF and Filter Building

DAF (Dissolved Air Flotation) and Dual Media Filters shall be housed in reinforced concrete building with access from two ends and sufficient walkway facilities and space for maintenance and inspection. The structure shall be constructed in RCC mix M35 as per the requirements for structures in contact with seawater. There shall be sufficient ventilation and glass windows with steel mesh to prevent birds entrance into the building. Details of the DAF and Filters have been provided in the Part-2 Section VI, Chapter 3 Particular Process Requirements.

5.8 RO Building, Warehouse and Workshop

The RO building, warehouse and workshop shall be PEB (Pre engineered Buildings) steel structures. Design of structure shall be based on the dead and live load requirements of the structure as it will be built. Snow, wind, and seismic loads shall be considered where they are applicable. Racking must be built stronger and be better braced. The structural design process will involve the steps of i) calculating the permanent actions and determining the variable actions, ii) identifying the load paths that carry the applied actions (vertical and horizontal) to the foundations and, iii) selecting preliminary sizes for the members.

All nuts and bolts and fasters shall be of stainless steel and all other steel items shall be hot galvanised. All steel beams and columns shall be polished and epoxy painted. For the roof and wall panel shall be steel sheets (PU sandwich panel). The door and window of the steel frame structure can be made of aluminium alloy. There will be sufficient fixed glass windows at roof and wall to lighten inside the building. There shall be sufficient crane runway beam designed according to your overhead crane parameter and EOTs of the required load bearing to meet the requirement.

RO building (Industrial Steel structure) of each stream shall house the RO skids, CIP system, RO flushing pumps and all system associated with RO system and also a local control Room at the Mezzanine floor area as per proposed drawing and shall be implemented after approval of the Engineer.

The warehouse and workshop shall be adjacent buildings of minimum area 80m x 40m and 50m x 40m respectively. Both the building shall have all features and facilities required for the purpose. Contractor shall design based on the Site requirements with IS code standards.

5.9 Limestone Filter

The Contractor shall provide reinforced concrete building as per Proposed and approved drawings for Limestone filter with access at the top of the filter. The structure shall be constructed in RCC mix M35. Details of the Limestone filter has been provided in the Part-2 Section VI, Chapter 3 Particular Process Requirements.

5.10 Water Retaining Tanks

All water retaining tanks such as Intake well, RO feed tank, Clear water tank, Sludge balance tank, Sludge holding tank, Outfall tank and other tanks shall be of reinforced concrete minimum M-35 or as per as per approved design mix based on the IS code of reference for sea water as special case consideration, along with access and walkway facilities as described elsewhere. All tanks where needed, shall overflow to the Outfall tank for discharge to the sea.

5.11 Sludge Thickener & Pump House

The sludge shall be pumped from the sludge balancing tank to gravity sludge thickeners and dosed with polymer to assist the thickening process. Two gravity thickeners shall be provided. The thickener tanks shall be of reinforced concrete (M-35) or as per IS codes for reference for special sea water design construction. The tanks shall have a sloping bottom with central hopper. The circular tank shall have a peripheral weir and collecting channel. Other facilities such as an access bridge to centre rotating scraper, walkways and stairs to ground with SS316 hand railing shall be provided as described elsewhere. The supernatant from the sludge thickeners shall flow by gravity to the Outfall tank.

5.12 Sludge Dewatering Building

The sludge dewatering building shall be a two storied structure. The polymer feed systems, belt filter press feed pumps, belt wash water pumps and chemical dosing system should be located on the ground floor of this building. The belt filter presses and electrical room should be located on the first floor of this building. The building should have necessary staircases. There shall be an intermediate platform along a conveyor belt below the first floor. Chutes shall be provided for discharging dewatered sludge cake into the trailer. Necessary foundations shall be provided for the BFPs. The floor slabs on which the BFPs are positioned shall be designed to account for the loadings from the BFPs in the event of the BFP vibration dampening equipment failing. A covered reinforced concrete service water storage tank shall be mounted on the roof of the sludge dewatering building. A toilet and washroom shall also be provided in the sludge dewatering building.

5.13 Substation Building

The construction of new substation buildings as essential including switchyard and transformer area shall be constructed with RCC framework looking to the space requirement. Suitable fencing shall be done of transformer area.

5.14 Administrative, Central Plant Control and Laboratory Buildings

Two buildings shall be constructed – one for the administrative works and another for the plant control plus the laboratory. The administrative building shall be G+2 story building. While a G+1 story building shall be constructed to locate the plant control room at the ground floor and laboratory at the first floor or vice versa with a record room for drawings and all plant information. An indicative plan of the building floors has been provided in the Part-2 Section VI, C Drawings.

The buildings shall be complete with minimum facilities to make a complete working place for the engineers and technicians to sit and work. Items will include but not limited to the Work Stations desks, Executive chairs, officers chairs, conference room chairs and tables, other desk, chairs with writing pad attached in the Training room writing boards, Over Head Projector in the meeting/conference room for minimum 25 officers and Computer desktop/laptop for

Engineers as needed, Chairs tables, Fans , Split (A/c) Air-condition room for all rooms, and as where required as per the Engineers, Water for Drinking and toilet /washroom facilities, Adequate Lighting facilities, contractor shall also propose for the Engineer's approval and few other Facilities proposed at Ground floor shall be Entrance corridor with Lift and Staircase, Security room, Reception, First Aid center, Safety Manager room, Client Manger's office, Conference room with screen view from Video Monitoring system and can view the complete plant with different area by control system, Contractor Manager's room, Night shift manager room, Engineer's office rooms, Canteen, adequate Toilets and Wash rooms and contractor shall note that all Technician room shall be in the respective buildings of RO and Workshop and for other MEP areas for easy maintenance and for fault attending purpose and In the First Floor Civil Engineer's room, MEP Engineer's Room, HR and Admin officer's room, Canteen, Toilets and wash room facilities and Lift and dining area with all Architectural, False ceiling , HVAC , MEP and other Facilities .

Second floor is for Guest room accommodation with bed room with full furnished facilities for the guest to come and stay with family. It will include all items in the guest house which is deemed essential to stay for a family. Each room with toilet and wash room attached with shower water shall be provided with fully furnished bed, tables TV room , chairs , tables drinking water and a small dining area etc. to the Engineer's satisfaction. Canteen Facilities and on the roof terrace will be Sea View room with telescopic arrangement and Lift and staircase facilities and video camera monitoring system and Emergency alarm system.

Another adjacent Control and Laboratory Building (G+1) will have the Computer, Laboratory, Microbiology and Record rooms plus the Multipurpose Training Room with all facility. The details of the buildings have been provided in the Part-2 Section VI, A3 Particular Process Requirements. All the works and all details and facilities shall be carried out by the Contractor as per the Drawing proposed and approved by the Engineer, and also special consideration will be taken for the Construction works for the Sea shore area especially for the type structural works and foundation. The building will have good finishes with Granite floor, and Vitrified floor finishes and tiles for the Toilet and Bathroom walls and false ceiling where required and Corners of the wall with gypsum finishes and the wide glass walls with Glass doors and adequate shelves and Cupboards for the Files. Doors and windows will be of teak wood unless if any other recommended by the Employer. Some windows can be aluminum as per drawing and all finishing works like painting, special lighting, solar fixing etc. and other decorations and aesthetics will be as per drawings proposed and Engineer's Choice. However, the contractor shall provide the facility to the utmost satisfaction of the Employer.

Contractor shall note that from the Central Control room a provision shall be made for Engineers to view the Plant and different buildings through glass set up and by Computer with Video Camera Monitoring System and other IT system as per the requirement of the Engineer. Also adequate internet facility shall be provided in the Administrative and Control buildings. Ten Laptops with latest required software shall be provided. All other facilities shall be proposed and implemented fulfilling the Engineer's satisfaction.

The facilities will include but not limited to the following.

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
1	Ground floor	Front corridor and Steps	• Floor finish – Granite stone with good polish .
		Security Room	• Floor finish – Granite • Ceiling fan- 1Nos, Wooden Table-01 Nos • Wooden Chair -01 Nos • Guest chair -02 Nos • Fan -1 No . • Telephone, internet , Intercom, Video monitoring and tracking and checking screen .
		Reception room	• Executive Sofa for 6 seaters -1 no and Chairs -3 nos. • Front Table -news paper -1 no
		First aid room	• Granite floor finish Steel Table-1 no. • Guest Chair-2 nos. • Office desk -1 no
		Lift	2 nos.as specified by Engineer.
		Stair case	2 nos. As per drawing .
		Canteen area	• Complete 30 nos. steel chair , steel table with glass top or mica sheet wood finish for dining • Fan 10 nos. • Hand Wash area 1.2 m length – 2nos with 4 taps each • A complete Solar and electrically operated Heaters will be used for heating prepared food and for some snacks , coffee and tea and milk and small food and ready made food only . and a small cool drinks and Big refrigerator
		Front side wall at corridor	• Plant Model display -1 no. • Tube lights in the ceiling 2 nos. 4o watts each .
		Client Manager's room, Contractor' room	• One big table 6 ft length X 5 Feet width , • chair -4 nos. • Executive Chair-1 no Normal chairs -3 no • A 100 liters fridge for each manager . • Attached Toilet and Wash areas . • Doors and windows – Teak wood Door and aluminium / Teak wood window . • Fan-1 no

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
			• 1.5 ton Samsung or any other specified wall mounted near ceiling Split A/c -1 no. • Telephone, intercom, Internet wifi, Lap top for every manager and TV with plant monitoring video screens .
		Conference room	• A big Conference 20 seater table 10 nos. on both side and Chairs20 nos. • Ceiling fan- 8 nos. at 1 .2 m distance minimum • Tube Lights 12nos. • Over Head projector with complete set up for meeting 1 no. • Presentation Screen -1 no and Boards and Marker and wifi internet access to monitor running Plant status as at site .
		General Male and Female toilets	• Exhaust fan -3 nos. each , • Hand wash 2 no. each , • urinals-3 nos. for Male toilet . M/F as per Drawing toilets-3 nos. each , Indian and western .
		Janitor room	• Ceiling Fan -1 no. • Ventilation fan-1 no.
		Client Engineer's room, Contractor's Engineer's Room , Safety engineers room , Supervisor's Room ,Junior engineer's room	• Office Table -1 no. each officer / Engineer • Executive chair I no each , • Guest Chair 2 nos. per room , • Visitor chair 4 nos. extra . • With ceiling fan 1 no. per officer , with split A/c 1.5 ton 4 nos. with 2 nos. per 3 Engineers . • Floor finish shall be Vitrified floor and at corridor – Granite Floor finish .Additional Chairs shall be as per drawing . • Doors and windows , natural Air ventilation and natural sun light as per drawing , as per bye laws of NBC . • Each engineer will have a small refrigerator of 50 litres. capacity .
		Drinking water and STP (Small Sewage Treatment plant and RCT (Rain Water Collection Tank)	• For the Total building and the Microbiology and Laboratory building

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
		Front walk way 1.2 m wide	• All round the Building and with adjacent is the Green Land scape with drip irrigation facility as per Drawing
		Laboratory room, Microbiology room	• Comfortable Chairs -minimum 12 nos. each room and • 12nos Table as per drawings or as per lab requirements and Drawings . • 20 tube lights each big room and Fan . • 1.5 ton Split type Air condition 4 nos. wall mounted and with Teak wood doors and windows . with entrance steps with Granite floor finish and corridor 1.2 m wide with anti skid tiles • Adjacent is plantation for the land scape with green grass and small plant . • Microbiology room and Laboratory floor will have acid proof tiles . • Sufficient, adequate air vent and Sun Light will be provided for Both the rooms . • A big toilet and Bathroom for male and Female will be provided as per drawing , • Minimum 3 no of urinals and two toilets will be provided for male toilet area a small hand wash area . • or female toilet one Hand wash area and two toilets will be provided with tile finish at the walls .
	Ground floor	Corridor area	• Adequate Lighting will be provided . • solar panels will be supported for back up lights and power support • Floor finish shall be granite floor of client approved colour .
2	First floor	Front portico	• 1.2 m wide all round the building with Tile for the floor • parapet wall 10 cm thick 1.2 m Ht • Stainless steel finish hand rail 0.5 m Ht .
		All staircase	• Anti skid Tiles finish . • with stainless steel hand rail .
		Electrician room	• Vitrified tile finish , • 1 ceiling fan , • a small office table • Two chairs , Two tube lights .
		Pantry	• A Micro oven , wash basin, and a ceiling Fan , 2 tube lights .

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
		Night shift manager's room both client and contractor	• 2 tube lights , • 1.5 ton Split a/c wall mounted , • A big Office table , • Executive chair- 1 no. • Lap top and fridge , • Two visitor chair and a small sofa 3 seater for each room . • Intercom, • telephone, • Mobile , • (walky talky for inside plant coordination), • Video monitoring provision for the Plant progress .
		Library room	• Adequate 5 seater table 2 nos. and • 10 single seater chairs . • with toilet facility for male only and • Female will use general toilet facility out side the library .
		Meeting room	• Will have 12 nos. seater table . • 5 nos. chairs on both side . • 2 nos. at center, opposite side . and additional chair and table if any required . • Sufficient lighting with 8 no tube lights and Doors and windows as per drawing and NBC minimum reference code .
		Supervisors room, HR room, plant Office Administrator room, Instrumentation Engineer room , Plumbing Engineer , Electrical Engineer room , Civil Engineer room ,	• Each room will have minimum 2 tube lights of 40 watts , Each room 1 fan and a lap top for all staffs and for Engineers and other officer vital person each with Internet • Each Intercom , telephone and Mobile and Walky talkie , and lap top monitoring for the Plant video progress provision and site coordination facilities • Each section ref Drawing one male toilet with Hand wash and Female Toilet, with Hand wash and • adequate Opening for natural air ventilation and also Sun light with Doors and Windows . • Floor finish shall be vitrified Tiles. • Each Section will have 2 split a/c 1.5 tons Samsung Model Unless specified or as per approved Drawing .
		Corridor 1.2 m wide	• Will be of Granite Finish and with sufficient sun light ventilation .
		Electrician room	• One tube light and a small 60 watts bulb and a ceiling fan and a Table and two Chair for workers.

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
		Pantry room	• Two tube light 40 watts .. A sitting chair . • A Micro oven provision , • Electric heaters • A ceiling fan and • 100litres refrigerator -1 no.
	First floor	Multipurpose meeting room	• Will have adequate 30 nos. Chairs and writing table and big table for the Trainer with executive chair • Adequate lighting Facility and • 8 nos. split a/c and • 8 nos. Ceiling fan and with Over head projector facility and video monitoring the plant facility with TV and PowerPoint Screen .and a Computer and Lap top will be provided as per requirement sufficiently . • Doors and windows adequate for natural air and Sun Lighting facility is provided as per NBC
	First floor	Research &Development Room and Record storage room	• A 20seater Workstation with laptop for each • chairs for all research staffs • A master table • A Executive chair for the Research Head. • Sufficient lighting with 20 nos. • Tube lights LED and • Internet facility, • Intercom, • Video came Tv screen to view the Plant 4 nos. at all side of wall and for each lap top . • Adequate natural air ventilation and Sun light facility provided . • A well-defined record storage room will be provided to Store all record and will be used as and when required .
		First floor toilet and wash area facility .	With adequate exhaust fans and wash area and urinals and closet for both male and female will be provided .
	Second Floor Area	VIP Suite room	• TV- 1 NO • Sofa three seater -1 no • Bucket seat sofa individual-2 nos. • Visitor seating sofa -4 nos. • A Table and executive Chairs -4 nos., • Visitor chairs -4 nos.

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
			• Executive Master Bed room with complete Master bed and cot and Blanket . • A Dressing table • 1 split 1.5 ton Air conditioner, • 4 tube lights, • Ceiling Fan 3 nos. each room and • Adequate 2 nos. doors and windows with teak wood or as per drawing , • A Small fridge and a Mirror wall mounted and clock and reading and writing chair and table with Internet, Intercom, Computer / Lap top, • TV screen to check the plant during emergency . • Alarm and fire extinguisher
		Conference room	• For the private and confidential discussion to the Plant Manager and for Engineer . this room shall be with 12 nos. tube lights , • 8 nos. Ceiling Fan and • 16 seater table and 16 Chairs and • A over Head projector and • Screen and video monitoring Tv for the Plant progress visualization .Adequate Doors and windows and Screen pointers and other accessories .
		Lift and staircase	Shall be up to second floor roof to see the plant and for sea view room with lift head room at the Second floor
		Toilet for male and female at the second floor .	• Adequate toilet facilities are provided 3 toilets for male and 3 toilets for female and • 3 urinals for male and • wash area facilities . • Sufficient lights are provided with 4 tube lights of 40 Watts each male and female areas and • 3 nos.Exhaust fan and a wall mounted mirror at the hand wash basin area .
		Engineers suite room or bed room 2 nos. of eight bed rooms	• Total Bed room are provided with sufficient Tube lights of 2nos each room of 40 watts • A small fridge commonly provided 100 litres for four Engineer total 2 nos. • Single bed cot and bed each engineer • 2 nos. blanket and pillow • Mirror and Common toilet facility one for two Engineers. • common Lobby for watching TV and Plant progress and with Internet facility • wifi and Intercom. • Reading table and chair • A two seater Sofa provided .

S. No.	Floor Levels	Name of the room	Facilities details and Finishing details .
			• Each room a single ceiling fan and • Common two no 1.5 ton Split a/c commonly controlled by two engineer per A/c. • Adequate Window and Door facilities are provided for each room one window .
		A big private room	• Provided with 4 nos Tube lights40 watts , • 2 no. ceiling fan, a door and Two windows and a small fridge • Meeting chairs 6 nos and • 3 nos sofa . • Intercom • Internet facilties • Telephone and mobile and • TV room • Sufficient Chair and work table with a single lap top and Tv to view the Plant progress.
		A portico at the second floor .	• Finishes of floor will be either Tiles or Granite as per Engineer's Choice 1.2 m wide and 1.2 m height and 120 mm thick with handrail .5 m ht to view the plant from the Balcony all round the building .
			• Comfortable emergency exit doors and sufficient air ventilation and Sunlight are provided for the entire building .
			• Roof terrace will be specified roof tiles with water proofing material and water tanks and sea view room
		Sea view room	• Floor with marble finish . • Drinking water facilities at roof level . • Wash room and Toilet facilities for emergency use. • Adequate sunlight and Air ventilation • 6 nos tube lights and 6 nos.chairs • Sofa 6 seater and work table , • Telescope to see the plant and sea view and floor is either Vitrified or Granite finish .

General facilities for the Plant area

S. No.	Plant area	Finishing Requirements	Additional Requirements
a)	Security room -2 Nos (at Entrance and Exit)	Desk 2 nos , table 6 feet length 1 no. , Chair – 3 nos , Intercom, telephone -1no., Television- 1no with video cam monitoring the vehicles and	Additional security room at the Sea Side Back side of the Plant .(with Chair , table,

		other people movements only , Adequate tube light 2 nos and ceiling Fan -1 no, table fan-1 , Computer Table and chair 1 no., Internet , Wifi , Mobile facilities .)	Intercom, Telephone, Mobile, Wifi

5.15 Design Submissions

Complete detailed design calculations of foundations and superstructure together with general arrangement drawings, architectural drawings, reinforcement drawings and other drawings shall be submitted to the Engineer /Employer's representative. Separate design calculations for foundations and superstructures submitted independent of each other shall deemed to be incomplete and will not be accepted. The design considerations described hereunder establish the minimum basic requirements of plain and reinforced concrete structures, masonry structures and structural steel works. However, any particular structure shall be designed for the satisfactory performance of the functions for which the same is being constructed. The Contractor shall also take care to check the stability of partly completed structures.

5.16 Design Standards

All designs shall be based on the latest Indian Standard (IS) Specifications or Codes of Practice. The design standards adopted shall follow the best modern engineering practice in the field based on any other international standard or specialist literature subject to such standard reference or extract of such literature in the English language being supplied to and approved by the Engineer.

In case of any variation or contradiction between the provisions of the IS Standards or Codes and the specifications given along with the submitted tender document, the provision given in this Specification shall be followed. All the reinforced concrete structural designs shall generally conform to the following publications of the Indian Standards Institution:

IS:456	Code of Practice for plain and reinforced concrete
IS:875	Code of Practice for design loads for buildings and structures (Part I to V)
IS:3370	Code of Practice for concrete structures for the storage of liquids (Part I to IV)
IS:1893	Criteria for earthquake resistant design of structures (Part-1)
IS:2974	Code of Practice for design and construction of machine foundations (Part 1 to 4)
IS:13920	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces- Code of Practice

All structural steel design shall generally conform to the following publications of the Indian

Standards Institution:

IS:800	Code of Practice for general construction in steel
IS:806	Code of Practice for use of steel tubes in general building construction

5.17 Design Life

The design life of all structures and buildings shall be 60 years.

5.18 Joints

Movement joints such as expansion joints, complete contraction joints, partial contraction joints and sliding joints shall be designed to suit the structure. However, contraction joints shall be provided at specified locations spaced not more than 7.5 m in both right angle directions for walls and rafts. Expansion joints of suitable gap at suitable intervals not more than 30 m shall be provided in walls, floors and roof slabs of water retaining structures. Construction joints shall be provided at right angles to the general direction of the member. The locations of construction joints shall be decided on convenience of construction. To avoid segregation of concrete in walls, horizontal construction joints are normally to be provided at every 2 m height. PVC waterstops of 150 mm width shall be used for walls and 230 mm width for base slabs.

5.19 Design Loadings

All buildings and structures shall be designed to resist the worst combination of the following loads/stresses under test and working conditions; these include dead load, live load, wind load, seismic load, and stresses due to temperature changes, shrinkage and creep in materials, dynamic loads:

5.19.1 Dead Load

This shall comprise all permanent construction including walls, floors, roofs, partitions, stairways, fixed service equipment and other items of machinery. In estimating the loads of process equipment all fixtures and attached piping shall be included, but excluding contents, shall be considered. The following minimum loads shall be considered in design of structures:

(i)	Weight of water	9.81 kN/m^3
(ii)	Weight of soil (irrespective of strata available at site and type of soil used for filling etc). However, for checking stability against uplift, actual weight of soil as determined by field test shall be considered	20.00 kN/m^3
(iii)	Weight of plain concrete	24.00 kN/m^3
(iv)	Weight of reinforced concrete	25.00 kN/m^3
(v)	Weight of brickwork (exclusive of plaster)	22.00 N/m^2 per mm thickness of brickwork

(vi)	Weight of plaster to masonry surface	18.00 N/m^2 per mm thickness
(vii)	Weight of granolithic terrazo finish or rendering screed, etc.	24.00 N/m^2 per mm thickness
(viii)	Weight of sand (filter media)	26 kN/m^3
(ix)	Weight of MS chequered plates	78.5 N/m2 per mm thickness of plates

5.19.2 Live Load

Live Load (LL) shall include the superimposed loads due to the use/occupancy of the structure/building not including dead, wind or earthquake load. Live loads shall be in general as per IS:875 Part (II). However, the following minimum loads shall be considered in the design of structures:

(i)	Live load on roofs	1.50 kN/m^2
(ii)	Live load on floors supporting equipment such as pumps, blowers, compressors, valves etc.	10.00 kN/m^2
(iii)	Live load on all other floors walkways, stairways and platforms	5.00 kN/m^2

In the absence of any suitable provisions for live loads in IS Codes or as given above for any particular type of floor or structure, assumptions made must receive the approval of the Engineer prior to starting the design work. Apart from the specified live loads or any other load due to material stored, any other equipment load or possible overloading during maintenance or erection/construction shall be considered and shall be partial or full whichever causes the most critical condition.

5.19.3 Wind Load

Wind loads shall be as per IS:875 Part (III).

5.19.4 Earthquake Load

This shall be computed as per IS:1893. An importance factor appropriate to the type of structure shall be considered for design of all the structures. Chennai comes under Earthquake zone III.

5.19.5 Dynamic Load

Dynamic loads due to working of plant items such as pumps, blowers, compressors, switch gears, travelling cranes, etc. shall be considered in the design of structures. Also, Natural disaster due to tsunami which occurred on Dec26 2004 at Chennai coastal area will also be considered now so that structures will be better safe with higher Stability and Durability.

5.20 Design Conditions for Liquid Retaining Structures

Water level is assumed at the ground level for design of all the structures. All underground or partly underground liquid containing structures shall be designed for the following conditions:

(i) Liquid depth up to full height of wall including free board: no relief due to soil pressure from outside to be considered

(ii) structure empty (i.e., empty of liquid, any material, etc.): full earth pressure and surcharge pressure wherever applicable, to be considered

(iii) partition wall between dry sump and wet sump: to be designed for full liquid depth up to full height of wall

(iv) partition wall between two compartments: to be designed as one compartment empty and other full

(v) structures shall be designed for uplift in empty conditions with the water table as indicated in geotechnical report

(vi) walls shall be designed under operating conditions to resist earthquake forces from earth pressure mobilisation and dynamic water loads

(vii) Underground or partially underground structures shall also be checked against stresses developed due to any combination of full and empty compartments with appropriate ground/uplift pressures from below to base slab. A minimum factor of 1.2 shall be ensured against uplift or floatation.

(viii) All the liquid retaining structures shall be designed for maximum design crack width of 0.1 mm for direct tension and flexure.

5.21 Foundations

(i) The minimum depth of foundations for all structures, equipment, buildings and frame foundations and load bearing walls shall be as per IS:1904 but in any case this shall not be less than 1.0 meter in the original soil.

(ii) Maximum safe bearing capacity of soil strata shall be taken as indicated in geotechnical reports.

(iii) Care shall be taken to avoid the foundations of adjacent buildings or structure foundations, either existing or not within the scope of this Contract. Suitable adjustments in depth, location and sizes may have to be made depending on site conditions. No extra claims for such adjustments shall be accepted by the Engineer.

(iv) Special attention is drawn to the danger of the uplift being caused by the ground water table. All underground structural slabs shall be designed for uplift forces due to ground water pressure.

5.22 Design Requirements

The following are the design requirements for all reinforced or plain concrete structures:

(i) All blinding and leveling concrete shall be a minimum 150 mm thick in concrete grade M15.

(ii) For all water retaining reinforced concrete structures, concrete shall be of a minimum

M35 grade (and as per IS 3370) and for all other reinforced concrete structures, reinforced concrete shall be of a minimum M35 grade (and as per IS 456). Maximum aggregate size shall be 20 mm for all the reinforced concrete works.

(iii) The concrete for reinforced concrete structures shall have a minimum cement content of 360 kg/m3 with a maximum 20 mm size aggregate. Reinforced concrete shall have minimum slump of 100mm with maximum water cement ratio of 0.45.

(iv) The minimum clear cover to all reinforcement including stirrups and links shall be 50 mm for all water retaining structures. As a design consideration to control the crack, though general requirement shall be as per IS:3370 but all the water retaining structures including roof slab shall be designed on permissible crack width of 0.1 mm (as per BS 8007).

(v) The amount of reinforcement in each of the two directions at right angles within each surface zone should not be less than 0.35% of the surface zone cross section (as per Clause 2.6.2.3 of BS 8007-1987). For slabs, minimum of 10 mm dia bars shall be used to avoid any deformation of lesser diameter bars under loads prior to construction.

(vi) The minimum cover to the main reinforcing bars for different members for non–water retaining structures shall be as follows unless stated otherwise:

Slab (Floor, Roof, Canopy, and Staircase)	:	30 mm
Beams (Sides, Bottom & Top)	:	40 mm
Columns	:	50 mm
Pedestals (in contact with earth)	:	50 mm
Basement wall, retaining walls		
a) Face in contact with earth	:	40 mm
b) Interior face	:	30 mm
Foundations	:	50 mm

(vii) For reinforced concrete structures, reinforcement shall be HYSD Steel of grade Fe 500 (coated) as per acceptance of the Engineer.

(viii) All buildings shall have a minimum 1.2 meter wide, 100 mm thick plinth protection paving in M20 grade concrete or stone slabs/tiles. All plinth protection shall be supported on well compacted strata.

(ix) All pipes and ducts laid below the structural plinth and road works shall be surrounded with concrete of minimum grade M15 over sand bedding or as per approved drawings.

(x) Detailing of the reinforcement and sizing of structural members shall be done as per latest IS:-13920.

(xi) Any structure or pipeline crossing below roads shall be designed for Class 'A' of IRC loading. All foundation shall have water proofing coating and wrapping as per Drawing due to sea shore / or as per IS code.

(xii) Sliding layer or slip layer shall be provided between sub base and structural slab (Raft). Polythene sheets of 1000 gauge shall be provided as sliding layer as per IS specification.

(xiii) Water tightness testing of water retaining structures shall be performed in accordance with IS:3370 (Part I). It is described in Clause 5.34 under this Part-5. The depth of water for testing shall be up to the soffit of the covering slab.

The following minimum thicknesses shall be used for different reinforced concrete members, irrespective of design thicknesses:

(i)	Walls for liquid retaining structures	300 mm
(ii)	Roof slabs for liquid retaining structures (other than flat slabs)	240 mm
(iii)	Bottom slabs/Raft for liquid retaining structures	300 mm
(iv)	Floor slabs including roof slabs, walkways, canopy slabs	150 mm
(v)	Walls of cables/pipe trenches, underground pits, etc.	150 mm
(vi)	Column footings	450 mm
(vii)	Parapets, chajja	125/150 mm
(viii)	Precast trench cover	75 mm

(xiv) Design of all reinforced concrete structures shall be as per IS:456, of pre-stressed concrete structures as per IS:1343. Water retaining structures as per IS 3370, The structural safety of all foundations on soil shall, in general be based on IS:1904.

(xv) For calculation purpose "Limit state Design" methods according to IS:456-2001 shall generally be adopted, except for water retaining structures where IS:3370 (Part I-IV) shall be referred and other special cases requiring design by working stress method.

(xvi) All grouting below machine/equipment bases, and pockets shall be non-shrinking grout of adequate thickness and minimum grade of M35 with 6mm and down aggregates. Grouting below structural column bases shall be minimum grade of M35 with 6mm and down aggregates.

(xvii) PCC grade M15 – Apron, plinth protection, screed concrete, foundation below masonry walls, encasing of underground pipes & conduits, ground floor at plinth level, toilet, rest room, etc.

(xviii) All foundations and concrete structures shall be designed to resist full operating dead and live loads, with appropriate combination of wind and seismic forces and with due allowance for impact, inertia loading, vibration, unbalanced dynamic loads, etc. as secondary effect of live loads, erection loads, temperature variation etc. While designing structures and foundations either the effect of seismic forces or wind loads, whichever produces the worst effect, shall be considered along with usual load conditions. Apart from the installation and operating loads indicated by the equipment manufacturers, the design of buildings and structures shall be based on dead and imposed loads calculated according to IS:875. All structures shall be designed for seismic load as per IS1893 2002/latest in the category one above as stated in the specified code.

(xix) Concentrated and uniformly distributed live load on floors and platforms shall be considered depending upon the usage and in accordance with maximum expected process requirements, to be indicated by the equipment manufactures. When the loads are movable, they shall be so placed as to get worst effect in moment & shear, axial load etc. for which the elements shall be designed. The effect of concentrated load shall not be reduced. Due allowance shall be made, wherever necessary, for installation and operation of any equipment as per equipment manufacturer's data and recommendations. The design shall be based on the maximum loading due to uniform live load and/or equipment loading including impact, vibration, unbalanced operating forces, etc.

(xx) Foundations for structures and equipment shall be proportioned to resist the worst combination of loading and shall generally be designed as per the provision of IS:1904 for open foundations on soil and IS: 2911 for foundations on piles.

5.23 Concrete and Allied Works

5.23.1 Materials in General

The term "materials" shall mean all materials, goods and articles of every kind whether raw, processed or manufactured and equipment and plant of every kind to be supplied by the Contractor for incorporation in the Works. Except as may be otherwise specified for particular parts of the Works, the provision of clauses in "Materials and Workmanship" shall apply to materials and workmanship for any part of the Works. All materials shall be new and of the kinds and qualities described in the Contract and shall be at least equal to approved samples.

As soon as practicable after receiving the order to commence the Works, the Contractor shall inform to the Engineer of the names of the suppliers from whom he proposes to obtain any materials but he shall not place any order without the approval of the Engineer which may be withheld until samples have been submitted and satisfactorily tested. The Contractor shall thereafter keep the Engineer informed of orders for and delivery dates of all materials.

Materials shall be transported, handled and stored in such a manner as to prevent deterioration, damage or contamination failing which such damaged materials will be rejected and shall not be used on any part of the Works under this contract.

The quality of materials and method and control of manufacture and transportation of all concrete work irrespective of mix, whether reinforced or otherwise, shall conform to the applicable portions of this specification. The Employer's representative shall have the right to inspect the source/s of material/s, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and Employer's representative approval obtained, prior to starting of concrete work.

5.23.2 Materials for Standard Concrete

The ingredients to be used in the manufacture of concrete shall consist solely of Portland cement, clean sand, natural coarse aggregate, clean water and admixtures, if specifically called for on drawings or specifications, or to the approval of the Employer's Representative if conditions at site warrant its use.

5.23.2.1 *Cement*

Unless otherwise specified in the Specification or called for by the Employer's Representative, cement shall be ordinary Portland cement (OPC-43 grade) Bags /SRS/ conforming to IS:269 unless specifically defined. The use of bulk cement will be permitted only with the approval of the Employer's Representative. Changing of brands or type of cement within the same structure should be avoided as far as possible.

However, cement for all works submerged under sea water shall be Portland Slag cemet43 grade in 50 kg. Bags conforming to IS:269 unless specifically defined. The use of bulk cement will be permitted only with the approval of the Employer's Representative. Changing of brands or type of cement within the same structure should be avoided as far as possible. Sample shall be tested at approved Laboratory at Contractor's cost from each lot of cement delivered at site.

The Contractor will have to make his own arrangements for the supply and storage of an adequate quantity of cement. Employer will not supply cement. It will be the responsibility of the Contractor to ensure adequate and proper storage and complete protection from dampness, contamination and minimize caking and false set. Cement bags shall be stored in a dry enclosed shed (storage under tarpaulins will not be permitted), well away from the outer walls, and insulated from the floor to avoid contact with moisture from the ground and so arranged as to provide ready access. Damaged or reclaimed or partly set cement will not be permitted to be used and shall be removed from the site. The storage arrangement shall be such there is no dead storage. Not more than 12 bags shall be stacked in any tier. The Employer's Representative shall approve the storage arrangement. Consignments cement shall be stored as received and shall be consumed in the order of their delivery.

Cement held in storage for a period of ninety (90) days or longer shall be tested. Should at any time the Employer's Representative have reasons to consider that any cement is defective, then irrespective of it origin, date of manufacture and/or manufacture's test certificate, such cement shall be tested immediately at the Contractor's cost at the approved laboratory and until the results of such tests are found satisfactory, it shall not be used in any work. The Contractor shall not be entitled to any claim of any nature on this account.

5.23.2.2 *Aggregates*

i) General

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

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

“Coarse Aggregate" is aggregate most of which is retained on 4.75 mm IS sieve.

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

Aggregates shall, except as noted above, consist of natural sands, manufactured Quarry Sand-M-Sand, crushed stone and gravel from a source known to produce satisfactory aggregate for concrete and shall be chemically inert, strong, hard, durable against weathering, of limited porosity and free from deleterious materials that may cause corrosion of the reinforcement or may impair the strength shall such as to produce a dense concrete of specified strength and consistency that will work readily into position without segregation and shall be based on the "mix design" and preliminary tests on concrete specified later.

ii) Sampling and Testing

Samples of the aggregates for mix design and determination of suitability shall be taken under the supervision of Employer's Representative and delivered to the laboratory, well in advance of the scheduled placing of concrete. Records of tests which have been made on proposed aggregates and on concrete made from this source of aggregates shall be furnished to Employer's Representative in advance of the work for use in determining aggregate suitability. The costs of all such tests, sampling, etc., shall be borne me by Contractor.

iii) Storage of Aggregates

All coarse and fine aggregates shall be stacked separately in stock piles in the material yard near the work site in bins properly constructed to avoid inter mixing of different aggregates. Contamination with foreign material and earth during storage and while heaping the materials shall be avoided. The aggregate must be of specified quality not only at the time of receiving at site but more so at the time of loading into mixer. Rakers shall be used for lifting the coarse aggregates from bins or stockpiles. Coarse aggregate shall be piled in layers not exceeding 1.20 meters in height to prevent coning or segregation. Each layers shall cover the entire area of the stock pile before succeeding layers are started. Aggregates that have become segregated shall be rejected. Rejected material after remixing may be accepted, if subsequent tests demonstrate conformance with required gradation.

iv) Specific Gravity

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

5.23.3 Fine Aggregate

Fine aggregate shall consist of natural or crushed sand conforming to I.S. 383 (latest version). The sand shall be clean, sharp, hard strong and durable and shall be free from dust, vegetable substances, adherent coating, clay, alkali, organic matter, mica, salt, or other deleterious substances, which can be injurious to the setting qualities/strength/durability of concrete.

a) Machine-made Sand – M-Sand

Machine-made sand will be acceptable, provided the constituent rock gravel composition shall be sound, hard, dense, non-organic, uncoated and durable against weathering.

b) Screening and Washing

Sand shall be prepared for use by such screening or washing, or both, as necessary, to remove all objectionable foreign matter while separating the sand grains to the required size tractions.

c) Foreign Material Limitations

The percentage of deleterious substance in sand delivered to, the mixer shall not exceed the following:

		Percent by weight	
		Uncrushed	Crushed
i)	Material finer than 75 micron I.S sieve	3.00	15.00
ii)	Shale	1.00	—
iii)	Coal and lignite	1.00	1.00
iv)	Clay lumps	1.00	1.00
v)	Total of all above substances including items (i) to (iv) for uncrushed sand and items (iii) and (iv) for Crushed sand	5.00	2.00

d) Gradation

Unless otherwise directed or approved by the Employer's Representative, the grading of sand shall be within the limits indicated hereunder.

	Percentage Passing for			
I.S. Sieve Designation	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Where the grading falls outside the limits of any particular grading zone of sieves, other than 600 micron I.S. sieve, by total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 micron IS. sieve or to percentage passing any other sieve size on the coarser limit of Grading Zone I or the finer limit of Grading Zone IV. Fine aggregates conforming to Grading Zone IV shall be used unless mix designs and preliminary tests shall show its suitability for producing concrete of specified strength and workability.

e) Fineness Modulus

The sand shall have a fineness modulus of not less than 2.2 or more than 3.2. The fineness modulus is determined by adding the cumulative percentages retained on the following I.S.

sieve sizes (4.75mm, 2.36mm, 1.18mm, 600micron, 300micron and 150micron) and dividing the sum by 100.

5.23.4 Coarse Aggregate

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

a) Screening and Washing

Natural gravel and crushed rock shall be screened and/or washed for the removal of dirt or dust coating, if so directed by the Employer's Representative.

b) Grading

Coarse aggregate shall be either in single size or graded, in both cases the grading shall be within the following limits:

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

The pieces shall be angular in shape and shall have granular or crystalline surfaces. Friable, flaky and laminated pieces, mica and shale, if present, shall be only in such quantities that will not, in the opinion of the Employer's Representative, affect adversely the strength and/or durability of concrete. The maximum size of coarse shall be the maximum size specified above, but in no case greater than 1/4 the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Plums above 160 mm and upto any reasonable size can be used in plain mass concrete work of large dimensions upto a maximum limit of 20% by volume of concrete when specifically approved by Employer's Representative. For heavily reinforced concrete members, the nominal maximum size of the aggregate shall be 5 mm less than the minimum clear distance between the reinforcing main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller. The amount of fine particles occurring in the free state or as loose adherent shall not exceed 1% when determined by laboratory sedimentation tests as per I.S, 2386. After 24 hours immersion in water, a previously dried sample shall not have gained more than 10% of its oven dry weight in air, as determined by I.S. 2386.

c) Foreign Material Limitations

The percentage of deleterious substances in the aggregate delivered to the mixer shall not exceed the following or refer Is code 383 -1970:

S.N.	Foreign Material	Percent by weight	
		Uncrushed	Crushed
i)	Material finer than 75 micron I.S Sieve	3.00	3.00
ii)	Coal and lignite	1.00	1.00
iii)	Clay lumps	1.00	1.00
iv)	Soft fragments	3.00	—
v)	Total of all the above substances	5.00	5.00

5.23.5 Water

Water used for both mixing and curing, shall be free from injurious amounts of deleterious materials. Product water is generally satisfactory for mixing and curing concrete.

In case of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in I.S. 456. The sample of water for testing shall be typical of the water proposed to be used for concreting, due account being paid to seasonal variation. The sample shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

Average 28-day compressive strength of at least three 15 cm concrete cubes prepared with water proposed to be used shall not less than 90% of the average strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the requirements of I.S. 516.

The initial setting time of test block made with the appropriate test cement and the water proposed to be used shall not be less than 30 minutes and shall not differ by more than ±30 minutes from the initial setting time of control test block prepared with the appropriate test cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of I.S. 4031.

Where water can be shown to contain an excess of acid, alkali, sugar or salt, Employer's Representative may refuse to permit its use. As a guide, the following concentrations represent the maximum permissible values:

(a) To neutralize 200 ml, sample of water, using Phenolphthalein as indicator, it should not require more than 2 ml. of 0.1 Normal NaOH. The details of test shall be as given in I.S: 3025.

(b) To neutralize 200-ml. sample of water, using methyl orange, as an indicator should not require more than 10 ml. of 0.1 Normal HCL. The details of test shall be as given in I.S:

3025.

(c) Percentage of solids, when tested in accordance with the method indicated below, shall not exceed the following:

Solids	Percent	Method of Test
		(Ref. to Cause No. In IS :3025)
Organic	0.02	10 and 11 (organic solids = total solids minus ignited residue)
Inorganic	0.30	11 (ignited residue)
Sulphates (as SO4)	0.05	20
Alkali Chloride (As Cl)	0.20	24
Suspended matter	0.20	12

5.24 Steel Members Encased in Concrete

Structural steel columns, beams, girders and bracings to be encased in concrete shall be unpainted. The encasing shall be done in concrete with 10 mm maximum size aggregate and works cube strength not less than 15 N/mm2 at 28 days unless otherwise specified. The steel member shall be wrapped with galvanised wire mesh of adequate size.

All stell members in the floor level in tanks contact with sea water shall be embeed in concrete for min. 450 mm above the fished floor level.

The galvanised wire mesh shall be at 20 mm from the edge or surface of the steel member and shall be held in position securely. The steel, member will have a minimum cover of 50 mm unless otherwise indicated on the drawings. Where the clear cover to steel is more than 75mm, mild steel bar and concrete with 20 mm coarse aggregate can be used.

5.24.1 Controlled Concrete

All concrete in the works shall be "controlled concrete" as defined in IS 456, except for M7.5 and M10 for which nominal mix concrete shall be used. Whether reinforced or otherwise, all concrete works to be carried out under this specification shall be divide into the following classification:

Minimum compressive strength of 15 cm. Cubes at 7 and 28 days after mixing conducted in accordance with I.S. 516						
Class	Preliminary test N/mm2		Works test N/mm2		Max. size of aggregate	Locations for use
	At 7 days	At 28 days	At 7 days	At 28 days		
M40	33.5	50.0	27.0	40.0	20	As indicated in the specifications or as
M35	30.0	44.0	23.5	35.0	20	

M30	25.0	38.0	20.0	30.0	40 or 20	required.
M25	22.0	32.0	17.0	25.0	40 or 20	
M20	17.5	26.0	13.5	20.0	40 or 20	
M15	13.5	20.0	10.0	15.0	40 or 20	

Notes: It shall be very clearly understood that whenever the concrete such M 20, etc. is specified it shall be Contractor's responsibility to ensure that minimum crushing strength stipulated for the respective grade of concrete is obtained at works.

Minimum cement content in the concrete used for liquid/ water retaining structure shall be 360 kg/m3 for 20 mm downgraded aggregate and 325 kg/m3 for 40 mm downgraded aggregate.

5.24.2 Mix Design

5.24.2.1 *General*

This is to investigate the grading of aggregates, water cement ratio, workability and the quantity of cement required to give preliminary and works cubes of the minimum strengths specified. The proportions of the mix shall be determined by weight. Adjustment of aggregate proportions due to moisture present in the aggregate shall be made.

Determination of mix proportions shall be carried out according to "Recommended Guidelines for Concrete Mix Design' conforming to IS: 10262.

Whenever there is change either in required strength of concrete, or water-cement ratio or workability or the source of aggregates and/or cement, preliminary tests shall be repeated to determine the revised proportions of the mix to suit the altered conditions. While designing mix proportions, over-wet mixes shall always be avoided. While fixing the value for water/cement ratio for preliminary mixes, assistance maybe derived from IS: 456.

The Contractor shall give the Engineer seven days' notice in writing, of the date on which, any of the materials will be ready for testing or inspection at the supplier's premises or at a laboratory approved by the Engineer. The Employer's representative shall attend the test at the appointed place within seven days of the said date on which the materials are expected to be ready for testing or inspection according to the Contractor, failing which the test may proceed in his absence unless instructed by the Engineer to carry out such a test on a mutually agreed date in his or his representative's presence. The Contractor shall in any case submit to the Engineer, within seven days of every test, such number of certified copies (not exceeding six) of the test results as the Engineer may require. Approval by the Engineer, as to the placing of orders for materials or as to samples or tests, shall not prejudice any of the Engineer's powers under the Contract. The provisions of this clause shall also apply to materials supplied under any nominated sub-contract.

5.24.2.2 *Preliminary Tests*

Test specimens shall be prepared with at least two different water/cement ratios for each class of concrete, consistent with workability required for the nature of the work.

The materials and proportions used in making preliminary tests shall be similar in all respects to those to be actually employed in the works as the object of these tests is to determine the proportions of cement, aggregates and water necessary to produce concrete of required consistency and to give the specified strength. It will be Contractor's sole responsibility to carry out these tests and he shall therefore furnish to Employer's Representative a statement of proportions proposed to be used for the various concrete mixes. For preliminary tests, the following procedure shall be followed:

Materials shall be brought to the room temperature and all materials shall be in a dry condition. The quantities of water, cement and aggregates for each batch shall be determined by weight to an accuracy of 1 part in 1000 parts.

(i) Mixing Concrete

It shall be done by hand or in a small batch mixer as per I.S. 516 in such a manner as to avoid loss of water. The cement and fine aggregate shall first be mixed dry until the mixture is uniform in colour. The coarse aggregate shall then be added, mixed and water added and the whole batch mixed thoroughly for a period of not less than two minute until the resulting concrete is uniform in appearance. Each batch of, concrete shall be of such a size as to leave about 10% excess concrete, after moulding the desired number of test specimens.

(ii) Consistency

The consistency of each batch of concrete shall be measured immediately after mixing, by the slump test in accordance with I.S. 1199. If in the slump test, care is taken to ensure that no water or other material is lost, the material used for the slump test may be remixed with the remainder of the concrete for making the specimen test cubes. The period of re-mixing shall be as short as possible yet sufficient to produce a homogeneous mass.

(iii) Size of Test Cubes

Compression tests of concrete cubes shall be made as per I.S.516 on 15 cm. cubes. Each mould shall be provided with a metal base plate having a plain surface so as to support the mould during filling without leakage.

The base plate shall be preferably attached to the mould when assembled shall be positively and rigidly held together. Before placing concrete, the mould and base plate shall be cleaned and oiled. The dimensions and internal faces of the mould shall be accurate within the following limits:

Height and distance between the opposite faces of the mould shall be of specified size +0.2 mm. The angle between the adjacent internal faces and between internal faces and top and bottom faces of mould shall be 90 +_ 0.5°. The interior faces of the mould shall be plain surface with a permissible variation of 0.03 mm.

(iv) Compacting

Concrete test cubes shall be moulded by placing fresh concrete in the mould and compacted as specified in I.S. 516.

(v) Curing

Curing shall be as specified in I.S.516. The cubes shall be kept in moist air of at least 90% relative humidity at a temperature of 27° ±_2° C for 24 hours ±1/2 hour from the time of adding water to the dry ingredients. Thereafter they shall be removed from the moulds and kept immersed in clean, fresh water and kept at 27° ± 2° C temperature "until required for test. Curing water shall be always clean without any chemicals and will be renewed every seven days. A record of maximum temperatures at the place of-storage of the cubes shall be maintained during the period they remain in storage.

(vi) Testing of Specimens

The strength shall be determined based on not less that five cube test specimens for each age and each water cement ratio. All these laboratory test results shall be tabulated and furnished to the Employer's Representative. The test results shall be accepted by the Employer's Representative if the average compressive strength of the specimens tested is not less than the compressive strength specified for the age at which specimens are tested subject to the condition that only one out of the five consecutive tests may give a value less than the specified strength for that age. The Employer's Representative may direct the Contractor to repeat the tests if the results are not satisfactory and also make such changes as he considers necessary to meet the requirement specified. All these preliminary tests shall be conducted by the Contractor at his own cost in the approved laboratory.

5.24.3 Proportioning, Consistency, Batching and Mixing of Concrete

5.24.3.1 *Proportioning*

(i) Aggregate

The proportions which shall be decided by conducting preliminary tests shall be by weight. These proportions of cement, fine and coarse aggregates shall be maintained during subsequent concrete batching by means of weigh batchers conforming to I.S. 2722 capable of controlling the weights within one percent of the desired value. Except where it can be shown to the satisfaction of the Employer's Representative that supply of properly graded aggregate of uniform quality can be maintained over the period of work, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions.

The different sizes shall be stocked in separate stock piles. The grading of coarse and fine aggregate shall be checked as frequently as possible, as determined by the Employer's Representative, to ensure maintaining of grading in accordance with the samples used in preliminary mix design. The material shall be stock piles well in advance of use.

(ii) Cement

Cement shall be measured by weight.

(iii) Water

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

(iv) Definition of Water/ Cement Ratio

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

(v) Water/ Cement Ratio

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

(vi) Proportioning by Water/ Cement Ratio

The W/C ratio specified for use by the Employer's Representative shall be maintained. The Contractor shall determine the water content of the aggregates as frequently as directed by the Employer's Representative as the work progresses and as specified in I.S. 2386 (Part ID) and the amount of mixing water added at the mixer shall be adjusted as directed by the Employer's Representative so as to maintain the specified W/C ratio. To allow for the variation in weight of aggregates due to variation in their moisture content, suitable adjustments in the weights of aggregates shall also be made.

5.24.3.2 *Consistency and Slump*

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

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

Table 5-1: Slumps for Various Types of Construction

Works Details	Slump in millimeters	
	Maximum	Minimum
Reinforced foundation walls and footings	75	25
Plain footings and substructure walls	75	25
Slabs, Beams and reinforced walls	100	25
Pumps & Miscellaneous Equipment foundations	75	25
Building Columns	100	25

Pavements	50	25
Heavy Mass Construction	50	25

5.24.3.3 *Batching and Mixing of Concrete*

The materials and proportions of concrete materials as established by the preliminary tests for the mix designs shall be rigidly followed for all concrete on the Works and shall not be changed except when specifically permitted by the Employer's Representative.

Concrete shall be produced only by weigh batching the ingredients. The mixer and weigh batchers shall be maintained in clean, serviceable condition. The accuracy of weigh batchers shall be periodically checked. They shall be set up level on a firm base and the hopper is empty. Fine and coarse aggregates shall be weighed separately. Volume batching will not be permitted. However, the Employer's Representative may permit volume batching by subsequent conversion of the weights of the aggregate into their equivalent volumes knowing their bulk densities, only in the case of small and less important pours involving weigh batching are not likely to be taken up. Concrete shall be of strength stipulated in the respective items. All concrete shall be mixed in mechanically operated batch mixers complying with I.S. 1791 and of the approved make with suitable provision for correctly controlling the water delivered to the drum. The quantity of water actually entering the drum shall be checked with the reading of the gauge or valve setting, when starting a job. The test should be made while the mixer is running. The volume of the mixed material shall not exceed the manufacturer's rated mixer capacity. The batch shall be charged into the mixer so that some water will enter the drum in advance of cement and aggregates. All water shall be in the drum by the end of the first 15 seconds of the specified mixing time.

Each batch shall be mixed until the concrete is uniform in colour, for a minimum period of two minutes after all the materials and water are in the drum. The entire contents of the drum shall be discharged in one operation before the raw materials for the succeeding batches are fed into the drum. Each time the work stops, the mixer shall be cleaned out and when next commencing the mixing, the first batch shall have 10% additional cement to allow for sticking in the drum.

5.25 Mix Design Reinforced Concrete

All water retaining structures shall be designed as per IS3370 part I to IV.

The works under this head covers all activities including raw materials, transportation to site, Reinforced Cement Concrete grades M15, M20, M30, M35, M40 shall be mix design as specified in General Specifications. In case WPC is required to be added (if specified), same shall conform with general specifications in all respects. Admixtures, as specified in General Specifications, shall be added, if directed by Employer's Representative depending on grade of concrete and construction requirements without any extra cost implication. Minimum M 30 grade for buildings and M-35 for Water Retaining Structures shall be used, no grade below the said is permissible. Care shall be taken to ensure proper cleaning and washing of the Drum.

Contractor shall comply with all testing requirements as specified in General Specifications for raw materials and concrete (for all grades of concrete).

5.25.1 Admixtures

5.25.1.1 *General*

Admixtures may be used in concrete where required, only with the approval of the Employer's Representative based upon evidence that, with the passage of time, neither the compressive strength nor its durability reduced.

Calcium chloride shall not be used for accelerating set of the cement for concrete containing reinforcement, or embedded steel parts. When calcium chloride is permitted to be used, such as in mass concrete works, it shall be dissolved in water and added to the mixing water in an amount not to exceed 1 1/2 % of the weight of the cement in each batch of concrete. When admixtures are used, the designed concrete mix shall be corrected accordingly. Admixtures shall be used as per manufacturer's instructions and in the manner and with the control specified by the Employer's Representative.

5.25.1.2 *Air Entraining Agents*

Neutralized vinsol resin or any other approved air entraining agent may be used to produce the specified amount of air in the concrete mix and these agents shall conform to the requirements of ASTM standard 6-20. Air entraining admixtures for concrete. The recommended total air content of the concrete is 4% ± 1%. The method of measuring air content shall be as per IS: 1199.

5.25.1.3 *Water Reducing Admixtures*

Water reducing lignosulfonate admixture may be added in quantities approved by the Employer's Representative. The admixtures shall be added in the form of a solution.

5.25.1.4 *Retarding Admixtures*

Retarding agents may be added to the concrete mix in quantities approved by the Employer's Representative.

5.25.1.5 *Water-Proofing Compound*

i) As directed by the Employer's Representative, the Contractor shall use approved waterproofing compound made by manufacturers as per list of makes herein, Volume-2, Employer's Requirement. In the reinforced concrete works. The quantity to be used shall be two percent by weight of cement or shall be in accordance with the manufacturer's instructions subject however to the approval of the Employer's Representative. The compound shall not contain calcium chloride and shall conform to IS: 2645.

ii) Mixing water proofing compound with cement. The compound should be mixed thoroughly with the cement by hand before the cement is mixed with aggregate. Thorough mixing is essential. The two materials should be heaped on a mixing board thoroughly turned over several times with a shovel and finally passed through a fine sieve. If labour is unsatisfactory the sieving should be done twice to ensure maximum dispersal of the compound throughout the cement.

iii) Mixing the concrete - The mixture of water proofing compound and cement should then be added to the aggregate, the dry materials turned over twice and the correct amount of water then added through a rose spray, A further thorough mixing by spade should immediately follow. Only the minimum quantity of water necessary to give workability should be used such that it will make the concrete just sufficiently plastic for purposes of placing and thorough consolidation without affecting its strength.

5.25.1.6 *Corrosion Inhibitors*

Corrosion Inhibitors shall be added to concreting for water retaining structures in contact with sea water as well for use of concrete to embed the structural steel.

5.25.2 Concrete in Alkali Soils and Alkaline Water

Where concrete is vulnerable to attack from alkali salts or alkaline water, special cements containing low amount of tricalcium aluminate shall be used, if so specified or directed. Such concrete shall have a minimum 28 days compressive strength of 25 N/mm2 and shall contain not less than 3.7 KN of cement per cubic metre of concrete in place. If specified, additional protection shall be obtained by the use of chemically resistant stone facing or a layer of Plaster of Paris covered with suitable fabric, such as jute thoroughly impregnated with tar.

5.25.3 Preparation Prior to Concrete Placement

Before the concrete is actually placed in position, the insides of the formwork shall be inspected to see that they have been cleaned and oiled. Temporary openings shall be provided to facilitate inspection, especially of bottoms of columns and wall forms, to permit removal of saw dust wood shavings, binding wire, rubbish, dirt, etc. Openings shall be placed or holes drilled so that these materials and water can be removed. Such openings/holes shall be later suitably plugged. The various trades shall be permitted ample time to install drainage and plumbing lines, floor and trench drains, conduits, hangers, anchors, inserts, sleeves, bolts, frames and other miscellaneous embedded to be cat in the concrete as specified or required or as is necessary for the proper execution of the work.

All embedded parts, inserts, etc., supplied by the Corporation or the Contractor shall be correctly positioned and securely held in the forms, to prevent displacement during depositing and vibrating of concrete.

All anchor bolts shall be positioned and kept in place with the help of properly manufactured templates unless specifically waived in writing by the Employer's Representative.

Slots, openings, holes, pockets, etc., shall be provided in concrete work in the positions specified or required or as directed by the Employer's Representative.

Reinforcement and other items to be cast in concrete shall have clean surfaces that will not impair bond.

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

Approval by the Employer's Representative of any and all materials and work as stated herein shall not relieve the Contractor from his obligation to produce finished concrete in accordance with the requirements of the specification.

5.25.3.1 *Rain or Wash Water*

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

5.25.3.2 *Bonding Mortar*

Immediately before concrete placement begins, prepared surfaces except formwork, which will come in contact with the concrete to be placed, shall be covered with a bonding mortar as specified.

5.26 Standards

Materials and workmanship shall comply with the relevant Indian Standards (with amendments) current on the date of submission of the tender. Where the relevant standard provides for the furnishing of a certificate to the Engineer, at his request, stating that the materials supplied comply in all respects with the standard, the Contractor shall obtain the certificate and forward it to the Engineer. The specifications, standards and codes listed below are considered to be part of these specifications. All standards, specifications, codes of practices referred to herein shall be the latest editions including all applicable official amendments and revisions. In case of discrepancy between the Specifications and the Standards referred to herein, the Specifications shall govern.

5.26.1 Materials

IS:269 Specification for 33 grade ordinary Portland cement

IS:278 Specification for Galvanized Steel Barbed Wire for Fencing

IS:383 Specification for coarse and fine aggregates from natural sources for concrete

IS:428 Specification for distemper, oil emulsion, colour as required

IS:432 Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement (Parts 1 & 2)

IS:455 Specification for Portland slag cement

IS:458 Specification for precast concrete pipes (with and without reinforcement)

IS:650 Specification for standard sand for testing of cement

IS:651 Specification for salt glazed stoneware pipes and fittings

IS:808 Specification for dimensions for hot rolled steel beam, column channel and angle sections

IS:814 Specification for covered electrodes for manual metal arc welding of Carbon and Carbon Manganese steel

IS:1003 Specification for timber paneled and glazed shutters (Parts 1 & 2)

IS:1038 Specification for steel doors, windows and ventilators

IS:1077 Specification for common burnt clay building bricks

IS:1398 Specification for packing paper, water proof, bitumen laminated

IS:1489 Specification for Portland pozzolana cement (Parts 1 & 2)

IS:1566 Specification for hard drawn steel wire fabric for concrete reinforcement

IS:1580 Specification for bituminous compounds for water proofing and caulking purposes

IS:1786 Specification for high strength deformed steel bars and wires for concrete reinforcement

IS:1852 Specification for rolling and cutting tolerances for hot rolled steel products

IS:1948 Specification for aluminum doors, windows and ventilators

IS:1977 Specification for structural steel (ordinary quality)

IS:2062 Specification for steel for general structural purposes

IS:2140 Specification for Stranded Galvanized Steel Wire for Fencing

IS:2185 Specification for concrete masonry units (Parts 1 & 2)

IS:2202 Specification for wooden flush door shutters (Parts 1 & 2)

IS:2645 Specification for integral cement water proofing compounds

IS:2750 Specification for steel scaffoldings

IS:2835 Specification for flat transparent sheet glass

IS:3384 Specification for bitumen primer for use in waterproofing and damp proofing

IS:3502 Specification for steel chequered plates

IS:4021 Specification for timber door, window and ventilator frames

IS:4350 Specification for concrete porous pipes for under drainage

IS:4351 Specification for steel door frames

IS:4990 Specification for plywood for concrete shuttering work

IS:8112 Specification for 43 grade ordinary Portland cement

IS:9862 Ready mixed paint, brushing, bituminous, black, lead free, acid, alkali, water and chlorine resisting

IS:10262 Recommended guidelines for concrete mix design

IS:12269 Specification for 53 grade ordinary Portland cement

IS:12330 Specification for sulphate resisting Portland cement

5.26.2 Tests

IS:516 Method of test for strength of concrete

IS:1182 Recommended practice for radiographic examination of fusion - welded butt joints in steel plates

IS:1199 Methods of sampling and analysis of concrete

IS:2386 Methods of test for aggregates for concrete (Parts 1 to 8)

IS:2720 Methods of test for soils (Parts 1 to 39)

IS:3025 Methods for sampling and test (physical and chemical) for water and wastewater (Parts 1 to 59)

IS:3495 Method of test for burnt clay building bricks (Parts 1 to 4)

IS:3613 Acceptance tests for wire flux combination for submerged arc welding

IS:4020 Methods of tests for wooden flush doors shutters: Type tests

IS:4031 Methods of physical tests for hydraulic cement (Parts 1 to 15)

IS:5807 Method of test for clear finishes for wooden furniture (Parts 1 to 6)

IS:7318 Approval tests for welders when welding procedure approval is not required (Parts 1 and 2)

IS:13311 Methods of Non-destructive testing of Concrete: Part 1 & Part 2

5.26.3 Codes of Practice

IS:456 Code of practice for plain and reinforced concrete

IS:783 Code of practice for laying of concrete pipes

IS:800 Code of practice for general construction in steel

IS:806 Code of practice for use of steel tubes in general building construction

IS:816 Code of practice for use of metal arc welding for general construction in mild steel

IS:817 Code of practice for training and testing of metal arc welders

IS:875 Code of practice for design loads (other than earthquake) for building structures (Parts 1 to 5)

IS:1081 Code of practice for fixing and glazing of metal (steel and aluminum) doors, windows and ventilators

IS:1172 Code of practice for basic requirements for water supply, drainage and sanitation

IS:1477 Code of practice for painting of ferrous metals in buildings (Parts 1 & 2)

IS:1597 Code of practice for construction of stone masonry (Parts 1 & 2)

IS:1742 Code of practice for building drainage

IS:1893 Criteria for earthquake resistant design of structures (Part 1)

IS:1904 Code of Practice for Design and Construction of Foundation in Soils: General Requirements.

IS:1948 Specification of aluminum doors, windows and ventilators

IS:2065 Code of practice for water supply in buildings

IS:2204 Code of practice for construction of reinforced concrete shell roof

IS:2210 Code for design of reinforced concrete shell structures and folded plates

IS:2212 Code of practice for brickwork

IS:2338 Code of practice for finishing of wood and wood based materials (Parts 1 & 2)

IS:2394 Code of practice for application of lime plaster finish

IS:2395 Code of practice for painting, concrete, masonry and plaster surfaces (Parts 1 & 2)

IS:2470 Code of practice for installation of septic tanks (Parts 1 & 2)

IS:2502 Code of practice for bending and fixing of bars for concrete reinforcement

IS:2571 Code of practice for laying in-situ cement concrete flooring

IS:2595 Code of practice for radiographic testing

IS:2751 Recommended practice for welding of mild steel plain and deformed bars for reinforced construction

IS:2974 Code of practice for design and construction of machine foundations (Parts 1 to 4)

IS:3114 Code of practice for laying of Cast Iron pipes

IS:3370 Code of practice for concrete structures for the storage of liquids
(Parts 1 to 4)

IS:3414 Code of practice for design and installation of joints in buildings

IS:3558 Code of practice for use of immersion vibrators for consolidating concrete

IS:3658 Code of practice for liquid penetrant flaw detection

IS:3935 Code of practice for composite construction

IS:4000 Code of practice for High strength bolts in steel structures

IS:4014 Code of practice for steel tubular scaffolding (Parts 1 & 2)

IS:4111 Code of practice for ancillary structures in sewerage system (Parts 1 to 4)

IS:4127 Code of practice for laying of glazed stoneware pipes

IS:4326 Code of practice for Earthquake Resistant Design and Construction of Buildings

IS:4353 Recommendations for submerged arc welding of mild steel and low alloy steels

IS:5329 Code of practice for sanitary pipe-work above ground for buildings

IS:5334 Code of practice for magnetic particle flaw detection of welds

IS:5822 Code of practice for laying of welded steel pipes for water supply

IS:7215 Tolerances for fabrication of steel structures

IS:9595 Recommendations for metal arc welding of carbon and carbon manganese steels

IS:10005 SI units and recommendations for the use of their multiples and of certain other units

5.26.4 Construction Safety

IS:3696	Safety code for scaffolds and ladder (Parts 1 & 2)
IS:3764	Safety code for Excavation work
IS:7205	Safety code for erection of structural steel work
IS:3696	Safety code for scaffolds and ladder (Parts 1 & 2)
IS:3764	Safety code for Excavation work
IS:7205	Safety code for erection of structural steel work

5.27 General Arrangement of Plant

The following general guidelines shall be followed in the preparation of general arrangement of Plant:

(i) Sufficient room shall be allowed between components of plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance.

(ii) An area adjacent to all mechanical Plant shall be provided as maintenance lay down area.

(iii) Fixed runways, lifting eyes or other means shall be provided to permit the removal of Plant that may be required to be removed during the course of its normal operational life for maintenance or any other purpose.

(iv) Areas where leakage is likely to occur, whether in normal use or during maintenance, shall be provided with covered drainage channels which shall direct spillage either to a suitable plant drain or to a sump from where it can be pumped to plant drain.

5.27.1 Buildings and Structures

All the building and structure works shall generally comply with the following requirements, unless otherwise specified elsewhere.

1. All building works shall be of reinforced concrete framework.

2. All external walls shall be in solid cement concrete blocks or brick masonry. Concrete Blocks shall be provided as per IS:2185 (Latest Revision) and shall be 200 mm thick or Brick masonry with one Brick wall thick (230 mm). Solid Concrete blocks shall have minimum compressive strength of 5 N/mm^2.

3. All internal partition walls shall be in solid concrete blocks or brick masonry. Concrete block shall be provided as per IS:2185 (Latest Revision) or Brick masonry with Half Brick thick (115 mm). Solid Concrete blocks shall have minimum compressive strength of 5 N/mm^2. All internal walls shall be 200/230mm thick except for toilets. Toilet partition walls shall be in 100/115 mm thick solid concrete block/brick.

4. (a) Finishes to concrete liquid retaining structures shall be:

    F2 External surfaces, buried

    F3 External surfaces exposed and up to 300 mm below ground level

    F2 Internal surfaces

    (b) Finishes to other concrete structures shall be:

    F2 Buried

    F2 Exposed, where plastering is specified

    F3 Exposed

5. All internal masonry surfaces finish shall have 12 mm thick plain faced cement plaster in cement mortar (1:4) with neat cement finish on top. Over this, one coat of primer and two coats of plastic emulsion paint of approved quality and shade shall be provided.
6. All external masonry surfaces and concrete surfaces with rough board finish shall have 20 mm thick sand faced cement plaster in two coats, base coat 12 mm thick in cement mortar 1:4 and finishing coat 8 mm thick in cement mortar 1:4. Waterproofing compound of approved make and quality shall be added to the cement mortar in proportions as specified by the manufacturer.
7. All external surfaces above ground level shall have one coat of primer and two coats of waterproof cement based paint of approved quality and shade. A coat of silicone water repellent paint shall also be applied thereon or as advised based on site condition by the Engineer.
8. Toilet areas, internal walls tiled up to 1.5m and rest and ceilings, shall have one coat of primer and two coats of plastic emulsion paint.
9. Toilet floor slab shall be filled with brick bat coba (broken bricks in lime) and provided with waterproofing as per the specifications of an approved specialist waterproofing company.
10. The finished floor level in toilet areas shall be 25 mm below general finished floor level elsewhere in the building.
11. The flooring in all other areas except control building, chemical building, store building, pump station buildings and toilets and staircases shall be in 450 mm x 450 mm x 25 mm thick polished Kota-stone of approved shade and pattern and placed in cement mortar to give overall thickness of 50 mm. Half tile skirting shall also be provided in these areas.
12. The flooring along with skirting in administration and control building shall be 20 mm thick mirror polished, machine cut granite slab of approved shade and pattern placed in cement mortar (1:4). Skirting for 150mm height shall be provided in these areas. Granite stone shall be provided for laboratory platforms fixed over double sandwiched cuddappah support as directed and the edges of granite is to be embedded into the wall.
13. The flooring in chemical building shall be of ceramic unglazed vitreous acid resisting tiles.
14. Pumping station buildings shall have cement concrete flooring with surface hardener.

15. All Chemical buildings shall have heavy-duty abrasion resistant tile flooring.
16. Toilet areas shall have glazed ceramic vitrified tiles placed in cement mortar 2000 mm high dado, in 150 mm x 150 mm x 6 mm thick glazed tiles placed in cement mortar shall also be provided in these areas.
17. The toilet facilities in control building shall include at least:
    (i) 2 Nos. water closets with white porcelain European pan minimum 580 mm long with flushing cistern of 10 liters capacity.
    (ii) 2 Nos. urinals of sizes 600 mm x 400 mm x 300 mm flat back type in white porcelain separated by a marble partition of size 680 mm x 300 mm with flushing water piping with water taps.
    (iii) 2 Nos. wash basins of size 510 mm x 400 mm in white porcelain with inlet, outlet and overflow arrangements.
    (iv) 2 Nos. mirror of size 400 mm x 600 mm wall mounted type fitted over wash basins.
    (v) 2 Nos. plastic liquid soap bottles
    (vi) 2 Nos. chromium plated brass towel rails minimum 750 mm long.
    (vii) All stopcocks, valves and pillar cocks shall be heavy duty chromium plated brass.
    (viii) All fittings such as `P' or `S' traps, floor traps, pipes, downtake pipes etc.
    (ix) The sewage from toilet blocks shall be led to STP.
18. In control building a canteen facility shall be provided with a washbasin, a sink, required electrical points, exhaust fan, an electric water heating pot, a micro-oven and a fridge as a minimum.
19. All staircases except in the buildings, shall have 25 mm thick polished Kotastone tiles for treads and 25 mm thick of approved shade for treads & risers set in cement mortar or lime mortar to give an overall thickness of 50 mm. Stairways with 1.5 m width shall be provided to permit access between different levels within buildings. All roof tops and overhead tanks shall be made accessible with ladder provision with SS316 hand rails. Vertical ladders fitted with landing point extensions will be permitted where approved by the Engineer to access areas not frequently visited. Plaster encapsulated Cast Iron/ GRP rungs or steps shall be provided on the inner side walls of all the water retaining structures at 300mm spacing.
20. All floor cut-outs and cable ducts, etc. shall be covered with precast concrete/GRP covers in outdoor areas and epoxy costed mild steel chequered plates of adequate thickness in indoor areas. All uncovered openings shall be protected with GI pipe hand railing 32 mm GI inside dia medium class with approved paint.
21. All staircases shall be provided with Stainless Steel 316 hand railing for protection. In existing structures damaged hand railing shall be replaced.
22. The reinforced concrete roofs shall be made waterproof by water proofing as approved by the Engineer. The finished roof surface shall have adequate slope to drain quickly the rain water to R.W down take inlet points.

23. For roofing drainage, cast iron rainwater downtake with C.I/uPVC. bell mouth and C.I./uPVC grating at top shall be provided. For roof areas up to 40 sq.m minimum two nos. 100 mm diameter downtake pipes shall be provided. For every additional area of 40 sqm or part thereof, at least one no. 100 mm dia. downtake pipe shall be provided.
24. Top surfaces of chajjas and canopies shall be made waterproof by providing a screed layer of adequate slope and sloped to drain the rain water.
25. Building plinth shall be minimum 450 mm above average finished ground level around building. Wherever cable trench shall be provided below the electrical panel, Bottom level of the cable trench shall be 100mm above the plinth level.
26. All doors, windows, rolling shutters shall have lintels above. Chajja protection to lintels on external walls shall be such as to prevent the rain water splashing into the building. Chajja projection of minimum 750 mm for rolling shutters, 600 mm for doors and 450 mm for windows shall be provided to prevent the rain water splashing into the building. Chajja shall be projected 250 mm on either side from size of doors/windows/rolling shutters.
27. All windows and ventilators shall have 25 mm thick Granite stone sills bedded in cement mortar (1:3) or 38 mm M15 RCC with 8mm dia or as per flooring material.
28. All doors, windows and ventilators shall be made of aluminium conforming to the latest version of IS:1948. All fixtures for doors, windows and ventilators shall also be of aluminium and shall be provided as per IS specifications. Aluminium grills shall be provided in all the windows. Doors shall be in two panel and both panels shall be glazed/unglazed. SS wire mesh shall be provided along with aluminium grills.
29. Openings of the windows & ventilators shall be minimum 25% of the wall area.
30. Ventilator shall also be provided where height of floor is more than 3m. All windows and ventilators shall have SS wire mesh. Frame of doors, windows and ventilators shall be of aluminium of standard rolled section. Doors, Windows and Ventilators shall be of size as per schedule to be submitted by the Contractor for approval of the Engineer. The minimum size shall be as per below:

    Door of opening size 1.2m x 2.1m

    Door of opening size 0.75m x 2.1m for toilets

    Glazed windows of minimum size 1.2m x 1.2m

    Ventilators of minimum size 0.6m x 0.6m

31. Rolling shutters shall be made of 80 x 1.25 mm MS laths. Rolling shutter shall be of minimum size 3m wide x 3.0m high. Rolling shutter shall be provided in MCC cum panel room, all chemical buildings, at entry and exit of the pump house for access to pumps, motors, valves, panels and as wherever required.
32. All structural steel members shall be painted with two coats of suitable epoxy paint over one shop and one field coat of red oxide zinc chrome primer.
33. All concrete channels and ducts used for conveying liquid shall have inside finish of type F2. The width of concrete channels shall not be less than 500 mm. All open

channels shall be provided with Type 304 stainless steel hand railings.

34. Kerbs to be provided below the hand railing on the catwalks/pathways should be as per relevant sections of Factory Act.
35. All rooms in the treatment plant buildings shall be provided with appropriate sign boards of approved material indicating the function of the rooms involved.
36. Wherever equipment and machinery are to be moved for inspection, servicing, replacement etc., suitable movable gantry of minimum capacity of 2 tonnes or more as required shall be provided with monorail and operating equipment.
37. The design of buildings shall reflect the climatic conditions existing on site. Process buildings shall as far as possible permit the entry of natural light, and the use of glazed panelling shall be kept to a minimum and preference given to wall openings protected by weather canopies.
38. Emergency exit doorways and safety features shall be provided from all buildings in order to comply with local and international regulations. Stairways and paved areas shall be provided at the exit points.
39. Toilet blocks in process buildings and control blocks shall be provided with a sink with two drinking water taps of 20 mm size with adequate inlet and outlet connections.
40. The side walls of buildings shall, except those used for storage and handling of chlorine, comprise at least 15% ventilated brickwork or louvers. Ventilated brickwork or louvers shall not be used where the ingress of driven rain could affect plant or stored materials. Flat roofed areas shall be provided with roof vents to further encourage a through flow of air.
41. All the walkways shall have minimum 1.0 m width and shall be covered with cement chequered tiles.
42. Hand railings shall be 38 mm pipe made up of SS316. Height of railing not less than 1100mm.The distance between 2 vertical posts shall not be more than 1.8 metres. This shall also match with existing hand railing.
43. All the buildings shall have adequate Lighting provision with Solar panel system as per drawing proposed and also the streetlights with adequate Lighting facilities supported by Solar Lighting and even for Parks and Garden and around Boundary walls and fence in The Plant lay out as per Drawings proposed.
44. All Other facilities shall be as per the drawings proposed for approval for firefighting , burglar intrusion alarm system, inside and outside plant with adequate Video Monitoring system, vehicle parking and service maintenance and workshops and lay down area .
45. Adequate rest shelters for the workers during hot days with toilets, bathrooms and dining area shall be provided as per the IS codes standards.
46. Adequate safety facilities and speed breakers for the road with signs and signals and integrated vehicle monitoring system with USB control for the vehicles shall be

provided for safe drive and at the Entrance Safety Statistics and importance of water logo board will be made for the value based information for the Desal Plant. All other additional facilities shall also be provided as per drawings approved by the Engineer.

5.27.2 Roads, Pathways & Hard standings

A comprehensive network of roadways shall be provided around the site and permit access to the plant for necessary maintenance, delivery of consumables and personnel access. All roads shall be of asphalt macadam and minimum 9 meters wide for the main roads and minimum 6 meters wide within the blocks of pre-treatment and RO/post-treatment as indicated in the attached plant layout. Vehicular access shall be provided for all Plant structures and buildings. All roads shall be provided with drainage and shall be constructed to prevent standing water. All roads shall have adequate Road Markings and traffic marking and signs with speed limit and shall strictly follow industry norms. All the roads will have adequate lighting facilities with Solar panels and electricity for stand by optional so as to save electricity consumption as per drawings proposed .All roads shall be as per Drawings proposed and approved by the CMWSSB / Client .

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

Hard standing areas shall be provided to permit the parking of vehicles involved in the delivery of consumables from blocking site roadways during unloading or loading. The road system shall be designed such that vehicles involved in the delivery of consumables can follow a continuous route through the works and out again without the need to reverse or carryout complicated maneuvers in order to exit the site. All the roads will have adequate lighting facilities with Solar panels and standby electricity optional so as to save electricity consumption.

5.27.3 Site Drainage

The contractor shall provide a site drainage system. The system shall comprise of the following:

- Storm Water Drainage
- Foul Drainage
- Process Drainage

All wastewater after treatment shall be drained in the plant Outfall Tank for discharge to the sea.

5.27.3.1 *Storm Water Drainage*

Storm water drains adjacent to the existing and proposed roads (under this Contract) shall be sized for a rainfall intensity of minimum 50 mm/hr, allowing for 100% runoff. Drains adjacent to roads shall be either with RCC floor and walls in M-20 concrete with minimum 150 mm thickness or in stone masonry (1:4) of appropriate thickness, topped with 75 mm thick M-15 concrete and 20mm thick plaster on internal surfaces in cement mortar (1:4). The minimum width of drain shall be 450mm wherever not existing and needed.

The storm water drainage system shall be designed to cater for the run-off from the existing water plants treatment areas and structures. Sufficient slope shall be provided to drain the rainwater in the Outfall tank considering maximum precipitation without any logging.

5.27.3.2 *Foul Drainage*

The foul drainage system shall accept discharge from toilets, washrooms, offices and the laboratory. The foul drainage system shall be directed to the sewage treatment plant provided by the Contractor for appropriate capacity as indicated in the Part-2, A3 document. The rainwater and treated domestic water shall be used for toilet flushing and irrigation around the plant site.

5.27.3.3 *Process Drainage*

Under this project, all the wastewaters at the plant including backwash wastewater from the Dual Media Filters will be directed to the Outfall Tank for discharge to sea. No discharge will directly go to the sea. All wastewaters (domestic and industrial) must be treated first to meet the surface discharge requirements as per the concerned regulatory guidelines before discharge to the sea via the outfall tank. The Contractor shall plan the pipeline alignment, draw longitudinal section of the pipeline showing the ground levels, pipe invert levels etc., and get approval from the Engineer prior to start of the work.

The Contractor shall provide all the services including interconnections of the drain pipes, site clearance with cutting of the trees, shrub etc. coming in the drain line alignment, excavation to the required level for the pipeline, bed preparation including required bed strengthening, laying and jointing of the pipeline, back filling etc. Manhole chambers shall be provided at every junction and bends and at 45 m interval on straight reaches.

5.27.4 **Cable and Pipe-work Trenches**

Cable and pipe-work trenches shall be constructed in reinforced concrete. However, 500 mm x 500 mm size or smaller trenches, not on fill may be constructed in Bricks/Concrete Blocks. The trenches shall be plastered internally with cement mortar (1:4) and externally in cement mortar (1:3).

Trenches within the buildings shall be covered with Fibreglass / Hot Dip Galvanized MS chequered plates, and those outside the buildings shall be covered with M30 precast R.C.C or more suitable material as per the consent of the Engineer. The trenches shall be suitably sloped to drain rain water.

Layout of trenches outside the buildings shall allow space for construction of future trenches where necessary with due consideration for planning for future developments. This aspect shall be brought to the notice of the Engineer while planning the works.

5.27.5 Pipes and Ducts

Reinforced concrete ducts/pipes for drainage shall have a minimum 1 metre cover while laid under roads. Access shafts of suitable size shall be provided. All drains shall be covered with precast reinforced concrete slab and designed structurally for appropriate loads. All interconnecting piping and channels in the plant shall be as per the requirements and as per specifications.

5.27.6 Valve and Flow meter Chambers

All the valves and flow meters shall be placed in the chambers as much as possible so that the ground surface remains available for free movement. The chambers are to be of adequate size to facilitate maintenance and operation. The base slab of chambers shall slope to drain the water to the common drain line or towards a sump pit from where water can be pumped out to a drain line to keep the chamber dry. The top of the valve chamber shall be 300mm above the FGL. All chambers shall be constructed in M20 reinforced concrete. Chambers shall have removable cast iron / reinforced concrete covers, as appropriate, with approach ladders and supports.

5.27.7 Pipeline Material

Due to saline environment, GRP/HDPE pipes of suitable schedule shall be used for the process at the plant. The use of mild steel pipelines shall be avoided and wherever provided in the plant with the consent of the Engineer shall be submerged arc welded with steel grade of Fe 410, conforming to IS:3589. The pipes shall have internal epoxy coatings and external polyurethane and epoxy coatings as approved by the Engineer. Polyurethane coatings shall be provided in 2 coats with total thickness not less than 500 microns over suitable primer coat. The thickness of pipes shall be adequate for internal pressure and external loading including live loads. In no case the thickness shall be less than the minimum specified in IS:3589.

5.27.8 Landscaping

The site shall be landscaped once the Works are substantially complete. Landscaping area shall be marked in layout plan. Landscaping shall include planting of suitable trees and development of grassed areas. Landscaping in general shall meet ecological and environmental conditions of the Site. Road widths shall determine the size of the tree height and spread to be selected for planting. Trees suitable for local conditions shall be selected. Plantation shall be started just after approval of the plant layout so that the plants become of good size at the completion of the capital works and start of the production at plant. Medicinal and fruit trees shall be avoided. Landscaping shall be maintained in good condition until the completion of Contract.

5.27.9 Tree Planting

Pits dug a few days in advance of actual planting shall be allowed to weather and be filled with top soil mixed with manure. Size of the pit shall be as per standard requirement. Only one tree shall be planted in each pit. A guard made of bamboo with wire mesh or bricks or MS rings as approved by the Engineer shall be provided.

5.27.10 Hydraulic Testing of Liquid Retaining Structures

In addition to the structural test of the structures, the liquid retaining structures shall also be tested for water tightness test at full supply level as described in 10.1.1,10.1.2 and 10.1.3 of latest revision of IS:3370 (Part I).

On completion of the structure and before its commissioning, the contractor shall carry out a water tightness test for the maximum water head condition with the water standing at full supply level (FSL). This test shall be carried out preferably in dry season in accordance with the procedure given below.

The water tightness test shall be carried out when the construction of liquid retaining structure is completed and when it is possible to fill the structure and ensure that uniform settlement of the structure as a whole or as directed by the Engineer. Before the filling operations are started the structure shall be inspected by the Engineer/Engineer's Representative and the Contractor's Representative and the condition of surfaces of walls, contraction joints shall be noted and it shall be ensured that the jointing material filled in the joint is in position and all openings are closed. The Contractor shall make necessary arrangement for ventilation and lighting of the structure by way of floodlights, circulators etc. for carrying out proper inspection of the surfaces and inner conditions if so desired by the Employer. Records of leakages starting at different levels of water in the reservoir, if any, shall be kept.

The liquid retaining structure once filled shall be allowed to remain so for a period of seven days before any readings of drop in water level are recorded. The level of the water shall be recorded against the subsequent intervals of 24 hours over a period of seven days. The total drop in surface level over a period of seven days shall be taken as an indication of the water tightness of the structure, which for all practical purposes shall not exceed 40 mm. Also, there shall be no indications of the leakages around the opening or on the walls.

If the structure does not satisfy the condition of test and the daily drop in water level is decreasing, the period of test may be extended for a further period of seven days and it the specified limit is then reached the structure may be considered as satisfactory.

The external faces of structure shall not show any signs of leakage and shall remain apparently dry over the period of observation of seven days after allowing a seven-day period for absorption after filling.

In case the drop in level exceeds the permissible level limit and signs of leakage with the stipulated period of test, the Contractor shall carry out such additional works and adopt such measures as may be directed by the Engineer/Engineer's Representative to reduce the leakage within the permissible limits. The entire rectification work that shall be carried out in this connection shall be at the Contractor's cost.

If the test results are unsatisfactory, the Contractor shall ascertain the cause and make all necessary repairs and repeat the water retaining structures test procedures, at his own cost. Should the re-test results still be unsatisfactory after the repairs, the structure will be condemned and the Contractor shall dismantle and reconstruct the structure, to the original specification, at his own cost.

During testing and during defect liability period the impression marks created due to seepage shall be rectified and made good. No separate payment shall be made for water tightness test and the cost thereof shall deem to be covered in the rates quoted for the works.

5.27.11 Non Destructive Testing of Reinforced Concrete Structures

Non-Destructive Testing (NDT) such as Rebound Hammer /Ultrasonic Pulse Velocity test or any other approved test shall be carried out as per latest IS:13311 codes as per the instructions given by the Engineer.

5.27.12 Site Clearance

The Contractor shall cut the trees, remove the shrubs and grass prior to marking the plant layout on the ground. Prior to cutting of the trees, permission of the concern authority as needed must be obtained by the Contractor for which required official help may be extended by the Engineer. Counting of the trees shall be done by the Contractor in presence of the Engineer's Representative. The cut trees shall be handed over to the CMWSSB. The Contract cost shall cover the job of site clearance as required and no separate payment shall be allowed against this job.

5.28 MATERIALS

5.28.1 CEMENT (ORDINARY AND PORTLAND)

All Portland Cement for use on the works shall comply in every respect with requirements of the Indian Standard Quality of Cement Specification for Portland Cement as issued and amended from time to time by the Indian Standards Institution. The Portland Cement used in the works shall be manufactured in India and shall be of a make and quality to be approved by the Engineer.

No other make/grade of cement, but that approved by the Engineer will be allowed on the works and the contractor shall not change his source of supply without the approval of the Engineering in writing.

Tests ⇒ Produce test certificates to show that the cement is fully up to the specification and notwithstanding this, the Engineer may at his discretion order that the cement delivered on the work and which he may consider damaged or of doubtful character for any reason whatsoever, must be retested by approved testers and fresh certificates of its soundness produced by the contractor at his sole cost. Cement ordered for re-testing shall be withdrawn from the work pending the results of re-testing. The decision of the Engineer in this respect shall be final binding on the Contractors.

Stores ⇒ Large stock of cement shall not be kept at the works but sufficient quantities to ensure continuity of the work. The contractors shall provide and maintain proper and sufficient storage sheds for the cement on the works. The floor of the stores shall be raised at least 9" from the ground in order to protect the bags from moisture. No cement damaged exposure or otherwise will be allowed to be used in work, but shall be removed at once from the site.

Packages ⇒ the cement shall be supplied in sound and properly secure sealed bags, weighing (1 bag) 50 kg. Net. The rates entered in the Bill of Quantities and Rates shall be held to include the cost of haulage to the work housing and protecting from the weather, risks of every kind and all expenses connected with preparing the cement for use and with using it in the work.

5.28.2 Sand

All the sand aggregate shall consist of clean, hard, strong, durable quality of river sand / M-Sand uncoated, well-graded particles when incorporated in the concrete mixture, the fine aggregate shall be free from frost, frozen lumps injurious amounts of dust, mica loam or other deleterious substances.

The sand shall be of river and taken from a source approved by the Engineer. If the Engineer considers it necessary, it shall be washed. The cost of washing must be included in this price for the concrete work. In case of non-availability of the river sand, Manufactured Sand (M-sand) from Quarry may be used after the Engineer's approval.

All sand shall pass through a sieve having meshes not more than (1/4" inch) 6 mm. Wide and if the Engineer shall require it, it shall be screened before use at the expense of the contractor. In no case shall fine aggregate be accepted containing more than two percent, dry weight, not more than three and half percent by dry volume of clay, loam or silt. If any sample of fine aggregate show more than five percent of day, loam silt in one hour's settlement, after shaking in an excess of water, the material represented by the sample will be rejected. If necessary, silt test shall be taken by the Engineer.

All fine aggregate shall be stored on the works in such a manner as to prevent the intrusion of foreign matter. The fine aggregate shall conform to IS 383 (latest).

5.28.3 Coarse Aggregate

The whole of the ingredients of the coarse aggregate shall be Quality coarse consisting of crushed rock, gravel or other aggregate material. The particles of coarse aggregate shall be clean, hard, tough, durable material, free from vegetable or other deleterious substances and shall contain no soft flat or elongated pieces. All coarse aggregate shall be stored on the works in such a manner as to prevent the institution of foreign matter. If it is considered necessary, the Engineer may order it to be washed and screened. The contractor shall state in his tender the source from where he will obtain the aggregate and he shall also include in his price the cost of washing. If screening is necessary and the cost shall be borne by the contractor.

The coarse aggregate shall consist of the following as per IS 383:

Grading of Coarse: 1.

1	Metal No.2	¾" to 1"	20 to 25 mm. Aggregate
2	Metal No. 1	¼" to ½"	6 to 12 mm

The whole of the aggregate shall all pass a screen having meshes not greater than 1" (2.54 cm.) square and shall be retained on a screen having meshes ¼" (6.35 mm) square. The materials may be tested for voids before the work is commenced and at intervals during the coarse of construction, as may be necessary and the proportion of the different grades in the coarse aggregate fixed by the Engineer so as to secure a well graded material varying from (1/4" to 1") 6.35 mm to 25.4 mm. The different grades of the coarse aggregate shall be measured by means of suitable boxes and in such proportion as may be approved by the Engineer.

5.28.4 Water

The water shall be clean and free from injurious amounts of oil, acid, alkali, organic or other deleterious substances, salt etc. The quality of water added to the materials for making concrete shall be properly under control and must be measured.

5.28.5 Reinforcement

The steel to be used in reinforced concrete work shall comply with the requirements of Indian Standard Specification I.S. No. 43 (Latest) for saline water use and refer IS Code 1786-2008 .IS-2062-2011.

If any steel does not in the opinion of the Engineer comply with any of the tests specified for the saline water environment, the Engineer may reject the lot or lots from which the sample or samples taken and the same shall not be used on the works but shall be removed from there.

All steel used for reinforcement shall be free from loose scales or rust, which must be removed with a stiff wire brush. Bars must also be free from oil or paint. The steel should be properly braced, supported and otherwise held in position strictly according to the contract and plans. This shall be checked over by a competent foreman personally and finally before pouring the concrete.

5.28.6 Polymers

The polymer modifier shall be a modified acrylic based compound suitable for use in marine environment. The product shall have minimum solids of 40% $\pm$ 2%. The polymer shall be capable of being used both as a bonding agent having a pull off bond strength not less than 1 Mpa and also as an additive for preparation of polymer modified repair mortar.

5.28.7 Coal Tar Epoxy

It shall be high build pitch extended epoxy coating and shall be 100% solids, solvent free, tough abrasion resistant coating.

The product shall exhibit excellent bond strength with substrate exceeding 2.5Mpa as per ASTMD4541.

The product shall be formulated to have high build thickness exceeding 150 microns per coat on average to achieve overall thickness of 300 micron in 2 coats.

The product shall be formulated to resist exposure to accelerated weathering test as per ASTMD4587 and shall not exhibit any flaking or blistering.

5.28.8 Epoxy

The Non Toxic High build epoxy coating shall be solvent free, taint free, potable grade protective coating. The product shall exhibit bond strength exceeding 1.5Mpa tested as per ASTMD4541. Product shall be formulated to have a thickness of 200 microns per coat on average to achieve overall thickness of 400 microns in 2 coats. Product shall be approved by CTRI (Clinical Trials Registry of India) for use in contact with product water.

5.28.9 Waterproofing Membrane

Self-adhesive elastomeric SBS (Styrene-Butadiene-Styrene) bitumen based waterproofing membranes with high mechanical performance polypropylene mesh, finish of upper side and easily removable silicone film on underside. Thickness of membrane shall be minimum 1.5mm.

5.28.10 Polypropylene Fibres: (For Concrete work / Mortar Work)

The material shall be virgin high tenacity polypropylene mesh fibre and multifilament combination in 10mm length for use in water retaining structures concrete work.

Dosage should be minimum 125gms/bag of concrete as per specified dosage of Consulting Engineer.

The fibres shall be Alkali and Acid resistance, non absorbent, and chemically Inert having a density of 0.93gms/cc and should conform to ASTM C-1116. Lengths of strands shall be 10mm blended for plaster work Dosages shall be 100g/bag of cement.

5.28.11 Glass Fibres

The Glass fibres shall be Alkali Resistance Glass fibre specially developed for Cementitious Mortars and Concrete Mixes.

They shall be monofilament having diameter of 14μ and a specific gravity of 2.6, length 12mm and an Aspect ratio of 857:1 and a specific surface area of 105m^2/Kg.

Dosage shall be minimum = 85g/per bag of cement but to be decided by the Employer's Representative.

5.28.12 Plasticizers

The liquid integral waterproofing shall be a ligno-sulphonate Polymer based waterproofing cum plasticizing admixture. The product shall comply with IS 2645:2005 when tested at a dosage of 100ml/50 kg bag of cement. The product must be free of chlorides and shall have a specific gravity of not less than 1.15 and shall comply to ASTM C 494 type A & D.

5.28.13 Pre-packed Ready-Made Plasters

The Prepacked ready-made plasters shall be coarse / fine water resistance mortar for internal / external use.

The blend shall be made of fillers which are silt free precisely graded sand with OP cement as binder and additives to improve workability water retention durability and adhesion of mortar.

The blend shall have PP (poly-propylene) fiber in proportion not exceeding 125gms / 50kg cement and fly ash not exceeding 25% as substitution of cement.

5.28.14 Expansion Joint Sealing Tape

The joint shall be treated with a highly elastic (having elongation > 600%) and share a hardness of 80 with special epoxy as adhesives. The expansion tape shall be supported by single component gun graded quality PU (poly-urethane) sealant followed by a backing material of polyethylene.

Width of expansion joints shall not exceed 150mm. Thickness of joint sealing tape shall be minimum 2mm.

The tape shall have tensile strength exceeding 6Mpa and resistance to cracking exceeding 600N/cm when tested as per DIN 53363.

5.29 SURGE CONTROL SYSTEMS

5.29.1 Design of Control System

Surge analysis for the sea water intake and pure water main, along with the design and provision of the required surge protection devices, shall be the responsibility of the Contractor. The surge control systems shall be designed so as to ensure that:

- the maximum residual surge shall be restricted to 10% of the maximum surge which would have developed without the surge control devices at any point in the pipeline or 10% of the design pump head, whichever is more; and
- the vacuum pressure developed in the pipeline at any place shall be restricted to –3 m (minus 3 meters); and
- the surge protection system provides adequate protection against damage for the valves, pipe delivery systems and pumps.

The surge analysis and design for surge protection system shall be got done from the Indian Institute of Science, Bangalore, or any other qualified agency approved by Employer's Representative. The detailed designs and drawings of the surge protection system shall be submitted for the approval of the Employer's Representative, but any such approval shall not relieve the Contractor from his responsibility for the safety of the system.

The feasible surge protection system in such a case shall be in the form of one way surge tanks, surge shaft, air vessel or any other better system as approved by the Employer's Representative, or any other better system suggested by Contractor and acceptable to the Employer's

Representative.

The Contractor shall also check the requirements for any protection devices downstream of the pipelines away from the intake to control negative pressures. The design shall be suitable to cater to the space requirements for the surge protection systems and the size of the available spaces.

The design agency shall finalize all particulars of the surge control system and submit calculations, including the number and capacity of air vessels, surge shafts, orifice plate diameters, interconnection details with pumping main, etc., depending on the adopted system. The detailed specifications for the proposed surge protection system along with designs shall be submitted for approval from the Employer's Representative.

The equipment used for the surge protection system must be procured from manufacturers who have previous experience of manufacturing such systems. The manufacturer shall submit certificates of test results for at least two systems manufactured and installed by him with for pumping mains of not less than 2000 mm diameter. For air vessels, the manufacturer must produce test results on at least two completed schemes with volume of the vessel recommended by the contractor and acceptable to the Engineer. In case of the surge shaft/tanks, all valves used shall be of reputed and accepted makes with proper opening characteristics.

5.29.2 Pure Water Surge System

The Contractor is cautioned that the constraints for installation of surge tanks/ pressure vessel are particularly severe in the pure water system. The pipeline to be protected is to be laid above ground on pedestals in the initial stretch, detached from the road. Besides this, space for laying and jointing of the pipeline and connecting the pipeline to the surge tank is restricted and constrained by the topography.

5.29.3 Technical Specifications for Air Vessel System

The technical specifications provided herein cover surge control systems with air vessels. This, however, is not intended to imply that a surge control system using air vessels is the best or only alternative to be considered; the Contractor will be fully responsible to analyze the requirements and recommend the type of surge control systems that are the most suitable and effective for the pure water pumping systems. In case any alternative surge protection system is recommended by the designer, he shall also submit the detailed specifications of the same for approval from the Employer's Representative.

5.29.3.1 *Air Vessel - General Specifications*

Air vessels should be suitable to take care of the water hammer/ pressure surges which may occur in the pipeline systems on which they are proposed. The air vessels shall be manufactured out of MS plates as per IS 2062. The nozzles shall be seamless conforming to SA 106 Grade B. Flanges up to 250 NB shall be of weld neck type of forged quality conforming to SA 105. The design and fabrication will be carried out as per latest version of IS 2825. At least 10% of the weld joints on the vessel shall be spot radio graphed. 100% of the weld joints, if any, on the dish shall be radio graphed. Air vessels will be provided with manholes and water outlets at the bottom, which will be connected to the rising mains along with an isolating valve and a differential orifice. Suitable drains are to be provided for maintenance. Air vessels will have standard fittings such as pressure relief valve, visual level indicators, control circuit inlets and outlets, etc., with isolating valves. Inspection for air vessels shall cover welding qualifications, radiography / UT / PT/ MT as applicable, Stage/ in-process inspection, and hydro/ leak tests.

Two air compressors shall be supplied along with each air vessel. These compressors will be operating at a slightly higher pressure than the pressure in the water main, and compressed air will be stored in the receiver from which requisite supply will be made to the air vessel. Inspection of compressors shall cover dimensional checks for mounting and overall dimensions, performance tests, and hydraulic leak tests.

The air vessel and air receiver will be painted internally and externally with zinc rich food grade epoxy paint.

The following additional equipment will be supplied as standard accessories for each air vessel:

- Receiver with compressor, with automatic on/off system.
- Visual water level indicator, covering full height or length of the air vessel.
- Isolating and drain valves for maintenance purpose

5.29.3.2 *Surge Suppression System*

The automatic control system shall be generally as described below. Contractor may propose alternative arrangement.

The surge protection system shall comprise of air compressors, common air receiver, surge vessel, field instruments and control panel with facilities for alarm annunciation and for operation and monitoring of compressor and air inlet valves of surge vessels. The surge vessels shall be connected with the common air header from the air receiver and at the base to the pumping station discharge header via the buffer manifold. The air inlet pipe to the surge vessels shall be provided with electrically / pneumatically operated valves to control air input to the surge vessels and an electrically / pneumatically operated valve to control air release from the surge vessel. For controlling the water level within the surge vessel, the vessel shall be provided with a conductivity type level switch. For continuous monitoring of water level within the surge vessel, capacitance type level measuring system shall be provided. A magnetic liquid level gauge shall also be provided to permit the visual monitoring of the water level in the surge vessels. The surge vessels shall be provided with safety air relief valve.

The electrically / pneumatically operated air inlet valve shall be provided in the air inlet line of the surge vessels to permit the entry and release of air from the surge vessels. Hand operated valves shall be provided in parallel with these valves for manual control of air addition and release.

5.29.3.3 *Normal Operation*

- The surge vessels are filled with water to a given level that is within a working level band. Air is added to the top of the surge vessels to act as a cushion and maintains the water level in the surge vessels within the working band. During normal operation, air will slowly dissolve in the water causing a gradual rise of the water level in the surge vessels.

- The mean working level (i.e. between upper working level and lower working level) is maintained constant by allowing more air from the compressor air receiver to enter the surge vessels.
- When the pumps stop supplying water to the discharge header (due to normal stopping, tripping, power failure, etc.) the non-return valve at the pump outlets will close. The water column continues to move away from the pumping station and in doing so will create a negative pressure in the discharge header.
- Water from the surge vessels is drawn into the discharge header through the surge non-return valve in order to limit the magnitude of this negative pressure and in doing so prevent damage to the pipe-work. When water column reverses water enters the surge vessels through the NRV bypass line and the air in the surge vessels is compressed providing a cushioning effect to the returning water column. Energy of returning water column is absorbed due to compression of the air.
- The water level in the surge vessels shall be maintained within the working band during steady state pipeline flow conditions. The steady state water level in the surge vessels shall be maintained between the upper and lower working level settings.
- The limits of the bands between upper and lower working levels shall be fine tuned during commissioning.
- The status of the surge protection system and associated alarms shall be monitored at the ICP (Instrumentation and Control Panel).
- The starting and stopping of the compressor shall be automatic with a manual override facility. The compressor shall start when there is a low air pressure in the associated air receiver and stop when the required air pressure is reached. Separate pressure switches shall be provided on air receiver for starting and stopping of compressor. The air receiver shall be provided with pressure gauge and safety relief valve.
- Conductivity type level switches shall be provided for monitoring the following levels in the surge vessel:
  - Upper emergency level
  - Upper working level
  - Mean working level
  - Lower working level
  - Lower emergency level
- The level switches shall be provided on the 'stand pipe' of the surge vessel. When the level in the surge vessel reaches the 'upper working level' and remains there for certain duration of time (adjustable), the pneumatic/ electric operated air inlet valve shall open.

The valve shall close when the 'mean working level' is reached.

- When the level in the surge vessels reaches the 'lower working level' and remains there for certain duration of time (adjustable), the pneumatic/ electric operated air release valve shall open. The valve shall close when the 'mean working level' is reached.
- An orifice plate shall be provided to restrict the rate of air release to ensure restoration of the mean working level within approximately 30 minutes (to be decided during commissioning).
- A silencer shall be provided on the discharge to limit the noise made by air release. When 'upper emergency level' and 'lower emergency level' are detected by conductivity level switch, alarms shall be annunciated on the surge protection system control panel and on the main ICP. In addition water level high high and low low alarms shall be configured on the surge vessel water level analogue signal. These alarms will be used when the surge vessel water level is being controlled by hand such as when the surge vessel containing the level switches is taken out of service for maintenance. The high high and low low limits shall be set outside the digital alarm levels.
- Manual override facilities shall be provided for operating the compressor and the air inlet and air release valves. A non-return valve shall be provided on the air inlet line to the surge vessel to prevent back flow of water from the surge vessels to the air receiver.
    - A separate control panel shall be provided for operation and monitoring of the surge suppression system. The panel shall comprise the following:
    - Incoming isolator
    - Starters for compressors
    - Automatic-Off-Manual selector switch
    - Status indication
    - Start / stop pushbuttons for use in manual mode
    - Duty / standby compressor selector switch
    - Auto-manual selector switch for surge vessel air supply
    - Manual controls for air inlet and air release
    - Indication of surge vessel water level
    - Alarm annunciator to indicate the following alarms as a minimum
    - Surge vessel water level high
    - Surge vessel water level high
    - Surge vessel water level low
    - Surge vessel water level low

- Compressor faults for each compressor as appropriate i.e. fail, oil temperature high, etc.
- Low air pressure in receiver
- All the critical alarms and signals required for safe efficient operation of pumping station shall be connected to the main PLC (Programmable Logic Controller) in ICP.

5.29.3.4 *Abnormal Operation*

- In case working compressor fails, the standby compressor shall come into operation automatically and an alarm shall be annunciated on surge suppression control panel and ICP.
- In case the control supply to surge suppression control panel fails an alarm shall be enunciated at the ICP and the operator shall carry out the operation of surge suppression system manually.

5.29.4 Technical Specifications for Surge Tanks/Pipe

The surge tank/pipe shall be designed considering the space available. The surge tank / pipe shall be of adequate size and capacity as per the requirement and approved design. It shall be provided with the isolation valve at inlet. The overflow arrangement shall be provided with the adequate arrangement for disposal of overflow water.

CHAPTER - 6

6. PIPELINES, PIPEWORK AND FITTINGS

6.1 Applicable Codes

The following general codes and standards unless specified herein shall be referred to, or equivalent to the approval of the Engineer. The specific codes and standards have been given in the specific chapters.

6.1.1 Materials

IS:210	Specification for grey iron casting
IS:456	Code of practice for plain and reinforced concrete
IS:458	Specification for pre cast concrete pipes (with and without reinforcement)
IS:516	Method of test for strength of concrete
IS:638	Specification for sheet rubber jointing and rubber insertion jointing
IS:783	Code of practice for laying of concrete pipes
IS:816	Code of practice for use of metal arc welding for general construction in mild steel
IS:1367	Technical supply conditions for threaded steel fasteners
IS:1387	General requirements for the supply of metallurgical materials
IS:1500	Method for Brinell hardness test for metallic materials
IS:1536	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage
IS:1537	Specification for vertically cast iron pressure pipes for water, gas and sewage
IS:1538	Specification for cast iron fittings for pressure pipes for water, gas and sewage
IS:1608	Metallic Material tensile testing at ambient temperature
IS:1916	Specification for steel cylinder pipes with concrete lining and coating
IS:3076	Specification for LDPE Pipes
IS:3597	Method of tests for concrete pipes
IS:3658	Code of practice for liquid penetrant flow detection
IS:4984	Specification for high density polyethylene pipes for water supply
IS:4985	Specification for PVC Pipes
IS:5382	Specification for rubber sealing rings for gas mains, water mains and sewers

IS:5504	Specification for spiral welded pipes
IS:6392	Specification for steel pipe flanges
IS:6587	Specification for spun hemp yarn
IS:7322	Specification for specials for steel cylinder reinforced concrete pipes
IS:8008	Specification for moulded HDPE Fittings
IS8360	Specification for fabricated HDPE Fittings
IS:12709	Specification for GRP pipes
BS:5480	Specifications for GRP pipes and fittings

Additional Indian and International code of practices and specifications have been given below which shall be followed as much possible with the consent of the Employer's representative.

6.1.2 Code of Practice

IS:783	Code of practice for laying of concrete pipes
IS:2379	Colour Code for Identification of Pipelines
IS:3114	Code of practice for laying pipes
IS:3764	**Excavation work - Code of Safety**
IS:4127	Code of practice for laying of glazed stoneware pipes
IS:5822	**Code of practice for laying of electrically welded steel pipes for water supply.**
IS:10221	**Code of Practice for coating and wrapping of underground MS pipelines**
IS:10990	**Technical drawings – Simplified representation of pipelines**
IS:11790	**Code of Practice for preparation of Butt welding ends for valves, flanges and fittings**

6.2 Materials for Pipelines

Each pipeline shall be constructed in a material compatible with the fluid conveyed through that pipeline, (i.e. the materials used in the pipes which are or can be in contact with the untreated or treated water, shall not contain any matter which could impart taste or odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed). Pipes shall not be adversely affected by the fluid being conveyed through that pipe.

Pipework and valve materials of the suitable schedule for the following duties shall be as follows and equivalent to the approval of the Engineer.

The material of construction of pipes and fittings shall conform to the following specifications:

Table 6-1: List of Material of Construction of Pipes and Fittings

Application/Location	Material	Remarks
Intake and outfall pipeline	HDPE	Refer Specification below
Raw seawater pumping	GRP/HDPE	Refer Specification below
Brine line	GRP/ HDPE	Refer Specification below
Sludge lines	GRP	Refer Specification below
Air Lines	SS-316L suitable for high temperature	Refer Specification below
RO piping (seawater/ brine) for high pressure lines	Super Duplex SS PERN≥43	As per the application
Permeate line	GRP/HDPE	Refer Specification below
Service water	HDPE/ GRP/PVC/SS316	As per approval of the Engineer
Chemical dosing Lines	Rubber lined carbon steel/ cPVC /GRP/HDPE as	As per approval of the Engineer
Chlorine solution	HDPE Valves shall be ball type-polypropylene	
Sewage and stormwater	HDPE/GRP pipes as per application	As per approval of the Engineer
Nut & Bolts	SS-316L	Refer Specification below
Fasteners	SS-316/ Monel 410/ K500	As per the application

6.3 Pipework

i) The term "pipework" means pipe of any description and includes associated flanges, dismantling joint adopters, couplings, jointing materials, fittings, supports, valves, traps and the like which are necessary to complete station pipework systems associated with pumping stations.

ii) The Contractor shall design, manufacture, supply, fabricate, and install the pipework in accordance with the Specification and to satisfy pipework function of Pump Station and other piping. The Contractor shall provide all the information given below clearly about the pipework. The Contractor's specification for the fabrication of pipework shall be submitted for the Employer's approval. The information provided shall be, when applicable, as listed below.

a) Purpose

b) Contents

c) Related documents

d) Definitions

e) Application standards

f) Drawings

g) Materials

h) Fabrication - general
   - tolerance
   - preparation
   - fit-up
   - threading
   - bends
   - welding
   - heat treatment
   - after fabrication treatment
   - inspection

i) Preparation and protection finishing of surfaces

j) Marking and color coding for identification and matching

k) Acceptable welder's qualification

iii) All pipes, fittings, bolts, nuts, jointing materials, pipe supports, thrust blocks and appurtenances for piping to be required for execution of the Works shall be manufactured and erected in accordance with the erection plans, specifications to be provided by the Contractor and approved by the Employer. All pipework and fittings shall be rated to the higher-pressure class in excess of the maximum pressure attained in service including any surge pressure. Minimum 2 mm corrosion allowance shall be considered. Where pipe material is specified as Mild steel, the pipe thickness shall be based on diameter and not be less than 12 mm. Buried pipes in addition to above, shall be designed to withstand external loading exerted by soil, water, and live loads as relevant. The external ground water shall be taken at ground level for design purposes.

iv) Underground pipelines must be shown the location by a concrete pole that indicates its lay underground depth and its flow direction.

v) The pipe-work installation shall be so arranged to offer ease of dismantling and removal of pumps or other major items of equipment. Expansion bellows which can take radial and axial misalignment of minimum 1 percent of valve nominal size with tie rods shall be included in the suction and delivery pipe-work of all pumps as well as on delivery header for easy dismantling, and provision shall be made for a flexible joint arrangement to building structures. All loose flanges shall be secured to fixed flanges by suitable tie-bolts.

vi) Support calculations shall be provided for piping considering the transient conditions and justifying the type of supports.

vii) Transient studies shall be done for all large diameter pipes and suitable type of anchoring shall be provided.

viii) All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipe-work and its associated equipment in an approved manner. Valves, meters, strainers and other devices mounted in the pipe-work shall be supported independently of the pipes to which they connect. All brackets or other forms of support, which can conveniently be so designed, shall be rigidly built up of steel by welding and coated by paint after wielding works.

ix) All pipework shall be adequately supported with purpose-made fittings. When passing through walls, pipework shall incorporate a puddle flange or other suitable sealing device.

x) Flange adapters and unions shall be supplied and fitted in pipework runs, wherever necessary, to permit the simple disconnection of flanges, valves and equipment. The final outlet connection of the pipework shall match the connecting point of the transmission main.

xi) Flanged joints shall be made with minimum 3 mm thick full face, neoprene rubber gaskets, pierced to take the bolts, and the face of all flanges shall be machined to give a true angle of 90^{o} to the centre line of the pipe or fittings. All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipework and its associated equipment in an approved manner. Valves, meters and other devices mounted in the pipework shall be supported independently of the pipes to which they are connected.

xii) Bolts for flange connection must be tightened using adequate force in compliance with international standards or approved by the Engineer.

xiii) Facilities shall be provided for draining the pipe system and releasing air.

xiv) The pipe-work layout within all process pumping area shall follow the recommendations of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.5 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.0 m/s except in case of HP piping for which up to 3 m/s may be permitted.

xv) The Contractor shall ensure that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

xvi) Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small-bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Employer.

xvii) Hydraulic shop test for pipes and fittings shall be conducted as per relevant code/standard requirement. After erection at Site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times design pressure.

xviii) Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

xix) Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fibre glass wraps set in coal tar enamel coats conforming to American Water Works Association Specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

xx) The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipework supplied by him. Particular care shall be taken to ensure that pipe-work thrusts are not transmitted to machinery or other associated apparatus. Surge and thrust calculations shall be provided to verify the location and size of thrust blocks.

xxi) Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Engineer.

xxii) Saddle type/ bracket type support wherever required shall be designed and supplied for the above ground pipelines. The Employer's Representative shall duly approve all supporting design.

xxiii) Air release valve shall be provided to release air when backwash by air is stopped. Type of valve shall be rubber pinch and shall be solenoid controlled.

xxiv) All pipelines shall be marked the flow direction, and print ink the name of liquid to be carried as well as name of the destination of facility.

xxv) All pipelines shall be identified by stick-on 90-micron thick vinyl film labels showing the name of the material to be carried by the pipeline and an arrow indicating the direction of flow. Letters of titles shall be pre-spaced on carrier tape and the complete title protected by one-piece removable liners. Titles shall be at intervals not less than 8 m, but shall in any case be provided in every space through which the pipe passes. Locations of labels shall be subject to prior approval by the Employers Representative. Letter sizes shall be between 16 mm and 75 mm in height depending on the size of the pipe. Pipes smaller than 22 mm outside diameter shall be labelled by the use of tags instead of labels. Tags shall be made of brass no smaller than 65 m x 16 mm by 1.5 mm thick, with lettering etched and filled with black enamel. Titles shall also be provided on all equipment in locations and in sizes to be approved by the Employer's Representative.

xxvi) The overhead portion of the pipeline inside building may be supported from the building structures, but in no case, support shall be taken from brick walls. The overhead pipe line wherein routed within the building shall have a clear head room of minimum 3.0 m from the operating floor.

6.4 GRP Pipes

The manufacturing, testing, supplying, joining and testing at work site of GRP pipes shall comply with all currently applicable statutes, regulations, standards and codes. In particular, the following standards unless otherwise specified here in, shall be referred. In all cases, the latest revision of the codes shall be referred to. If the requirements of this specification conflicts with the requirements of the codes and standards, this specification shall govern.

Design of GRP Pipes shall confirm to AWWA C-950/AWWA M45/ASTM 3517/ASTM 2310 or equivalent. The surfaces and edges of the pipes shall be well defined and true and shall have squareness of pipe ends as specified in IS: 14402 and ASTM D 3262.

The pressure class shall be established based on long term hydrostatic or pressure design basis in accordance with ASTM D 2992.

The resin and fiber glass to be used for pipe construction shall be suitable for handling fluid with deleterious effect for minimum 30 years and be in accordance with relevant clauses of IS 14402 and ASTM D 3262The materials sued shall be in accordance with the relevant clauses of IS : 6746, IS 14402, IS : 11320 and IS : 11551 and ASTM D 3262.

GRP Pipes shall be Filament wound, with inorganic filler, with Vinyl ester Resin, 1.6 mm Resin rich layer inside and outside, thickness to suit the pressure class requirements, Stiffness class of 2500 (min)for overground and 5000 (min) for underground pipes. Hand layup may be permitted for fittings.

Manufacturing method for the fittings shall be submitted for review and approval. Pipe thickness calculations shall be submitted for approval. Buried pipes shall have a soil cover of at least 1 meter above crown. Underground road crossings shall be either RCC encased or through culverts. Outdoor pipes above ground shall be with UV protection. Pump suction and discharge velocities shall not exceed 1.5 m/sec for suction and 2 m/sec for discharge. All support sand thrust blocks shall be designed and the calculations provided to the employer for review. Pipe joints shall be either through REKA coupling or Butt wrap. Further details are provided below.

6.4.1 Codes for GRP pipes

(i) I.S. 14402: 1996

Glass-fibre reinforced plastics (GRP) pipes, joints and fittings for use for Sewerage, Industrial waste & Water (other than potable)- specification

(ii) I.S. 12709: 1994

Specification for glass fibre reinforced plastics (GRP) pipes for use for water supply and sewerage.

(iii) I.S. 6746: 1972

Unsaturated, polyester resin systems for low pressure fibre reinforced plastics,

(iv) I.S. 11273: 1985

Woven roving fabrics of 'E' glass fibre,

(v) I.S. 11320: 1985

Glass fibre roving for the reinforcement of polyester and of epoxide resin systems.

(vi) I.S. 11551: 1986

Wherever for certain specific requirements the information given in above mentioned IS codes is found to be inadequate, following international codes shall be referred to. However, in case of any discrepancy, decision of Employer / Employer's Representative shall be final and implemented by the Contractor.

(vii) ASTMD2412:

W Standard test method for determination of external loading characteristics of plastic pipe by parallel plate loading."

(viii) ASTM D 3262:

Standard specification for reinforced plastic mortar sewer pipe,

(ix) ASTM D 3517:

Standard specification for glass fibre reinforced thermosetting resin pressure Pipe,

(x) ASTM D 3618:

Test for chemical resistance of reinforced thermosetting resin pipe in a deflected Condition.

(xi) ASTM D 3839:

Standard practice for underground installation of flexible reinforced Thermosetting resin pipe and reinforced plastic mortar pipe.

(xii)ASTM D4161:

Standard specification for "Fibre glass" (glass-fibre - reinforced thermosetting resin) pipe joints using flexible elastomeric seals.

(xiii) ASTM D 477:

Standard specification for elastomeric seals (Gaskets) for joining plastic pipe.

(xiv) ASNI/AWWA C 950-88

AWWA standard for fiber glass pressure pipe.

(xv) IS 13916: 1994

Installation of GRP piping system - code of practice

(xvi) IS 5382: 1985

Rubber sealing rings for gas mains, water mains and sewers.

(xvii)American Society for Testing & Material (ASTM) 2563

Standard practice for clarifying visual defects in glass reinforced plastic laminated parts,

(xviii) ASTM D 5421

Standard specification for contact molded "Fiber glass" flanges,

(xvix) British Standard (BS) - 5480

Specification for Glass Fibre resin forced Plastic Pressure Pipes, Joints & Fittings.

6.4.2 Manufacturing of GRP pipes

The method of manufacturing of GRP pipes shall be such that the form and the dimensions of the finished pipes are accurate within the limits specified in the relevant clauses of the Design Standard. The pipe shall be machine with continuous moving/filament winding. Hand woven pipes are not acceptable. The pipes shall preferably be supplied in lengths of 12 meters.

The basic structure wall composition shall consist of thermo-setting resin, glass fibre reinforcement and inorganic filler. The resin shall be Vinyl Ester. Thermoplastic or thermosetting liner and / or surface layer may be included. UV protection shall be applied on above ground pipe. No glass fibre reinforcement shall penetrate the interior surface of the pipe line. The pipe shall meet minimum longitudinal tensile strength and hoop tensile strength as per relevant clauses of design standards.

The GRP pipes and joints shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality. Each pipe should have permanent ISI mark. Employer/ Employer's Representative shall at all reasonable times have free access to the place where the pipes and joints are manufactured for the purpose of examining and testing the pipes and joints and of witnessing the test and manufacturing.

a) Dimensions

Pipes shall be designated by nominal standard diameters. The nominal diameters, minimum wall thickness, length of barrel, joints etc. Shall be within the tolerance limits specified in IS: 14402, ASTM D 3262 and ASTM D 3517.

b) Workmanship and Finish

The inside surface of each pipe shall not have any visible defects such as bulges, dents, ridges foreign inclusion, cracks, crazing, pin holes and bubbles of 1.3 mm and above to the extent that it does not detrimentally affect the performance of the interior surface of the pipe wall.

Joint sealing surfaces shall be free of dents, gauges and other surface irregularities that will affect the integrity of the joints.

c) Structural Properties

The minimum initial ring stiffness for withstanding above load conditions with maximum 5% of long-term deflection shall be appropriately determined by manufacturer for actual execution.

d) Beam Strength

The pipe shall meet or exceed the minimum longitudinal tensile / compressive strength as per relevant clauses of IS: 14402, ASTM D 4262 and ASTM D 3517.

e) Hoop Tensile Strength

The pipes shall meet or exceed the minimum hoop tensile strength as per relevant clauses of IS: 14402, ASTM 3262 and ASTM D 3517.

f) Hydraulic Properties

Each length of pipe including specials shall withstand without leakage of cracking the internal hydrostatic proof pressures as per relevant clauses of IS: 14402, ASTMD 3517

g) Sampling and Inspection

In any consignment all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of this specification shall be ascertained on the basis of tests on pipes selected from it. Unless otherwise agreed upon between the purchaser and the supplier one lot shall consist of maximum of 100 m of each pressure class, stiffness class and size of pipe produce.

Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every *'r'* the pipe be selected till the requisite number is obtained, 'r' being an integral part of N/n where 'N' is the lot size and 'n' is the sample size.

Each pipe shall be checked for dimensions, soundness, workmanship finish and deviation from straight.

The lot shall be declared as conforming to the requirements of this specification, if the sample pipe taken from the lot meets the requirements of all the tests, otherwise not.

6.4.3 Testing of GRP pipes

GRP pipes manufactured by the above process shall be subjected to the following tests.

All tests specified either in this specification or in the relevant clauses of Indian Standards or International Standards shall be performed by Supplier/ Contractor at his own cost and in presence of Employer / Employer's Representative if desired. For this, sufficient notice before testing of the pipes shall be given to Employer/ Employer's Representative. If the test is found unsatisfactory, Employer/ Employer's Representative may reject any or all pipes of that lot. The decision of Employer/ Employer's Representative shall be final and binding on Contractor and not subject to any arbitration or appeal.

(a) Testing of pipe at factory

After selecting pipe specimens randomly from the lot as per clause no. above they shall be tested at factory for following tests.

(b) Critical dimensions

All pipes will be measured for compliance with critical dimensions as specified in relevant clauses of IS 14407, ASTM D 3262 and ASTM D 3517 after allowing for the specified tolerances. The dimensions shall include diameter, wall thickness, squareness and length. Pipes not in compliance will be rejected.

(c) Visual Acceptance

Generally, the pipe shall be free from all defects, including de-laminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions and resin-starved areas that due to their nature, degree or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in colour, capacity, density and other physical properties as per specification and standard BS 7152, AWWA, ASTM D2567, ASTM D3567 and ANSI B16.5.

Mechanical tests on spool shall be in accordance with ASTM- D.

(d) Tests for Specific Initial Ring Stiffness (SIRS)

Pipe ring samples shall be taken as discussed above from each diameter manufactured and tested for SIRS as per relevant clauses of IS 14407, ASTM D 2412 and ASTM D 3517. If a pipe sample from a lot fails to meet the required stiffness, a further two samples shall be tested from that lot. If they both pass, the lot will be accepted. If they fail Pipes will be tested on an individual basis and only pipes which pass will be accepted.

(e) Hydrostatic Soundness Test

The manufacturer shall hydrostatically test pipes by hydrostatic proof test in accordance with the relevant Clause of IS 14407 and ASTM D-3517. Pipes shall be tested for 1.5 times of maximum allowable working pressure (MAWP) that can be generated at any abnormal working condition foreseen by hydraulic surge study, etc. Piping shall be also tested against full vacuum. The procedure should be as follows:

Each length of pipe shall be placed in a hydrostatic pressure test machine which seals the ends and exert no end loads. The pipe shall be filled with water, expelling all air and an internal water pressure shall be applied at a uniform rate not to exceed 300 Kpa/S until the test pressure of two times the pressure class is reached. This pressure shall be maintained for one minute. The pipe shall show no visual signs of weeping leakage or fracture of the structural wall. Integral bells, including reinforcement sleeves, if any, or affixed coupling shall be tested with the pipe. Any pipes failing to pass this test will be rejected. Rejected pipes may be repaired and retested, if they pass, they will then be accepted.

(f) Beam Strength Test

The manufacturer shall test the pipe for longitudinal tensile strength as per the relevant clauses in IS : 14407, ASTM D 2412, ASTM D 3262 and ASTM 3517. The sample size shall be selected as per clause above. If may sample should fail to meet the requisite value specified in the IS/ASTM codes, five (5) further samples should be taken and tested. If the results comply with requirement, all pipes will then be acceptable. However, if these five samples fail then all pipes from that lot will be rejected unless individually proven acceptable.

(g) Hoop Tensile Strength

The manufacturer shall test the pipe for hoop tensile strength as per relevant clauses in IS : 14407, ASTM D 3262, ASTM D 3517. The sample size shall be selected as per clause above. Every sample piece should meet or exceed the hoop tensile strength specified in IS : ASTM codes. If any sample fails to meet the requisite value five (5) further samples shall be taken and tested. IF the results comply with requirement, all pipes will then be acceptable. However, if these five samples fail then all pipes from that lot will be rejected unless individually proven acceptable. Rejected pipes will, however, be acceptable for use at a lower working pressure as per the criteria stated in the specification.

(h) Long Term Hydrostatic Strain Test

The pressure as classes as given in relevant clause shall be based on long term hydrostatic design pressure data obtained as per relevant clauses of IS: 14407, ASTM D 3262 and ASTM D 3517. For those products where no previous long term hydrostatic testing has been performed on similar products the full type testing shall be carried out to define design pressure classes based on extrapolated strengths at 50 years. When a hydrostatic design basis has already been established for a nominally similar pipe using the same manufacturing process, the manufacturer need only conduct the re-qualification test as described in the relevant clauses of IS : 12709.

(i) Test Certificate for Chemical resistance of GRP Pipes in a deflected Condition

The manufacturer / supplier / contractor shall produce a test certificate for chemical resistance of GRP pipes in a deflected condition that when installed within 5% deflection the pipes will last over 60 years under highly acidic and corrosive condition and stand guarantee for the same.

6.4.4 Marking

Both ends of each length of pipe and fitting shall be marked at least in letters not less than 12 mm in height and of bold type style in colour and type that remains legible under normal handling and installation procedures. The marking shall be embedded under the final coat of resin on the pipe and shall be visible through the resin coating. The marking shall include the following:

Serial Number of Pipe

Proper quality documentation for traceability of the serial number shall be available.

All pipes and fittings shall have ISI mark.

6.4.5 Handling

The manufacturer / Supplier shall be responsible for safe delivery of pipes and fittings as per order place and as per the schedule. If the contractor for works is other than manufacturer / supplier, then M/s shall submit a complete manual of instruction/ guide / Procedure for handling of pipe before installation. Broadly following instructions/ procedures shall be followed. The pipes shall be fabricated and installed under the supervision of the manufacturer or by the manufacturer himself.

Rubber ring gasket shall be shipped separately from the couplings and shall be stored in the shade in their original packaging and shall not be exposed to sunlight except during utilisation. The gaskets shall also be protected from exposure to greases and oils which are petroleum derivatives and solvents and other deleterious substances.

Gasket lubricant shall be carefully stored to prevent damage to the container. Partially used buckets shall be prevented from contamination of the lubricant.

Unloading, lifting and lowering

Adequate control shall be ensured during unloading and lifting of pipes with guide ropes attached to pipes or packages. Spreader bars shall be sued when multiple locations are necessary. The pipes shall not be dropped to avoid impact or bump, particularly at pipe ends.

Non-utilised stack of pipes shall not be handled a single bundle. Non-utilised pipes shall be handled separately, one at a time. Pipes shall be handled or lifted with pliable straps, slings or ropes. Steel cables or ropes shall not be used for lifting and transportation of pipe. Ropes shall not pass through the section of pipe, end to end. If any time during handling or installation of pipe, any damage, such as gouge, crack or fracture occurs, the pipe shall be repaired or replaced as directed by Employer / Employer's Representative before installation.

6.4.6 Jointing Pipes

Pipe sections shall be jointed utilising double bell couplings and shall be assembled as indicated in the following paragraphs and as per the relevant clauses of ASTM D 3517, ASTM D 4161. The gasket used for jointing purpose shall be as per ASTM F447, specification for Elastomeric Seals (gasket) for joining plastic pipes.

(a) Clean Coupling

Double bell coupling grooves and rubber gasket ring shall be thoroughly cleaned to make sure no dirt or oil is present.

(b) Install Gaskets

The gasket shall be inserted into the grooves, leaving two to four uniform loops of rubber extending out of the groove. There should be a minimum of one loop for each 450 mm of gasket ring circumference.

(c) Lubricate Gaskets

Uniform pressure shall be applied to push each loop of the rubber gasket into the gasket groove. Then using a clean cloth, a thin film of lubricant shall be applied to the rubber gasket.

(d) Clean and Lubricate Spigots

Pipe spigots shall be thoroughly cleaned to remove any dirt, grit, grease, etc. Using a clean cloth, a thin film of lubricant shall be applied to the spigots from the end of the pipe to the black positioning stripe.

(e) Fixing of Clamps

The first clamp is fixed anywhere on first pipe or left in position from previous joint. The second clamp is to be fixed on the pipe to be connected in the correct position relative to the alignment stripe on the spigot end so as also to act as a stopper. Clamp contact with the pipe shall be padded or otherwise protected to prevent damage to the pipe and have high friction resistance with the pipe surface. Care shall be taken in the alignment of the coupling.

(f) Pipe Placement

The pipe to be connected shall be placed on the bed with sufficient distance from the previously joined pipe to allow lowering the coupling into position.

(g) Join Coupling

Come along jacks shall be installed to connect the pipe clamps and two 10 cm x10 cm timbers or similar (large diameters may require a bulkhead) are placed between the pipe previously connected and the coupling. While these are held in position, the

new pipe shall be entered into the coupling until it rests against the second pipe clamp. Come-along jack might need a protective plank in order not to rub against the pipe.

(h) Join Pipes

Come - along jacks shall be loosened and the timbers removed before retightening the jacks for entering the coupling onto the previously connected pipe. Correct position of the edge of the coupling to the alignment stripe home line shall be checked.

(i) Angular Deflection

Maximum angular deflection (turn) at each coupling joint shall not exceed the amounts given below. Also, the pipes should be joined in straight alignment and thereafter deflected angularly if necessary.

(j) Layup Joints

The manufacturer / tenderer shall provide full details of the layup joints and polymer resin which will be used for connection of pipes to Chambers/manholes.

Joining pipes with different wall thickness when two pipes of same diameter but of different wall thickness are required to be joined at the site, the contractor is required to execute the joint very precisely so as to have straight alignment of pipe inverts. Facilities shall be provided for draining the pipe system and releasing air.

The pipe-work layout within all process pumping area shall have the approval of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.5 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.0 m/s.

The whole of the jointing work and materials necessary to fix and connect the pipes, including adequate and efficient pipe support shall be included in the Contract. The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Employer.

In the design of pipes above ground pipelines, the supports and guides for the pipe become important considerations because of thermal expansion. In addition to pressure resistance and life limitations, the effect of thermal expansion and contraction shall be considered while designing the pipe. Expansion joints shall be used whereas necessary to accommodate the changes in length associated with thermal expansion.

Hydraulic shop test for pipes and fittings shall be conducted as per relevant code/standard requirement. After erection at Site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times design pressure.

Dimensions of all fittings should be approved by Employer's Representative. Each fitting shall be supplied with necessary coupling and flanges.

6.5 Super Duplex Piping and Fittings

For high pressure piping in SWRO system, Super Duplex Stainless Steel (SDSS) shall be used which will have PREN $\geq$ 43 and CF $\geq$ 35. For low pressure piping in SWRO system, SDSS can have PREN>41. It can have Victaulic type quick release flexible coupling for pipe jointing for smaller diameters of the pipe (up to 250 mm) and flanges for larger diameter. Welding procedure shall be submitted for review and approval. Valve connections shall be dismantling type and shall be flange connected with valves above 250 mm. Flanges shall be weld-neck type with raised face. MOC of coupling shall be Duplex stainless steel and the fastener shall be SS 316 (minimum). Pipe thickness shall be calculated after deduction of groove depth for Victaulic joint. All supports/anchors shall be designed also considering transient conditions and calculations shall be provided to the Employer for review. Velocities in the pipes shall be less than 3 m/sec. The pipes and fittings shall be as further detailed below.

6.5.1 Manufacturing

The pipe shall be made by the seamless or an automatic welding process, with no addition of filler material in the welding process as per the ASTM A790 specification.

The pipe shall be pickled free from Scale. When bright annealing is used pickling is not necessary.

The pipes and joints shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality. Employer/ Employer's Representative shall at all reasonable times have free access to the place where the pipes and joints are manufactured for the purpose of examining and testing the pipes and joints and of witnessing the test and manufacturing.

Care shall be taken that the resulting wall thickness does not become less than the minimum specified. If the wall thickness becomes less than the minimum specified, as per ANSI B36.19, the damaged portion should be cut out as cylinder and replaced by an undamaged piece of pipe at no extra cost to the Employer

6.5.2 General

This specification covers Seamless and straight seam welded Austenitic/ferritic steel pipe intended to use under corrosive service with particular emphasis on resistance to stress corrosion cracking.

The manufacturing, testing, supplying, joining and testing at work site of Super duplex pipes shall comply with all currently applicable statutes, regulations, standards and codes. In particular, the following standards unless otherwise specified here in, shall be referred. In all cases, the latest revision of the codes shall be referred to. If requirements of this specification conflicts with the requirements of the codes and standards, this specification shall govern.

6.5.3 Applicable Codes

ASTM A 815	Standard specification for Wrought ferritic, ferritic / Austenitic, and Martensitic stainless-steel fittings
ASTM A 262	Practice for detecting Susceptibility to intergranular Attack in Austenitic stainless Steel
ASTM A 388/ A388 M	Practice for ultrasonic examination of heavy steel forgings
ASTM A 960/A	Specification for common requirements for wrought steel piping

960M	fittings
ASTM A 763	Practice for detecting Susceptibility to intergranular Attack in Ferritic S Steel
ASTM A 234/ A 234M	Specification for piping fitting of wrought carbon steel and alloy for moderate and elevated temperatures
ASTM A 275/275M	Test method for magnetic particle examination of steel forgings
ASTM A 336/336M	Specification for steel forgings alloy for high press and high temperature parts
ASTM A 403/403A	Specification for Wrought austenitic stainless-steel piping fittings
ASTM A 479/A 479M	Specification for stainless and heat resistant bar and shapes for use in boilers and other pressure vessel
ASTM A 484/A 484M	Specification for general requirements for stainless steel and heat-resistant bars, billets and forgings
ASTM A 739	Specification for steel bars, Alloy, Hot-Wrought for elevated temperature for pressure containing parts, or both
ASTM A 751	Test methods practices, & terminology for Chem Analysis of steel products
MSS SP-43	Standard practice for light weight stainless butt-welding fittings
MSS SP-79	Socket welding reducer inserts
MSS SP-83	Steel pipe unions, Socket-Welding and threaded
MSS SP-95	Swage nipples and plugs
ASME B 16.9	Wrought Steel Butt-welding fittings
ASMEB 16.11	Forged Steel fittings, socket welding and threaded
ASME B 16.5	Dimensional Standard for steel pipe flanges and flanged fittings
ASMEB 16.10	Face-to-face and End-to-End Dimension of ferrous fittings
ASME Section IX- Welding Qualification	
SFA- 5.4	Specification for corrosion-resistance chromium and chromium-Nickel steel covered welding electrodes
SFA- 5.5	Specification for low-Alloy steel covered arc welding electrodes
SFA- 5.9	Specification for corrosion-resistance chromium and chromium-Nickel steel welding rods and electrodes

6.5.4 Properties

The material shall withstand under severe corrosive environment and pipe shall meet or exceed the minimum longitudinal tensile / compressive strength as per relevant clauses of ASTM A790 specification.

The material shall conform the chemical requirements as prescribed in ASTM A790 specification. The PREN number shall be calculated through the following formula:-

PREN = %Cr + 3.3 x %Mo + 16 x %N, Where Cr- Chromium, Mo- Molybdenum, N-Nitrogen

The steel shall conform to the tensile and hardness properties prescribed in ASTM A790 specification.

6.5.5 Dimension

Pipes shall be designated by nominal standard diameters. The nominal diameters, minimum wall thickness/schedule number, length of barrel, joints etc. Shall be within the tolerance limits specified in ANSI B36.19/ASTM A999.

6.5.6 Heat Treatment

Unless otherwise stated in order, all pipes shall be furnished in the heat treated condition as specified in ASTM A790 specification.

For seamless pipe, as an alternative to final heat treatment in a continuous furnace or batch type furnace, immediately following hot forming while the temperature of the pipe is not less than the specified minimum solution treatment temperature, pipes shall be individually quenched in water or rapidly cooled by other means.

6.5.7 Workmanship and Finish

The finished pipe shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thickness are not decrease to less than that permitted , in the permissible variation in wall thickness section of specification A999/A999M.

6.5.8 Testing

6.5.8.1 *Mechanical Testing*

One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension test shall be made on specimens of more than 100 pipes.

For a pipe heat treated in a batch type furnace, flattening test shall be made on 5% of the pipe from each heat-treated lot. For a welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of weld any be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of tests methods and definitions ASTM A 370.The ductility of the weld shall be acceptable when there is no evidence of cracks in the weld or between the base material after bending.

Brinell or Rockwell hardness tests shall be made on specimen from two pipes from each lot.

6.5.8.2 *Hydrostatic / Non-destructive Electric Test*

Each pipe shall be subjected to non-destructive electric or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in purchase order. The hydrostatic test shall be in accordance with specification ASTM B31.3.

Non-destructive electric test shall be in accordance with practice ASTM E213.

For eddy current test the maximum eddy-current coil frequency used shall be as per the given value in ASTM A 790.

Pipes shall be tested for 1.5 times of maximum allowable working pressure (MAWP) that can be generated at any abnormal working condition foreseen by hydraulic surge study, etc. Piping shall be also tested against full vacuum.

6.5.8.3 *Repairing by Welding*

For welded pipes of size NPS 6 or larger with a specified wall thickness of 0.188 inch (4.8 mm) or more, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedure specified for plate defects in section on repair by welding of ASTM A999/A999M.

Weld repairs of the weld seam shall not exceed 20% of the seam length.

6.5.9 **Marking**

The following information shall be clearly marked on each pipe and special: Manufacturer's name or trademark.

Material identification, either the ASTM or ASME grade designation Schedule number or nominal wall thickness in mm

Size - the nominal pipe size (NPS) identification number related to the end connections shall be used.

Class of pipe (Grade or UNS number) and special with its serial number

6.5.10 **Jointing**

6.5.10.1 *Flanged Joint*

The flanges for pipes and specials shall be Weld-neck Raised Face, with suitable rating applicable for the designed pressure. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer. All bolts, nuts and packing material required for flanged joints shall be provided by the Contractor. Bolts /studs, nuts and washer shall conform to ANSI B 18.2.1/ANSI B 18.2.2. Whereas metallic gasket with flexible graphite filled with carbon steel outer ring of required thickness shall conform to ASME B 16.20.

All the piping flanges and counter flanges & their drilling shall generally conform to ANSI B 16.5 of relevant pressure & temperature class.

6.5.10.2 *Welded Joint*

Where pipes or fittings are joined together by welding, following process can be used to weld Tungsten arc welding/ Plasma arc welding/Submerge arc Welding/ Metal Arc welding or any similar approved welding process as per approved Welding procedure specification (WPS) & Procedure Qualification Record (PQR). All welding work shall be carried out by qualified welders as per standard code ASME Section IX.

Pipes below 50 NB shall be plain end and the same shall be square groove welded, whereas pipes 50 NB & above shall be butt welded.

For Duplex Stainless-steel fittings and flanges shall be forged (wrought) or casting having the same schedule and equivalent material of construction having similar grade

Welded duplex/super duplex stainless steel piping need not be stress relieved except where specified in PQR. Such stress relieving may be done by uniformly heating welded area with nichrome/induction coil to 660± 15° C, holding the temperature for one hour for each 25 mm of wall thickness or fraction thereof, and then cooling at a rate not in excess of 315° C per hour in still air.

6.5.10.3 *Dismantling Joints*

The Contractor shall provide flexibility in the pipework at joints in the main structures and shall submit proposals for the approval of the Employer's Representative. Flexible joints shall also be provided for case of erection and future dismantling. Flexible couplings and flange adaptors shall be meeting with the requirements set forth by AWWA C 227 or similar approved pattern and be assembled in accordance with the manufacturer's instructions and protected.

Where steel and cast flanges are mated together the steel flange shall be machined over its full face, after welding to its respective pipe is completed.

Flexible joints shall be provided to facilitate installation and removal and or differential movement of plant. Where required, flexible joints shall be provided with tie bolts or other means to transfer longitudinal thrust along the pipework as a whole.

6.5.11 Pipe Fittings

The information under this clause covers the material specification, manufacturing, testing and other information for the piping fittings for the super duplex steel. Fittings shall be constructed of super duplex stainless steel material having PREN number equivalent to pipe system in which it is installed.

Fittings below 50 NB shall be forged fitting, and butt weld ends with relevant pressure rating not less than 3000#. The material shall be UNS S32750 as per ASTM A182/182M, Grade F 53 with PREN number equivalent to that of pipe, the formula for calculating PREN number is given above in this document. The dimensional standard shall be as per ASMEB 16.11.

The ferritic steel may be made by the open hearth, electric furnace, or basic-oxygen process with separate degassing and refining optional. A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

After the hot working, forgings shall be cooled to a temperature below 538°C prior to heat treatment in accordance with the requirement as given in ASTM A182/182M.

The chemical properties/composition of the material shall be in accordance with ASTM A182/182M. Mechanical testing, cast analysis, product analysis, shall be governed by relevant ASTM specification.

Fittings 50 NB and above shall be wrought ferritic-austenitic stainless steel (seam welded) with butt-welded end. The material shall be UNS S32750 as per ASTM A815/ASTM 815M, Grade WP-W, with PREN number not less than 43, the formula for calculating PREN number is given above in this document. The dimensional standard shall be in accordance with ANSI B 16.9.

The fittings ordered as class WP-W shall meet the requirements of specification ASTM A 960/960M and shall have all welds made by fitting manufacturer of all pipe welds made with the filler material radio graphically examined throughout the entire length.

All welding shall be done prior to the heat treatment and all fittings shall be heat treated in accordance with the requirements specified in ASTM A815.

Fabricated elbows shall be made of a contiguous piece of pipe of the same material as the pipe system in which it is being installed. Cut grooves shall be integral on the elbow. No weld joints shall be accepted without X-ray inspection report of the weld. Groove must conform to coupling manufacturers published tolerances for cut grooves. No deviation shall be allowed. All Grooved Fittings must conform to an internationally recognized quality assurance program or meet and conform to ASTM B31.3 severe cycle standards. Certificate of conformance shall be provided.

Factory trained representative shall visit job site to verify proper installation of fittings and couplings. Couplings manufacturer's installation instructions for couplings and fittings shall be followed.

6.5.12 Pipe Flanges

All flanges shall be forged and Weld-neck Raised Face, the material for flanges shall be UNS S32750 as per ASTM A182/A182M with MOC of SDSS PREN≥43.

Flanges below 50 NB shall be Stub End + Lapped flange (FF) with pressure class rating of 600#, while Flanges 50 NB and above shall be RF with pressure Class 600#. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer.

All bolts, nuts and packing material required for flanged joints shall be provided by the

Contractor. Bolts /studs, nuts and washer shall conform to ANSI B 18.2.1/ANSI B 18.2.2. Whereas metallic gasket with flexible graphite filled with carbon steel outer ring of required thickness shall conform to ASME B 16.20 as per table below.

All UNS 32750 material shall have a PREN ≥ 43 in the table below.

Description	**Size**	**Dim. Std.**	**Material**	**Remark**
Pipe	Below 50 NB	B36.19	ASTM A790 UNS S32750	Seamless, PE
Pipe	50 NB and Above	B36.19	ASTM A790 UNS S32750	Seamless/Straight seam welded, BW end
Flange	Below 50 NB	ANSI B 16.5	ASTM A182 GRF53, UNS S32750	600#, WNRF
Flange	50 NB and Above	ANSI B 16.5	ASTM A182 GRF53, UNS S32750	600#, WNRF
Elbow 90	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	1.5DBW
Elbow 90	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	1.5D.BW
Tee	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Tee	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Reducer	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Reducer	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Weldolet-Branch Butt Weld	Below 50 NB	MSS SP-97	ASTM A815 UNS S32750	Seamless
Gasket		B 16.20	3mm THK, spiral wound, SS 316, flexible graphite filled with carbon steel outer ring,	To suit Class 600#

Description	Size	Dim. Std.	Material	Remark
Bolt / Stud, Nut& Washer		ANSI B 18.2.1/ANSI B 18.2.2	STUD: A193 GR.B8M. NUT: A194 GR.8M	

6.6 HDPE Piping

6.6.1 Applicable Codes

Polyethylene pipes shall comply with below mentioned Indian Standards /BS 6437.

The following Indian Standards /BS 6437, unless otherwise specified herein, shall be referred. In all cases the latest revision of the Codes shall be referred to. If requirements of this specifications conflict with the requirements of the standards /Codes, this specification shall govern. The welding method shall be adapted to international standard and contractor shall obtain the approval of the Engineer before proceeding with such works.

Code No.	Title/ Specification
ISO 4427E, EN12201	High Density polyethylene pipes
IS:2530	Methods of test for polyethylene moulding materials and polyethylene compounds
IS 4984 Amendment No. 21995	High Density polyethylene pipes for Water Supply
IS 5382	Rubber sealing rings for gas mains, water mains and sewers
IS:7328	High density polyethylene materials for moulding and extrusion
IS 7634	Laying & jointing of polyethylene (PE) pipes
IS 2530	Methods of test for polyethylene moulding materials and polyethylene compounds
IS 4905	Methods for random sampling
IS 9845	Methods of analysis for the determination of specific and / or overall migration of constituents of plastics material and articles intended to come into contact with foodstuffs.
IS 10141	Positive list of constituents of polyethylene in contact with food stuffs, Pharmaceuticals and drinking water.

The High-Density Polyethylene (HDPE) Pipe shall be made from base polymer and shall conform to the requirements as specified in ISO4427. The base polymer shall be a single grade of polyethylene. All raw material used shall be approved and certified Pipe Grade material for the transportation of product water.

Pipes shall be of PE100. SDR requirements shall meet PN6 for gravity lines and PN 10 for any pressure line. Support arrangements shall be designed, and calculations provided for review. Supports shall be designed.

The Contractor shall provide the certified information (as per BIS) about the properties of PE-100 material as stated in the document for manufacturing the pipes for this project. Density, flexural strength, compressive strength, modulus of elasticity, short term and long term yield value, allowable circumferential stress in pipes intended for 40-50 years of service at normal temperature, volume resistivity, thermal conductivity, specific heat, linear coefficient of expansion, ignition by flame, burning rate, maximum operating temperature (under pressure) and any other properties which may affect the serviceability of pipe at project site. The Contractor shall submit original copy of the pipe manufacturer's sworn certificate of inspection and testing of all pipes and fittings used on the job. All pipes and fittings shall be subject to inspection and approval by the Engineer/ Employer's representative before and after delivery at the project site. Any pipe or fittings found to be unsatisfactory or otherwise damaged shall not be approved for use.

No additives that may contribute to toxic hazard, impair the fabrication of properties and chemical and physical properties in particular to long term mechanical and strength is allowed.

The colour of the pipes shall be black with blue stripes. Each pipe shall contain minimum three equi-spaced longitudinal stripes of width 3 mm (Min) in blue colour. These stripes shall be more than 0.2 mm in depth. The material of the stripes shall be of the same type of resin, as used in the base compound for the pipe.

All HDPE pipes shall conform to IS: 4984-1995 (with amendment) high density polyethylene pipes (HDPE) for product water supplies (Fourth Revision) or ISO 4427-1996 with nominal outside diameters. The pressure rating of the pipes shall be governed by the design. The raw material of pipes shall conform to ISO 4437. The produced pipes shall pass the internal pressure test (acceptance test) using the test method per EN 921.

The flanges system will follow systematically these requirements:

Nominal Pressure: 10 bars

Flange norms: ISO PN10, EN 1092-2 and ISO 7005-2.

The rubber gasket will follow these requirements:

Material: nitrile rubber

Thickness: min 4mm

For PN10 flanges

The bolts and nuts shall be Electro-galvanized steel;

Flanges will be used to fit together elements of different materials such as valves (in cast iron or ductile iron) with HDPE pipes through the use of a flange adaptor.

6.6.2 Appearance

The internal and external surfaces of pipes must smooth, clean and free from scoring, cavities and other surface defects which may affect pipe performance. The ends of pipe shall cut cleanly and square to the axis of the pipe. Appearance shall be checked at the point of manufacture.

Each straight length of pipe shall be clearly marked in indelible ink/paint on either end and for coil at both ends or hot embossed on white base every meter throughout the length of pipe/coil with the following information:

a) Manufacture's name and/or Trade-mark,

b) Designation of pipe

c) Lot No./Batch No.

d) BIS certification marking on each pipe/Equivalent in case of Import.

Ovality shall be measured at the manufactures end as the difference between the maximum outside diameter and minimum out-side diameter measured at the same cross section of the pipe, at 300mm away from the cut end. For pipes to be coiled, the ovality shall be measured prior to coiling For coiled pipes, however, re-rounding of pipe shall be carried out prior to the measurement of ovality.

6.6.3 Pipe Fittings:

Pipe fittings shall be laid so as to form a close concentric joint with the adjoining pipe to avoid sudden offsets of the flow line. Pipe sections shall be joined together in accordance with the manufacturer's recommendations.

6.6.4 Butt Fusion Joining

Plain end pipe and fittings shall be made using butt fusion. The butt fusion procedures shall be in accordance with the manufacturer and the relevant codes. The fusion equipment operator shall receive training using the recommended procedure. The Contractor shall be responsible to verify that the fusion equipment is in good operating condition and that the operator has been trained within the past twelve months. The fusion equipment shall be equipped with a Data logger. Records of the welds (heater temperature, fusion pressure, and a graph of the fusion cycle) shall be maintained for five (5) years. Fusion beads shall not be removed.

Butt fusion fittings shall have a manufacturing standard of ASTM D 3261. Molded & fabricated fittings shall have a pressure rating equal to the pipe unless otherwise specified in the plans.

Flange adapters shall be attached to pipe and fittings using butt fusion. The flanges adapters shall be aligned and centered relative to the pipe. Flange adapters should be square with the valve or other flange before tightening of bolts. Bolts should not be used to draw flanges into alignment. Bolt threads shall be lubricated, and flat washers shall be used under flange nuts. Bolts shall be tightened using a "star tightening pattern". Twenty-four hours after first tightening the flange bolts, they must be re-tightened using the same "star tightening pattern used above. The final tightening torque shall be as indicated by the manufacturer.

Heat Fusion Training. The supplier of the pipe and fittings shall provide a person certified by the pipe manufacturer and the fusion equipment manufacturer to train contractor fusion equipment operators and inspectors representing the Owner.

Inspection

On both sides, the double bead should be rolled over to the surface, and be uniformly rounded and consistent in size all around the joint.

The gap between the two single beads must not be below the fusion surface throughout the entire circumference of the butt joint.

The displacement between the fused ends must not exceed 10% of the pipe/fitting minimum wall thickness.

For the intake pipes of HDPE material, the bead projection inside of the pipe shall be made suitable for "Pig" movement while cleaning.

6.6.5 Electrofusion Couplings.

Polyethylene pipe and fittings may be joined using approved electrofusion couplings. Electrofusion Fittings shall have a manufacturing standard of ASTM F 1055. Fittings shall have a pressure rating equal to the pipe unless otherwise specified on the plans. All electrofusion fittings shall be suitable for use as pressure conduits, and per AWWA C906, have nominal burst values of three and one-half times the Working Pressure Rating (WPR) of the fitting.

6.6.6 Pipe Manufacturer's Quality Control.

The pipe manufacturer shall have an ongoing Quality Control program for incoming and outgoing materials. High-density polyethylene (HDPE) resins for manufacturing of pipe shall be checked for density, melt flow rate, and contamination. The manufacturer of the HDPE resin shall certify the Cell Classification as per his format. These incoming resins shall be approved by plant Quality Control before being converted to pipe. Pipe shall be checked for outside diameter, wall thickness, length, roundness, and surface finish on the inside and outside and end cut. Testing Pressure testing shall be conducted in accordance with ASTM standard.

6.6.7 Transport and Handling

Vehicles for transporting HDPE pipes should have a clean flat bed, free from nails and other projections which might cause damage. Each pipe should be supported along its length but, where this is not possible; timber supports of at least 75mm bearing width and placed at most 60 cm apart should be used. The above recommendations may not apply when rigid bundles of pipes are being transported. In that case the overall height of the bundles should not exceed 2.5 m. Side supports should not be less than 1.5 m apart; they should be flat and have no sharp or rough edges. When loading pipes with integral sockets, the sockets should be placed at alternate ends of the vehicle in such a way that they do not make contact with the neighbouring pipes. When transporting a mixed load of pipes, it is important that the larger, generally thicker-walled, and thus heavier, pipes are placed at the bottom. Pipes should not be allowed to overhang the vehicle.

6.6.7.1 *Pipe and Large Fitting Handling*

HDPE pipes are light in weight, they are therefore easy to handle. With reasonable care, damage to the pipes can be easily avoided. Pipes should not be dragged along the ground nor should they be lowered on skids. Whenever mechanical handling techniques are used, all equipment coming into contact with the pipes should be made of a soft material. A nylon fabric choker sling capable of safely handling the weight of the pipe or fitting, shall be used to lift, place and move pipe and fittings or For example, textile slings and Hessian ropes may be used and it should be ensured that all metal hooks are covered.

While unloading pipes from vehicles, do not drop them on the ground. Pipes should always be carefully lowered onto the ground or stacked where they are to be stored. Whenever pipes have been transported one inside another, the inner pipes should always be removed first and stacked separately.

6.6.7.2 *Storage*

Generally, similar requirements apply to storage of HDPE and uPVC pipes.

Pipes may be stored in loose stacks up to a maximum height to 2 m.

When pipes are stored outside in climates having high ambient temperatures (greater than 23 °C), the following is recommended:

a) The height of the stacks should not exceed 1 m;

b) all stacks should be shielded from continuous and direct sunlight and shall be arranged to allow the free passage of air around the pipes; specials & fittings should always be stored in boxes or sacks manufactured so as to permit the free passage of air.

c) When pipes are stacked in the form of rigid bundles, a maximum of three bundles having a height of 1 m each should be stacked on top of each other.

6.7 CPVC Pipe:

This specification outlines minimum manufacturing requirements for Chlorinated Polyvinyl Chloride (CPVC). This pipe is intended for use in applications where the fluid conveyed does not exceed 140°F. This pipe meets and or exceeds the industry standards and requirements as set forth by the American Society for Testing and Materials (ASTM), ISO and the National Sanitation Foundation (NSF International).

The material used in the manufacture of the pipe shall be a rigid chlorinated polyvinyl chloride (CPVC) compound, Type IV Grade I, with a Cell Classification of 23447 as defined in ASTM D1784. This compound shall be light grey and shall be approved by NSF for use with product water. The pipe shall be manufactured in strict compliance to ASTM F441, consistently meeting the Quality Assurance test requirements of this standard with regard to material, workmanship, burst pressure, flattening, and extrusion quality. The chlorine content in pipe at a time shall not be less than 66.5%.

The pipes shall be as per IS 15778, latest edition for water supply.

Solvent-cemented joints should be utilized when working at or near maximum temperatures. The use of PVC for threaded connections at temperatures above 110°F; is not recommended, above the same flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures shall be used.

Thread only Schedule 80 or heavier walls. Threading requires a 50% reduction in pressure rating stated for plain end pipe @73°F. Threading of Schedule 40 PVC pipe is not a recommended practice due to insufficient wall thickness.

Chemical resistance data should be referenced for proper material selection and possible de-rating when working with fluids other than water.

6.8 Hydrotesting

6.8.1 Hydro-testing of HDPE/CPVC Pipes

Hydro pressure testing shall be done on the laid pipe length for a minimum pressure of 1.5 times the designed working pressure (but not less than 6 bar) for retaining period of 4 hours, and as mentioned in IS 4984 -1995 including its latest amendments. A report shall be prepared by the Contractor and submitted to the Employer’s representative to provide the details of the pipe laid, source of water to be used for hydrotesting with the proposal of hydrotesting on a given date. The acceptance criteria for hydrostatic test are no permanent deformation of any part of the pipeline fitting or equipment and there shall not be any leakage through any of the joints.

All the necessary consumables, equipment, tools & tackles required for the testing & inspection has to be arranged by the Contractor.

Hydro pressure testing has to be done for all the valves as per IS 13095 -1991 including its latest, at the manufacturer's end and a report has to be submitted to the Employer's Representative.

6.8.2 Hydrotesting of Valves and Other Fittings

Suitable section shall be chosen for such testing in consultation with Employer's Representative from time to time during progress of the work and satisfactorily tested. All testing apparatus, gauges, connections, etc. and water required for testing shall be arranged by the contractor at his cost. The water for testing has to be arrange by the Contractor after discussion with the Engineer.

Satisfactory hydraulic test shall be recorded when the section under test shall withstand the pressure for about 15 minutes without operating the test pump. The test pressure being maintained at the specified figures during that 15 minutes interval.

The field test pressure to be imposed should be not less than the maximum of following.

a) 1.5 times the maximum sustained operating pressure.

b) 1.5 times the maximum static pressure in the pipeline

During testing if any joints are found leaking, they shall be repaired and / or reinstalled by the

Contractor at his cost till the test is found satisfactory. Similarly, any pipes collars, specials, show hair cracks, leaks etc. during testing the contractor shall replace them with sound pipes and specials etc. free of cost. The hydraulic test shall be carried out after noticing the Employer's Representative.

Water tightness of the valve joints shall be tested in the same manner as described for mains. These tests may be carried out along with the tests of the pipe mains and separate tests are not essential.

6.8.3 Testing of Pipes & Specials, Pipeline and Joints

All tests specified in this specification, relevant Indian Standards as per codes followed and manufacturer's instruction manual, applicable for HDPE and uPVC pipes respectively and specials, shall be carried out by the contractor at his own cost.

Before commencing the factory testing of pipes and specials and fittings, notice period of 15 days shall be given to the Employer's Representative.

Certificate from the manufacture, certifying compliance to all tests for all lots and diameter of pipe needs to be submitted before transporting the pipe to site.

The under given test shall be carried out for HDPE pipes:

(i) Resistance to internal pressure - Test method

The internal pressure test is standardized in ISO 1167. The test specifies a method for determination of the resistance to constant internal pressure at a constant temperature.

(ii)The Pipe notch test

The Pipe notch test is standardized in ISO 13479 as "Polyolefin pipes for the conveyance of fluids - Determination of resistance to crack propagation - Test method for slow crack growth on notched pipes (notch test)". The test simulates slow crack growth and record time to failure on notched pipes.

(iii) The Small-scale steady-state test

The small-scale steady-state test (S4 test) is standardized in ISO 13477 "Thermoplastics pipes for the conveyance of fluids - Determination of resistance to rapid crack propagation (RCP)." The test simulates the phenomenon of RCP in plastic pipes and measures the determination of arrest or propagation of an initiated crack. In pipelines RCP, caused by a brittle crack, could undergo the length of several hundred meters almost at the sound of speed.

Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fiber glass wraps set in coal tar enamel coats conforming to American Water Works Association Specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipework supplied by him. Particular care shall be taken to ensure that pipe-work thrusts are, as far as possible, not transmitted to machinery or other associated apparatus.

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Employer.

6.9 Ductile Iron Pipes and Fittings

6.9.1 Pipes and Fittings

6.9.1.1 *General*

Ductile iron pressure pipes and fittings (Class K9) shall comply with IS:8329 and IS:9523. All fittings shall be socketed unless specified otherwise.

6.9.1.2 *Materials*

The materials used in the manufacture pipes and fittings shall comply with IS:8329 and IS:9523.

6.9.1.3 *Tests*

Tests on pipes and fittings shall be carried out in accordance with IS:8329 and IS:9523. The test method shall be submitted for approval of the Engineer.

The Engineer shall be permitted free access to the place of manufacture for the purpose of examining, inspection and witnessing the testing of pipes and fittings

6.9.2 Joints

6.9.2.1 *Spigot and Socket Joints*

These shall have sockets which are integral with the pipe and incorporate an elastomeric rubber ring gasket conforming to IS:12820.

6.9.2.2 *Flanged Joints*

These shall comply with dimensions and drilling details shall be to BS EN 1092-2. All flanged joints of dissimilar material such as between steel and ductile iron pipe-work shall be electrically isolated joints. These shall have isolation gaskets between the flanges, isolation sleeves around all bolts and isolation washers under all bolt heads and nuts. All materials shall be supplied by a specialist manufacturer and be to the approval of the Engineer.

6.9.3 Linings

Ductile iron pipes and fittings shall have a cement mortar lining, in accordance with IS:11906 or ISO 4179. Pipe linings shall be inspected on site and any damage or defective areas made good to the satisfaction of the Engineer. The Contractor may use specialist mortars, mortar additives or curing agents only with the approval of the Engineer.

Certain sections are amplified as follows:

No additives shall be used without the written approval of the Engineer, and shall be used strictly in accordance with the manufacturer's recommendations.

The minimum thickness of the lining at one point shall not be less than that specified in IS:8329.

6.9.4 Coating

6.9.4.1 *General*

Ductile iron pipes and fittings shall be zinc coated with bitumen over coating, all in accordance with the following Specifications. Buried pipes and fittings shall also have a site or factory applied polythene sleeving. Pipe coatings shall be inspected on site and any damage or defective areas made good to the satisfaction of the Engineer.

6.9.4.2 *Zinc Coating*

Zinc coating shall comply with ISO 8179 and shall be applied as a spray coating. The mass of sprayed metal shall not be less than 130 g/m^2 as described in Clause 5.2 of ISO 8179.

6.9.4.3 *Bitumen Coating*

Bitumen coating shall be of normal thickness 0.07 mm unless otherwise specified. It shall be a cold applied compound complying with the requirements of BS 3416 Type II, suitable for tropical climates, factory applied in accordance with the manufacturer's instructions.

Damaged areas of coating shall be repainted on site after removing any remaining loose coating and wire brushing any rusted areas of pipe.

6.9.4.4 *Polythene Sleeving*

Where polythene sleeving is specified (generally for all buried DI pipes) to be applied in addition to bitumen coating it shall comply with ISO 8180. Site applied sleeving shall be stored under cover, out of direct sunlight, and its exposure to sunlight shall be kept to a minimum. Pipes having a factory applied sleeving must be stored in the same conditions.

6.10 Steel Cylinder Pipes and Specials

6.10.1 Design

In general, the design of steel cylinder pipes with concrete lining and coating shall conform to clause 8 of IS 1916. In addition to above, in case of buried pipeline, the pipe shall also be designed for the Earth load, and traffic load.

6.10.2 Manufacturing

6.10.2.1 *General*

Steel cylinder pipes and specials with concrete lining and coating shall be systematically checked for any manufacturing defects by experienced supervisors and a very high standard of quality shall be maintained. The pipes and specials shall be inspected by the Engineer at site and factory, and defects noticed, if any, such as protrusions, grooves, dents, notches, etc. shall be rectified, if agreed to by the Engineer. Care shall be taken that the resulting wall thickness does not become less than the minimum specified. If the wall thickness becomes less than the minimum specified, as per Table 1 of IS:1916, the damaged portion should be cut out as cylinder and replaced by an undamaged piece of pipe at no extra cost to the Engineer. The Engineer shall at all reasonable times have free access to the place where the pipes and specials are manufactured for the purpose of examining, inspection and testing the pipes and specials and for witnessing the test and manufacturing.

All tests specified either in this Engineer Requirement or in the relevant Indian Standards shall be performed by Supplier/Contractor at his own cost and in presence of the Engineer, if desired. For this sufficient notice before testing of the pipes and specials shall be given to the Engineer.

If the test is found unsatisfactory, the Engineer may reject any or all pipes and specials of that lot. The decision of the Engineer in this matter shall be final and binding on the Contractor.

6.10.2.2 *Materials*

All material shall conform to Clause 7 of IS:1916.

6.10.2.3 *Manufacturing Process*

Steel cylinder pipes with concrete lining and coating shall be manufactured as per Clause No.9 of IS:1916 and specials shall be manufactured as per Clause 7 of IS:7322. In case of spiral welded pipes, they shall be manufactured as per Clause 3 of IS:5504. Internal lining shall be up to the full length of the pipes and specials. However, external coating shall be done leaving about 100 mm length of the pipes and specials from their ends. The internal lining and external coating to pipes and specials shall be done at factory. Before lining/coating by concrete/mortar the surface of pipes and specials shall be thoroughly cleaned. In the event that loose mill scale, tuberculation, or an accumulation of dirt, debris, oil or grease is present, it shall be removed from the surface by hand, by machine or both and given a coating of neat cement slurry.

6.10.2.4 *Dimensions*

The clear cover to the reinforcement whether steel cylinder or cage shall be not less than 9 mm for lining of pipe/special and 12 mm for coating of the pipe/special.

The permissible tolerance for diameter and length of pipe shall be as per Clause 4 of IS:1916, whereas for diameter, arm length and angular deviation of specials the tolerance limit shall be as per Clause 6 of IS:7322.

6.10.2.5 *Workmanship and Finish*

Workmanship and finish of pipe shall conform to Clause 4 of IS:1916.

6.10.2.6 *Testing*

Each steel cylinder shall be subjected before lining/coating to a hydrostatic test under a water pressure equivalent to the test pressure in accordance with Clause 10 of IS:1916 and relevant provisions of IS:3597, provided that the whole of the area of the calculated reinforcement is used in the steel cylinder. In the case of pipes where a part of the principal reinforcement is provided in the cage, the steel cylinder shall be subjected to proportionately less hydrostatic test pressure.

Manufacturer's standard specials shall be hydrostatically tested before lining/coating. Where feasible, other specials shall be hydrostatically tested (before lining/coating) at factory. However, when this is not practicable, at the discretion of the Engineer, the unlined specials shall be tested by penetration test as per IS:3658 or other approved means.

All of results of test and inspection data must be prepared by contractor at site so that the Engineer shall make decision of "fail or pass" at once. All cost for the inspection shall be borne by the Contractor.

6.10.2.7 *Penetration Test*

A suitable liquid penetrant (kerosene oil/Dye) is applied to the surface of the portion under examination and is permitted to remain there for sufficient time to allow the liquid to penetrate into any defects open at the surface. After the penetrant time, the excess penetrant which remains on the surface is removed. Then a light-coloured powder absorbent called a developer is applied to the surface. This developer acts as a blotter and draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out it diffuses into the coating of the developer, forming indication of the surface discontinuities or flaws.

6.10.2.8 *Marking*

The following information shall be clearly marked on each pipe and special:

- Internal diameter, external diameter and thickness
- Class of pipe and special with its serial number
- Date of manufacture and
- Name of manufacturer or his registered trademark or both

6.10.3 **Jointing**

6.10.3.1 *General*

Jointing of steel cylinder pipes and specials with concrete lining and coating be done as per the relevant IS. After jointing, extraneous material if any shall be removed from the inside of the pipe and special. The welding of joints for pipes and specials at work sites shall comply with IS:816. Electrodes used for welding shall comply with IS:814.

6.10.3.2 *Butt Welded Joint*

After pipes and specials are laid in the trench, the faces of pipes/specials shall first be tack-welded alternately at one or more diametrically opposite pairs of points. After completing tack welding, full welding shall be carried out in suitable runs following a sequence of welding portions of segments diametrically opposite. After jointing the exposed surface of the steel cylinder of pipes and specials shall be coated with M20 cement concrete of sufficient thickness so as to make it flush with the adjoining both inner and outer faces of pipes and specials. The gap in the internal lining at the joints shall be filled with cement mortar (1:2) for pipes and specials larger than 600 mm diameter. The lining/coating shall be done after the field test in the section has been successfully completed.

6.10.3.3 *Lap Welded Joint with Slip-in-ends*

In the case of pipes with plain or slip-in-ends, swaged end of the steel cylinder may be formed by heating one of its ends and expanding it or rolling it out to the required shape. The minimum depth and maximum clearance between the swaged end and the plain end of pipes for field welding shall be provided as directed by the Engineer. Lap welding shall be done from the external face at the junction of pipe and socket. After jointing the exposed surface of the steel cylinder of pipes and specials shall be coated with M20 cement concrete of sufficient thickness so as to make it flush with the adjoining both inner and outer faces of pipes and specials. The gap in the internal lining at the joints shall be filled with cement mortar (1:2) for pipes and specials larger than 600 mm diameter. The lining/coating shall be done after the field test in the section has been successfully completed.

6.10.3.4 *Flanged Joints*

The flanges for steel cylinder pipes and specials shall be as per BS EN 1092-1. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer. All bolts, nuts and packing material required for flanged joints shall be provided by the Contractor. Bolts and nuts shall conform to IS:1367 whereas rubber gasket of required thickness shall conform to IS:638.

The bolts shall be evenly tightened in comply with relevant BS standard. Random inspection shall be carried out by jointly the Engineer and the Contractor.

6.10.4 **Cleaning of Pipes and Specials**

Contractor shall ascertain that each stretch of pipeline is absolutely clear and without any obstruction by means of visual examination of the interior of pipeline suitably lighted by projected sunlight or otherwise. The open end of an incomplete stretch of pipeline shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.

If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipeline, he shall be entitled to order the stretch to be tested immediately. Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.

6.10.5 Testing at Work Site

After laying and jointing of steel cylinder pipes and specials with concrete lining and coating is completed the pipeline shall be tested at work site as per the following Employer's Requirement and as directed by the Engineer. All equipment for testing at work site shall be supplied and erected by Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be Contractor's responsibility and shall be rectified by him to the full satisfaction of the Engineer. Water used for test shall be removed from pipes and not released to the excavated trenches.

Each section of the pipeline shall be slowly filled with clean water and all air shall be expelled from the pipeline. The pressure in the pipeline should then be raised and maintained by means of pump to the test pressure. The test pressure should not be less than 1 1/2 times the working pressure at the lowest point or the static head pressure, whichever is higher. Under the test pressure no leak or sweating shall be visible at the welded joints. The duration of test shall be not less than 24 hours. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be rewelded. Any cracked or defective pipes and specials in consequences of this pressure test shall be removed and replaced by sound material by Contractor and the test shall be repeated to the satisfaction of the Engineer. Proper arrangement of thrust blocks shall be provided during pressure testing or pipe laying works.

6.11 Steel Pipework

Pipe/fitting material and dimensional standard shall conform to following:

Size mm (NB)	Material Specification (Steel)	Dimensional Standard
Pipes upto 150 mm	1239 PT, ERW, Black PT-1 HVY	1239 ERW
200 to 2400	2062	3589 – ERW 3589 for dimensions and minimum thickness. Pipe thickness shall be as per 2825
Elbows up to 25	ASTM–A 105	ANSI B 16.11 3000 # S.W.
40 to 150	ASTM-A 234 GR WPB	ANSI B 16.9
200 & above (meters)	2062	LR. BE. Sch 40 ANSI B 31.1
Coupling upto 25	ASTM-A 105	ANSI B 16.11 3000 # S.W.

Size mm (NB)	Material Specification (Steel)	Dimensional Standard
Tees 40 to 200	ASTM – A 234 GR WPB	ANSI B 16.9 BE, Sch 40
Above 200	IS 2062	IS 2825 (min. Pipe thickness)
Reducers up to 25	ASTM-A 105	ANSI B 16.11 3000 S.W.
40 to 200	ASTM-A 234 GR WPB	ANSI B 16.9 BE, Sch 40
Above 200	2062	IS 2825 (min. Thickness for larger pipes)
Flanges	2062	BS EN 1092-1
Bolts and all nuts	1367 C1 4.6/4.0 (except under-water service which shall be in SS-316)	1364
Gaskets All	Natural Rubber to hardness 65+/- 5 shore A	3 mm thickness

Facilities shall be provided for draining the pipe system and releasing air.

The pipework layout within pump stations shall have the approval of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.5 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.4 m/s.

The whole of the jointing work and materials necessary to fix and connect the pipes, including adequate and efficient pipe support shall be included in the Contract. The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small-bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Engineer.

Hydrostatic shop test for pipes and fittings shall be as per code/standard requirement. After erection at site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times operating pressure.

Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fibre glass wraps set in coal tar enamel coats conforming to American Water Works Association Specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipe-work supplied by him. Particular care shall be taken to ensure that pipe-work thrusts are, as far as possible, not transmitted to machinery or other associated apparatus.

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Engineer.

Buried pipes shall in addition be designed to withstand external loading exerted by soil, water, and live loads as relevant. The external ground water shall be taken at ground level for design purposes.

Saddle type/bracket type support wherever required shall be designed and supplied for the above ground pipelines.

All pipe joints shall be of the butt-welded type. End preparations and fabrication requirements shall generally conform to I.S. 2825. Flanges, if fabricated in segments, shall be fully radiographed and stress relieved.

Laying of welded steel pipes shall meet the requirements of I.S: 5822.

6.11.1 Welded Joints for Steel Pipes

Welding of joints in steel pipes shall be carried out manually by the metal arc welding process complying with AWWA Standard C206.

Before starting the welding of pipe joints in the Works the Contractor shall submit for the Engineer's 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.

Welding shall only be carried out by welders approved by the Engineer and each welder shall identify his work by means of a stencilled mark.

Welded joints other than for closing lengths shall be of the spherical spigot and socket type. For pipes of smaller than 600 mm diameter the pipe joint shall be welded externally. For pipes of 600 mm and larger, the pipe shall be welded internally, and a sealing weld made externally.

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.

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 leg 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 9/10th and not less than 7/10th 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 on to the parent metal without proper fusion or containing any other defects whatsoever shall be cut out and rewelded to the satisfaction of the Engineer at the Contractor's expense.

At closing lengths where two plain ended pipes are to be joined by a welded 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 and the end of each pipe shall then be fillet welded to the sleeve collar in accordance with the above procedure.

No weld or adjacent parts of the pipe shall be painted prior to inspection by the Engineer.

6.11.2 Welder Performance Test

The Contractor shall submit for the Engineer's approval the names of persons whom he proposes to employ as welders with evidence that, as a minimum preliminary qualification, they have passed the qualifying tests prescribed in Clause 11 of BS 2633 and possessed certificates from an independent testing authority. The Engineer may further require any such person to perform satisfactory test welds under Site conditions and on pipes similar to those for use in the Works, before approving his employment as a welder. The Contractor shall maintain an up-to-date list of welders approved by the Engineer and if ordered by the Engineer, he shall remove from the approved list any welder whose workmanship, as demonstrated by the results of air pressure tests on individual welded joints, is below a reasonable standard of quality of consistency in the Engineer's opinion.

6.11.3 Testing of Welded Joints

Where directed by the Engineer welded joints on pipes larger than 600 mm diameter shall be subject to a nitrogen gas test after welding.

A tapped hole (approximately 6 mm diameter) shall be made in the socket end of each pipe by the Contractor and shall be fitted with a suitable non-return valve. Nitrogen, at 400 kPa pressure, shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

If no drop in pressure occurs over the ensuing period of 30 minutes the test shall be deemed to be successful. If the test pressure cannot be maintained for 30 minutes all defects in the weld shall be cut back and rewelded and the test reapplied until successful. The cost of initial and subsequent testing of defective welds shall be at the Contractor's own expense.

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

6.11.4 Hydraulic Losses

The frictional losses due to water flow in pipe-work shall be computed, as per the Hazen-William formula and as specified in the Central Public Health and Environmental Engineering Organisation (CPHEEO) Manual on Water Supply and Treatment, including losses in valves and specials, penstocks etc. c)Fittings, specials.

For specials like reducers, bell-mouths, tees, elbows, etc, the `k' values shall be as recommended by the British Hydromechanics Research Association (BHRA), Volume 5, in the BHRA fluid Engineering Series.

6.11.5 Pipework Protection

All underground steel piping shall have their external surfaces protected by application of one coal tar enamel coat, wrapping of fibreglass, one more coat of enamel and a final wrap of enamel impregnated fibreglass. Pipe surface shall be thoroughly cleaned by shot or sand blasting. Primer paint recommended by the enamel manufacturer for the grade of enamel used shall be applied over this cleaned surface within four hours of cleaning. The primer paint shall be thoroughly mixed and applied as recommended by the manufacturer and the coating shall be free of bubbles, globules, drips and runs. The primer shall be thoroughly dry before enamel is applied, and the latter shall not be applied later than 3 days after application of primer. First flood coat of enamel shall be overlaid by a single spiral wrap of fibreglass overlapping at least 2.0 mm on pipe upto 250 mm diameter and 2.5 mm on larger diameter pipes. Enamel shall be heated slowly in clean kettles, equipped with indicating or recording thermometers (100°C to 350°C range), to the recommended temperature. The enamel shall be stirred continuously. It shall be seen that fibreglass impregnates in the flood coat. Second coat of enamel and second wrap of bitumen impregnated fibreglass shall be applied in the same way. The total thickness of the coating shall not be less than 4.5 mm. Each end of the pipe left bare for a distance of 150 mm for welding shall be hand coated and wrapped after field welding is completed and hydro tested. Testing of pipe protection shall be done as directed by the Engineer using elcometers, coating thickness gauges, bond test and holiday detectors.

For pipe-work partly below ground and partly above ground the protective wrapping provided for underground pipeline shall be extended 300 mm above FGL and suitable clamps shall be provided at the end of wrapping to secure it properly.

All underground pipe-work having a cover less than 0.9 m shall be encased with M 15 concrete of minimum 200 mm thick all around.

All above ground and steel pipes in galleries shall be externally painted with two coats of epoxy with minimum thickness of 180 microns for each coat.

6.11.6 Flexibility in Pipework

The Contractor shall provide flexibility in the pipework at joints in the main structures and shall submit proposals for the approval of the Engineer. Flexible joints or collars and cut pipes shall be allowed on all pipework where necessary to allow for some margin of error in the building work. Wherever possible, flexible joints shall be provided with tie bolts or other means to transfer longitudinal thrusts as a whole so that external anchorages may be kept to a minimum. Flexible joints shall also be provided for case of erection and future dismantling. Particular care shall be taken to ensure that pipework thrusts are not transmitted to machinery or associated apparatus. The Contractor shall indicate on his detailed drawings what thrust blocks are required.

6.11.7 Puddle Flanges

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawing and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the Engineer prior approval.

6.11.8 Small Bore Pipes and Hoses

Small bore pipes and hoses shall be of non-flame propagating materials. They shall be arranged for easy dismantling for cleaning where appropriate, and if screwed joint or joints formed by solvent welding are proposed for any chemical line, a sufficient number of flanged or flexible joints shall be provided to enable the pipe-work to be removed in sections without working from one end to the other of a particular run. Tees and cocks shall also be provided at convenient points for the connection of a pressure water supply to flush pipe-work through as required.

All pipes and hoses shall be labelled to enable individual lines to be identified throughout their run. Racks or trays shall be fixed to the duct walls or walls of tanks and buildings and the chemical pipes shall be fixed to these racks or trays with clips which can easily be removed without dismantling adjacent pipes. The Contract includes for the supply and fixing of all such racks or trays. Full details of the type of hoses, pipes and racks of trays proposed, shall be submitted at the time of tendering.

6.11.9 Support of Pipework and Accessories

All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipe-work and its associated equipment in an approved manner. Valve, meters, strainers, and other devices mounted in the pipe-work shall be supported independently of the pipes to which they connect.

All brackets or other forms of supports, which can conveniently be so designed, shall be rigidly built up of steel by riveting or welding in preference to the use of castings.

No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Engineer.

After the collars and boxes or other fitting have been fixed in position, the floors, walls and roof structure shall be made good by the Contractor.

6.12 Pipes Identification and Site Testing

6.12.1 Marking

Each pipe and fitting shall have cast, stamped or indelibly painted on it the following appropriate marks:

- *Nominal diameter*
- *Flow direction and line marks for installation*
- *Class reference*
-
- *Date of manufacture and*
- *Manufacturer's name, initials or identification mark.*

Marking shall be done as per relevant IS code.

6.12.2 Flanged Pipes

The gaskets used between flanges of pipes shall be compressed fibre board or natural/synthetic rubber conforming to IS:638, of thickness 3 mm. The fibre board shall be impregnated with chemically neutral mineral oil and shall have a smooth and hard surface. Its weight per square metre shall be not less than 112 g/mm thickness.

Each bolt should be tightened a little at a time taking care to tighten diametrically opposite bolts alternately. The practice of fully tightening the bolts one after another is highly undesirable. The bolts shall be of mild steel unless otherwise specified.

6.12.3 Cleaning of Pipes and Fittings

The Contractor shall ascertain that each stretch of pipeline is clear and without any obstruction by means of visual examination of the interior of pipeline suitably lighted by projected sunlight or otherwise. The open end of an incomplete stretch of pipeline shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.

If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipeline, he shall be entitled to order the stretch to be tested immediately. Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.

6.12.4 Testing at Work Site

After the pipes and fittings are laid, jointed and the trench partially backfilled except at the joints the stretch of pipeline as directed by the Engineer shall be subjected to pressure test and leakage test. Where any section of the pipeline is provided with concrete thrust blocks or anchorages, the pressure test shall not be made until at least five days have elapsed after the concrete was cast. If rapid hardening cement has been used in these blocks or anchorages, the tests shall not be made until at least two days have elapsed.

Each section of the pipeline shall be slowly filled with water and all air shall be expelled from the pipe by tapping at points of highest elevation before the test is made and plugs inserted after the tests have been completed. The specified test pressure based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe as directed by the Engineer.

The duration of test shall not be less than 5 minutes. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be recalked until watertight. Any cracked or defective pipes and fittings in consequence of this pressure test shall be removed and replaced by sound material by Contractor at no extra cost to the Engineer and the test shall be repeated to the satisfaction of the Engineer.

After the satisfactory completion of pressure test, the section of pipeline shall be subjected to leakage test. The duration of test shall be 2 hours. No pipe installation shall be accepted until the leakage is less than the number of cm3 /h as determined by the formula:

$$q_L = \frac{ND\sqrt{P}}{3.3}$$

Where,

q_L	=	The allowable leakage in cu. m/hr
N	=	Number of joints in the length of the pipeline
D	=	Diameter in mm, and
P	=	The average test pressure during the leakage test in kg/sq.cm

Should any test of pipe laid indicate leakage greater than that specified above, the defective joints shall be repaired by Contractor at no extra cost to the Engineer until the leakage is within the specified allowance.

Necessary equipment and water used for testing shall be arranged by Contractor at his own cost. Damage during testing shall be Contractor's responsibility and shall be rectified by him at no extra cost to the Engineer. Water used for testing shall be removed from the pipe and not released in the excavated trenches.

After the tests mentioned above are completed to the satisfaction of the Engineer, the backfilling of trenches shall be done as per the Employer's Requirement specified elsewhere.

6.13 Unplasticized PVC Pipes and Fittings

Unplasticized polyvinyl chloride pipes, fittings and specials, gaskets shall be conforming to the below mentioned Indian Standards / BS 4346: Part 1for product water.

IS:4985	Unplasticized PVC pipes for product water supplies
IS:12235	Methods of test for unplasticized PVC pipes for product water supplies
IS:5382	Rubber sealing rings for gas mains, water mains and sewers
IS:7328	High density polyethylene materials for mouldings and extrusion
IS:10151	PVC and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals, and drinking water
ISO: 2045	Single socket for uPVC and uPVC pressure pipes with elastic sealing ring type joints - Minimum depth of engagement
ISO: 3603	Fittings for PVC pipe with elastic sealing ring joints pressure test for leak proofness

The pipes shall be of the spigot and socket type with approved gasket type flexible joint.

Where PVC pipes, fittings and specials are to be connected to Ductile iron, stainless steel or steel pipes, 'Viking Johnson' type flange adaptors or stepped couplings shall be used.

6.14 Rubber Hosing

Rubber hosing shall conform to BS 5119, Type 2. It shall be capable of handling chlorine and sulphur dioxide solutions at a working pressure of 12 bar.

6.15 Copper Tubes and Fittings

Copper tubing and fittings for work above ground level shall comply with BS 2871 and BS 864: Part 2 respectively and be jointed with capillary joints. For underground location the copper pipe shall be to BS 2871: Part 1.

6.16 Flanged Joints

All flanges shall comply with BS EN 1092-1. The nominal pressure rating for particular flanges shall be at least equal to the highest-pressure rating of the pipes or fittings to which they are attached, but with a minimum nominal pressure of PN 10. All flanges shall be provided with all necessary nuts, bolts, washers and gaskets. In general, valves shall have flanged body ends.

All flanged joints which are buried or in chambers shall be protected with Densomastic and Densotape wrapping, applied in accordance with the manufacturer's instructions.

Flanges shall be installed on the pipes in the factory and field welding of flanges shall only be allowed with the approval of the Engineer.

Where pipework outside pumping stations and surge vessel chambers is cathodically protected, an insulated flange shall be incorporated at the first flange inside the structure. These flanges shall be tested to ensure that electrical insulation is achieved.

6.17 Gaskets and Joint Rings

Joint rings shall be manufactured to conform to BS 2494 or relevant Indian Standard and shall be of chloroprene rubber or other approved synthetic material suitable for temperatures up to 80^{o}C.

Gaskets may be inside the bolt circle type and shall comply with BS 4865: Part 1. Alternatively the gasket shall be to the full diameter of the flange, drilled to suit the appropriate bolt provisions.

Chloroprene rubber with a hardness of 71 to 80 IRHD shall be used.

Joints shall be made in accordance with manufacturer's instructions or as specified herein.

Until immediately required for incorporation in a joint, each rubber ring or gasket shall be stored in the dark, free from the deleterious effects of heat or cold, and kept flat so as to prevent any part of the rubber being in tension.

Only lubricants recommended by the manufacturer shall be used in connection with rubber rings and these lubricants shall not contain any soluble constituent, shall be suitable for the climatic conditions at the Site and shall contain an approved bactericide.

After cleaning the flanges the gaskets shall be fitted smoothly to the flange and the joint shall be made by tightening the nuts to finger pressure first. Thereafter the final tightening of the nuts shall be made by gradually and evenly tightening bolts in diametrically opposite positions using standard spanners.

Graphite grease shall be applied to the threads of bolts before joints are made.

6.18 Flexible Couplings and Flange Adaptors

Flexible couplings and flange adaptors shall be of the Viking Johnson or similar approved pattern and be assembled in accordance with the manufacturer's instructions and protected, if buried or in chambers with Densomastic and Densotape wrapping applied in accordance with the manufacturers' instructions. Flexible joints shall be harnessed or tied where necessary.

6.19 Storage & Shipment

6.19.1 Protection of Pipes and Fittings for Shipment

Except where otherwise specified all items shall have received their complete protective coatings before dispatch from the manufacturer's works and shall be additionally protected by approved means for the period of transit, storage and erection, against corrosion and accidental damage.

For the protection of pipe linings and in particular for protecting cement mortar linings from drying out, protective metal or timber discs shall be fitted over the ends of pipes and fittings. Similar timber protective discs shall be attached to all flanges of pipes and fittings, by means of bolts specifically provided for the purpose and which shall be discarded when the item is incorporated in the Works. The sleeves and flanges of flexible joints shall be wired together in suitable bundles.

6.19.2 Storage of Pipeline Materials

Pipes and fittings shall be stored raised off the ground, and shall be carefully supported, cushioned and wedged. Pipes shall not rest directly on one another and shall not be stacked more than four pipes high or two pipes high in the case of pipes of 500 mm diameter or over. Special care shall be taken to ensure that flexible pipes are cradled and supported in a manner that prevents any distortion of the pipes.

Couplings and joints (and all components thereof) and other similar items shall be stored in dry conditions, raised from the ground in sheds or covered areas.

Storage areas shall be carefully set out to facilitate unloading, and checking of materials with different consignments stacked or stored separately with identification marks clearly visible.

Where items to be stored have a limited shelf life or require special storage arrangements, the method of storage shall be to the approval of the Engineer and in accordance with the manufacturer's instructions.

All pipes and fittings supplied as spares shall have end covers which are proof against the entry of sand and vermin. Mortar lined pipes and fittings shall have end covers which form a complete seal, provision being made to accommodate the effects of temperature changes. Pipes and fittings supplied as spares shall have a temporary white external finish and shall be stored sheltered from the direct rays of the sun.

End covers and protection shall not be removed until incorporation of the pipes and fittings into the Works.

6.19.3 Transportation of Pipes and Fittings

Any vehicle on which pipes are transported shall have a body of such length that the pipes do not overhang. Large pipes shall be placed on cradles and the loads properly secured during transit. The pipes shall be handled in accordance with the manufacturer's recommendations.

Approved slings shall be used and all hooks and dogs and other metal devices shall be well padded. Hooks engaged on the inner wall surface at pipe ends shall not be used. Steadying ropes shall be employed. The positions of lifting slings shall ensure that stresses and tendency towards deformation in the pipes are kept at a minimum.

Pipe handling equipment shall be maintained in good repair and any equipment which in the opinion of the Engineer may cause damage to the pipes shall be discarded. Under no circumstances shall pipes be dropped, be allowed to strike one other, be rolled freely or dragged along the ground.

6.20 Inspection of Pipes and Fittings

Before incorporating into the Works each pipe shall be brushed out and carefully examined for soundness. Damaged pipes, which in the opinion of the Engineer cannot be satisfactorily repaired, shall be rejected and removed from Site.

Damage to pipe coatings or linings shall be repaired to the satisfaction of the Engineer.

6.21 Built-in Pipework and other Plant

The pipes and other Plant in water retaining structures shall, wherever possible, be built in as the work on the structure proceeds. The Contractor shall ensure that delivery of the requisite pipe-work and other Plant is in accordance with the requirements of the programme.

Where a pipe subject to thrust passes through a concrete structure or where an external seal is required, a puddle flange shall be used. The puddle flange dimensions shall be to BS EN 1092-1 but shall be undrilled. The exterior of the pipe shall be cement washed symmetrically about the puddle flange by the manufacturer for a length at least equivalent to the thickness of the wall through which it passes.

The Contractor shall be responsible through every stage of the Works for checking the correctness of the setting of built-in Plant and shall satisfy himself they are positioned in accordance with his approved drawings.

6.22 Pipe Laying

6.22.1 Carting & Handling

Pipes and fittings /specials shall be transported from the factory to the work sites at places along the alignment of pipeline as directed by the Engineer. Contractor shall be responsible for the safety of pipes and fittings/specials in transit, loading/unloading. Every care shall be exercised in handling pipes and fittings/specials to avoid damage. While unloading, the pipes and fittings/specials shall not be thrown down from the truck on to hard surfaces. They should be unloaded on timber skids with steadying ropes or by any other approved means. Padding shall be provided between coated pipes, fittings/specials and timber skids to avoid damage to the coating. Suitable gaps between pipes should be left at intervals in order to permit access from one side to other. In case of spigot socket pipes, care should be taken regarding orientation of pipes while unloading. As far as possible, pipes shall be unloaded on one side of the trench only. The pipes shall be checked for any visible damage (such as broken edges, cracking or spalling of pipe) while unloading and shall be sorted out for reclamation. Any pipe which shows sufficient damage to preclude it from being used shall be discarded. Dragging of pipes and fittings/specials along concrete and similar pavement with hard surfaces shall be prohibited.

6.22.2 Storage

Each stack of pipes shall contain only pipes of same class and size, with consignment or batch number marked on it with particulars of suppliers wherever possible. Storage shall be done on firm level and clean ground and wedges shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes placed lengthwise and crosswise in alternate layers. The pyramid stack shall be made for smaller diameter pipes for conserving space in storing them. The height of the stock shall not exceed 1.5 m.

Fittings/Specials shall be stacked under cover and separated from pipes.

Rubber rings shall be stored in a clean, cool store away from windows, boiler, electrical equipment and petrol, oils or other chemicals. Particularly in the field, where the rubber rings are being used, it is desirable that they are not left out on the ground in the sun or overnight under heavy frost or snow conditions.

6.22.3 Laying

6.22.3.1 *Excavation*

Before excavating the trench the alignment of pipeline shall be approved by the Engineer. The excavation of trenches and pits for manholes/ chambers shall be carried out in accordance with the Employer's Requirement described elsewhere and shall be done such that it does not get far ahead of the laying operation as approved by the Engineer.

To protect persons from injury and to avoid damage to property, adequate barricades, construction signs, red lanterns and guards as required shall be placed and maintained during the progress of the construction work and until it is safe for the traffic to use the roadways. The relevant Indian Standards and the rules and regulations of local authorities in regard to safety provisions shall be observed.

Suitable fencing shall be provided along the sides of trenches and pits. The posts of fencing shall be of timber securely fixed in the ground not more than 3 m apart and they shall not be less than 75 mm in diameter or less than 1.2m above surface of the ground. There shall be two rails, one near the top of the post and the other about 450mm above the ground and each shall be from 50mm to 70mm in diameter and sufficiently long to run from post to post to which they shall be bound with strong rope. The method of projecting rails beyond the post and tying them together where they meet shall not be allowed on any account. All along the edges of the excavation trenches, a bank of earth about 1.2 m high shall be formed, where required by the Engineer for further protection.

The road metal and also the rubble packing shall first be stripped off for the whole width of the trench/pit and separately deposited in such place or places as may be determined by the Engineer.

During excavation, large stones and rubble shall be separated and removed from the excavated soil and stacked separately. The material from excavation shall be deposited on either side of the trench leaving adequate clear distance from the edges of the trench and pit, or as may be necessary to prevent the sides of the trench pit to slip or fall, or at such a distance and in such a manner as to avoid covering fire hydrants, sluice valves, manholes and covers etc. and so as to avoid abutting the wall or structure or causing inconvenience to the public and other service organizations or otherwise as the Engineer may direct.

Contractor shall take into account additional excavation if any as the Engineer may require in order locating the position of water pipes, drains, sewers etc. or any other works which may be met with, in or about the excavation of trenches/pits while quoting the rates of excavation. Such service lines if met with during excavation shall be properly maintained by Contractor, by means of shoring, strutting, planking over, padding or otherwise as the Engineer may direct, and shall be protected by the Contractor from damage during the progress of the work. All precautions shall be taken during excavation and laying operations to guard against possible damage to any existing structure /pipeline of water, gas, sewage etc.

Utmost care shall be taken to see that the width of the trench at the top of pipe is not more than the minimum requirement. In case additional width is required it shall be provided only in the top portion from the ground level up to 300 mm above the top of pipe. If any extra width is provided in the area below this portion, Contractor shall have to provide remedial measures in the form of lime concrete or rubble masonry otherwise at the discretion and to the satisfaction of the Engineer. If rock is met with, it shall be removed to 15 cm below the bottom of pipes and fittings/specials and the space resulting shall be refilled with granular materials and properly consolidated. Bottom of trenches/pits shall be saturated with water and well rammed wherever the Engineer may consider it necessary to do so.

Wherever a socket or collar of pipe or fitting/ special occurs, a grip is to be cut in the bottom of the trench or concrete bed to a depth of at least 75 mm below the bed of the pipe so that the pipe may have a fair bearing on its shaft and does not rest upon its socket. Such grip shall be of sufficient size in every respect to admit the hand all around the socket in order to make the joint and the grip shall be maintained clear until the joint has been approved by the Engineer.

When welding is to be carried out with the pipes and specials in the trench, additional excavation of not more than 60 cm in depth and 90 cm in length shall be made at joints in order to facilitate welding.

The excess excavated material shall be carried away from site of works to a place up to a distance as directed by the Engineer. This shall be done immediately so as not to cause any inconvenience to the public or traffic. If the instructions from Engineer are not implemented within seven days from the date of instructions to cart the materials and to clear the site, the same shall be carried out by the Engineer at the cost of Contractor and any claim or dispute shall not be entertained in this respect.

6.22.3.2 *Dewatering*

During the excavation, if subsoil water is met with, Contractor shall provide necessary equipment and labourers for dewatering the trenches. The Contractor shall also make necessary arrangement for the disposal of drained water to nearby storm water drain or in a pit if allowed by the Engineer. In no case the water shall be allowed to spread over the adjoining area. Before discharging this water into public sewer/drain, the Contractor shall take necessary permission from the local authorities.

6.22.3.3 *Special Foundation in Poor Soil*

Where the bottom of the trench and sub grade is found to consist of material which is unstable to such a degree that in the opinion of the Engineer, it cannot be removed and replaced with an approved material thoroughly compacted in place to support the pipe properly, a suitable foundation for the pipes, consisting of piling, timbers or other materials, in accordance with relevant drawings to be prepared by the Contractor and as instructed by the Engineer shall be constructed.

6.22.3.4 *Wooden Shoring*

Contractor shall suitably design polling boards, waling and struts to meet different soil conditions that might be encountered in excavating trenches/pits. The horizontal and vertical spacing of struts shall be such that not only the sides of trenches shall be prevented from collapse but also easy lowering of pipe in trenches shall be ensured without creating undue obstructions for the excavation of the work. Any inconvenience and/or delay that might be caused in lowering pipes in trenches, as a result of adopting improper spacing of struts by the Contractor, shall be his sole responsibility. No part of shoring shall at any time be removed by Contractor without obtaining permission from the Engineer. While taking out shoring planks the hollows of any form must simultaneously be filled in with soft earth well rammed with rammers and with water.

The Engineer may order portions of shoring to be left in the trenches /pits at such places, where it is found absolutely necessary to do so to avoid any damage which may be caused to buildings, cables, gas mains, water mains, sewers etc. in close proximity of the excavation, by pulling out the shoring from the excavations. The Contractor shall not claim on any reason whatsoever, for the shoring which may have been left in by him at his own discretion.

6.22.3.5 *Steel Plate Shoring*

Where the subsoil conditions are expected to be of a soft and unstable character in trench/pit excavation, the normal method of timbering may prove insufficient to avoid subsidence of the adjoining road surfaces and other services. In such circumstances, the Contractor shall be required to use steel trench sheeting or sheet piling adequately supported by timber struts, waling etc., as per the instructions, manner and method directed by the Engineer. Contractor shall supply pitch, drive and subsequently remove trench sheeting or piling in accordance with other items of the Engineer's Requirements.

6.22.3.6 *Boning Staves and Sight Rails*

In laying the pipes and fittings/specials the centre for each manhole/chamber or pipeline shall be marked by a peg. Contractor shall dig holes for and set up two posts (about 100 x 100 x 1800 mm) at each manhole/chamber or junction of pipelines at nearly equal distance from the peg and at sufficient distances there from to be well clear of all intended excavation, so arranged that a sight rail when fixed at a certain level against the post shall cross the centre line of the manhole/chamber or pipelines. The sight rail shall not in any case be more than 30 m apart;

intermediate rails shall be put up if directed by the Engineer.

Boning staves of 75 mm x 50 mm size shall be prepared by Contractor in various lengths, each length being of a certain whole number of metres and with a fixed tee head and fixed intermediate cross pieces, each about 300 mm long. The top-edge of the cross piece must be fixed below the top-edge of the tee-head at a distance equal to the outside diameter of the pipe or the thickness of the concrete bed to be laid as the case may be. The top of cross pieces shall indicate different levels such as excavation for pipeline, top of concrete bed, top of the pipe etc. as the case may be.

The sight rail of size 250 mm x 40 mm shall be screwed with the top edge resting against the level marks. The center line of the pipe shall be marked on the rail and this mark shall denote also the meeting point of the center lines of any converging pipes. A line drawn from the top edge of one rail to the top edge of the next rail shall be vertically parallel with the bed of the pipe, and the depth of the bed of pipe at any intermediate point may be determined by letting down the selected boning staff until the tee head comes in the line of sight from rail to rail.

The post and rails shall be perfectly square and planed smooth on all sides and edges. The rails shall be painted white on both sides, and the tee-heads and cross-piece of the boning staves shall be painted black.

For the pipes converging to a manhole/chamber at various levels, there shall be a rail fixed for every different level. When a rail comes within 0.60 m of the surface of the ground, a higher sight-rail shall be fixed for use with the rail over the next point.

The posts and rails shall in no case be removed until the trench is excavated, the pipes are laid and the Engineer gives permission to proceed with the backfilling.

6.22.3.7 *Laying of Pipes and Fittings/Specials*

All precautions shall be taken during excavation and laying operations to guard against possible damage to any existing structure/pipeline of water, gas, sewage etc. After excavation of trenches, pipes shall not be lowered unless the dimensions of trenches and bedding work for pipes at the bottom of the trenches are approved and measured by Engineer's Representative. Pipes and fittings/specials shall be carefully lowered in the trenches. Special arrangements such as cranes, tripods with chain pulley block for lowering the pipes and fittings/specials shall be made by Contractor. In no case pipes and fittings/specials shall be dropped. Slings of canvas or equally non-abrasive material of suitable width or special attachment to fit the ends of pipes and fittings/specials shall be used to lift and lower the coated pipes and fittings/specials. The pipes and fittings /specials shall be inspected for defects and be rung with a light hammer preferably while suspended to detect cracks. If doubt persists, further confirmation shall be done by pouring a little kerosene/dye on the inside of the pipe at the suspected spot. No sign of kerosene/dye should appear on the outside surface. Pipes and fittings/specials damaged during lowering or aligning shall be rejected by the Engineer.

All the pipes are to be laid perfectly true both in alignment and to gradient specified. In case of spigot and socket pipes, the socket end of the pipe shall face upstream when laid on level ground, when the pipeline runs uphill, the socket ends should face the upgrade. The laying of pipes shall always proceed upgrade of a slope. After placing a pipe in the trench, the spigot end shall be centered in the socket and the pipe forced home and aligned to required gradient. The pipes shall be secured in place with approved backfill material tamped under it except at the socket. Pipes and fittings/specials which do not allow a sufficient and uniform space for joints shall be removed and replaced with pipes and fittings/specials of proper dimensions to ensure such uniform space. Precautions shall be taken to prevent dirt from entering the jointing space. At times when pipe laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means approved by the Engineer. During the period that the plug is on, the Contractor shall take proper precautions against floating of the pipe owing to entry of water into the trench. Wherever it is necessary to deflect pipe from a straight line, either in the vertical or horizontal plane, to avoid obstructions or where long radius curves are permitted the deflection allowed at joints shall not exceed 2 ½^0. In case of pipes, with joint to be made with loose collars, the collars shall be slipped on before the next pipe is laid. The pipes shall be laid such that the marking on pipes appears at the top of the pipes.

The cutting of pipe for inserting valves, fittings, or specials shall be done in a neat and workman like manner without damage to the pipe so as to leave a smooth end at right angles to the axis of the pipe. For this purpose, pipe cutting machine shall be used.

6.22.3.8 *Thrust Blocks*

Thrust blocks shall be provided, to counteract hydraulic thrust, after due calculations of thrust force and the size of the thrust block wherever required.

6.22.3.9 *Jointing*

Jointing for pipes and fittings/specials shall be done in accordance with the relevant Employer's Requirement depending upon the type of pipes being used.

6.22.3.10 *Testing and Commissioning*

Testing and commissioning of pipes shall be done in accordance with the relevant Employer's Requirement.

6.22.3.11 *Backfilling*

On completion of the pipe laying operations in any section, for a length of about 100 m and while further work is still in progress, refilling of trenches shall be started by the Contractor with a view of restricting the length of open trenches. Pipe laying shall closely follow the progress of trench excavation and the Contractor shall not permit unreasonably excessive lengths of trench excavation to remain open while awaiting testing of the pipeline. If the Engineer considers that the Contractor is not complying with any of the foregoing requirements, he may prohibit further trench excavation until he is satisfied with the progress of laying and testing of pipes and refilling of trenches. Filling to a level of 300 mm above the crown of the pipe shall be done in accordance with the requirements of the clause on bedding. Care shall be taken during backfilling, not to injure or disturb the pipes, joints or coating. Filling shall be carried out simultaneously on both sides of the pipes so that unequal pressure does not occur. Walking or working on the completed pipeline shall not be permitted unless the trench has been filled with the instructed bedding and surround material up to height of at least 300 mm over the top of the pipe except as may be necessary for tamping etc., during backfilling work.

The remaining portion of the trench shall be filled in with selected excavated material free from and topsoil, vegetation or boulders and clods of earth larger than 75 mm in size. Filling shall be done in layers not exceeding 150 mm in thickness accompanied by adequate watering, ramming etc., so as to be compacted to 90% of the maximum dry density as per Part 7 of IS:2720. The water contents of the soil shall be kept as near the optimum moisture content as possible. The trench shall be refilled so as to build up to the original ground level, keeping due allowance for subsequent settlement likely to take place. The surface of the refilled excavations shall be left slightly higher than the adjacent ground and be maintained by the Contractor to a smooth even slope.

The Engineer shall, at all times, have powers to decide which portion of the excavated materials shall be used for filling and in which portion of the site and in what manner it shall be so used.

If suitable material for refilling is not available from already excavated material, the Contractor shall import material of approved quality as directed by the Engineer.

Regular measurement of the field dry density shall be taken by the Contractor at various levels in the backfilling as required by the Engineer.

No mechanical plant other than approved compacting equipment shall run over or operate within the trench until backfilling has reached its final level or the approval for the Engineer has been obtained.

Should any subsidence take place either in the filling of the trenches or near about it during the works the Contractor shall make good the same at his own cost.

Surplus excavated material shall be used to fill in any low spots above the pipeline which are identified on the Drawings or are instructed by the Engineer. Such material shall be evenly placed and compacted in layers not exceeding 200 mm thick after compaction. The method of compaction employed shall achieve not less than 90% maximum dry density as determined from IS:2720 (Part 7). Unless approved of by the Engineer, the width of areas to be filled shall not exceed 20m.

6.22.3.12 *Reinstatement of Road/Footpath*

Reinstatement of road/footpath shall be done as per the requirements of local authorities and the Employer's Requirement after completion of work.

6.22.3.13 *Clearing of Site*

All surplus materials, and all tools and temporary structures shall be removed from the site as directed by the Engineer and the construction site left clean to the satisfaction of the Engineer.

CHAPTER - 7

7. MECHANICAL REQUIREMENTS

7.1 Introduction

This part of the Employer's Requirements sets out the general standards for mechanical Plant used by the Contractor for the Works. Reference to any specific item does not necessarily imply that such plant is to be included in the Works. All Plant used for the Works shall, unless otherwise specified, comply with the provisions of this part. However, nothing in this Specification shall remove the Contractor's obligation from drawing the attention of the Employer's Representative to any feature of the Works which is not consistent with safety, or prevent him making proposals for incorporating equipment or designs which would increase the safety of plant equipment. In case the material of construction or type specified in this document for any equipment is not suitable for the particular use, it shall be changed by the Engineer/ Employer's representative during review of the specification at the time of procurement of the equipment. The Contractor shall ensure that the whole of the Works as installed is safe for use by the operating and maintenance staff, and by any other persons having access thereto. Guards, electrical safety devices, thermal insulation, noise-supervision devices, written notices, safety colours and the like shall be provided where necessary during erection permanently. The equipment layouts shall provide easy and safe assess to all operating devices, free from hazardous obstructions.

7.2 Noise Level and Vibration Limits

The noise level produced by any equipment like blowers, compressor sets, etc. shall not exceed 85 dBA measured at a distance of 1.0 m from the outer surface of the equipment. At the time of operation, the mechanical vibration of all rotating equipment shall not exceed the limits given in the Table below, at recommended points of measurement as per ISO 10816:1995.

Table 7-1: Vibration Limits

Equipment	Velocity of Vibration mm/sec
All rotating equipment not having reciprocating parts with motor kW less than or equal to 15 kW	1.12
All rotating equipment not having reciprocating parts with motor kW more than 15 KW and less than or equal to 75 kW	1.8
All rotating equipment not having reciprocating parts with motor kW greater than 75 kW	2.8

7.3 Design Criteria for Pumping Stations

The submergence shall be based on Hydraulic Institute Standard and American National

Standards for Intake. A baffle wall or other suitable corrective arrangement as recommended in Hydraulic Institute Standard, Pump handbook by Karassik or other recognised literature shall be provided in the suction sump to break vortices.

Level switches and indicators shall be provided for automatic start and stop operation of pumps. Necessary switches/alarms required for safe operation of plant shall be provided. Instruments provided shall be compatible with SCADA/DCS.

The clearance between pumps/piping/valves shall be not less than 900 mm. The total head of the pump shall be selected considering combined flow and mean design level in the wet well for normal conditions of operation, and checked for entire operating head range for satisfactory operation under extreme conditions of operation i.e. single pump operation at maximum WL and all duty pump operation in parallel corresponding to lowest WL. The pump capacity and head shall be selected such that the total pump output is as per design flow and the pump is suitable for the entire head range.

A minimum 15% margin over the power input to pump at duty point or 10% margin above maximum power input to the pump over the entire operating head range, whichever is higher shall be kept while selecting the motor rating.

Flanged pipe shall be provided at pump delivery. The pump delivery pipe shall be connected from side of the header. Dismantling joint suitable for pump duty shall be provided at pump delivery valves for ease of installation and dismantling.

Pump delivery butterfly valves shall be with electric actuators as these are to be opened and closed when pumps are started and stopped.

Quick closing dual plate check valve shall be provided at pump delivery pipe to prevent back flow. The check valve shall be located between pump and delivery valve.

Electrically operated travelling (EOT) crane or manually operated travelling (HOT) crane shall be provided as specified.

Ventilation shall be provided for the pumping stations based on minimum six air changes per hour or to restrict temperature rise to 5^0C above the shed temperature considering the heat dissipation of motor and installed equipment.

The design, materials, construction, manufacturing, inspection, testing and performance of all equipment shall comply with all currently applicable statues, regulations and safety codes where the equipment is to be installed. The equipment shall also conform to the latest applicable Indian or equivalent standards for the type of water to be handled. Other International standards are also acceptable, if these are established to be equal or superior to the listed standards. Nothing in this specification shall be construed to relieve the Contractor of his responsibility to provide the appropriate equipment in all respect for the use.

7.4 Pumps

The pump shall be centrifugal, or VT pump as specified. Pumps shall be selected considering the fluid being pumped, using appropriate IS or international standard as appropriate.

Baffle wall shall be provided in the suction sump to prevent the sucking of air by the pumps when free fall of liquid occurs. Level switch and indicators shall be provided for automatic start and stop operation of pumps. Necessary switches/ alarms required for safe operation of plant shall be provided. Instruments provided shall be compatible with SCADA/DCS, when implemented in future.

The clearance between pumps/piping/valves shall be not less than 1000 mm. + 5% margin on the pump capacity shall be provided for all the pumps. The total head of the pump shall be selected considering peak flow and maximum design level in the wet well for normal conditions of operation and checked for satisfactory operation under extreme conditions of operation. The pump capacity and head shall be selected such that the total pump output is in excess of the design flow to ensure free flow at all flow conditions.

Flanged connection will be provided at pump delivery. The pump delivery pipe will be connected from side of the header.

Pump delivery Butterfly valves will be with auto actuators as these are to be opened and closed remotely when pumps are started and stopped for valves mainly bigger than DN 400 mm.

Quick closing Dual Plate check valve will be provided at pump delivery pipe to prevent back flow. Pumping stations requiring handling equipment up to 1 ton will be with manually operated travelling crane/hoist. Pumping stations requiring above 1 ton will be with electrically operated travelling crane (EOT).

Minimum velocity in rising main shall be 0.6 m/sec while operating one pump and maximum 2.0 m/sec while operating all working pumps will be ensured.

Electromagnetic full-bore Flow Meter, Dual Plate check valve, Butterfly valve with actuator (where required), and air valves (where needed) shall be provided on rising main outside the pumping station.

The design, materials, construction, manufacturing, inspection, testing and performance of all equipment including pumps shall comply with all currently applicable statutes, regulations and safety codes in the locality where the equipment will be installed. The equipment shall also conform to the latest applicable Indian or equivalent standards. Other International standards are also acceptable, if these are established to be equal or superior to the listed standards. Nothing in this specification shall be construed to relieve the Contractor of this responsibility. Pumps shall be designed so that the impellers and other accessories of the pump is not damaged due to flow reversal. All pumps (casing, shaft and impeller) in contact of low pressure seawater shall be made of super duplex steel with PREN>41 and for product water with SS316.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

<u>List of Applicable Standards</u>

IS: 1710 : Vertical Turbine Pumps for clear cold fresh water.

IS: 5120 : Technical requirement of rotor dynamic special purpose pumps.

HIS : Hydraulic Institute Standards U.S.A.

API: 610 : Centrifugal pumps for general refinery purposes.

IS: 1520 : Horizontal Centrifugal Pumps for clear cold fresh water.

IS: 5639 : Pumps Handling Chemicals & corrosion liquids.

IS: 5659 : Pumps for process water

ISO 5199: Technical specifications for centrifugal pumps -- Class II

ISO 9906: Roto dynamic pumps - Hydraulic performance acceptance tests -- Grades 1, 2 and 3

IS 9137: Code for acceptance tests for centrifugal, mixed flow and axial pumps - Class C

ASTM-l-165-65- Standard Methods for Liquid Penetration Inspection

In case of any contradiction with aforesaid standards and the stipulations as per technical specifications as specified hereinafter the stipulations of the technical proposal shall prevail unless the proposed material or type of the item is inferior to the aforesaid standards.

7.4.1 Centrifugal Pumps

Pumps shall generally comply with the requirements of standard codes as above. Pumps shall be so selected as to have a maximum capacity of not less than 125% of the rated capacity. Pump sets shall be suitable for the required duty conditions and shall be designed and constructed for 24-hours' continuous duty at full load.

Each pump shall be subject to performance test at the manufacture's work under near actual site conditions as far as possible as per ISO 9906.

7.4.1.1 *Design Features*

The pumps shall be designed for continuous operation at any point of the head capacity curve between 25% and 125% of pump rated flow without undue vibration or overheating.

Centrifugal pumps shall have stable head/quantity characteristics, which fall continuously from the maximum pressure at closed valve conditions. The design speed of any pump shall not exceed 1500 rpm (synchronous).

Pumps of a particular category shall be identical and shall be suitable for parallel operations with equal load distribution. The head Vs Capacity and BHP Vs Capacity Characteristics should match to ensure load sharing and trouble-free operations throughout the range. Components of identical pumps shall be interchangeable.

The pump shall preferably horizontal split casing with double suction impeller. Horizontal end suction pump shall be accepted in exceptional cases and only when horizontal split casing pumps are not in manufacturing range. The number of stages should not exceed two numbers.

The direction of rotation shall be clearly marked on the pump. Waterways through the pump shall be smooth in finish and free from recesses and obstructions. Impeller passageways shall be as large as possible. The leading edges of the impeller vanes shall be rounded and smooth.

Water velocities in the pump suction side shall not exceed 1.5 m/s and on delivery branches of a pump the velocity shall not exceed 2.0 m/s and within working range there shall be no discernible noise due to hydraulic turbulence or cavitation within either the pump or its associated pipe-work and valves.

The NPSH requirements of the pumps, based on the 3% output drop criterion shall be at least 2 m less than the NPSH available at every working condition.

Pumps shall run smooth without undue noise and vibration. Noise level produced individually or collectively shall not exceed 65 dB(A) measured at a distance of 1.0 meters from the source in any direction.

All parts exposed to wear shall be adequately protected by means of renewable sleeves, bushes, wear rings etc. which shall be arranged for easy inspection, adjustment, or replacement without removal of the pump casings, pipe-work etc. or the need to disturb the drive shaft alignment.

The pump thrust shall be taken by a combined thrust and radial type bearing assembly capable of taking the weight of the moving parts and the hydraulic loads under all conditions of operation with a minimum life of 1,00,000 hours.

The pump casing and other parts of the pump subject to pressure shall be hydraulically tested by the manufacturer to at least one and a half times the shut off head.

Integral inlet and discharge flanges shall be provided, and integral lifting lugs shall be incorporated. Facilities shall be provided for the removal of air during priming and for draining. The pump may be fitted with mechanical seals or conventional soft packing. The arrangement shall be designed for easy adjustment and removal of the seal. When soft packed glands are used, suitable means shall be provided for collecting and preventing splashing of the gland leakage water. Drainage and gland leakage water shall be piped into the building drainage system. The shafts of pumps fitted with conventional packed glands shall be fitted with removable gland sleeves.

The rotating element of the pump and the motor shall be readily removable from the pump casing without the need to disconnect the adjoining pipework. The pump casing and other parts of the pump subject to pressure shall be hydraulically tested by the manufacturer to at least one and a half times (1.5 times) the maximum working pressure.

Rotating assemblies of pumps of 100 mm diameter inlet and over shall be statically and dynamically balanced and shall be designed so that the first critical speed is at least 50% greater than the maximum operating speed.

Lubrication arrangements shall be so designed that there is no contamination of the pumped fluid.

The pumps shall be horizontally mounted complete with drive motor on a common base plate. The pump/drive coupling shall be of flexible rubber bushing to facilitate removal of the pump rotating element and bearing housing without dismantling the pump casing, adjoining pipe-work or drive motor. End suction pumps may be used for filter backwash, chlorination motive water and service water pumping applications etc.

The dimensions of the pump shall be metric conforming to applicable IS. The velocity at the entrance to the pump impeller shall not exceed 3.5 m/s. The bedplate shall be of substantial fabricated steel construction with floor fixing bolt holes ready drilled. All holding down bolts etc. shall be supplied with the units.

The pumps and associated pipe-work shall be, wherever possible, arranged so that air can be completely expelled during priming. Where this is not possible, facilities shall be provided for the removal of the trapped air. Adequate facilities shall be provided for drainage of the pumps for inspection purposes.

Tapping shall be provided at both the suction and discharge flanges for pressure gauge equipment.

The minimum motor rating shall be larger of the following:

a) 115% of the power requirement by pump at duty point

b) 110% of the power input within any operating point between minimum and maximum resistance curves.

7.4.1.2 *Construction Features*

The pump shall be single stage double suction (split casing) type. Thrust bearing antifriction type at one end to take up thrust, should be provided in addition to bush bearings, if required.

In addition to static balancing, impeller and balancing drum shall be balanced dynamically at or near the operating speed. The impeller shall be keyed to the shaft and held tight. The impeller/s shall be independently retained against thrust (no applicable at submersible pumps). In case of impellers which are held tight by lock nuts and washer, the direction of threads of the shaft and nut shall be such that the nut shall tend to get tightened when the impeller is in motion. Pump shall be provided with renewable type casing ring.

Pump having capacity 1,000 m3/h and above, in case pump is provided with impeller wearing ring in addition to casing ring. The hardness of impeller ring shall be 50 BHN higher than that of casing ring.

Individual impellers and completed rotor assembly shall be subject to static and dynamic balancing test (as per ISO 1940 or JIS 0905 G6.3 or equivalent).

The casing shall be tested to withstand a pressure of 1.5 times the shut off pressure or twice the rated pressure whichever is higher. Delivery flange shall be as per ANSI B16.5

Bearing shall be oil-lubricated or grease-lubricated and shall have a life of 100,000 hours of working. In case of oil-lubricated bearing, constant oil leveller with magnetic drain plug shall be provided Replaceable shaft sleeves shall be provided to protect the shaft where it passes through stuffing box Stuffing box shall be of such design that it can be repacked without removing any part other than the gland and lantern ring. Mechanical seals shall be provided if needed. If required, a flushing line shall be furnished, complete with strainer and orifice, from the pump discharge to the sealing face. When pumping liquid is not suitable for this purpose, a flushing connection shall be provided so that it can be connected to an external source. Auxiliary piping and plan shall be in accordance with Appendix - D of API 610.

For better efficiency Special Surface Treatment shall be provided to the inner surface of pump casing, if it is required for design conditions. The coating used for bringing about efficiency improvement shall be polymer-based system, which is a cold cured highly modified chemically resistant, two-pack resin system filled with stabilizing enforcement to improve flow characteristics.

The casing shall be provided with priming funnel and air release vent, Tapping shall be provided for installing suction and delivery pressure gauges. Each pump should be provided with combination gauge on suction side and suitable pressure gauge on delivery side. Gland leakage shall be laid to the channel provided in the pump house by bleeding SS-316L pipes.

All forging and casting shall be subject to 100 % UT or RT and MPE or DPT check, all welding subject to 100% UT or RT as per ASME sec VIII.

Impellers

Impeller shall be double suction enclosed type/ semi-enclosed as per usage specified, and balanced both statically and dynamically. Renewable wearing rings shall be provided on both impeller and casing, when required.

Pump Shaft

The critical speed of the pumps shall not be less than 130% of the normal operating speed of the pump.

The shaft shall be of one-piece construction solid type and will be designed to take all types of loads such as torsion, tensile, bending and dynamic etc. The pump shaft shall be hard chrome plated steel or alloy steel (SS-420) for pumps not in contact with seawater /brine. Super-duplex PREN > 41 shall be used for pumps in contact with seawater/brine as per the manufacturer's standard. Sleeves shall be of stainless-steel SS 316 L. The shaft be ground and polished to final dimensions and shall be adequately sized to withstand all stress from rotor weight, hydraulic loads, vibration and torque coming during operations.

Shaft Sleeves shall be fastened to the shaft to prevent any leakage or loosening. Shaft and Shaft Sleeve assembly should ensure concentric rotation. The impellers and shaft sleeves shall be secured to the shaft by means of a key or keys. The impeller retaining nut shall be fitted with a locking device. For product water, the pump casing shall be of Cast iron to IS:210 Gr. FG260, wearing rings shall be of Bronze to IS:318 Gr. LTB2 and shaft sleeve shall be of stainless steel to ASTM A 743 CA 15.

Pump Bearings

Pump bearings shall be of the antifriction type or plain bearing. The bearings shall be able to take normal thrust loads due to unbalanced hydraulic loads on the impellers plus the weight of all rotating parts of the pumps. Pump bearings shall be designed with a minimum life of 100,000 hours of continuous operations at maximum axial and radial loads and rated speed. Bearings shall be easily accessible without disturbing the pump assembly. A drain plug shall be provided at the bottom of each bearing housing.

Proper lubricating arrangements for the bearings shall be provided such that lubricating element doesn't contaminate the liquid pumped.

Flexible Coupling:

The pump shaft shall be coupled to motor shaft through flexible coupling. The coupling shall comprise pin and rubber bushes or any other better than the proposed. Each half shall be statically and dynamically balanced for transmission of the power without vibration and shall be keyed to respective shaft. The coupling halves shall have precise machined surfaces for facilitating alignment. Suitable guard for coupling shall be provided.

Base Plate (Base Frame):

The pump and motor shall be installed on common base plate, to accommodate both pump and motor. Suitable machined sole pieces shall be welded on top of base plate for mounting pump and motor. The base plate shall be constructed from steel channels with suitable coating. The base plate shall be fabricated and supplied by pump manufacturer only. Base plate and pump supports shall be constructed, and the piping unit be so mounted to minimize misalignment caused by mechanical forces such as normal piping strain, internal differential thermal expansion and hydraulic piping strain, internal differential thermal expansion and hydraulic piping thrust. Suitable drain troughs and drip lip shall be provided.

Assembly and Dismantling

Assembly and Dismantling of each pump with drive motor shall be possible without disturbing the grouting base plate or alignment.

7.4.1.3 *Material of Construction for Centrifugal Pumps*

For HPP, ERD booster, RO and ERD feed Booster Pumps

Pump Casing : Super-duplex PREN $\geq$ 43
Pump Impeller : Super-duplex PREN $\geq$ 43
Pump Shaft : Super-duplex PREN $\geq$43

For CIP, Permeate Pumps

Pump Casing : AISI316L
Pump Impeller : AISI316
Pump Shaft : AISI316

For Product water Pumps

Pump Casing : Cast Iron
Pump Impeller : AISI316
Pump Shaft : AISI316

Motor

Motor	: Triphasic squirrel cage rotor
Nominal power (kW)	: As required
Speed (rpm)	: As required
Voltage	: As required
Drive type	: Fixed / Variable frequency (VFD)

7.4.2 Vertical Turbine Pumps

Vertical turbine pumps (VT), shall be with discharge head, column pipes and sole plate. The pump assembly includes pump and motor. The basic components of the pump are discharge head, column pipe and bowl assembly which will be combined and customized to match duty needs. The pump shall be self-water lubricated. Each column pipe shall be of maximum 1.5 m length. Column pipe shall be sized to velocity less than 2.25 m/s.

7.4.2.1 *Design Features*

The design, manufacture and performance of the VT pump shall comply with all currently applicable statues, regulations and safety codes in the locality area where the equipment will be installed. The equipment shall also confirm to the latest applicable Indian Standards as under:

IS 1710	Vertical turbine pump for clear water.
IS 5120	Technical requirements for roto-dynamic special purpose pumps.

Pumping assembly including pump and motor shall be designed to operate within vibration and temperature limits specified over the full operation range of the pump performance. Provide pump with number of stages to meet the specified and indicated performance.

Provide room and facilities for inspection, repair and adjustment. Equipment pumping assembly with all specified and required accessories including lifting arrangements and pressure gauges.

Pumps shall generally comply with the requirements of IS: 5120 and IS:9137. Pumps shall be so selected as to have a maximum capacity of not less than 125% of the rated capacity.

Pump sets shall be suitable for the required duty conditions and shall be designed and constructed for 24-hours' continuous duty at full load. The pumps shall be designed for continuous operation at any point of the head capacity curve between 25% and 125% of pump rated flow without undue vibration or overheating. The pump shall be capable of developing the required bowl head at rated capacity for continuous operation.

Pump/Pump Motor shall be suitable for withstanding reverse rotation due to back-flow of water without mechanical damage to any component of the pump. Pumps of a particular category shall be identical and shall be suitable for parallel operation without any possibility of hunting. Components of the identical pumps shall be interchangeable.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

For high flow rate above 2000 m3/h, the pump discharge header shall be kept at the ground floor of the pump house concrete building while motor and MCC to be placed at the first floor to allow more space for the maintenance of pump and motor. The load-bearing mounting of the pump shall be done at the first floor.

The noise level shall not exceed 65 dBA measured at 1 m from the outline of pump set. Pumps shall be selected so as to have stable characteristics. The total head capacity curve shall be continuously rising towards shut-off, with the highest at shut off. Pumps shall operate at one of the standard motor speeds not exceeding 1000 rpm. The direction of rotation of the pumps shall be clockwise looking from drive-end. The direction of rotation shall be clearly marked on the pump. The critical speed of the pumps shall not be less than 130% of the normal operating speed of the pump. The impeller adjustment shall be such that the impellers run free in any installed condition despite extension of line shaft (caused by hydraulic down-thrust) the weight of shafting and weight of impellers. The minimum motor rating shall be larger of the following:

a) 115% of the power requirement by pump at duty point

b) 110% of the power input within any operating point between minimum and maximum resistance curves.

7.4.2.2 *Construction Features*

Pumps shall be of vertical, wet pit type complete with bowl, column and head assemblies. The bowl assembly shall consist of rotating impellers, which are housed in stationary bowls having guide vanes. The bowl shall also include the housing of the bottom pump shaft bearing. The column assembly shall consist of the column pipe to convey the liquid handled from bowl assembly to head assembly, shaft enclosing tube, if required, and shaft assemblies. If shaft-enclosing tube is called for the line shaft, bearing shall be supported from shaft enclosing tube. If shaft-enclosing tube is not specified, the line shaft bearings shall be supported from the column pipes.

Individual impellers and completed rotor assembly shall be subject to static and dynamic balancing test (as per ISO 1940 or JIS 0905 G6.3 or equivalent).

Head assembly shall consist of the base from which the column shaft assembly is suspended. The discharge can be surface discharge, or an underground discharge as required.

Bell Mouth and Strainer

A bell mouth shall be fitted to the suction nozzle to limit the velocity. Net opening area in strainer shall not be less than 3 times of entrance area of bell mouth. The bowls shall be cast, free from blowholes, sand holes and other detrimental defects.

The bowls shall be equipped with replaceable wearing rings on suction side of enclosed impellers. Liquid passage shall be smooth finished. The bowls shall contain bushes to serve as bearings for the impeller shaft. In case of oil lubricated units, the discharge casing shall be provided with means to prevent the leakage of liquid into the shaft enclosing tube. Suction bell shall be designed for smooth inflow of water with minimum losses. A pump bowl /bowls shall be flanged with machined matching of faces. The bell mouth to bowl assembly, to column and to discharge case i.e. all joints shall be flanged joints.

Impellers and Shaft

The impellers shall be statically and dynamically balanced so as not to cause any vibrations during operation.

The impeller shall be of the enclosed type and shall be properly balanced dynamically. The impeller shall be properly machined, with liquid passage hand finished. Impeller shall be adjustable vertically by means of an adjusting nut in the head assembly. Open impeller shall be offered, if close type is not suitable. In such a case, the pump shall be designed to take care of the additional thrust produced.

The Impeller shaft shall be straight within 0.125 mm for 3 metres length total dial indicator reading. The maximum permissible error in the axial alignment of the thread axis with the axis of the shaft shall be 0.05 mm in 150 mm.

The shaft shall be furnished with interchangeable sections. The butting faces of shaft shall be machined square to the shaft axis and the shaft ends shall be chamfered on the edges. Couplings shall be designed with a safety factor of 1.5 times the shaft safety factor and shall have threads to tighten during pump operation. The shaft shall be properly balanced so as not to cause any vibrations during operation. Line shaft bearings shall be external water or oil lubricated or self-lubricated type. For the self-water lubricated type a pre lubrication connection with all accessories shall be provided to wet the bearings. The selection of material for such bearings shall suit the quality of water to be pumped and suspension length. If shaft-enclosing tube is not specified, the shaft bearings shall be lubricated by the liquid being pumped.

The pumps shaft bearings i.e. bush bearings would be water lubricated. Extra-long bearing shall be provided for suction and discharge bowls. The hardness of bush bearing shall be less by at least 50 BHN than that of shaft.

Wearing Rings

Wearing rings shall be renewable type and shall be provided for both impeller as well as bowl. These shall be held in place by screwing against rotation, press fit or locked with pins, flanged and screwed. Hardness of wearing rings shall be less by at least 50 BHN than the impeller.

Lubrication System

Pumps, shall be self-water lubricated.

Shaft Enclosing Tube and Column Pipe

The standard length of these shall be same as that for the shaft. No part of the column pipe shall exceed the outside diameter of bowl. The size of the column pipe shall be such that the friction loss will be limited to 0.5 M per 10 M of length at rated capacity. The column shaft shall be of Super Duplex with PREN>41 and CF>35.

Discharge Head and Motor Stool

The discharge head shall have an arrow indicating the direction of rotation of shaft. For oil lubricated type, an automatic lubricator shall be installed for electric motor driven pumps and manual or other types of lubricator for engine driven pumps. A tube tension plate shall be installed on the discharge to tighten up the shaft tubes for the purpose of aligning the shafts. A gland shall be provided at the tube tension plate to seal off any leakage from the discharge head. For water lubricated pumps, the discharge head shall have a stuffing box with a renewable bushing. The discharge elbow shall be designed to directly connect to the discharge pipe without reducer/expander.

It shall incorporate full diameter elbow, mounting flange of motor for solid shaft motor, stuffing box with renewable gland packing, & tapping for pressure gauge mounting etc. The discharge head shall be of robust construction and shall be designed to support entire load of pump assembly, water column and motor etc. & shall withstand all static, dynamic, torsional loads & hydraulic thrust imposed during operation from shut off to stipulated operating conditions and thrust due to change in direction of flow, without any vibrations. The power shall be transmitted from motor to vertical shafting through a flexible coupling. Both halves of the coupling shall be machined all over, securely keyed to their respective shafts. The pins shall be of stainless steels. The arrangement of two halves shall be suitable to check alignment and parallelism. A self-aligning thrust bearing shall be housed in the head gear adequately designed to accommodate entire weight of rotating parts and hydraulic thrust and shall be designed for 100000 hours life. The bearing shall be of oil-lubricated type and shall be provided with oil level gauges and suitably positioned temperature probes. Two sets of adjustable contacts shall be provided, one for an alarm and other for tripping the water pump motor. This shall be connected to scanner panel so the digital temperature can be read out with alarm and tripping.

Motor stool shall be provided for mounting the electric motor. The motor stool shall accommodate the pump thrust bearing and non-reversible ratchet or similar mechanism to prevent pump from rotation in reverse direction.

The motor stool shall be robust construction and of either cast iron or fabricated mild steel and adequately sized with openings to work on the flexible coupling.

Sole Plate

M.S. hot dip galvanized Sole plate arrangement shall be provided under the discharge head for precise horizontal and vertical alignment. Thickness of sole plate shall not be less than 40 mm. It shall be independent of the base plate integral with the discharge head. The contact surfaces of the sole-plate arrangement as under shall be machined for precise levelling and shall ensure vibration free operation of the pump.

All joints between machined contacts surfaces shall be with nut bolts/tapped studs/bolts. All contact surfaces shall be blue matched to ensure proper contact to the extent of 60% of contact area after necessary site finish if required. The opening in the sole-plate/frame shall be of adequate size to pass the bowl assembly etc. very easily. M.S. epoxy coated channels shall be anchored in the floor ensuring complete rigidity. Entire structural fabrication & foundation arrangement shall be designed & submitted for approval. M.S. plates grouted on pump supporting R.C.C. beams are to be provided in civil structure. The anchoring of channels shall be the responsibility of pumping machinery contractor with all related works.

Air Release Arrangement

Arrangement shall be made for release of Air in the column pipes of pumps. A flanged branched tee of required size and an air release Valve shall be provided in the pipe-work after discharge head for automatic air release arrangement. Size of the air-vent valve and piping shall suit the actual requirements of the installation and recommendation of the pump manufacturer. Check valve: Provide a check valve to prevent reverse rotation when stopping.

Driver

Pump shall be complete with base plate and foundation bolts. Pumps and motors shall be mounted on a fabricated common base-frame, on the first floor of the building for large pumps. The base-frame shall be stress relieved after fabrication and machined. The base-frame shall be adequately sized and shall be suitable for fixing coupling guard. Convenient access to the fixing bolts associated with the equipment and base-frame shall be ensured.

Flexible Coupling and Guard

The flexible coupling for connecting the two shaft ends shall be of tyre type conforming to IPSS-1-01-004-95. Removable coupling guards shall also be supplied and mounted. Guards shall be sufficiently heavy and rigid to provide adequate safety.

7.4.2.3 *Materials of Construction for VT Pump and Motor*

For Seawater Application

Bowl	: Super duplex PREN >41
Suction Bell	: Super duplex PREN >41
Column pipe	: Super duplex PREN >41
Pump Impeller	: Super duplex PREN >41
Pump Shaft	: Super duplex PREN >41
Motor	: Triphasic squirrel cage rotor
Nominal power (kW)	: As required
Voltage	: As required
Drive type	: Fixed / Variable frequency (VFD)

For product water Application:

a) Pump bowl: Cast iron ASTM A48 Class 30, free from blow- holes, sand-holes and other defect and faults.

b) Pump shaft: ASTM A126 Type 316 Stainless Steel

Impeller:

a) Type – Turbine

b) Bronze ASTM B584 C83600 or C875 or Stainless Steel 316.

c) Provide a means of impeller adjustment through a top shaft adjusting nut.

d) Dynamically balanced impeller

Suction Bell: ASTM A48 class 30 cast iron flared inlet, designed for velocity not exceeding 1.4m/sec.

Strainer: A bronze or stainless-steel strainer shall be furnished at the pump suction.

Suction bell bearing: Bronze ASTM 505 Alloy 932 and shall be grease packed.

Provide a sand collar of ASTM 505 C9300 Bronze attached to shaft with stainless steel 316 set screw arrangement.

Provide a suction bowl plug or cap of cast iron.

Intermediate bowl bearings: Provide bronze ASTM 505 Alloy 932 and shall be water lubricated.

Discharge bowl: Provide flanged discharge bowl of ASTM A48 class 30 cast iron

Discharge head:

a) Type: above ground

b) Material: ASTM A48 class 30

c) Provide sole plate of cast iron ASTM A48 class 30 or fabricated steel ASTM A36.

Connections:

a) Flanged, PN 10 standards.

b) Provide pump head and base plate design to withstand all thrust conditions imposed by the pump & driver during the operation at the specified conditions and the future conditions.

c) Provide Neoprene gasket between top column flange and discharge head.

d) Provide 316 stainless steel guard & hardware.

Column and Shafting:

a) Type: flanged with open line shaft

b) Column size: the velocity shall not exceed 2.25 m/sec.

c) Material ASTM A53 Grade B maximum section length of 300mm

d) Provide a section of column and shafting to accommodate one future stage.

e) Pipe thickness shall be in accordance with the AWWA standard.

f) Line shaft coupling AISI type 316 stainless steel.

g) Bearing retainer: Bronze ASTM B584 Alloy 836

h) Line shaft sleeve at bearing: Type 316 stainless steel

Execution: Installation shall be done as per the manufacturer's printed instructions as specified.

7.4.3 Submersible Pumps

Submersible pumps shall be of the single-entry design supplied complete with boltless self-aligning duck-foot (not applicable for drainage /sump pumps) assemblies giving automatic connection to the discharge pipe-work.

Submersible pumps shall be used for thickener feed and waste wash water pumping applications.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

The total head capacity curve shall be continuously rising towards the shut off with the highest at shut off.

Pumps shall be suitable for single as well as parallel efficient operation at any point in between the maximum and minimum system resistances.

Pumps shall run smoothly without undue noise & vibration. Noise level shall be limited to 65 dBA at 1.0 m.

The pump set shall be suitable for starting with discharge valve open or closed.

The pump set shall be capable of withstanding accidental rotation in reverse direction.

7.4.3.1 *Construction Features*

a) Pump shall be centrifugal, vertical spindle, wear resisting, and single stage type.

b) Pump casing shall be of robust construction. Liquid passages shall be finished smooth and designed as to allow free passage of solids. The volute tongue shall be filed to a smooth rounded edge.

c) Double mechanical seals shall be provided to protect the motor from ingress of liquid along the shaft. The preliminary and secondary seals shall be oil-lubricated with tungsten carbide or silicon-carbide faces and they shall be equipped with an electrical monitoring system for seal failure detection, for pumps higher than 50 kW. Sensors are to be provided to detect if leakage of liquid into the oil housing is above 30 % concentration.

d) Impeller shall be non-clog enclosed type with smooth blunt edges and large waterways to allow free passage of the large size solids. It shall be free from sharp corners and projections likely to catch and hold rags and stringy materials. The number of impeller vanes for pumps up to 1000 m3/hr shall be limited to two and shall be limited to three for the pumps higher than 1000 m3/hr.

e) The critical speed of the rotor shall be at least 20% above the operating speed.

f) Pump sets shall have double bearings. The bearing life shall be minimum 100,000 hrs of operation.

g) Each pump shall be complete with a cast iron delivery connection arrangement for fixing to the concrete floor of the suction well. All necessary stainless-steel fixtures required for guiding the pumps during lifting / lowering shall be provided. The installation shall facilitate automatic installation and removal of pump without a person entering the wet well. Each pump shall be provided with a corrosion resistance material lifting chain with suitable provision for engaging the hook of the crane at 1 m interval.

h) Each pump shall be provided with an automatic coupling device for attaching the chain pulley block hook to the pump at low level, even whilst the pump is submerged, without the need for personnel to enter the well. This automatic coupling device shall easily and automatically couple and uncouple the hoist hook and be complete with necessary accessories. All links and cables shall be corrosion resistance material.

i) The submersible pumps shall be suitable for operation with or without submergence.

j) The synchronous speed shall not exceed 1500 rpm at 50 Hz supply.

Material of construction of seawater shall be mostly super duplex steel with PREN>41 except for high pressure use where it will be PREN≥43. Material test certificates shall be furnished by the Contractor and shall have the approval of Employer's Representative.

The submerged cable shall be a multi-core flexible cord, vulcanized rubber insulated with tough rubber sheath and outer PCP sheath to BS 6500.

Where both thermal protective and moisture-sensitive devices are incorporated within the pump, both devices shall be brought out via separate conductors within the motor cable, although one such conductor may be common.

7.4.3.2 *Materials of Construction*

The materials of construction for submersible pumps for product water shall be as follows:

Sl. No.	Component	Material
1	Impeller	Stainless Steel: ASTM A 743 CF8M
2	Casing	Cast Iron to IS:210 Gr. FG 200 with 1.5 to 2% Nickel

Sl. No.	Component	Material
3	Shaft	Stainless steel: AISI Gr.316
4	Guide System	Stainless Steel: AISI Gr. 316
5	Fasteners and Foundation Bolts	Stainless Steel: AISI Gr. 316

For seawater use, the Minimum Super Duplex PERN>41 shall be used as applicable for the above components.

Material test certificates shall be furnished by the Contractor and shall have the approval of the Engineer.
The submerged cable shall be a multi-core flexible cord, vulcanized rubber insulated with tough rubber sheath and outer PCP sheath.

Where both thermal protective and moisture-sensitive devices are incorporated within the pump, both devices shall be brought out via separate conductors within the motor cable, although one such conductor may be common.

7.4.4 Dewatering Pump

The pump motor shall be suitable for working with or without submergence in water/wastewater. The motor rating shall be more than the maximum power required by the pump.
Pump shall be vertical, centrifugal, submersible, non-clog & single stage type. The pump set shall be portable with necessary hooks.
The pump shall have double mechanical seals to prevent ingress of moisture in to the motor. The pump impeller shall be mounted on the extended shaft of the motor. The pump shall be supplied with flexible hose pipe of 80 mm dia. & 50 m length. Suitable cable of 50 M length shall be supplied with the pump.

7.4.5 Sump Drainage Pumps

Sump drainage pumps shall be of the open impeller centrifugal type vertically mounted close coupled to their fully submersible electric drive motors.

Sump pumps of 3 kW and under shall incorporate an integral level detector, control and motor starter and shall be powered only with a suitably fused three-phase or single-phase low voltage supply and with supply isolation at the building distribution board.

Sump pumps over 3 kW shall be controlled and started from the building distribution board and be fed with a 3-phase supply. Control shall be via adjustable float level switches mounted adjacent to the pump. Min. four nos. of Drainage pumps of 125 KW to drain the inlet sump shall be provided in addition to the required drainage pumps as required for proper drainage of site.

The pumps shall be supplied with all necessary discharge pipe-work, including nonreturn and isolating valves and suitable lifting gear for lowering and removing the pump from the sump. Pumps weighing 40 kg and more shall be lowered in the sump via guide rails and be located to their respective discharge pipe-work with an angle flange connection and self-locating clamps.

The pump impeller shall be designed to pass solids of sizes which pass through the inlet ports of the pump and shall be capable of pumping solids of up to 20 mm diameter.

7.4.6 Progressive Cavity Pumps

These pumps shall be used for handling thickened sludge transfer and BFP feed applications.

Pumps shall be of the type in which a pumping action is generated by a helical rotating eccentrically within a resilient stator in the form of a double internal helix. The eccentric motion of the rotor shall maintain a constant seal across the stator as it travels through the pump to give a uniform positive displacement.

Pumps shall be arranged generally with a single shaft seal at the suction end. Mechanical seals shall be used. If a flexible shaft is used to accommodate the eccentric motion, a corrosion resistant shroud shall be fitted to prevent fibre build-up on the shaft. Enlarged inspection access holes shall be fitted to the suction chambers of all pumps for periodic removal of accumulated debris.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

The shaft bearing shall be positively isolated from the fluid being pumped.

The rotor material shall be selected for corrosion and abrasion resistance for the fluid being pumped, and for prolonged service life. Hard chrome or other approved coatings shall be not less than 250-micron thickness and shall be diffused into the base material. The rotor shall generally be single-stage and shall incorporate not less than 360° of twist, but for high-head applications, it may be necessary to use more than a single-stage. The stator shall be of a resilient material selected for chemical and abrasion resistance for the fluid being pumped.

Pump speed shall suit the application, where variable delivery output is needed; the pump shall be provided with a variable-speed drive. The size and speed range of the pump shall ensure that the highest expected duty point shall lie within the available speed range.

Pumps shall normally be driven by a fixed-speed electric motor through reduction gearing and the combined drive shall be continuously rated. Pump and motor shall preferably be mounted in-line on a common base plate. Alternatively, the drive motor may be top-mounted above the pump to minimize floor area and shall be connected by external V-belts and pulleys. V-belt drives shall have full guards of the type that allow the belts observed without the removal of the guard. Facilities shall be provided for ready adjustment of belt tension.

Coupling guards shall be provided, which shall be rigid, securely fixed, and designed so that removal is not necessary during normal operation, routine maintenance, and routine inspections.

All motor enclosures shall be provided with ingress protection to IP55. Motor anti-condensation heaters shall be provided and shall be suitable for use on a 220V single-phase, 50Hz supply.

All bearing shall have a B10 design life of not less than 40,000 running hours and shall be designed for loading 20% in excess of calculated maximum loading. Pumps shall be fitted with individual dry-running protection to initiate pump trip. Dry-running protection by 'under-current' monitoring or 'pipeline-intrusive' device shall not be used.

7.4.6.1 *Material of Construction for Progressive Cavity Pumps*

MOC shall be suitable for sea water application.

7.4.7 **Chemical Bulk Transfer Pumps**

Pumps shall be selected taking into account the chemical being pumped, form of chemical, wear leakage and resistance to corrosion.

Typically, the MOCs shall be as below

1. Ferric Chloride Unloading / transfer pumps –
   a. Casing & Impeller – FRP with Vinyl ester resin / Polypropylene
   b. Shaft and all other wetted Parts - Suitable material for service
2. Sulfuric Acid Unloading / transfer pumps –
   a. Casing and Impeller - Alloy 20
   b. Shaft and all other wetted parts - Suitable material for service
3. Sodium Hypochlorite Unloading / transfer pumps –
   a. Casing & Impeller – FRP with Vinyl ester resin / Polypropylene
   b. Shaft and all other wetted Parts - Suitable material for service

Each pump shall be provided with inlet and outlet isolating valves and where necessary, with pressure relief and non-return valves and Pressure Gauges with stopcock.

A relief valve shall be incorporated in the delivery lines under conditions where the pump discharge pipe can be shut off or where pressure may rise to an excessive point. The relief valve shall be sized to handle the system pressure and to discharge maximum pump output freely and shall be located in the discharge line between the pump and the first downstream isolating valve. Relief valves when used on pumps handling non-hazardous chemicals shall discharge the vented liquid to waste. When used on hazardous chemicals the valve outlet shall be piped back to the suction supply tank or bunded-area. The open end of the return pipe shall be located where it is visible, so that any relief valve leakage/operation can be detected.

Pump transferring chemicals to systems under pressure shall incorporate a pressure gauge on the pump delivery. Air cocks shall be provided for release of air where necessary.

Flushing connections shall be provided at each pump inlet and flushing shall be manual. When flushing, water shall be discharged either locally through a drain valve or to the point of application of the chemical. Facilities shall also be provided for flushing chemical pump suction and delivery manifolds and delivery lines to point of application.

7.4.8 Chemical Dosing Pumps

Chemical Dosing Pumps shall be piston diaphragm or mechanical diaphragm type as specified. Pumps may be simplex or duplex arrangements to suit the capacity or process requirements. The pump design shall incorporate positive stroke return. The maximum stroking speed shall not exceed 100 strokes per minute (spm). Pump, motor and driving arrangement shall be mounted on a robust combined baseplate.

Pump liquid ends shall be selected for compatibility with the pumped liquid. Suction and discharge valves shall be the single ball type allowing a free flow self-cleaning action. Ball and seat materials shall be resistant to abrasion. Strainers shall be provided with each pump.

Pumps shall incorporate a variable stroke mechanism to allow the output to be varied while the pump is running. Stroke adjustment shall be manual or where specified by electrical or pneumatically controlled stroke positioner. A stroke length indicator and digital stroke counter shall be fitted. Pumps shall be driven by a flange mounted IP 55 motor, via an oil bath reduction gearbox and variable stroke mechanism giving stepless adjustment between zero and maximum stroke length. Where flow proportional dosing is required the variation of output shall be achieved by varying the speed of the pump motor and not the pump stroke length.

The normal operating range of dosing pump shall be not less than 6:1.

a. Mechanical Diaphragm rigidly coupled to the drive train. Single suction Pumps and discharge valves. Glandless. Accuracy: ± 3% of stoke.

b. Piston Diaphragm Pumps hydraulically operated by liquid displaced by a plunger and protected from excess pressure via a relief valve. Accuracy: ± 2% of stroke.

Materials shall be selected to suit the chemicals being pumped. Liquid ends shall be polypropylene, AISI 316 stainless steel, glass, or Hastelloy C. Diaphragm materials shall be butyl rubber, PTFE, or Hypalon and glands shall be PTFE or Neoprene.

Each pump shall be provided with inlet and outlet isolating valves and where necessary, with pressure relief and non-return valves. Dosing pumps shall be provided with back pressure loading valves and pulsation dampeners in the delivery lines depending on the downstream conditions.

A relief valve shall be incorporated in the delivery lines under conditions where the pump discharge pipe can be shut off or where pressure may rise to an excessive point. The relief valve shall be sized to handle the system pressure and to discharge maximum pump output freely, and shall be located in the discharge line between the pump and the first downstream isolating valve or in the case of dosing pumps the back pressure loading valve. Relief valves when used on pumps handling non-hazardous chemicals shall discharge the vented liquid to waste. When used on hazardous chemicals the valve outlet shall be piped back to the suction supply tank or bunded area. The open end of the return pipe shall be located where it is visible, so that any relief valve leakage/operation can be detected.

Pump transferring/dosing chemicals to systems under pressure shall incorporate a pressure gauge on the pump delivery. Air cocks shall be provided for release of air where necessary. Unless otherwise specified flushing connections shall be provided at each pump inlet and flushing shall be manual. When flushing, water shall be discharged either locally through a drain valve or to the point of application of the chemical. Facilities shall also be provided for flushing chemical pump suction and delivery manifolds and delivery lines to point of application.

Dosing pumps and motors shall preferably incorporate an integral reduction gearbox drive which shall be totally enclosed and oil bath lubricated. The gear box shall incorporate the cams for the diaphragm drive and shall be provided with filling and drain connections and visible oil level indication.

7.4.9 Submittals

The Contractor shall submit minimum the following documents:

(i) Certified shop and erection drawing.

(ii) Equipment Manufacturer shall submit electronic files of the proposed equipment in the capacity, size, and arrangement as indicated and specified.

(iii) Data regarding pump and motor characteristics and performance:

(iv) Prior to fabrication and testing, provide guaranteed performance curves based on actual shop tests of mechanically duplicate pumps, showing they meet indicated and specified requirements for head, capacity, motor kW, efficiency and NPSH.

(v) For units of same size and type, provide curves for a single unit only.

(vi) Provide catalogue performance curves at maximum pump speed indicated and specified showing maximum and minimum impeller diameters and number of stages available.

(vii) Results of shop performance tests as specified.

(viii) Submit curves for guaranteed performance, and shop performance tests on A4 sheets one curve per sheet.

(ix) Shop drawing data for accessory items.

(x) Certified setting plans, with tolerances, for anchor bolts.

(xi) Manufacturer's literature as needed to supplement certified data.

(xii) Operation and Maintenance instructions and parts lists

(xiii) Listing of reference installation as specified with contact names & details.

(xiv) Certified results of hydrostatic testing.

(xv) Certified results of dynamic balancing.

(xvi) Bearing temperature operating range for the service condition specified.

(xvii) Shop and field inspection reports.

(xviii) Shop and field testing procedures and equipment to be used.

(xix) Provide a scaled drawing showing the pumps, motors and hoist including equipment weights, lifting attachments and clearance for equipment removal and maintenance together with the location of discharge pressure gauges.

(xx) Manufacturer's product data and specifications for painting.

(xxi) The latest ISO 9001 certification.

(xxii) Material Certification:

- Provide certification from the equipment manufacturer that the material of construction specified and recommended and suitable for the service conditions specified and indicated.
- When material is not specified, technical data and certification that the proposed material are recommended and suitable for the service conditions.

7.4.10 Pump Performance Guarantees

The pump performance guarantee shall relate to the flow rate, the total head and the efficiency of the pump when tested at the manufacturer's works and shall obtain approval of Engineer.

The pump shall operate at its design point within acceptance tolerances for flow rate and total head laid down in BS: EN ISO 9906:2000.

Each pump shall be tested at the manufacturer's factory in accordance with IS 9137 or other relevant standards in conjunction with one of the contract motors.

This test shall be carried out on at least one pump set using the flexible coupling and contract drive shaft arrangement to establish that the drive arrangement with supports and couplings operates satisfactorily under all operating conditions.

Where similar drive shaft arrangements have been installed by the Contractor and have been proven satisfactory in service this requirement may be withdrawn subject to the approval of the Engineer.

A test shall be carried out of the performance from closed valve to the maximum quantity that can be delivered under abnormally low discharge heads.

Sufficient readings shall be taken at each test to produce accurate curves of the heads, flow, pump speed and power required at pump coupling throughout the operating range of the pump.

Vibration and noise dB(A) levels shall be measured and shown to be acceptable levels as per the contract and shall have Employer's Representative approval. The Contractor shall have Employer's Representative approval and provide acceptable test certificates, showing the

NPSH requirement for the pump is at least 2 m less than the NPSH available under all working conditions.

Proto type pump shall be tested over the full operating range, covering from minus 70 percent of the bowl head to the shut-off head. The duration of tests shall be minimum one hour. A minimum of five readings shall be taken for plotting the performance curves. Hydrostatic pressure test shall be conducted for 30 minutes for all pressure parts. The test pressure shall be minimum 1.5 times the pump shut off pressure

The Contractor shall have Engineer's approval and provide acceptable test certificates, showing the NPSH requirement for the pump is at least 2 m less than the NPSH available under all working conditions.

In the absence of the approved test certificates the supplier shall carry out a test on one pump of each type to verify the NPSH requirement based upon the 3% output drop criterion and shall take approval of the Engineer.

Test Certificates in duplicate shall be submitted to the Engineer immediately following each of the tests mentioned above. Performance curves shall also be incorporated in the Operation and Maintenance Manual.

7.4.11 Single/Parallel Pump Operation

a) Head/quantity curve

b) Motor kW input/quantity curve

c) Overall efficiency/quantity curve

d) NPSH required/quantity curve

e) Vibration and Noise dB(A) levels

f) Head/quantity curves for parallel operation of pumps superimposed on system head curve.

7.5 Vacuum Gauges and Pressure Gauges

Pressure gauges shall not be less than 150 mm in diameter and shall be in conformance with specification detailed in Particular Instrumentation specifications Vol 2, Part 8 & 9.

Pressure gauge on delivery pipe and compound gauge on suction pipe of each horizontal centrifugal pump set of suitable range. Pressure gauge on delivery pipe of each vertical turbine pump set of suitable range. The gauges with dial size of 100 mm diameter complete with 3-way cock, isolation valve and connecting pipe.

The maximum range of the Pressure gauge shall be appropriately selected taking into considerations all operating pressures including water hammer encountered.

Vacuum gauge shall be calibrated in mm Hg.

Unless otherwise specified, scales shall be calibrated in meters head of water, with zero representing atmospheric pressure. The lettering shall be in black.

Compound gauges shall read at least 5 m below atmospheric pressure using red lettering.

Where the working fluid is of a corrosive or dirty nature the pressure gauge shall be protected from the working fluid by a diaphragm or similar arrangement.

Each pressure gauge shall be fitted with a stopcock immediately adjacent to the gauge and all pressure gauge piping shall be fitted with an isolating valve at the point of connection to the main system. Where pressure gauges are mounted within or on a panel a suitable connection for a test gauge shall be provided.

7.6 Air Compressors and Blowers

7.6.1 Air Compressors

The operation of all valves and instruments will be done electrically. However, if a compressor system is required, it shall comprise compressors, after-coolers and refrigerant type air dryer, duty/standby air receivers together with control equipment, oil eliminating filters, flow regulators and oil mist lubricators and auto drain units as required.

Type of air compressor shall be reciprocating type.

Electrically driven air compressor sets shall operate up to minimum 10 bar working pressure. Working pressure and capacity shall be adequate for the required duties.

Compressor sets with at least 1 standby shall be provided complete with the following:

a) Common base frame for Compressor & Motor
b) Single stage air-cooled unit
c) Isolating valves
d) Air filter and silencer
e) Pressure relief valve or excess pressure safety device
f) Pressure reducing valves
g) Pressure gauges
h) Pressure switches
i) Offloading piston
j) Automatic changeover (failure of duty unit)
k) Drain pipes
l) Isolating valve
m) V-belt drive arrangement with Belt Guard
n) Stoppers
o) Air-receivers
p) Air dryer (refrigerant type with auto drain.
q) Others necessary appurtenances

Compressors shall be arranged for automatic changeover on failure of the duty unit. Failure of the duty unit shall initiate an alarm. Control equipment shall include automatic unloading valves, pressure switches for duty standby and alarm, and lockable changeover switches. 1 duty

& 1 standby after coolers shall be provided. Water-cooled or air blast types will be considered. Air receivers shall be designed and fabricated in accordance with relevant approved standards, they shall be mounted vertically on steel feet so that sufficient space is allowed for each access to the whole outside surface. Receivers shall be provided with drain cocks piped to drain pressure gauges and relief and check valves.

Supply of all necessary electrical components, devices, equipment, control panels. Etc. together with cabling, earthing provisions, etc. shall be responsibility of the Contractor.

Interconnecting pipework shall be arranged to avoid low points, which may trap water. Unavoidable low points shall be provided with drain cocks piped to waste.

Pipe hood shall be provided on the top of headstock to protect the spindle from damage, dirt, dust, water etc. The hood shall be made of transparent fracture resistant polycarbonate material. The hood shall have vent holes to prevent condensation. All pipe-works shall be SS-316 L

7.6.2 Air Blower for Backwash of Filter Beds

Air blowers twin lobe root type shall be provided for washing filter beds of each stage conforming to specifications hereunder:

- Twin lobe type Root Air blower shall have capacity to wash one filter bed at required pressure. Speed of blower shall not exceed 1500 RPM (synchronous)
- The number of blowers shall consider the number of filters provided, their backwashing sequence, and the number of blowers required with one under maintenance and one on standby.
- The main body, side covers shall be manufactured from Graded Cast Iron as per I.S. 210 / FG – 260.
- The Rotors shall be of forged construction (with Integral Shafts) in Twin Lobe Compressors with EN-8 Shafts.
- All components shall be machined to accurate dimensions with extremely tight tolerance with guaranteed interchangeability. The Castings of Casing and main Covers (Bearing Housing) shall be stress relieved after pre-machining for dimensional stability at elevated temperature.
- The Lobes of Rotors shall have uniform clearances between rotor to rotor in any position of two rotors. The profile shall ensure uniform clearances between casing and Lobes.
- Sealing of main chamber shall be with labyrinth seal.
- Air blower shall be oil lubricated for driving and non-driving end. Grease lubrication shall not be acceptable. Both sides of casings shall be oil-filled. All bearings and gears shall be splash lubricated for increased life of bearings and gears.
- The Timing Gears shall be helical teeth, hardened and machined to ensure low noise level.

- The Gears as well as the bearings shall be oil lubricated on both sides (Driving and non-driving side) of the Blower.
- All the Blowers shall be individually tested as per IS-10431/ IS-5456 for capacity, pressure, power consumption, temperature rise, noise level and vibration level.
- Each Twin Lobe Blower shall be equipped with various accessories like Two Silencer (for Suction and Discharge), Suction Filters, Safety Valves, Non-Return Valves, Anti Vibration Pads, Flexible Bellows, Air pressure gauge with isolating valve for delivery side of air blower.
- Each air blower shall be driven with electrical motor as per specification detailed for the motor. The motor shall have at least 15 % margin over the power required.
- Both Air blower and Electric motor shall be installed on common base with rigid concrete foundation. Air blower shall be coupled with electric motor by love joy type couplings. Radial and axial alignment of Air blower and electric motor shall be perfect.
- The blowers shall be equipped with all piping, valves and automatic change over to start standby blower if duty blower fails to start.

7.6.2.1 *General Design Requirements*

The air blowers shall be of such design as to achieve energy efficient operation continuously over the range of design airflow rates at the discharge pressure that shall remain practically constant.

The sizing of the blower units shall ensure that the peak airflow demand can be met by one duty blower with one unit on stand-by (two duty and one 50% standby will also be considered). Each blower shall be fitted with a variable speed motor and be capable of operating between 80% and 110% of its nominal peak airflow demand.

The discharge pressure shall be calculated by the Contractor dependent on the final design layout of the aeration system and of the delivery manifold.

The blowers shall also be capable of supplying the design "mass flow" rate at maximum ambient inlet temperature of 50°C.

Each of the blowers shall be capable of operating without surge in parallel with the other duty blower at the maximum mass flow against designed maximum gauge pressure at the outlet pipe. The Contractor shall demonstrate this during testing and commissioning. Performance curves for the blower system shall be submitted. Standard certified factory test sheets showing the results of each test shall be supplied in triplicate to the Employer's Representative prior to delivery of the blowers. The blower unit shall be capable to operate at maximum duty for continuous operation. The blower motor shall not exceed a maximum speed of 1500 rpm and the blower shall not exceed the manufacturer's recommended maximum speed.

Each blower shall be fitted with an acoustic enclosure. The arrangement shall be such that all blowers are accessible for operation and maintenance and the installation of additional blowers in the future is possible.

The inlet air to the blower house shall be filtered to suit the blowers and aeration diffusers selected. Vacuum switch, pressure switch, oil level indicator and any other monitoring device shall be mounted outside the acoustic enclosure. Inlet and outlet pressure gauges shall be mounted outside the acoustic enclosure. Vibration absorbing mounting pads shall be used.

A blower removal system shall be provided so that any one blower can be removed as a single unit and loaded on to a truck. The blower building shall be acoustically designed to minimize both noises inside the building and noise breaking out of the building. The building ventilation system shall be designed to limit the temperature rise not more than 3° C above ambient temperature.

Filters and Silencers

The blowers shall receive filtered air individual replaceable filter elements suitable for the intended duty.

The filter elements shall be housed in an airtight housing which shall allow easy replacement of the filter elements. Replacement of elements shall be possible without the use of tools.

If the filter/silencer elements supplied are located out of doors a weatherproof cover shall protect the filter element from rain.

The filter unit shall be fitted with suitable vacuum gauges to indicate the suction pressure into each blower. The gauges shall be industrial Bourdon of Schaffer type gauges with a nominal diameter of 150 mm. The scale shall be suitably selected and shall include a red line to indicate the point at which the filter elements require renewal.

Each blower intake shall be fitted with a differential pressure switch, which shall indicate an alarm signal in the event of excessive pressure drop in the blower intake.

Flexible Connections

The blower discharge shall be fitted with an approved flexible sleeve with fixing clamps and a flanged outlet spigot for connection to site pipework. If the blower inlet is via a common plenum the inlet pipe shall be also fitted with a flexible connection.

Sleeves shall be manufactured from an approved non-metallic material suitable for the duty and location in which the blowers are to be installed.

Pressure Relief Valve

The pressure relief valve shall be sized and adjusted to allow the full flow of the blower to be discharged in the event of a blockage or valve closure in the downstream pipeline and without overloading the drive motor.

Each blower shall be fitted with a suitable pressure switch, which shall shut down the blower in the event of excessive discharge pressure. The pressure setting shall be lower than the set pressure of the pressure relief valves.

The pressure relief valve shall be installed at a height above 2m from the floor and away from blower suction point. The pressure relief valve shall be fitted with a silencer.

Non-Return Valves

A non-return valve shall be installed on the discharge pipework of each blower, upstream of the blower isolation valve.

Isolating Valves

Isolating valves shall be installed on the delivery pipework of the blowers, such that each blower and all associated pipework and valves upstream of the common distribution manifold can be dismantled without disruption to the normal operation of the plant

Temperature Measurement

Temperature sensor complete with gauge of an approved type shall be supplied for each main distribution pipework and for the blower room.

Piping Vibration

If the blower type selected produces a discharge flow with a pulsating characteristic, flow pulsation dampers shall be installed on the blower intake and discharge, as required, to eliminate excessive noise or vibration from this source.

7.6.2.2 *Blower Noise limits*

The blowers supplied under this Contract shall be quiet in operation. The Contractor shall guarantee that the total sound power noise emission for the aeration system shall be broad band and free from any tonal or intermittent components. Under any loading condition from no load to full rated, the blower supplied shall comply with the noise requirements.

7.6.2.3 *Positive Displacement Blower*

The air rotary positive displacement blowers (Roots type or equivalent) shall consist of lobed rotors rotating designed for continuous operation at the required pressures and flows. The blowers shall be controlled by variable speed drives. The bowers shall be able to operate over a speed range to deliver the range of airflow rates nominated above.

Rotors and shafts shall be of one-piece construction and shall be of forged steel or shall comprise cast iron rotors on steel shafts. The rotors shall have two or more lobes and shafts shall be geared together with timing gears so that the lobes do not make contact during operation.

Bearing housings and rotor shafts shall be fitted with suitable oil seals to exclude dirt and moisture and to prevent oil carryover into the discharge air. Where bearings are oil lubricated the housings shall be fitted with effective oil level indicators.

The blower and motor shall be mounted on a base frame incorporating an integral silencer, non-return valve, pressure relief valve, discharge connection with flexible joint and flexible mounting pads (vibration dampers shall be placed under blower mounts.

The complete assembly including drive motor and lubrication system shall be mounted and aligned on a substantial galvanised sub-frame. Heavy-duty anti-vibration mountings are to be located on the underside of the sub-frame.

7.6.2.4 *Materials of Constructions*

The materials of construction for the blowers shall be at least equal in quality to the following:

COMPONENT	MATERIAL
Casings	Cast Iron
Base plate	Steel, Galvanized
Rotor/impeller	SS316 or Manufacturer's std
Shaft	SS316 or Manufacturer's std
Nuts and Bolts	Stainless Steel 316

7.7 Pressure & Storage Vessels:

i) Design of all vertical atmospheric storage tanks containing water, acid, alkali and other chemicals shall conform to IS:803 in case the material is carbon steel.

ii) Atmospheric vertical storage tanks shall be fabricated of mild steel as per IS:2062-Tested quality. Plates shall be cold rolled through plate bending machine by several number of passes to true curvature and joined by welding.

iii) Design of all pressure vessels shall conform to ASME Code Section VIII Div 1 Design pressure should be the maximum expected pressure to which the vessels may be subjected plus 5% extra margin. Maximum expected pressure for vessels placed in the discharge line of pumps shall be based on the shut-off head of the pumps plus static head at pump suction.

iv) Design temperature of vessels shall be 10 deg C higher than the maximum temperature that any part of the vessel is likely to attain in course of operation.

v) Block and bleed type arrangement shall be provided for storage tanks in hazardous area.

vi) All Carbon Steel vessels without inside rubber lining (including vessels with inside painting only) shall have a corrosion allowance of 2 mm (minimum) on shell and dished ends. Suitable mill allowance shall also be considered for shell and dished ends. Thinning/scaling allowance of 2 mm (minimum) shall be considered for dished ends. The minimum plate thickness of either pressure vessel or atmospheric storage tank shall be 6 mm.

vii) Manholes shall be provided in all vessels for providing easy access into the same. The size shall be minimum 500 mm and it will be provided with cover plate, nuts, bolts and gaskets to ensure leak tightness at the test pressure.

viii) Adequate supporting arrangements like straps, saddles, skirt boards, pillars etc. shall be provided to transfer all loads to civil foundation. All foundation bolts, inserts etc. will also be included.

ix) All vessels shall be provided with lifting lugs, eye bolts etc. for effective handling during erection.

x) Suitable seal shall be provided with the vent line of atmospheric tanks containing fuming liquids and also to prevent contamination from atmospheric air.

7.8 Sluice Gates and Electric Actuator

7.8.1 Sluice Gates

a) **Design Requirements and Construction Features:** The construction of sluice gates shall be in accordance with the specification and generally as per AWWA C 560-00 /IS:13349-1992 or other applicable standard. All sluice gates shall be thimble mounted and of the rising spindle type.

b) **Frame:** The frame shall be of the flange back type and shall be machined on the rear face to bolt directly to the machined face of the wall thimble.

c) **Seating Faces:** Seating faces shall be made of full width, solid section; dove-tail strips of stainless steel. They shall be secured firmly by means of counter sunk fixings in finished dove-tail grooves in the frame and slide faces in such a way as to ensure that they will remain permanently in place, free from distortion and loosening during the life of the sluice gates.

d) **Wedging Devices:** Sluice gates shall be equipped with adjustable side, top and bottom wedging devices as required to provide contact between the slide and frame facing when the gate is in closed position.

e) Lifting Mechanisms

- Sluice gate shall be operated through suitable lifting mechanism which shall incorporate suitable gearing if required, to keep the torque requirement within 7 kg.m.
- Lifting mechanism shall incorporate a strong locking device suitable for use with a padlock or padlock and chain.
- Lift mechanism shall be provided with a suitable position indicator to show the position of the gate at all times.

f) **Wall Thimbles:** The cross section of the thimble shall have the shape of the letter 'F'.

g) **Lifting Lugs:** Lifting lugs shall be provided for all gates.

h) **Flush Bottom Seal:** When sluice gates are provided with flush bottom seals, the wedging device and facing along the bottom edge of the slide and frame shall be omitted. A solid square cornered, resilient rubber seal shall be provided on the bottom facing of slide. The seal shall be securely fastened to the bottom face of the slide by a retainer bar and corrosion resistant metal fasteners. The top surface of the bottom facing of frame shall be flush with invert of the gate opening. Bottom facing of the slide shall be accurately machined to make contact with the seal when the slide is closed.

i) Suitable arrangement shall be made on all the sluice gates and actuators such that the actuator is capable of operating specific size of sluice gate, under this contract.

j) Headstock meant for mounting on operating platform shall be supplied with a pedestal/floor stand to provide a convenient operating height of approximately 900mm.The pedestal of the headstock shall be provided with a covered window opening to enable cleaning and greasing of stem threads.

k) All the Gears in the headstock shall be kept completely encased in cast iron housing to protect them from dirt. Dust, damage etc. and other atmospheric effects and thus ensure smooth operation. Grease nipples shall be provided at proper places for lubricating with grease.

l) Pipe hood shall be provided on the top of headstock to protect the spindle from damage, dirt, dust, water etc. The hood shall be made of transparent fracture resistant polycarbonate material. The hood shall have vent holes to prevent condensation.

m) The material of construction of sluice Gate suitable for sea water application. All inserts/embedment shall meet the PREN requirements for steel in contact with sea water.

7.8.2 Electric Actuator

Electric actuator for closing and opening of each sluice gate shall be provided as per the process requirement mentioned elsewhere in this document, so that the closing and opening operation time shall be maximum of 10 minutes. The local control shall be protected by a Lockable cover.

The Actuator shall be adequately sized to operate all the penstocks and be continuously rated to suit the modulating control required. The gear box shall be oil or grease filled, and capable of installation in any position. All operating spindles, gears and headstocks shall be provided with adequate points for lubrication.

The Actuator shall be capable of producing not less than one and half times the required torque and shall be suitable for at least 15 minutes continuous operation.

The Actuator starter shall be integrally housed with the Actuator in robustly constructed and totally enclosed weatherproof housing. The motor starter shall be capable of starting the motor under the most severe conditions.

The starter housing shall be fitted with contacts and terminals for power supply, remote control and remote positional indication.

Each starter shall be equipped as follows:

a) Three phase magnetically operated line contactors with no-volt release and electrical and mechanical interlock.

b) Three phase thermal cut-out device.

c) Control circuit transformer fully protected by fuses on primary and secondary circuits.

d) "Open", "Close" and "Stop" push buttons.

e) Local-off-Remote switch with padlocking facilities.

f) Torque and Limit switches for "open" and "Close" positions.

g) Auxiliary limit switches in each direction.

h) Gate position indicator and Handwheel for Manual operation.

i) Reduction Gear unit.

7.9 Valves

7.9.1 General

a) Valves shall be as per internationally recognized standards. Flanges shall be machined on faces and edges and drilled to applicable IS.

b) Valves shall be double flanged and the face shall be parallel to each other and flange face should be at right angles to the valve centerline. Backside of valve flanges shall be machined or spot faced for proper seating of the head and nut. Valve buried or installed in underground chamber, where access to a hand wheel would be impractical, shall be operated by means of extension spindle and/or keys. Valve shall be suitable for frequent operation as well as operation after long periods of idleness in either open or closed position.

c) The valve stem, thrust washers, screws, nuts and all other components exposed to the product water shall be of a corrosion resistant grade of stainless steel 316/316L as needed. The valves in contract with sea water and /or brine shall be of nickel aluminum bronzes, or 9010 Cu-Ni with 1.5% Chromium alloys or SDSS. All these alloys shall be characterized by good resistance to static seawater (necessary for shut-down conditions) and to flowing seawater. Valves shall be free from sharp projections. Large size butterfly and non-return valves shall be provided with bypass arrangement having rising spindle gate valves. Bypass may be integral with valve or connected between pipes. A positive seal between the lining and the stem is provided to prevent access of seawater to the cast iron body.

d) The work of fixing appurtenances, i.e. butterfly valves, sluice valves, air valves, scour valves, etc. shall be carried out carefully so as not to damage them during handling, erection and fixing.

e) All the butterfly valves and sluice valves for pumping plants and isolation valves on pumping main (except scour valves on pumping main and the isolation valves for air valves) shall be electrically operated. The valves shall have arrangement for manual operation also, operated through a suitable gearbox, by hand wheel. Valves for operation shall be so geared that under the operating conditions as specified herein, the maximum force on the rim of the hand wheel, crank, or other necessary for operation shall not exceed 10 kg and the maximum torque shall not exceed 5.5 kg/m. Operation must be possible by one man against maximum design working pressure. For butterfly valves the gearbox shall be provided with self-locking devices. A locking facility shall be provided for the BF valve in either the fully open, fully closed or intermediate position. Gate valves and butterfly valves shall be provided with position indicators, to show whether the valve is in the open or close position.

f) Scour valves shall be provided with extension spindle with supports for operation from operating level / ground level.

g) Gaskets shall be of NBR/Nitrile based rubber and ready-made matching with respective flanges. Gaskets cut out from rubber sheets are not acceptable.

7.9.2 Butterfly Valves

Butterfly valves shall be of double eccentric and resilient seated type generally as per IS:13095 and ASME B16.5 and should be tested as per ISO 5208-EN 1074.

Butterfly valves shall be suitable for bi-directional pressure testing with dead-tight shut off even after long period of operation of 5 years. The valves shall be of double flanged long type.

The valves shall be electrically/pneumatically and 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 replaceable design. When the valve is fully closed, the seal shall seat firmly. The seat surfaces shall be machined smooth to provide a long life for the seal. All fasteners shall be set flush so as to offer the least resistance possible to the flow through the valve.

The shaft shall be stainless steel with Bronze or equivalent seal with self-lubricating bearings. Disc pins shall be stainless steel 316L. For seawater/brine, the shaft shall be of super duplex steel and disk pin be of Duplex/ Monel K 500 / Inconel 625 as applicable. Rings shall be bi-directional self-adjusting suitable for pressure or vacuum service. Removal and replacement of seals shall be possible without removing the operating mechanism, valve shaft and without removing the valve from the pipeline. 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.

All valve spindles and hand wheels shall be positioned to give good access for operational personnel. 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 weatherproof. 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:

Item	For product water application	For seawater application
Body	Cast Iron IS:210 Gr FG 220	DI with Ebonite lining / Cast 70-30 Cu-Ni/ SDSS
Disc	Cast Iron IS:210 Gr FG 220	ASTM A 890 Grade 5A (PREN>41 / PREN≥43)
Shaft	SS BS:970 Grade 431 S 29	254 SMO/ Super duplex steel
Body Seat	Nickel weld overlay micro-finished	Manufacturer spec
Seal	NBR/EPDM	NBR/EPDM
Seal Retaining ring	Stainless steel AISI 316	254 SMO/ manufacturer spec
Shaft Bearing	Bronze with EPDM 'O' ring seals	Manufacturer spec
Internal Fasteners	Stainless steel AISI 316	Duplex SS/ Monel K 500 / Inconel 625
Nuts, bolts & washers for pipe flanges	Stainless steel AISI 316/316L	Stainless steel AISI 316/316L

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).

7.9.3 Sluice Valves

Sluice valve shall generally conform to IS:14846 and as per ASME B16.5. They shall be of non-rising spindle type except for the valves for bypass. The gate face rings shall be securely pegged over the full circumference. Valve of 400 mm and above shall be furnished with a bushing arrangement for replacement of packing without leakage. They shall also have renewable channel and shoe linings. The gap between the shoe and channel shall be limited to 1.5 mm. Valve of 200 mm and above shall be provided with thrust bearing arrangement for ease of operation.

Valve of diameter 400 mm and above shall be provided with enclosed gear arrangement for ease of operation. The operation gear of all valves shall be such that they can be opened and closed by one man against an unbalanced head 15% in excess of the maximum specified rating.

Valve and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 200 N.

Valves spindles and hand-wheels shall be positioned to give good access for operational personnel. 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.

Valves shall have two position marked at the shut end of the scale, first one corresponding to the position of the gate tangential to the bore of the seating and the second position below the first, corresponding to the position of the gate as it sits on the seating after moving a further distance equal to the depth of the seating.

All valves on pump suction and delivery piping shall be with electrical actuators. Operation of valves shall be with electric actuators mounted on floor stand at motor floor. The remaining sluice valves shall be manually operated unless specified elsewhere in this tender document.

Suitable arrangement shall be made on all the sluice gates and actuators such that the actuator is capable of operating specific size of sluice gate, under this contract.

Headstock meant for mounting on operating platform shall be supplied with a pedestal/floor stand to provide a convenient operating height of approximately 900mm.The pedestal of the headstock shall be provided with a covered window opening to enable cleaning and greasing of stem threads.

All the Gears in the headstock shall be kept completely encased in cast iron housing with suitable coating to protect them from dirt. Dust, damage etc. and other atmospheric effects and thus ensure smooth operation. Grease nipples shall be provided at proper places for lubricating with grease.

All Sluice valves shall be open-end tested.

Bypasses for valves 400 mm and over shall be fitted with integral bypasses as per diameter in IS: 14846.

Material of construction shall comply with the requirements given below:

Item	For product water application	For seawater application
Body, Door, Dome, Bonnet	Cast Iron IS:210 Grade FG220	Cast 70-30 Cu-Ni/ 254 SMO/ ASTM A 890 Grade 5A
Wedge	Cast Iron IS:210 Grade FG220 Rubber lined with EPDM	ASTM A 890 Grade 5A (PREN>41 / PREN≥43) / manufacturer spec
Seat, Face ring	IS:318 Gr. LTB 2	254 SMO/ Monel K 500/ Cast 70-30 Cu-Ni
Spindle / Stem	SS: IS:6603 04 Cr17 Ni12	254 SMO/ Monel K 500

	Mo2 / AISI 316L	
Bonnet Gasket	NBR/EPDM	NBR/EPDM
Internal Fasteners	Stainless steel SS316L	Duplex SS/ Monel K 500 / Inconel 625
Nuts, bolts & washers for pipe flanges	High tensile steel Hot dip galvanized	Stainless steel AISI 316/316L

7.9.4 Plug Valves

This Specification covers the minimum requirements for design, manufacture and supply of plug valves of size DN 50 mm (2 inch) and above and ANSI Class 150# thru 600#.

All valves shall be manufactured and supplied in accordance with the American Petroleum Institute (API) Specification 6D, Twenty Second Edition, 2002 including supplement 1 & 2 thereof with additions and modifications as indicated in the following sections of this specification.

The ASME Boiler & Pressure Vessel Code, Section VIII, Division 1 shall be used to design the valve body. Allowable stress requirements shall comply the provisions of ASME B31.3. However, the minimum valve thickness shall not be less than the minimum requirement of ASME B16.34. The manufacturer should have valid license to use API monogram on valves manufactured as per API 6D.

Valves shall be provided with plug position indicator and stops of rugged construction at the fully open and fully closed positions. Valves shall have locking devices to lock the valve either in full open (LO) or full close (LC) position. Locking devices shall be permanently attached to the valve operator and shall not interfere with operation of the valve

Reference has also been made in this specification to the latest edition of the following Codes, Standards and Specifications.

ASME B3 1.3 - Process Piping.

ASME B 16.5 - Pipe Flanges and Flanged Fittings.

ASME B 16.25- Butt-welding Ends

ASME B 16.34- Valves - Flanged, Threaded and Welding Ends.

ASME B16.47 - Large Diameter Steel Flanges.

API 1104 - Welding Pipelines and Related Facilities.

ASME Sec IX - Boiler and Pressure Vessel Code.

ASTM A 370 - Test Methods and Definitions for Mechanical Testing of Steel Products.

MSS-SP-6 - Standard Finishes for Contact Faces of Pipe Flanges and Connecting-end Flanges of Valves and Fittings.

MSS-SP-44 - Steel Pipe Line Flanges.

V SSPC-VIS-I - Steel Structures Painting Council Visual Standard.

Design Characteristics

Fluid	: Sea water
Diameter	: According to service
Design pressure	: ANSI 600 Ib
Connections	: BW Sch 40S - flanged

MATERIALS

Body and stem	: Super Duplex ASTM A-890 Gr 5A
Joint	: PTFE

7.9.5 Non-Return Valves

a) The valve shall be suitable for mounting on a horizontal pipeline and flow direction shall be clearly embossed on the valve body.

b) Valves shall possess high speed closing characteristics and be designed for minimum slam condition when closing.

c) Dual plate check valves shall conform to API 594 and API 598 (dimensions) and ASME B16.5 (connections). They shall have metal to metal sealing. The spring action shall optimize the equal closing rates of each plate especially when the friction coefficients are uneven due to one plate resting upon one another. The plates shall not drag on the seat while opening. The plates shall not vibrate under full or partial flow condition. Valves shall possess high speed closing characteristics and be designed for minimum slam condition when closing.

d) The minimum body-wall thickness shall conform to those given in Table 1B of API Standard 594. For low pressure piping, Class 150# and for high pressure piping Class 600# shall be used.

e) The face-to-face dimensions of valves (including valves with ring-joint facings) shall conform to those mentioned in Table 2B of API Standard 594.

f) The valve body shall be furnished with a clearly visible forged, machined-in, or die-stamped arrow to indicate the direction of flow through the valve.

g) Maximum permissible seat leakage is 7cc/Hr/cm nominal diameter of valve.

h) Material of construction of valves shall comply with IS code and as follows for seawater application.

Rating	Class#150/600 for low/high Pressure piping
Body	ASTM, A 890 5A with PERN>41 / PREN≥43 as applicable
Plate	ASTM, A 890 5A with PERN>41 / PREN≥43 as

Hinge & Stop Pin	Inconel 625
Springs	Inconel 625
Seat	ASTM, A 890 5A with PERN>41 / PREN≥43 as applicable
Retainer	Inconel 625
End Connection	RF, 150# as per ANSI B 16.5/ for 600# Grooved
Tag/Name plate	316 Stainless Steel (Engraved)

7.9.6 Air Valve

The air valve shall be double orifice kinetic type and conform to IS 14845. The valve shall be capable of exhausting air from pipework automatically when being filled, the air being released at a sufficiently high rate to prevent the restriction of the inflow rate. Similarly, the valve shall be capable of ventilating pipework automatically when being emptied, the air inflow rate being sufficiently high to prevent the development of a vacuum in the pipelines. The valve shall also automatically release air accumulating in pipework during normal working conditions.

Air valves shall thus be designed to automatically operate so that they shall:

- positively open under internal pressure less than atmospheric pressure to admit air in bulk during pipeline draining operation.
- exhaust air in bulk and positively close as water, under low head, fills the body of the valve during filling operation.
- not blow shut under high velocity air discharge.
- exhaust accumulated air under pressure while the pipe is flowing full of water.

All air valves shall be constructed so that internal working parts which may become necessary for repairs shall be readily accessible, removable, and replaceable without use of special tools and removing the valve from the line.

Air valves shall be of single chamber double orifice type and tamper proof unless otherwise directed by the Engineer. A buoyant rigid float shall seal the large orifice and the chamber housing shall be designed to avoid premature closing of the valve by the air whilst being discharged. Small orifice shall discharge small air volume during operation under full internal pressures. All air valves shall be provided with isolating sluice valve and flanged end connection.

The aperture of valves must be properly designed for which the Contractor shall submit design calculations for necessary approvals before the procurement of valves.

All branched outlets including air valve tees shall be provided with one ½" BSP coupling duly plugged for measurement of pressure in due course. The closing plug shall be in Stainless Steel (AISI 304 or equivalent) with Hex. Head and shall be provided with copper washer for sealing.

Material of construction of air valve shall comply with following requirement.

Body, Bonnet and cover	SG Iron 1865 Gr 400/12 or Grade GGG 40
Float	Polycarbonate up to 50 NB and SS 316 Ti/ AISI 316 Ti for above 50 NB
Internal Linkages	Stainless Steel 316L
Seat Ring	Dexine (Nitrile Rubber) on Bronze seat
Gasket / Seal	EPDM/NBR
Shut off Device	Stainless Steel (ASTM A240 Grade 321/AISI 321)

Bidders are encouraged to submit alternative design. Alternative design of air valve is subjected to approval by the Engineer.

7.9.7 Pressure Relief Valve

a) Pressure relief valves shall be capable of relieving pressure in the system to prevent the system being pressurised in excess of a preset maximum allowable pressure. The valves shall be drop tight under normal operating conditions.

b) The valve operation shall be achieved by the interaction of the inlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valves.

c) The pilot valve or relay system shall be actuated by a diaphragm connected to the inlet pressure on its underside and a constant pressure on its upper side derived either from weight or from a spring.

7.9.8 Pressure Reducing Valves

a) Pressure reducing valves shall be capable of maintaining a constant downstream pressure from a higher constant or variable upstream pressure and they shall be drop tight under no flow conditions.

b) The valve operation shall be achieved by the interaction of the inlet pressure, outlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valve.

c) The pilot valve or relay system shall be actuated by a diaphragm connected to the outlet pressure on its underside and a constant pressure on its upper side derived either from weights or from a spring.

d) Body ends shall be flanged and drilled to applicable IS.

7.9.9 Diaphragm Valves

Diaphragm valves shall be of the full-bore type to suit the maximum working pressure ratings required. Body ends shall be flanged and drilled to applicable IS or BS EN 1092-2.

Indicators shall be supplied where specified showing both OPEN and CLOSED positions shall be supplied, and provisions made for initiating the operation of remote indicator lights in the fully OPEN and CLOSED positions.

Valves used for toxic or hazardous fluids shall be provided with an additional `O' ring seal of nitrite rubber or other approved material.

Diaphragms shall be composed of moulded reinforced, flexible material attached by studs to the compressor. Diaphragm materials shall, where required, be composed of corrosion resistant material.

7.9.10 Isolating Cocks

For isolation of small-bore pipework tapings for instrumentation equipment etc., and for individual component isolation, the cocks shall be stainless steel, 0.25 turn ball or plug valve with the operating handle arranged to indicate the open and closed positions. Where specified, means shall be provided for securing the valve body to a front panel or near surface.

7.9.11 Valve Actuators

Control actuators for fan dampers, control valves and miscellaneous modulating dampers can be electrical, pneumatic, hydraulic or hybrid, depending upon application requirement. For high torque/high thrust applications, electro-pneumatic/electrohydraulic actuators are used.

All control actuators shall have stalled torque rating of at least 150 per cent of the maximum required torque for the driven element.

7.9.11.1 *Electric Actuators*

The sluice valve on pump suction and discharge lines and butterfly valve on pump discharge line and pumping main shall be operated by electric actuator and the operating mechanism shall consist of the following accessories:

a) AC Electric Motor.

b) Reduction gear unit.

c) Torque switch mechanism

d) Limit switch mechanism complete with set of limit switches and additional two spare sets for open/close position.

e) Hand wheel, for manual operation.

f) Valve position indicator.

g) Hand-auto lever with suitable locking arrangement.

h) Single phase space heater in the switch compartment

i) Indication throughout the valve operation.

j) Junction box for terminating power and control cables.

The actuator shall be suitable for operation on 415V, 3 phase, 50 Hz power supply in the climatic conditions given in the Specification. The motor winding insulation shall conform to Class B as per relevant BS and motor shall be protected by suitable thermal overload relays. The actuator shall be capable of producing not less than 1.5 times the required torque at the required time cycle of valve operation. The transmission shaft connecting the actuator to the valve shall be provided with 2 bearings one at actuator end and one at valve end with universal couplings at suitable places. Adequate no. of switch/contacts shall be provided to meet following requirements.

Valve close/open/in operation indications:

a) To prevent starting of motor if discharge valve is not fully closed.

b) To trip the motor, if the discharge valve fails to open within specified time.

Each motor shall be suitable for operation in the site climatic conditions. They shall also be suitable for operating on the specified electric supply and shall satisfactorily open and close the valve under variations of electric supply specified.

The electric motors shall be of the squirrel cage type as per IS: 325 with insulation to IS: 1271 Class The windings shall be impregnated to render them non-hygroscopic and oil resistant. All internal metal parts shall be painted. The motor shall be rated for 15 minutes.

Motor shall be protected by suitable overload protection device.

The reversing contactor starter and local controls shall be integral with the valve actuator. The starter shall comprise mechanically and electrically interlocked reversing contactors of appropriate rating transformer. The common connection of the contactor coils at the transformer shall be grounded. HRC cartridge type primary and secondary fuses shall be provided.

Local control shall comprise pushbuttons for open, close and stop operations and a Lockable Local/Remote/off selector switch. The control schematics shall be subject to approval.

Internal wiring shall be of 650/1100 Volt grade PVC insulated stranded copper conductor of minimum 1.5 sq. mm for control circuits and of minimum 4 sq.mm copper for the power circuit. Each wire shall be number identified at each end. The terminals shall be of stud type. Cable entries shall be suitable for PVC insulated/ sheathed, armoured cables. A separate terminal box shall be provided for the heater. A separate terminal box shall be provided for cabling to control circuits.

The actuator enclosure shall be fully weatherproof and hose proof to IP 67 and shall be fitted with an anti-condensation heater, which shall be switched off when the motor is running.

Reduction Gear Unit shall be of the totally enclosed oil bath lubricated type. The gear box shall be provided with the first charge of oil lubricants and appropriate filling and drain connections.

Gearing shall be adequate to open and close the valves under full indicated maximum operating pressure differential at a speed sufficient to cover the full extent of travel.

The operator shall have a hammer-blow device to loosen stuck valve or retrieve jammed valve position.

The torque switch mechanism shall function as follows to stop the motor on closing or opening of the valve, or upon actuation by the torque when the valve disc is restricted in its attempt to open or close.

The torque switch in the closing direction shall interrupt the control circuit if mechanical overload occurs during the closing cycle or when the valve is fully closed.

The torque switch in the opening direction shall interrupt the control circuit if mechanical overload occurs during the opening cycle or when the valve is fully open. The mechanism shall facilitate adjustment of the torque at which the switches are required to operate.

Non-adjustable limit switches shall stop the motor and give indication when the disc has attained the fully open or closed position.

The adjustable limit switches shall have control rated 2A, 48 V DC for specified system interlock, at the desired value position in both the opening and closing directions.

Motor operators shall be provided with clearly visible local valve position indicators mounted on the operator assembly to give an indication whether the valve is fully open, fully closed or in an intermediate position.

A hand wheel of Stainless-Steel construction shall be provided for emergency operation. The hand wheel drive shall be mechanically independent of the motor drive and any gearing should be such as to permit emergency manual operation in a reasonable time.

7.9.11.2 *Pneumatic Actuators*

Pneumatic actuator shall operate the valve as per torque requirement of valve for the function and duty. Working temperature range: From - 20° to +80 °C.

Pneumatic actuators shall be provided complete with line filter, regulator, positioner when required, manual operating handle, solenoid valve and air lock system. Actuators shall be sized for shut-off differential pressure. All pneumatic valve positioners shall be supplied with local pressure gauges to indicate supply pressure, control pressure and feed-back pressure. SMART valve positioners (with HART or field bus compatible) shall be considered wherever required. All pneumatic control valves shall have facility for position feedback (4-20 mA) for transmission to control room. For spring-opposed diaphragm type actuators, the spring shall be corrosion resistant and cadmium or nickel-plated.

a) MOC
    - Body-Cast iron FG260
    - Fasteners-stainless steel
    - O rings/seals – BUNA-N (Nitrile)

- Tonner – Aluminum Alloy LM4 / LM6
- Shaft – Carbon steel

b) These actuators shall be pneumatically operated, travelling a minimum of 90° in each direction and be able to over travel at 3° more in each direction past 90°. Pneumatic actuator shall develop required torque to operate of valve.

c) The Actuator shall be totally enclosed and contained in a single enclosure with no external moving part.

d) Air junction box shall be provided for opening and closing of valve. All pneumatic passageways must be integral to the actuator housings.

e) Air junction box shall be having air control arrangement for inlet and outlet for connection of air inlet and outlet at least 10 mm dia size threaded connection arrangement shall be provided.

f) Pneumatic Actuator shall be designed for the automation of ¼ turn valves (butterfly valve,) with double acting pneumatic arrangement.

Valve positioners or boosters may be considered for actuators for the following applications:

- To split the controller output to more than one valve.
- To amplify the controller output beyond the standard signal range (i.e., 0.2- 1kg/cm2), in case of actuators with greater thrust or stiffness is required.
- To achieve minimum overshoot and fast recovery in control action, as in the case when long control air lines have to be used.
- In all the above applications, whether or not a positioner or booster is to be used, shall depend on the speed of response of the system.
- Wherever required, boosters shall be used for systems with a fast response (e.g. Pressure and flow control loops etc.) and positioners shall be used for relatively slower control loops (e.g., temperature and level loops etc.).
- Actuator casing and diaphragm shall be designed to withstand at least twice the maximum pneumatic operating pressure of the control valve.

7.9.12 Control Valves Design

Control valves for modulation service shall generally be pneumatically or electrically operated. Control valves shall be sized in accordance with ISA-S75-01. The noise level produced by any equipment like pump sets, compressor sets and blower sets etc. shall not exceed National Standards

Control valves shall be sized so that at minimum and maximum flow, the valve lift is always between 10% to 90% for equal% and 20% to 80% for linear characteristics.

Globe type control valves shall be, in general, used in throttling applications for valve applications up to 500 mm line size, when the line pressure is not very low & fluid is non-viscous.

Single seated globe valves with top guided plugs shall be generally used for low & medium flow applications & for clean fluid applications as well as fluid with suspended particle applications. Cascaded trim shall be used for cavitation services.

Globe valves with cage guided plugs are pressure balanced & shall be used for high flow applications where the fluid is clean or if there is a chance of flushing/cavitation. Generally, single seated globe valves with cage-guided plug shall be used from the viewpoint of maintenance & for better leakage class. However, double seated cage guided valves shall be used for better pressure balance, based on the process application.

Top & bottom guided double port double seated straight through type globe valves shall be used for very high flow applications & where wide range ability is required.

Wide range ability is possible, as the valve operation is quite steady throughout the stroke due to relatively low unbalanced force & because of the guiding at top & bottom. Another advantage of this type of valve is that valve action can be reversed without change of actuator.

Other types of valves (e.g. Butterfly, angle, eccentric-disk, ball, V-notch ball type, etc.) shall be used only when operating conditions do not allow globe type valves.

For high viscous liquids, V-notch ball valves shall be used.

Angle valves shall be used wherever piping layout so desires. It is devoid of dead pockets & possible to achieve fine control through it. It can be used in slurry application also. In case of high-pressure drop application, multistage single seated cage guided angle valves shall be used. In very high-pressure drop applications, the multi stage pressure reduction trim prevents the liquid pressure falling below the saturation pressure at vena contract, thereby eliminating the chance of cavitation. Due to its geometry, the chance of erosion & noise level is comparatively less than similarly constructed conventional globe type valves.

Three-way valve shall be used in mixing & diverting services

Butterfly valves may be used for modulating service but shall not be used for, shut-off service if the maximum differential pressure across the valve exceeds 3 kg/sq cm.

Concentric disc type/ eccentric disc type butterfly valves shall be used in large line sizes & mainly in low-pressure applications or where allowable pressure loss across the valve is very low. Concentric disc type butterfly valves shall be designed for maximum opening angle of 60°. The maximum permissible opening for eccentric disk type butterfly valves shall be 90°. Applications where wide range ability is required, eccentric disc type butterfly valve shall be used instead of concentric disc type butterfly valves.

Flange facing and drilling shall, be according to either Indian or similar other international flange standard.

Control valves of sizes 40 mm and above shall have flanged end connections.

In general control valves of sizes 25 mm and below shall have screwed connection except as follows:

i) Other types of end connections shall be used when required by piping specification.

ii) Stainless steel valve bodies shall have flanged connection for sizes 25 mm and larger.

Valves sizes shall be based on specified allowable pressure drop at 130 percent of normal process design flow conditions.

Valves shall be sized so that the valve will operate properly when upstream pressure is 10 per cent above maximum inlet pressure and downstream pressure is atmospheric.

Extended bonnets and high temperature packings shall be used for high temperature application. Extension-bonnets shall be provided in control valves for services above 200°C or below (-) 30°C, or as recommended by the manufacturer. Teflon asbestos packing shall be used up to 200^{o}C temperature and graphite lubricated asbestos shall be used for operating temperature higher than 200oC.

Valve trim for most application shall be stainless steel for pressure drops of up to 7 kg/sq cm. For pressure drops above 7 kg/sq cm hard trim shall be used. Other alloys shall be substituted if required for corrosive conditions.

Minimum valve size shall be 25 mm for line size 25 mm and larger, using reducers, if necessary.

Hand-wheels, isolating valves and by-pass valves shall in general be provided for each control valve application. Isolating valves shall be of line size whereas by-pass valves shall be of control valve size.

For on-off control in small pipelines below 50 mm diameter, 2-way or 3-way solenoid valves shall be provided. Coil voltage shall be 24 V DC or 110/240 V AC rating and shall be suitable for continuous operation.

Control valves used in safety shut-off service shall be single seated tight shut-off valve. Leakage class of all fuel gas safety shut off valves shall be as per ANSI Class-VI. For other media, the shut off valves shall be of Class-V/Class-VI. Leakage class for control valves used for modulating action shall be as per ANSI Class IV.

Noise level of the control valves shall be as per accepted standard and shall be within 65 dBA from 1 meter of valve body.

Wherever required, line mounted Solenoid Valves may be used up to line size of 50 mm beyond which, pneumatic valve with internal pilot operated solenoid valves made of stainless steel shall be used.

Valve stem-position indicator shall be provided for all the control valves.

Solenoid valves installed in the control air supply line shall be of Universal type having minimum Class F insulation and shall be continuously rated direct-acting type. Solenoid valves shall be full-bore type with minimum bore size 3 mm.

7.9.13 Support of Pipe-work and Valves

Pipe-work, valves and other connected equipment, or forming part of the operating system, shall be provided with adequate supports, brackets, thrust blocks and fixtures, as necessary and in an approved manner, to restrict any induced vibration to a minimum, under any operating condition. Valves, meters, strainers and other devices mounted in the pipe-work shall be supported independently of the pipes to which they connect. All brackets or other forms of support, which can conveniently be so designed, shall be rigidly built up of steel by welding in preference to the use of castings. No point of passage of pipes through floors or walls shall be used as a point of support. Vibration measurements shall be taken on site by the Contractor at various points on each complete machine as defined above. If any item is found to be vibrating

beyond the level considered by the Engineer to be a reasonable minimum, the Contractor shall reduce the vibrations to the required level as specified in the relevant standards.

7.10 Hand Railing

Hand - railing shall be double rail 1100 mm high measured vertically from the nose of the tread. All components for hand railing shall be SS-316 with cathodic protection.

7.11 Adjustable Weir Plates

The adjustable weir plates shall be manufactured from suitable stainless steel/ GRP and the design shall have the approval of the Engineer.

Weir plates shall be complete with fixing nuts, bolts and washers and suitable for a total vertical adjustment of 100 mm. Fixings shall be designed for ease of accurately levelling the plates, securing the plates, and shall enable the plates to be adjusted during the life of the Works to accommodate differential settlement of the structure.

7.12 Mixers

All mixers supplied under this Contract shall be of a standard and proven design for which spare parts are readily available in India. The number, size and position (including depth and orientation) of mixers shall be designed to maintain a fully mixed homogeneous solution within the entire volume of the tank or zone being mixed. Solids shall remain in suspension in a homogenous mixture for each cell.

The design and arrangement of the mixer(s) shall be determined and verified by hydraulic and mixing performance modelling. All modelling and analysis shall be based on the specific mixer design proposed and all modelling results shall be submitted for approval. The performance modelling shall verify that the velocity profile across the entire floor area of the mixing tank/zone shall be sufficiently high so as to eliminate potential "dead-spots". The effectiveness of the installed mixers shall be such that the % w/vol solids at any single point within the tank or zone do not vary by more than ± 10%. The mixer shall be designed so as not to entrain air or promote surface vortices. The Contractor shall design the necessary features to prevent any ragging in the mixer impeller. The mixers and shall comply with the following requirements:

- The mixers shall provide continuous operation at their calculated design duty point. All calculations and drawings shall be submitted.

- The continuous rated output of the electric motor driving the pump and mixers shall be at least 10% in excess of the maximum power required by the unit under all operating conditions.
- Each submersible mixer and its motor shall withstand without damage to the mixer or any other equipment the effects of reverse rotation up to 120% of normal direction rated speed.

The Contractor shall purchase mixers and driving units from one source (the mixer manufacturer) to ensure the parts are compatible mechanically and electrically.

The materials of construction for mixers shall be of the following quality:

- Impeller .... SMO 254/Solid GRP
- Shaft construction .... SMO 254/Solid GRP
- Mechanical Seal .... Silicon carbide/silicon carbide
- Guide Bar with Brackets, Lockplates .... Stainless steel: AISI 316L
- Fasteners .... Monel K 500/Incoloy 625

7.12.1 Submersible Mixers

Each submersible mixer shall be supplied complete with the following:

- Mounting arrangement, complete with coupling devices, guide rails and support brackets;
- Swivel mechanism for rotation of the mixer in horizontal and vertical planes;
- Placement / Removal Apparatus, including swing type lifting davit, stainless steel grade 316L lifting cable, stainless steel winch and shackles,
- Composite power and control cable length;

The mixers shall be provided with adjustment for depth and mixing direction. Mixers shall include a motor and impeller; in a close-coupled configuration, forming a compact, and robust mixing unit. Four-pole motors are preferred to multi pole motors.

Appropriate shroud arrangements shall be provided where necessary to prevent air entrainment and vortices. The design of the casing and propeller shall allow an uninterrupted flow across the units, allowing the mixing media not to be caught and allowing cooling of the mixer.

The mixers shall be manufactured from stainless steel materials selected by the manufacturer to suit the duty requirements, fluids and operating conditions. The guide rail arrangement shall permit easy adjustment of the submersible mixer orientation in the vertical and horizontal planes, by an operator standing on the access platform.

Mixers shall be readily removable for inspection and maintenance using the lifting equipment, without the need for personnel to enter the tank. The lifting arrangement shall enable a single operator to easily lift each mixer from its installed location and place it on the access walkway/platform without removing the handrails. Similarly, a single operator shall be able to easily replace each mixer to its installed location. No portion of the mixer shall be permanently fixed to the base of the tank.

A stainless steel 316 lifting chain of sufficient length to reach from the mixer to the platform level shall be provided with each mixer. All holding down bolts shall be of 316 grade stainless steel. For lifting facilities by a davit, the mixer shall be fitted with stainless wire rope and brake winch.

Electrical cables for each mixer shall be suitably protected and supplied in place so as to prevent any damages.

The mixers shall have the following features:

- Can be used in every shape of tank.
- Self-cleaning & non-clogging propeller with Energy saving
- Hydrodynamic shape for optimum flow formation
- Drive unit optimised for mixing applications
- Little maintenance and long operating life.
- The mixer shall be driven by a high efficiency 3 phase motors IP68 Class F. Motor shaft and rotor shall be dynamically balanced.
- The mixers shall have the flexibility to be located at different depths and thereby avoiding dead zones.

The motor shaft shall be supported by two no's of single row double shielded anti-friction bearings with rating of life of minimum 100000 hours.

Scope of supply of each mixer shall include but not limited to Mixer with motor, Gear reducers, Seal monitoring relay, Moisture sensors, Guide mechanism complete with rope winch, power & control cable, chain, vibration dampeners and standard repair kit.

7.12.2 Flash Mixers and Top Entry Mixers

The mixers shall enter tanks vertically from the top and normally operate continuously.

The mixer shall be complete with mounting unit, reduction gearbox and motor. The design should be suitable for outdoor mounting and enclosure protection shall be provided to IP 55.

The mixer paddles and shafts shall be of Duplex stainless steel with PREN>41. The shafts shall be sufficiently rigid to prevent flexing. Maximum deflection shall be limited to shaft length/1000. The shafts shall be fitted to the gearboxes in a positive manner, which may take the form of keyed flanges with retaining bolts or equivalent. Mixers can be supported near the blades.

7.12.3 Inline Static Mixers

Inline static mixer shall be provided as per the process requirement. The maximum pressure drop due to static mixers shall be restricted to 0.5 bar.

The materials of construction for mixers shall be of the following quality:

Impeller:	FRP/GRP
Body:	SMO 254/Super Duplex/GRP
Mechanical Seal:	Silicon carbide/silicon carbide
Fasteners:	Monel K 500/Incoloy 625

7.12.4 Shaft Seals

7.12.4.1 *General Requirements*

The Contractor shall provide all mixers with mechanical seals. The seals provided shall be capable of allowing the mixers to run. Two independent mechanical face seals assembled in tandem shall be fitted to provide reliable and durable sealing performance.

The seals shall be designed for a minimum operating life of 5 years under normal operating condition. Spare mechanical seals shall be supplied to the extent of the life of pumps. The seals shall be of the balanced type, cartridge mounted, incorporating bellows or multiple helical springs of stainless-steel grade 316 and high nitrile synthetic rubber or ethylene propylene static "O" rings. Seal faces shall be lapped flat to within two (2) helium light bands and the depth of interface roughness shall not exceed 0.3 microns.

7.12.4.2 *Seal Failure Detection*

Submersible type pumps and mixers shall be fitted with seal failure probes for moisture and oil leakage. The probe shall be fitted in the oil bath between the two mechanical seals and shall be arranged to detect the presence of water in the oil bath, e.g. to detect failure of the propeller seals. A moisture detection device shall be fitted in the motor stator housing and cable termination housing. Sensors shall be compatible with Tritronics RT1 relay.

7.12.4.3 *Motor Protection*

All mixers shall be protected from overheating by a positive temperature coefficient (PTC) thermistor in each phase of each stator winding. Each thermistor shall be connected in series to terminals adjacent to the stator terminals and encapsulated and compatible with motor selected; or sensors shall be compatible with Tritronics RT1 relay.

7.13 Glass-Fused-to-Steel Bolted Tank

7.13.1 Materials

Plates and sheets used in the construction of the tank shell, optional floor and roofs, shall comply with the minimum standards of ISO 28765:2008 Section 9.2. Such sheets shall be produced by a hot rolling process and shall be sourced from reputable International steel mills.

Raw materials delivered to the Manufacturer's plant shall be tested / inspected to ensure compliance with the Manufacturer's requirements for strength.

Test Certificates issued and conducted by third party reputable international organization shall be available for the Engineers inspection if required. Such Certificates shall be requested before the time of issue of the Purchase Order.

7.13.2 Horizontal Wind Stiffeners

The top stiffener of the roof shall provide a flat, horizontal, continuous surface at tank rim level.

Wind stiffeners shall be steel, hot-dipped galvanised, rolled steel angle bar.

7.13.3 Bolt Fasteners

Bolts used in tank lap joints shall conform to BS 3692 and shall be V2" - 13 UNC-2A rolled thread with hot-dipped galvanised coating.

All bolts for tank shell and Glass-Fused-to-Steel roof (where applicable) shall be installed such that the head portion is located inside the tank and the washer and nut are on the exterior.

All lap joint bolts shall be properly selected such that threaded portions will not be excessively exposed in the "shear plane" between tank sheets. Also, bolt lengths shall be selected to achieve a neat and uniform appearance. The torque values (as set down in the Manufacturer s Construction Guide) shall not be exceeded during tank construction.

All lap joint bolts shall be designed to prevent rotation during tightening.

7.13.4 Bolt Head Encapsulation

All tank shell and Glass-Fused-to-Steel roof structure bolts shall have UV resistant polypropylene encapsulation of the bolt head and be certified to meet Regulation 31 or NSF Standard 61 for indirect additives.

All other bolts shall be hot deep galvanized conforming to BS 3692 and shall be Vz -13 UNC-2A rolled thread with hot-dipped galvanised coating.

7.13.5 Sealant

The sealant shall be used to seal lap joints, bolt connections and sheet edges. The sealant shall cure to a rubber-like consistency and have excellent adhesion to the glass coating, have low shrinkage, and be suitable for interior and exterior exposure. The sealant shall be a one component moisture cured polyurethane compound.

Where required, the sealant shall be suitable for contact with product water and meet Regulation 31 or NSF Standard 61 where specified.

Bidder should submit Certification of conformity of the Manufactured to Regulation 31 or NSF Standard 61 issued by NSF to ensure compliance to the above section.

EPDM or Neoprene gaskets and tape type sealer shall not be used other than for shell manway door/hatch.

7.13.6 Glass Coating

In cases where both the inside and outside surfaces of the sheet are in contact with the stored liquid both surfaces shall be treated as the inside surface for the purposes of this specification.

Coating Standards

The tank coating shall meet the quality requirements of ISO 28765:2008 and should conform to NSF Standards.

Surface Preparation

Sheets shall be steel grit-blasted to a silver-grey finish on both sides to remove mill scale and surface oxidation.

Grit blasting shall be performed to the equivalent of SA21/4 or SSPC-SP10.

The surface anchor pattern shall be in the range of 20um to 100um with a target value of 60um.

7.13.7 Cleaning

Immediately after fabrication and grit blasting and prior to application of the coating materials, all sheets shall be thoroughly cleaned by an alkali wash.

Following the alkali wash all sheets shall be rinsed in hot water containing a nitrite-based rust inhibitor.

The rust inhibition process shall be followed by heat drying to ensure the sheets are clean and dry ready to be coated.

7.13.8 Coating

All sheets shall receive a coat of catalytic nickel oxide-based pre-coat to both sides. The pre-coat application weight is controlled and measured and sheets that do not meet the required specification, in accordance with the Manufacturer's specified parameters, shall be rejected at this point.

All pre-coated sheets shall be heat dried to ensure that a moisture free surface has been achieved before the glass coating layer is applied.

A coat of cobalt rich glass slip shall be continuously applied to both sides of the sheet followed by heat drying.

The coated sheets shall be visually inspected and sheets with spray or glass defects shall be rejected at this point.

The thickness of the coating system shall be measured using an electronic instrument; the instrument shall have a valid calibration record. Interior and exterior dry film coating thicknesses are controlled and measured and sheets that do not meet the required specification, in accordance with the Manufacturer s specified parameters, shall be rejected at this point.

After inspection the sheets shall be fired through the furnace at approximately 850°C in accordance with the Manufacturer s procedures.

The firing process shall form a composite glass surface having general acid/alkali resistance to solutions in the range pH 3 to pH 9, subject to temperature and chemical composition.

Tank inside sheet colour shall be as specified by the manufacturer. Tank external colour shall be Blue (20-C-40) or Green (12-B-29).

Sample tests shall be carried out by the Manufacturer to ensure that enamel materials meet the physical properties and chemical resistance characteristics as published in the Manufacturer's product Quality Standard. The Manufacturer shall provide published product Quality Standards detailing the International Standards used for testing.

Bidder should submit Manufacturer's Product Quality Standards detailing International Standards used for Manufacturing and Sheet Coating Procedure and Process.

7.14 Flocculation and Clarification

7.14.1 Flocculation

The flocculator shall be paddle type designed to achieve flow mixing in flocculation chamber to G ranging between 20^{-s} to 40^{-s}. The design shall be based on G value to be selected. Justification for G value selection shall be furnished. The electric motor shall be suitable for outdoor duty as per specification.

7.14.2 Clarification

Tube Settler process shall be provided.

Clarifier shall be single design for each work and shall be of concrete construction each with identical internal dimensions.

7.14.2.1 *Tube settler*

The media shall be in PVC construction, simple hexagonal configuration and robust. The tube module shall to be kept at inclination $55\text{-}60^0$ to horizontal. The media shall be supported on structural steel members in symmetrical manner.

7.14.2.2 *Sludge Draw-off*

The hopper shall be provided to collect the sludge in the hopper bottom under gravity. Sludge draw-off arrangement shall include the following:

- Sludge line of suitable diameter but not less than 200 mm from each hopper of the clarifier to common header
- Common header not less than 300 mm discharging into sludge balancing tank.
- The line from hopper to common header shall incorporate Tee and rising spindle type sluice valve with electrical actuator.
- All connections in common header and line shall be with flange joint and flange adaptor to facilitate dismantling to manually remove clogging in the pipe.
- Sampling and rodding point for jet cleaning of the sludge line shall be provided.

- Sluice valve shall be provided in the pipeline below each hopper with remote ON/OFF facility.
- In common header, a knife value shall be provided with ON/OFF facility.
- Sufficient valve shall be provided to make the cleaning of a hopper using water jet.

7.14.2.3 *Equipment for cleaning tubes in tube settler*

The Contractor shall provide complete cleaning system for cleaning the tubes in place without removing the tubes. Conceptual arrangement is cleaning by jetting.

The length of the hose provided shall be adequate to reach all the tube settlers.

7.15 Dissolved Air Floatation (DAF)

DAF shall be provided to treat clarified water to eliminate the rest over floating material. Sufficient provision shall be given to isolate and bypass the DAF in case not required. In case of bypassing the facility shall be provided to clean the DAF system completely so that seawater is fully drained and replaced by the product water to avoid the corrosion of the civil and mechanical system during idle condition.

7.16 Dual Media Filtration

Dual Media Filtration (DMF) shall be provided with all mechanical gates and valves. Minimum 8-10 valves/gates will be there in each filter. Each filter will have two beds. The mechanical items shall be provided as per the process details provided in Part-2 A3 of bid document.

7.17 RO System

RO system shall be constructed mostly of SS316L/ Duplex steel (PREN>41) in the low-pressure area and of Super Duplex Steel (PREN≥43) in the high-pressure area and GRP/FRP/HDPE for other associated items. The selection of materials for RO system shall be proposed after discussion with the Employer's representative. All material selection shall be approved by the Employer's representative before the procurement of equipment.

7.18 Thickeners

The circular reinforced concrete thickeners tapering at bottom shall be provided for sludge thickening. The suspension from sludge balancing tank shall be fed to thickeners. Design shall be such that the sludge can become compacted and can be extracted from the bottom. Interstitial liquid flows through peripheral weir at top. Tanks shall be deep enough to allow the sludge to settle. At least 50 cm freeboard shall be provided. Provision shall be made to remove the sludge from top if there is a serious risk. Provision shall be made for collection of thickened sludge and pumping it to BFP.

A full diameter bridge with central drive shall be provided with central platform for the installation of the scrapers and their drives and for the local control panel; a radial scraper system with bottom scraper blades, suspended on the bridge.

The thickeners shall have a full diameter fixed bridge complete with 1200mm walkway for personnel access to the centre, access stairs to ground level and hand railing, a motor-driven sludge scraper complete with all necessary controls, delivery pipe-work, a stilling well and overflow steel weir plates. Walkways, access steps etc shall be galvanised. Handrails shall be of tubular Type 316 steel construction and made of 32NB pipes. Especially where mild steel is proposed for underwater structure, the part shall be coated with polyurethane.

The scraping gear shall be supported from the tank base and from a fixed bridge carrying the central electrical drive for the rotating gear. The equipment including driving motor, gears, shafting and scrapers shall be designed for continuous operation and sized for the most arduous operating condition including starting from rest with an accumulation of sludge in the thickeners. The electric motor, gearbox etc., shall be provided with a sunshade.

The fixed bridge, access steps and the feed well shall be galvanised steel. The main drive shall be cast Iron construction and shall be enclosed in a dustproof enclosure with oil bath lubrication. All underwater hardware shall be of Type 316L stainless steel/ cupronickel. All fasteners shall be Monel 410/K500. All other material shall be corrosion resistant.

Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and an emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and over torque protection to alarm in the event of a failure.

Corrosion allowance of 2 mm shall be taken in the structural sections of scraper arm, bridge etc.

Structural design calculations shall be submitted for all structures including scraper arm, bridge etc. and also the calculation for drive head selection including the Torque Rating. V-notch weir in SS 316L construction of size minimum 4 mm thick and 250 mm wide shall be provided along the launders for uniform draw-off of the overflow. The weir plate shall be fixed to the launder by means SS 316L grade clamping plates and fasteners. The weir plate shall be adjustable to achieve uniform level.

The hydraulic equipment will consist of the SS 316L/Duplex SS inlet pipe (runs along the bridge) to the central feed well of the thickener; sludge draw-off pipe with an manual & Motorised Knife Gate valve (in Duplex SS material of construction) for intermittent operation according to an adjustable timer; a drain pipe with manually operated gate valve for the complete emptying of the unit; a discharge pipe from the peripheral collecting channel to the upstream of fine screens either by gravity flow or with pump.

The sludge thickener mechanism shall be generally in SS316L/Duplex SS/GRP/Polyurethane construction, suitable for installation in a circular RCC tank and shall include the following:

a) Mechanism support beam spanning the diameter of the tank

b) Walkway (GRP) and handrail SS316 from the edge to the centre of the tank

c) Drive mechanism with internal gear type

d) Reduction gear box

e) Chain and sprocket with guard

f) Central shaft with scrapper arm and picket fence

g) Skimmer Scum Baffle and Scum trough

h) Overflow weir:

i) Vertical pickets

j) Torque Indicating Device

k) Overload Alarm protection

7.19 Chlorine Solution (Hypochlorite) Delivery Pipe-work and Valves

The Contractor shall provide all necessary rigid pipe-work, valves and fittings for the delivery of the chlorine solution from pumps to the points of application.

The chlorine solution delivery lines shall be of HDPE/cPVC or approved equivalent. The pipe-work shall be adequately protected externally against corrosion and installed complete with necessary supports, thrust restraints, etc., and incorporate sufficient flexibility to allow for any thermal expansion effects.

When selecting material for pipe-work, consideration shall be given to the deteriorating effect on some synthetic materials due to the action of ultra-violet rays. Where such materials are employed, particularly in the case of uPVC, pipe-work shall be shielded from direct sunlight.

7.19.1 Safety Equipment

Materials and equipment necessary to ensure the safety of personnel working in the vicinity and others shall be provided at each chlorine storage area.
Each set of safety equipment shall be mounted in a glass-fronted, non-locking PVC coated steel cabinet in approved locations on the outside of the Chlorine building.

Emergency showers shall be provided and shall be installed near the Chlorine storage tank. The shower shall be operated automatically by a quick-acting hand or foot valve. Foot operating arrangement

Two eyebaths shall be supplied. One eyebath shall be adjacent to the shower. The eye bath unit shall be fitted with fine mesh filters with built-in pressure regulating device to ensure a safe rate of flow to prevent foreign matter being further embedded into the eye and instead flush away contamination.

Water for the shower, etc, shall be drawn from the service water supply.

Following safety aids shall be provided for safe handling of Chlorine system:

a) Display of hazardous chemicals data sheet on plant entry gates and at the use / application in local language and in English,

b) Emergency Toolbox and spares

c) First Aid box

d) Portable Emergency lights

e) Display boards of telephone/ mobile of important plant personnel

All the applications, permission /license and other clearances for storage and operation of chlorination system from concerned govt. authority shall be under the scope of contractor.

In case of enclosed area where chlorine solution is stored shall be provided with a forced ventilation system. Air intakes shall be sized to allow uniform ventilation and positioned to prevent possible recirculation. Extract air shall be ducted from low level and discharged at high level.

The ventilation systems shall be designed to provide for general day to day use an air change rate of four per hour. Extract fans shall be heavy duty industrial pattern manufactured from chlorine resistant materials.

7.19.2 Chlorine Residual Monitors

One chlorine residual monitor shall be provided for monitoring the final water downstream of the each of the chlorine injection points.

The monitor installation shall be located in a covered location easily accessible for viewing and maintenance and shall be provided complete with sample pumps as necessary to ensure the continuity of the sample.

The sampling pipework complete with isolation valves, etc. shall be designed to ensure the sample reaches the monitor in a time not greater than 1 minute. The monitor drainage pipework shall permit the visual checking of the presence of flow and shall discharge to the plant drain. Sample water not passed through the monitor shall be returned to the process. The residual signals shall be displayed at the local control panel and at the central HMI. High and low chlorine residual levels shall raise alarms at the local control panel and at the central HMI.

7.19.3 Chlorination Power and Control

A combined MCC and control panel shall be provided at each chlorination plant and located in a suitable location protected from the weather and the effects of the process. The control panel shall provide facilities for the:

- display status and values associated with the chlorination systems
- duty pump selection
- annunciate alarms associated with the chlorination systems
- operator adjustment of process set points

The chlorination systems shall operate using a fixed manually/automated set dose rate. The quantity of chlorine dosed shall therefore be adjusted in direct proportion to the process flow at the dosing point through PLC/SCADA. The chlorine residual monitor to be provided shall be used for monitoring and alarm purposes.

The duty booster pumps shall be manually started at the control panel. The action of starting the duty booster pump shall start the chlorination process concerned. The operation of the room ventilation and fume detection systems shall be independent of any PLC controls and shall operate in any mode. Cable support systems throughout the chlorine installation shall be constructed of u-PVC or GRP.

7.20 Belt Filter Presses

Continuous-feed dewatering belt filter press (BFP) that uses the principles of chemical conditioning, gravity draining, and mechanically applied pressure shall be used for the sludge dewatering operations. Sludge shall be first conditioned using polymer prior to dewatering on the belt filter press. The optimum polymer dosage shall range up to 5 kg/1000 kg of dry solids. Polymer (non-food grade) shall be dosed to the sludge flow via an in-line static mixer. The conditioned sludge shall be first introduced on a gravity drainage section where it is allowed to thicken. Following gravity drainage, pressure is applied on the opposing porous belts where sludge is squeezed and dewatered.

Each belt press shall be designed and sufficiently automated to involve minimal operator attention. The operation of each BFP shall be controlled by the operator at a unit control panel. Operation of each BFP and its associated dedicated sludge feed pumps, polymer dosing system, and belt washing system and other plant shall be automatic once the start-up procedure has been initiated by the operator. A low-level sensor in the thickened holding tank shall automatically stop the flow of sludge to the BFP.

The BFP shall produce a dewatered sludge cake of no less than 25% dried solids. At least 98% of the solids shall be in the dewatered cake and less than 2% of the solids shall be in the wash water. The wash water will be drained to the plant drain while the solid sludge from BFP will be transported out of the plant for appropriate disposal i.e. landfill.

The BFP shall comprise the following components. All component of the BFP will be made of SS316 or better as per application.

7.20.1 Main Structural Frame

The structural frame shall be of all welded construction and shall be fabricated from channel designed to adequately support all components. The design permits roll removal without requirement of disassembly of frame.

7.20.2 Extended Gravity Drainage Section

To maximize gravity water removal, adequate gravity drainage area shall be provided or vacuum system shall be provided to enhance drainage. A set of gravity dispersion device shall be provided to disperse sludge for effective removal of water. Dispersion devices shall be constructed of ultra-high molecular weight polyethylene. Each set of devices shall have the capability of being rotated out of the flow by handles, for maintenance purposes or process flexibility.

Sludge shall be contained within the drainage section by a barrier equipped with replaceable rubber seals on each side. The gravity drainage belt shall be supported by polyethylene grids over the complete length and width of the gravity drainage section that are also used for effective removal of gravity and capillary water.

7.20.3 Adjustable Wedge

Following gravity dewatering, adjustable wedge section for process flexibility shall be incorporated into the press. Gradual increased pressure shall be applied as belt passes through the adjustable wedge section.

7.20.4 Pressure Section

A minimum diameter roll shall be used as the initial roll in contact with gravity concentrated sludge. A S-shaped roll configuration shall be used to apply maximum pressure and shear. To ensure optimum cake dryness, a minimum number of rolls shall be used in the pressure area.

7.20.5 Filtration Belts

Each belt shall be a continuous design woven from monofilament polyester strands. Each belt shall incorporate a mechanical seam that does not interfere with press operation and also allows simple, periodic belt replacement.

7.20.6 Doctor Blade

For removal of dewatered cake, the press shall incorporate a doctor blade for each filtration belt. Blade pressure shall be field adjustable against the belt by means of spring tensioning mechanism and shall be replaceable, reversible with two useable edges and fully accessible to the operator.

7.20.7 Rolls

All rolls, including guide and tracking, shall be of low deflection design.

7.20.8 Roller Bearings

All bearings shall be pillow block type with split, cast iron, two bolt housings. All bearings shall be capable of compensating for misalignment without seal distortion. Each bearing shall be grease lubricated.

7.20.9 Filtrate Collection

Drainage pans shall be located under all gravity and pressure section of the press. Drain pans with standard NPT connections shall collect gravity filtrate and pressure filtrate to common drainage points.

7.20.10 Belt Washing Device

Following cake discharge, each polyester belt shall be continuously washed using a high pressure, low volume steel shower assembly. A Y-strainer (stainless steel) to be provided in wash water line to remove any particles which may enter the shower assembly. Each shower assembly shall have stainless steel nozzles. The shower assembly shall be designed to completely contain the high velocity water spray and remove any solids trapped in the belt.

Pumps required for belt washing shall be integral to the BFP system. The belt washing shall be automatic with minimum flow of water. Spent washwater shall be directed to the plant drain.

7.20.11 Belt Tracking

Belt positioning for each belt shall be continuously and automatically monitored by an arrangement which shall be installed with guide devices. The guide device shall ride the edge of the polyester cloth belt. The micro-torque unit shall sense belt misalignment and shall automatically walk the belt back to the normal operating position by means of a live hydraulic tonner which shall be attached to tracking rolls. The opposite end of the tracking roll shall incorporate self-aligning pillow block bearings which allows the tracking rolls to pivot in a horizontal plane. Belt tracking shall be automatically operated by the hydraulic power pack. A limit switch shall be provided on each side of each belt to sense extreme belt travel and initiate a shut-down signal and sound an alarm. The limit switches for the pressure section shall be positioned to sense both belts simultaneously.

7.20.12 Belt Tensioning

Each belt in the pressure section shall be equipped with a hydraulic tonner belt tension system operated by the hydraulic power pack to automatically ensure proper preset belt tension while dewatering varying thickness of sludge. The belt tension system shall assure parallel movement of the tension rolls by use of rack and pinion system.

7.20.13 Belt Press Drive & Component Operation

The belt press drive shall comprise of an electric geared motor unit coupled to the drive roll through a flexible coupling. A local electrical control panel complete with control logic, variable frequency drive etc. shall also be supplied along with the belt filter press.

7.20.14 Sludge Treatment and Disposal Power and Control

A combined MCC and control panel shall be provided. The control panel shall provide facilities for the:

- display status and values associated with the sludge treatment systems
- duty pump selection
- annunciate alarms associated with the sludge treatment systems
- all necessary controls for BFP installation
- The BFP manufacturers proprietary control panel/s may be provided in addition to the above providing the requirements for BFP status and alarm annunciation are fulfilled locally and at the central HMI.

7.20.15 Conveyor System

a) For the disposal of dewatered sludge, a common motor driven endless belt conveyor shall be provided. The conveyor shall be designed in accordance with IS 11592 or equivalent. The conveyor and chutes shall be suitable for handling occasional heavy objects which will cause shock loads.

b) The construction of the frame and support shall be robust and torque resistant. Belt conveyor shall be of 20 deg. trough type complete with drive assembly structures, idlers, pulleys and belt cleaners. Idlers and pulley shall be provided with anti-friction bearings.

c) The belt material shall be two ply nylon or equivalent with minimum 3 mm neoprene covering on carrying side. Splicing shall be employed to make the belt endless. The belt shall operate over three roll twenty degree, troughing idlers. The idlers shall rotate on precision type, deep groove, single row ball bearing with built-in close-fitting triple labyrinth grease seal. The ends of the outer shell shall be counter bored and a full length centre tube journaled concentricity. The outer shell, centre tube and precision die formed steel ends shall be brazed into an integral unit to provide concentricity. The ends of the centre tube shall be bored concentrically with each other after roll assembly to provide correct bearing alignment and to provide prestressing of boring. The centre tube shall be grease fit after assembly. Troughing idlers shall have means of adjustment or ensuring belt tracking. On the return run the belt shall operate over flat roll idlers having bearing, shaft and lubrication arrangements as above for carrying idlers. Spacing of idlers shall be of 1200 mm on carrying run and 2400 mm on return run.

d) The head and tail pulleys shall be manufactured from welded steel/any alloy steel and shall be provided with rubber lagging. Lagging for drive pulleys shall have herringbone grooving. Pulleys shall be equipped with taper lock bushings. The tail pulley shall incorporate a screw rake for adjusting belt tension. Head and tail pulleys shall be adequately guarded.

e) Shafting for pulleys shall be of material suitable for seawater contact. They shall be forged, ground and polished to obtain close diameter tolerances. The head shaft shall be provided with roller bearing pillow blocks.

f) The belt conveyor shall be driven by a squirrel cage, TEFC motor. A V-belt drive arrangement shall be provided between the motor and a helical speed reducer, the latter shall be mounted on the end of the head shaft. The driving pulley shaft shall have back stops to prevent backward movement of the belt.

g) The conveyor shall be supported on appropriate channel sections with 14 gauge steel deck plate between the two runs of the belt and the necessary supports to the floor. The floor supports shall be made out of steel plates having minimum 6 mm thickness. The conveyor shall be protected from weather by a 'dog box' type canopy.

h) An adjustable belt scraper shall be provided on the hopper end of the conveyor belt. The scraper and attachments shall be of fibreglass/fibre-reinforced plastic/PVC.

i) Sludge cake discharge Hoppers shall be provided to transfer the sludge cake from the BFP to the troughed belt conveyor and from the conveyor discharge to skip. The latter chute shall extend beneath the belt scraper and shall allow access for maintenance of the belt scraper. Chutes shall be designed to minimize the accumulation of rags and stringy materials.

The conveyor shall be fitted with an emergency stop operated by wire rope at foot level. Two Nos belt sway switches shall be provided on conveyor.

7.21 Hoist and Crane

7.21.1 Electrically Operated Hoists

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 o r 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 with minimum ultimate tensile strength of 1.6 x 106 kN / sq. m.

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.

A 25% overload test, speed tests, limit switch tests and brake test shall be conducted for the hoist and trolley at the manufacturer's works.

7.21.2 Hand Operated Hoists and Trolleys

Manual hoists shall be complete with hand-chain, trolley, pulley block, hook, hand and load chains, brake and other accessories. They shall comply with the latest applicable standards, regulations and safety codes in the locality where equipment will be installed.

Each hoist shall be operated on a monorail (I-Beam). The factor of safety shall not be less than 5. The load chain may be heat-treated to give ductility, toughness and conforming to IS:3109/BS:1663/BS:3114. The load wheel is to be made from heavy duty malleable castings. The hand chain is to conform with BS:6405:1984 and hand chain wheel may be made from pressed sheet steel with roller type guarding. Gears shall be cut from solid cast or forged steel blanks or shall be stress – relieved welded steel construction. Pinions shall be of forged carbon or heat-treated alloy steel. Strength, Quality of Steel, heat treatment, face, pitch of teeth and design shall confirm to BS:436, BS:545 and BS:721. Spur and helical gears must comply with BS:436 and worm with BS:721. Bearing must be ball and roller type conforming to IS:2513/BS:2525-32:1954. 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 proof testing of each chain pulley block is to be carried out as per latest applicable standards. The safe working load is to be marked in such way that is clearly visible from the operating level.

7.21.3 Hand Operated Travelling Crane

The crane bridge shall consist of a single bridge girder carrying two wheels at each end of the span. Steel used shall be tested quality steel conforming to IS 2062. The girder shall have enough strength to carry the test load without causing undue stress or deflection.

The long travel bridge wheels shall be rim toughened, heat treated carbon steel or low alloy steel or C.I. They shall be double flanged type. The wheels shall have antifriction ball/roller bearings. The wheels shall be machined on their treads to match the runway rail section. The bridge shall have a geared shaft and pulley connecting to opposite wheels of the span, to achieve the long travel motion of the bridge, by means of a chain. The runway rails of adequate strength and rigidity, rail clamps and other accessories for mounting the rails and suitable end stops for the bridge shall be supplied by the Contractor.

The chain pulley block shall be operated on the lower flange of the bridge girder.

The load chain shall be made of alloy steel as per IS:3109. It shall be heat treated to give ductility and toughness so that it will stretch before breaking. It shall be of welded construction with a factor of safety not less than 5.

The hand chains for the hoisting and traverse mechanism shall hang well clear of the hook and both the chains shall be on the same side. The hand chain wheel shall be made from pressed sheet steel and shall be provided with roller type guarding to prevent snagging and fouling of the chain.

All the gearings shall be totally encased. Proper lubricating arrangements shall be provided for bearings and pinions. Gears shall be cut from forged steel blanks. Pinions shall be of heat treated alloy steel. Gears shall be as per BS:436/IS:4460.

The trolley track wheels shall be rim toughened, heat treated carbon steel or low alloy steel or C.I. and shall be single flanged and shall have antifriction ball bearings. The wheels shall be machined on their treads to match the flanges of the track joints.

The travelling trolley frame shall be made of rolled steel conforming to IS:2062. The side plates of trolley frame shall extend beyond wheel flanges, thus providing bumper protection for the wheels. The two side plates shall be connected by means of an equalising pin.

Axles and shafts shall be made of carbon steel and shall be accurately machined and properly supported.

The lifting hooks shall be forged, heat treated alloy or carbon steel of rugged construction. They shall be of single hook type provided with a standard depress type safety latch. They shall swivel and operate on antifriction bearings with hardened races. Locks to prevent hooks from swivelling shall be provided. Hook shall be as per IS:3815.

The brake for the lifting gear shall be automatic and always in action. It shall be of screw and friction disc type self-actuating load pressure brake. Brakes shall offer no resistance during hoisting.

Ratchet and Pawl mechanism shall be provided to arrest the full load from lowering due to gravity. The ratchet and pawl shall be of steel, hardened and tempered so as to attain required wear resistance and toughness.

7.21.4 Electrically Operated Overhead Travelling Crane

The crane shall be electrically operated, bridge type complete with all accessories including down shop conductor, crane rails and fixtures, and shall conform IS:3177 or relevant internationally approved standards.

The crane bridge shall consist of bridge girders on which a wheeled trolley is to run. The bridge trucks and trolley frames shall be fabricated from structural steel. Access walkway with safe hand railing as is required along the full span length of the bridge girder. Steel shall be tested quality conforming to ASTM A36 except that, plates more than 20 mm thick shall conform to IS:2062, or relevant internationally approved standards. The bridge shall be designed to carry safely the loads specified in IS:807 or relevant internationally approved standards. All anti-friction bearings for bridge and trolley track wheels, gear boxes and bottom sheaves on hook shall be lubricated manually by hand operated grease pump through respective grease nipples.

Wheelbase and structural frame of the wheel mounting of the end carriages shall be designed so as to ensure that the crane remains square and prevent skewness. Bridge and trolley track wheels shall be of forged steel and shall be double flanged type. The wheel diameter and rail sizes shall be suitable for the wheel loads. The crane rails shall be manufactured from wear resistant austenitic manganese steel. Mountings of the wheels shall be designed to facilitate easy removal for maintenance. Walkways shall be at least 500 mm clear inside width with a 6 mm thick non-skid steel plate surface. Steel rail stops to prevent rails from creeping and trolley from running off the bridge shall be abutted against ends of rails and welded to the girders. Bridge and trolley stops to match the wheel radius shall be provided before the buffer stops.

All exposed couplings, shafts, gear, wheels, pinions, and chain drives etc. shall be safely encased and guarded completely to prevent any hazard to persons working around. All bearings and gears shall have a design life of 100000 hours. Electro-magnetic and hydraulic thrustor brake shall be provided for the main hoist. One electro-magnetic brake shall be provided for each of the cross travel and long travel motions.

Hook shall be solid forged, heat treated alloy or carbon steel suitable for the duty service. They shall have swivels and operate on ball thrust bearings with hardened races. The lifting hooks shall comply with the requirements of IS 8610 or relevant internationally approved standards and shall have a safety latch to prevent rope coming off the hook.

Hoist rope shall be extra flexible, improved plough galvanized steel rope with well lubricated hemp core and having six strands of 37 wires per stand with minimum ultimate tensile strength of 1.6×10^6 kN/m2 of Right Hand Ordinary (RHO) lay construction. The ropes shall have a 6:1 safety factor on the specified safe working load and shall conform to IS:2266. Rope drums shall be grooved and shall be either cast iron or cast steel of or welded steel conforming to IS:3177, BS:466 or relevant internationally approved standards.

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 applicable standards.

Name Plate showing the capacity, year of manufacture and rated capacity of hoist, in figures not less than 150 mm height, shall be placed on each side of the crane girder.

The maximum deflection under full load shall not exceed 1/900 of the span (as per IS:3177).

All accessory and auxiliary electrical equipment including drive motors, electrically operated brakes, controllers, resistors, conductors, insulators, current collectors, pendant push button station, protective devices, operating devices, cables, conduits, etc. necessary for the safe and satisfactory operation of the crane shall be provided.

Power to the crane shall be provided by down shop conductors manufactured from high conductivity hard drawn copper. Conductors shall be completely shrouded such that they have no exposed current carrying surfaces. Pendant type push button station shall be sheet steel enclosed and shall comprise the following push buttons and indicating lamps:

a) `Start' and `Stop'.

b) Long travel - `Right' and `Left'.

c) Cross travel - `To' and `Fro'.

d) Hook - `Hoist' and `Lower'.

e) Red indicating lamp for supply `ON' indication.

Pendant type push button shall be supported independently of the electrical cable and shall be earthed separately, independent of the suspension. Automatic reset type of limit switches shall be provided to prevent overtravel for each of the following:

a) For `UP' and `Down' motions of the hook.

b) Long travel motion

c) Cross travel motion

Crane structures, motor frames and metal cases of all electrical equipment including metal conduit and cable guards shall be earthed. All motors, brakes, limit switches, panels, drum controllers, resistor unit sets shall be provided with two studs for earthing.

All motors shall be of the quick reversing type with electric mechanical brakes suitable for the duties specified. All movements shall be electrically powered suitable for operating with the hook loaded. Facilities shall be provided for the accurate location of the hook by means of `inching' the cross travel and down shop travel motions.

Sufficient slings, ropes, shackles, lifting beams, etc shall be supplied to handle all items of plant covered by the crane. They shall be labelled or marked with the Safe Working Load (SWL) and the purpose for which they are intended.

The crane, and all slings, ropes, shackles and other lifting equipment supplied shall be tested by the manufacturer at his works. The tests shall be carried out at 125% of Safe Working Load, and Test Certificates shall be supplied.

The Contractor shall include with the cranes all necessary contactors, control cubicles and protection equipment necessary to operate the crane and provide adequate electrical protection against overload, phase and earth fault and fail-safe protection in the event of an interruption in the power supplies. All access ladders and platforms necessary to carry out maintenance and repairs shall be provided and installed by the Contractor.

All electrical equipment shall be fully tropicalised.

Site tests shall be carried out by the Contractor who shall supply the necessary materials for the test load. The test load shall be removed from site by the Contractor after successful tests have been carried out.

7.21.5 Jib Cranes

Fixed jib cranes shall be provided in for lowering/removal of equipment/parts. The crane capacity shall be 1.25 times the maximum weight to be handled or 1.5 Tonnes, whichever is more. The lift and reach of the cranes shall be suitable for the equipment/parts to be handled. The crane shall be capable of being swivelled by 360. Adjacent halves of clarifiers may be provided with common jib crane if feasible. All materials used in the construction shall be corrosion resistant. Mild steel used shall be galvanised. Ropes, chains and pulleys shall be of stainless-steel construction. Hardware shall be of SS 316. The Jib crane shall also be provided for handling submersible mixers in Wastewater balancing tank, thickened sludge sump (sludge holding tank) and Backwash recovery tank (Backwash Waste water tank).

7.22 Reduction Gear Units

Reduction gear units, wherever provided shall be double reduction units without V-belt and pulley. Gears shall be cut from solid cast or forged steel blanks or shall be of 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 applicable standards. Split gears shall not be used. Gears and pinions shall be pressed on and keyed to shafts. All pinions and gears are to be of the totally enclosed type up to the last stage of reduction in all motions and shall be carried in fabricated steel gear cases which must be dust-proof and firmly sealed to prevent oil leakages and shall be oil bath lubricated. The gear boxes shall have covers split horizontally and arranged so that top half can be removed for inspection. They shall be fitted with bolted type machined inspection covers and with cast steel cartridge housings for carrying roller bearings. Dip sticks or indicator shall be provided for indicating the oil level. Guards shall be strong enough to retain the whole gear or any part that might otherwise fall. No overhanding gears shall be used. Drain plugs shall be provided on all gear cases. Lifting lugs shall be provided for handling purposing.

7.23 Ventilation System

7.23.1 Scope

The scope of work covers the design, manufacture, inspection and testing of performance at the manufacturer's and / or his sub-contractor's works delivery to site, storing and handling at site, erection, commissioning and carrying out acceptance tests at site of the Ventilation System for Desalination Plant and its buildings.

7.23.2 Code and Standard

The design, manufacture, inspection and testing of ventilation system shall comply with all currently applicable statutes, regulation and safety codes in the locality, where the equipment are to be installed. The equipment shall also conform to the latest applicable Indian / British / American Standard. Nothing in this specification shall be construed to relieve the contractor of his responsibility. In particular, the equipment shall conform to the latest edition of the following standard.

IS: 2312	Propeller type AC ventilation fans
IS: 3588	Specification for Electrical Axial flow fans
BS: 848	Fans: Part 1: Methods of testing performance; Part 2: Fan Noise Testing
AMCA: 210	Test Code for Air Moving Devices
BS:6540(Part-1)	Method of test for air filters used in air conditioning & General Ventilation.
BS: 3928	Sodium flame tests for air filters (other than for air supply to I.C. Engines & Compressors).
VS-FED-2098	Method of cold DOP & Hot DOP test MIL - STD-282 DOP smoke penetration method.
ASHRAE-5276	Method of testing air cleaning device used in general ventilation for removing particulate matter.

In case of any conflict in the standard and this specification, the decision of Employer shall be final and binding.

7.23.3 Description of Ventilation System

The inside dry bulb temperature (DBT) temperature to be maintained shall be limited to maximum 5 ^oC over than the ambient dry bulb temperature at all times of the year considering ambient air conditions mentioned above.

The following are the areas provided with mechanical type ventilation system with combination of supply air fans and / or exhaust air fans/TURBO ventilators (Roof ventilators, wall mounted type)

a) All pump houses
b) DAF and Lamella Buildings
c) RO Buildings
d) Chemical Houses
e) Workshop and Warehouse
f) Limestone Filters
g) Toilets in all buildings including the following (30 Air Changes per Hour)

7.23.4 Design Philosophy

Number of air changes per hour in evaporative / mechanically ventilated areas shall be as follows.

S. No.	**Area**	**Air Changes per hour**
1.	Chemical Houses, Pump (enclose) houses & Other areas like toilets etc.	20
2.	RO buildings and over	40

However, in areas producing lot of heat, the temperature limitation should be the criteria, which is as follows:

a. Inside dry bulb temperature shall be minimum 5 ^oC below the design ambient temperature during summer for evaporative cooled areas.

b. Inside dry bulb Temperature shall be maximum 3 ^oC above the design ambient temperature during summer for mechanically ventilated areas.

The criterion which gives higher number of air changes / higher quantity of air in either of the conditions as mentioned above shall be the basis for selecting the required air flow for that area.

All ventilation systems shall operate on 100% fresh air. All mechanically ventilated areas shall be positively ventilated by means of supply air fans, generally in combination with exhaust fan / gravity operated back draft damper. The ventilation system shall be designed for continuous operation of 24 hours a day. All GS sheets shall be hot dip galvanized or spray galvanized unless otherwise specified and minimum zinc deposition shall conform to class 275 of IS 277.

7.23.5 Equipment Description

7.23.5.1 *Axial Flow Fans*

These fans shall have single piece cast aluminium impeller with blades of aerofoil design.

The fan casing shall be of heavy gauge sheet steel construction minimum thickness of 3 mm up to a fan diameter of 750 mm, 5 mm for fans with impeller diameter of 750 mm and above and the same shall be spray or hot dip galvanized.

Necessary rain protection cowl, inlet and outlet cones, bird protection screen, adjustable damper, vibration isolators, back draft dampers etc. shall be provided.

The speed of the fan shall not exceed 960 rpm for fan with impeller diameter above 450 mm and 1400 rpm for fan with impeller diameter 450 mm or less. However, for fans having static pressure of 30 mm WC or above the speed of the fan shall not exceed 1440 rpm for fan with impeller diameter of above 450 mm and 2800 rpm for fan with impeller diameter of 450 mm or less. The first critical speed of rotating assembly shall be at least 25% above the operating speed.

All other accessories like supporting structure etc. as required shall be provided.

7.23.5.2 *Air Filters*

a) Pre - filter

Filter medium shall be either fabric or metallic type consisting of

i) Fibrous material (extruded polyethylene) or felt filter fabric Dry type with element of 5 ply construction for Fabric type.

ii) V-fold galvanized wire mesh inters spaced with a flat layer of galvanized wire mesh for Metallic type pre-filters.

b) Frame

Gl sheet (minimum 18 gauge thick) or Aluminium alloy of (minimum 16 gauge) supported by galvanized steel wire mesh of 10 mm square with handles.

c) Other requirements

Suitable aluminium spacers be provided for uniform air flow; Casing shall be provided with neoprene sponge rubber sealing. Filter shall be capable of being cleaned by water flushing. Wire mesh edges shall be suitable hemmed to eliminate the danger of abrasion during handling.

d) Efficiency:

Average arrestance of 65 - 80% when tested in accordance with BS: 6540/ASHRAE -52 - 76.

e) Minimum thickness shall be 50 mm.

f) Face velocity shall not be more than 2.5 m/sec.

g) Pressure drop (Initial pressure drop) shall not exceed 5.0 mm WC at rated flow. Final Pressure drop - Up to 7.5 mm WC.

7.23.5.3 *Fine Filter (Micro-vee type)*

a) Construction -

By pleating a continuous sheet of filter medium into closely spaced plates separated by heavy corrugated aluminium spacers

b) Frame:

Aluminium alloy of (Minimum 16 gauge conforming to IS: 737) with handles.

c) Other requirements

A neoprene sponge rubber sealing shall be provided on either face of the filter frame. Shall be capable of being cleaned by air or water flushing.

d) Efficiency:

Average arrestance of 80-90% when tested in accordance with BS: 6540/ASHRAE -52 - 76.

e) Thickness:

150 or 300 mm

f) Face Velocity:

Not more than 1.2 m/sec for 150 mm and not more than 2.4 m/sec. for 300 mm size.

g) Pressure drop:

Initial pressure drop - not to exceed 10 mm WC at rated flow. Final pressure drop - up to 25 mm WC.

7.24 Fire Extinguishers

Portable fire extinguishers are to be provided for all units as per the requirement of Tariff Advisory Committee (TAC) or meeting the requirement of local regulations whichever is stringent. All the extinguishers shall have ISI mark / TAC approval.

7.24.1 Firefighting Water Pumping Subsystem

This subsystem is, basically, composed of the dedicated pump house and of the pumps and other equipment, such as Diesel fuel oil tank, etc. Fire Hydrant system shall be designed in line with the relevant codes and standards.

The following are the major equipment items:

- electrically driven firefighting pump
- diesel driven firefighting pump
- Minimum Two (2) Jockey pumps (One (1) for duty, One (1) for stand-by)
- Accessories: pipework, pump controller, etc.

7.24.2 Indoor and Outdoor Hydrants Subsystem

7.24.2.1 *Indoor Hydrant subsystem*

The indoor hydrants and the related hose reel cabinets will be provided inside the following buildings:

- Intake Pump house building
- Lamella and DAF Building
- Filter House
- R.O Building
- Chemical Dosing Building
- Electrical & Control room Building
- Switchyard, Transformers and cable alleys etc
- Workshop & Warehouse Building
- Air Compressor Building
- Fire Fighting Pump House
- Any Other building that is deemed necessary.

The indoor hydrant system shall be served by the hydrant main isolated pipe.

7.24.2.2 *Outdoor Hydrant Subsystem*

The outdoor hydrants subsystem is provided to protect the desalination units and remineralization plant areas etc. The outdoor hydrants and the related (fire) hydrant cabinets shall be located at strategic locations along the hydrant main. The spacing between the hydrants shall not exceed 80m.

7.24.3 Portable Fire-Fighting Subsystem

The fire Extinguishers distributed all over the water plant building shall be suitable to be operated by the operating personnel of the respective buildings. This will allow a quick response to fires at early stage. Various types of portable extinguisher shall be provided.

The following portable extinguishers shall be provided:

- Carbon Dioxide Extinguisher
- Dry Powder Extinguisher

The fire extinguishers will be reasonably provided inside the buildings according to the authorised norm.

All the extinguishers shall have ISI mark approved.

7.24.4 Fire Detection, Monitoring and Alarm System.

A manual and automatic fire detection and alarm system shall be provided with detection devices, selected to suit particular risks and with a control system designed to provide operation and fire brigade staff with sufficient information to identify and respond correctly to any fire detected.

To ensure that the fire is detected at an earlier stage, the areas of high risk shall be monitored with automatic fire detectors. The following types of detectors are used:

- Smoke detectors (Optical),
- Flame detectors,
- Heat detectors.

In addition to the automatic fire detectors, non-automatic fire alarms (manual push button alarms) shall be installed at the entrances to the acoustic enclosure and at the building exists.

Each fire detector and manual push-button alarm for the fire alarm system shall be labelled in such a way that it is possible to identify to which group the fire detector or manual push button alarm belongs.

A signal will initiate an alarm (in the central control room) and indicates the related fire detector. The detection / initiation signal of water plant from automatic / manual fire initiation devices will be summarized at local control panel, and zone fire alarm signal will be transferred to the main fire alarm panel at central control room.

The annunciator panel will be installed in the Central Control room.

In addition to the automatic fire detector, non-automatic fire alarms (manual push-button alarms) are installed at the entrances to the acoustic enclosure and at the building exits.

7.25 Propeller Exhaust Fan

The fan should comply with IS:2312. The blades shall be of mild steel and properly balanced so as to avoid noise and vibration. The blade and blade carriers shall be securely fixed so that they do not loosen in operation. The means provided for securing the fan mounting or fan casing to the wall partition or window shall be such as to provide a secure fixing without damage to the fan or wall.

Suitably designed guards shall be fitted to the inlet and the outlet side to prevent accidental contact. No flammable material shall be used in the construction of fan. Moulded parts, if used, shall be of such materials as to withstand the maximum temperature attained in the adjacent component parts.

The fan shall have protective insulation or be capable of being earthed. A fan with protective insulation may be of all insulated construction or have either double insulation or reinforced insulation. Each fan should be provided with a 10 sq.mm mesh bird screen. The sheet used for the cowl should be 14 G and Motors shall be TEFC, IP-54.

Fans used to extract from areas storing or handling chlorine/ chemicals shall be constructed from materials resistant to attack by chlorine/stored chemical.

7.26 Air-conditioning Equipment

The air conditioning units shall be of split type, with the outdoor condensing unit mounted on the terrace of the room or grouted on external side of the wall with suitable brackets. Unless otherwise specified, equipment shall conform to the latest applicable Indian or IEC Standard.

Equipment Complying with other authoritative standards such as British, USA, ASHRAE etc. will also be considered if it ensures performance equivalent of superior to Indian Standard.

7.26.1 Proposed Areas to be Air Conditioned

- All Control rooms
- Complete Administrative building
- Laboratory rooms
- All MCC Rooms,
- Battery rooms in various buildings.

7.26.2 Type of Air Conditioning Units

7.26.2.1 *Design Capacity up to 3TR*

Split type AC unit: Non-ductable unit with outdoor type air Cooled condensing unit (2 x 100% capacity for each areas and fan-coil (evaporator) units (2x100%) distributed / placed at desired locations in the area which is air-conditioned. Condensing unit may be located in the roof of the building with local sunshade cover and approach through staircase up to the roof.

7.26.2.2 *Design Capacity above 3 TR and up to 10 TR*

Packaged Air Conditioner: Ductable with outdoor type Air (2 x 100% capacity) Cooled condensing (outdoor) units and indoor evaporator (2 x 100%) units placed inside the plenum area (in the space between ceiling and false - ceiling); Air supply distribution shall be through duct and return air shall be through plenum space to evaporator unit. Condensing unit may be located in the roof of the building with local sunshade cover and approach through stair case up to the roof.

7.26.2.3 *Design Capacity above 10 TR up to 50 TR*

Indoor type, ductable air cooled, Packaged Air (2 x 100% capacity) conditioners shall be provided for each area / building. The PAC room shall be located in proximity to the area to be air-conditioned.

The capacity of PAC and other equipment shall be designed as per the Design Philosophy & Equipment specification elaborated below. Sizing calculations for all the equipment shall be submitted for approval of Employer.

The Split (SAC) type AC & PAC units shall be air cooled type.

Number of fresh air changes per hour shall be minimum 1.5 or minimum 0.45 cum/min per person (16 cfm) whichever is higher for Conference rooms / common rooms.

The occupancy for general / office area shall be minimum one person per 10 sq. and for conference room the same shall be one per 3 sq. m for design of AC System. In the control rooms, control, equipment rooms etc., the occupancy may be one person per 25 sq. m (Minimum).

All the equipment of Air Conditioning system shall be designed for continuous duty. In Air conditioning system provided with ducts, false ceiling shall be provided with appropriate under deck insulation.

A minimum design margin of 15% shall be considered while sizing AC Plant Capacity.

All GS sheets (duct material) under Air conditioning system shall be not dip galvanised or spray galvanised unless otherwise specified and minimum zinc deposition shall conform to class 275 of IS:277.

7.27 Air Hose Apparatus

It shall consist of full vision face mask with inhalation and exhalation valve, connected to a corrugated tube ending in a manifold non-return valve, mounted on a harness belt worn around the waist, tested to applicable IS. The 50m long, 20mm canvas reinforced wire embedded hose, connected to the manifold shall be uncrushable and shall not kink.

The radial blower connected to the hose shall be housed in a strong carrying box which can hold the breathing apparatus with hose and fittings. The blower shall be suitable for supplying air to two people simultaneously.

7.28 Safety

Safety signs All signs providing health and safety information on instructions shall comply with BS: 5499-5:2002 and equivalent local standards. Signs shall be of durable quality and shall comprise a substrate of 22 gauge aluminium, predrilled for fixing and with radiuses corners free of burrs or sharp edges. Symbols and lettering shall be screen printed.

7.29 Quality

Product of an experienced Equipment manufacturer should satisfy the following criteria:

a) Shall demonstrate equal or larger capacity installations using similar equipment.

b) Equipment installed and successfully operating for at least five years having specified constructional features equal to or higher than the specified size and rating. This shall be supported by certificates from the end users.

c) Provide names and phone numbers of contacts at referenced installations to verify performance.

d) Demonstrate to satisfaction of the Engineer that equipment to be provided is equal to that specified.

7.30 Warranty

a) Comply with the requirements of each type of equipment and specification mentioned elsewhere in this document.

b) Warrant all components to be free of defects in materials or workmanship for 12 months from date of satisfactory completion of performance and process proving tests.

c) Individual warranties by component manufacturer in lieu of single source responsibility by the main equipment manufacturer shall not be acceptable.

d) Items which fail during the warranty period and the period of operation and maintenance under the Contract, excluding expendable items, shall be replaced without cost to the Employer.

e) Provide manufacturer's guarantee and warranty certificates prior to equipment start-up.

7.31 Packing and Protection

Before any Plant is dispatched from a manufacturer's factory it shall be adequately protected and packed to ensure that it will arrive on the Site in an undamaged condition. The methods employed for protection and packing must be suitable for withstanding the conditions which may be experienced during shipment, delivery to the Site and prolonged periods of storage in the open, whether the items are shipped in packing cases, crates or only partially protected according to their nature.

Bright parts and bearing surfaces shall be protected from corrosion by applying a rust preventive lacquer, high melting point grease or similar temporary protection. A sufficient quantity of solvent shall be supplied with the plant to enable this coating to be removed on the Site.

All machined flanges and other mating surfaces shall be protected by means of wood templates. The bolts for securing these templates shall not be reused in the final installation.

No one crate or package shall contain items of Plant intended for incorporation in more than one part of the Works. All items of Plant shall be clearly marked for identification against the packing list, which shall be placed in a waterproof envelope inside every packing case or crate.

Every packing case and crate shall be indelibly marked to show its weight, serial number, top and bottom, shipping marks and handling instructions or sling marks. Electrical Plant shall be enclosed in sealed airtight packages with dehydrating material, before being placed in packing cases on shock-absorbent material and secured by means of battens.