QUALITY CONTROL MANUAL

February
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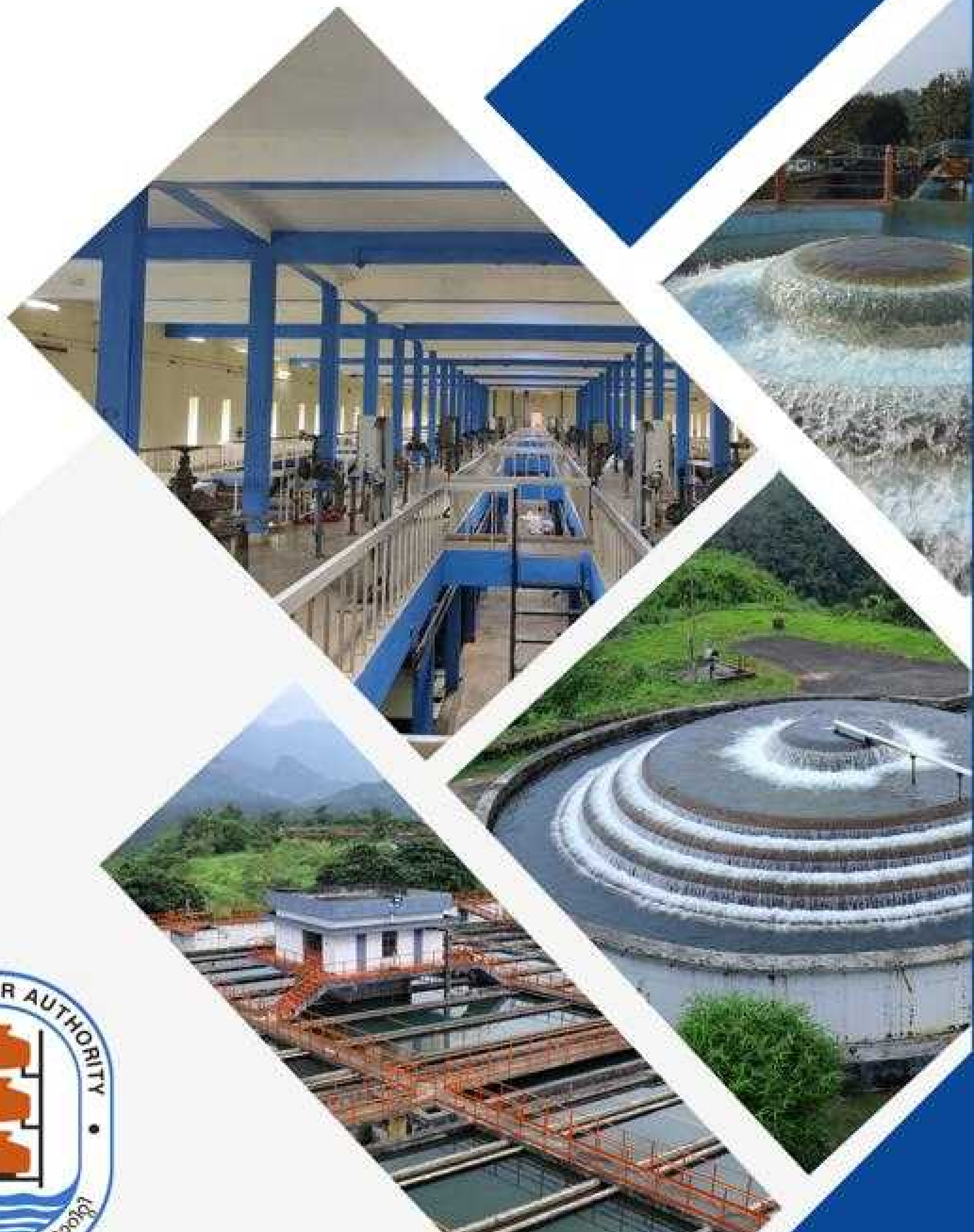

Kerala Water Authority

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PART A

CHAPTER 1 ORGANISATIONAL SETUP

1.1. INTRODUCTION

Kerala Water Authority implements various water supply schemes and sewerage schemes in the State. The works mainly comprise design, construction and commissioning of intake structures, water treatment plants, service reservoirs, laying transmission and distribution lines, installation of pumping and electrical systems and other mechanical components. Quality assurance and quality control has to be exercised at various stages for the successful implementation of the projects. Besides ensuring quality, the time line for commissioning also has to be strictly adhered to.

The PWD has already prepared a Quality Control Manual to provide a base document to affect quality control in construction of projects undertaken by Kerala Public Works Department. This is intended to enable the engineers and supervisory staff to check the different activities of construction with reference to the quality aspects and ensure that standards envisaged are achieved. The above manual has to be made applicable in KWA also. However, the Quality Control Manual of PWD does not include some specific activities relevant to KWA. So in addition to the Kerala Public Works Department Quality Control Manual, the Quality Control Manual for the activities pertaining to KWA has been prepared to have a comprehensive coverage of quality assurance and quality control of all the activities.

The main additional sections included comprise activities related to water supply and waste water or sewerage sector. The topics covered consist of the practices to be followed during the implementation of water supply and sewerage projects. The activities from construction of treatment plant to laying pipes and providing service connection has been incorporated in this manual. An insight to the procedures including electromechanical works, automation and instrumentation will be an added advantage for the field staff to execute the project qualitatively. The Manual can also be used as a reference book for the practicing personals including engineers and contractors in the field.

For implementation and practice of the quality assurance and control a separate organisational setup has to be established.

1.2. SCOPE OF THE MANUAL

The Manual does not attempt to suggest technical specifications, since these are stated in the relevant codes and contract documents. However, it will provide guidance on good engineering practices and quality control and its recommendations are not intended to be exhaustive. The QC Manual aims to ensure that the works are executed as per specifications. All tests shall be done as per the guidelines in this Manual. It should be read along with the Quality Control Manual of PWD. If any quality test required to be performed is not covered in this Manual, the same shall be done in line with the stipulations/provisions of relevant code of practice published by BIS. If any difference is observed between the tests or quality control procedures given in this Manual and those stipulated in the contract documents and specifications, the later shall prevail.

The terms “quality assurance” and “quality control” are often used interchangeably to refer to ways of ensuring the quality of a service or product. The terms, however, have different meanings. Quality Assurance (QA) is the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled. Examples of quality assurance include process checklists, project audits, methodology statements and standards development. Quality Control (QC) is the observation techniques and activities used to fulfil requirements for quality. Quality control is used to verify that the product delivered are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, close review of the product and the testing process.

Quality control test results shall accompany the bill submitted for payment. It shall be the responsibility of the Assistant Engineer to ensure that bills for payment are not submitted without attaching the first-tier quality test results. Second-tier test results shall also be attached, if the QC wing has carried out any test for the items covered in the bill.

The main components covered under the Manual are as enumerated below

A. Water Supply

- Intake Structure
- Pump House
- Water Treatment Units
- Water Retaining Structures
- Electromechanical
- Pipe Laying Works
- Automation / Instrumentation
- Service Connection

B. Waste Water / Sewerage

- Sewer Laying Works
- Pump House
- Sewage/Septage Treatment Unit
- Reuse/ Recycle
- Electromechanical
- Service Connection

1.3. EXISTING SETUP

The existing setup for quality control is mainly limited to ensuring quality of supplied water and the quality of chemicals supplied for water treatment. The Quality control wing is under Director, State Referral lab which report to the Technical Member.

For enquiring allegations and specific cases related to misappropriation of fund, anomalies in work, etc., there is a vigilance wing functioning under the direct control of a Deputy Chief Engineer. The Technical Member is the head of Vigilance Committee also.

In addition, the inspection of pipes, JJM work has been outsourced to a third party agency. KWA presently executes many projects both water supply and sewerage under various heads such as KIIFB, AMRUT, NABARD, State Plan, RKI, Deposit works, etc. and about to take up work under ABD and other heads. Projects worth more than Rs.12000 crores are being executed by KWA presently. Hence a standardised procedure for quality assurance and quality control is required for the successful implementation of the projects. By this manual this objective could be achieved to some extent if required manpower and infrastructure is provided for the same. The ensuing section give an overview of the organisational setup and infrastructure required for effective functioning of the quality assurance and quality control in the ongoing projects.

1.4. ORGANISATIONAL SET UP FOR IMPLEMENTATION

Quality Control is an essential part of any production. QC is required in infrastructure development also. KWA presently has only quality control labs for water and chemical testing. The testing of materials / other parameters of works is being done outside in some reputed firms / engineering colleges, etc. Hence as such KWA does not have a full independent mechanism for quality assurance and quality control in the ongoing works. For this we need to set up district QC laboratories with offices and three Regional laboratories with all amenities like building, testing equipment, vehicles, computers, software, etc. For projects amounting to more than Rs.100 crores, the contractor should be insisted to set up a QC lab at site and a qualified engineer should be in charge of the lab. The QC tests should confirm to relevant IS specifications

As the QC involves checking the quality of the works being executed under Regional Chief Engineers, the QC wing should function as an independent agency under the control of a Chief Engineer (Quality Control) or Member (Quality). The QC activities in a district should be under an Assistant Engineer. He will be in charge of the District level lab. The

AEE(QC) will have the control of 2 or 3 districts depending on the quantum of work and area of jurisdiction. There will be Regional labs in each region and Executive Engineer (QC) will be in charge of those labs. All the QC activities of the state will be under the control of Director (QC) who will be reporting to Chief Engineer (Quality Control) or Member (Quality). The Director (QC) shall monitor the working of the Quality Control laboratories and implementation of second tier quality control in the Department. The Director (QC) shall also conduct quarterly review of QC activities and submit recommendations to the Chief Engineer (QC) / Member (Quality).

The committee headed by Chief Engineer (QC) / Member (Quality) shall give timely instructions for effective implementation of the QC system in the department. The proposed Quality Control organizational set up is as given in figure 1. Hence for implementation of QC wing the manpower requirement are as follows.

- Member (Quality) /Chief Engineer(QC) - 1
- Director (QC) / SE - 1
- EE, QC, Regional Lab - 3
- AEE, QC - 7
- AE, QC - 14
- Other establishment staff, chemist, driver, etc. as per requirement

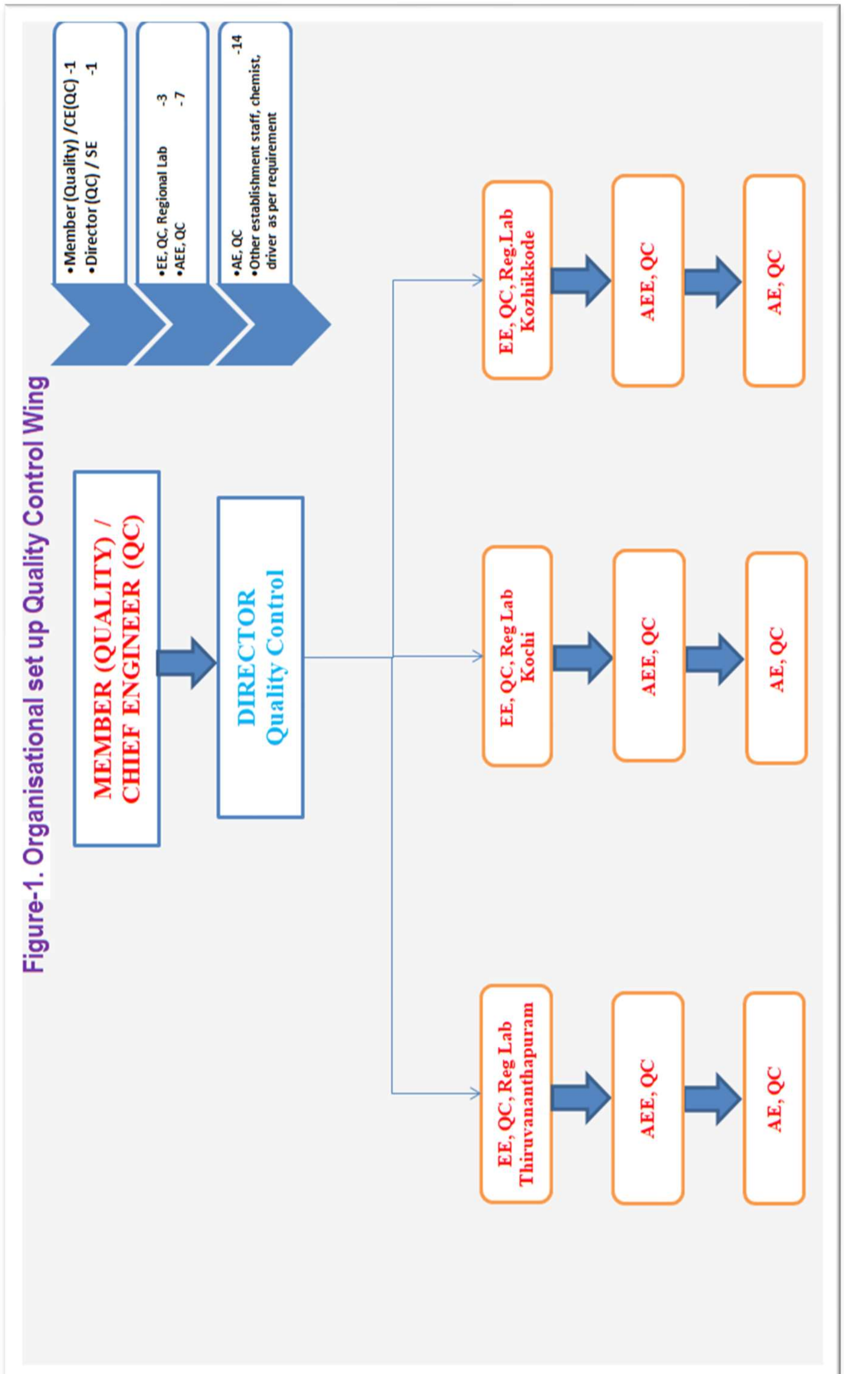


Figure-1. Organisational set up Quality Control Wing

1.5. ROLES OF OFFICERS AND CONTRACTOR

The main roles of the officers in field and QC wing and contractors in ensuring quality assurance and quality control in the work are briefly explained below.

i. **Contractor** : Primary responsibility for ensuring quality control in each item of work in a project shall vest with the Contractor. As the agency entrusted for carrying out a project, it shall be the Contractor's responsibility to supply materials conforming to standards and to carry out the works as per specifications so that the desired quality is achieved. The Contractor shall also carry out tests prescribed in this Manual for each item as per the frequency stipulated. It shall also be responsibility of the Contractor to carry out rectification works as directed by the Engineer, if test results do not comply with the requirement. In order to fulfil the responsibilities in ensuring quality control, the Contractor shall employ qualified technical personnel at site, as agreed in the contract. The technical personnel so employed shall have thorough knowledge regarding all quality control aspects of the project including QC tests. The Contractor cannot evade from the responsibility of ensuring quality control in the items of work done on the plea that he does not possess sufficient technical knowledge or that the works done are supervised by the departmental officers.

ii. **Overseer / Draftsman** : It shall be the responsibility of the Overseer in charge to directly supervise all items of work and ensure that works done are as per the specifications and that quality standards are achieved. Overseer shall inspect all materials supplied then and there and ensure that the materials conform to standards. He shall not allow the Contractor to supply materials not conforming to specifications and standards. He shall ensure that only good quality work is done at site. Any instance of violation of his instructions during supply of materials or carrying out work shall be recorded and reported to the Assistant Engineer in writing immediately. He shall not permit the Contractor to proceed with the work in case his instructions are not complied with.

iii. **Assistant Engineer**: Assistant Engineer shall ensure that work is being carried out by the Contractor as per specification and standards. He shall visit the site of work frequently and issue instructions enabling adherence to specifications and strict quality control. If any defective work is noticed during inspection, the Contractor or his authorised representative at site shall be instructed to stop bad quality work and rectify the defects of the work done. The Assistant Engineer shall record details of such defective work noticed and instructions issued therein. The fact of having done rectification satisfactorily shall also be noted subsequently. Notice shall be issued under intimation to the Agreement Authority, in case of non-compliance of instructions issued at site. The Agreement Authority shall initiate action to terminate the contract and initiate penal action, if the desired level of quality is not exercised in the construction. The Overseer and the Assistant Engineer shall ensure that the Contractor takes samples and carries out tests as per frequency suggested in the Manual for the first tier QC testing. It shall be their responsibility to obtain the test results from the Contractor and to record them in the Quality Control Register kept in the Section office. Copies of test results shall be made available at site for verification by the inspecting officers. They shall also ensure that Contractor carries out all rectification works including dismantling and reconstruction in case of unacceptable works.

iv. **Assistant Executive Engineer**: Assistant Executive Engineer shall monitor the entire quality control process and ensure that his subordinate officers are carrying out their duties promptly. In case of lapse on the part of any officer, he shall report to the Executive Engineer for initiating disciplinary action. He shall also report lapse, if any on the part of the Contractor to the Agreement Authority for penal action as per rules of registration and contract conditions.

v. **Overseer (QC wing)** : The Overseer attached to the QC laboratories shall be responsible for collecting representative samples from the work site, labelling, and sealing, wherever necessary, and transporting the samples safely to the laboratory without any damage. On reaching the laboratory, the sample details shall be entered in the sample register with a unique number. This number shall be referred as sample number in all the tests. The tests to be carried out on the sample received also shall be indicated in the sample register. The Overseer is responsible to conduct the required tests as per the guidelines in the QC Laboratory Manual or relevant codes and instructions of the Assistant Engineer. The Overseer shall check and ensure that the laboratory equipment are kept clean by the support staff and are functioning properly. Any defects noted shall be reported to the Assistant Engineer. The laboratory data and results shall be recorded in the required format by the Overseer, get it verified by the Assistant Engineer and approved by the Assistant

Executive Engineer of the QC wing. The Overseer shall record the results in the register kept in the laboratory and affix signature in the register. The Overseer shall ensure that the test reports are forwarded to the officers executing the work. He shall also be responsible for making entries in the required register or software. The Overseer, on a daily basis, shall compile all the intimations forwarded by the field engineers regarding the commencement of the work or execution of an item of the work, bring them to the notice of the Assistant Engineer and Assistant Executive Engineer and abide by their instructions in the matter of field inspections/testing, collecting samples and laboratory testing.

vi. **Assistant Engineer (QC wing)** : The Assistant Engineer of the QC laboratories shall be responsible for second-tier QC testing. He shall supervise the tests conducted by the Overseer, giving necessary instructions for proper conduct of the tests. He shall verify the test results recorded in the laboratory register, software if any and submit the test reports to the Assistant Executive Engineer (QC) for forwarding to the officers executing the project. He shall inspect the project sites, verify the field tests and arrange to take representative samples for laboratory testing. Any instances of violation in the QC procedures observed at site shall be brought to the notice of the field officers immediately. A report of such instances shall be made to the Assistant Executive Engineer, QC wing. The Assistant Engineer shall prepare monthly progress report of QC activities in the desired format and submit to the Assistant Executive Engineer, QC on or before the third working day of the succeeding month for submission to the higher officer. The Assistant Engineer shall be responsible for arranging the repairs, regular maintenance, and calibration of the laboratory equipment.

vii. **Assistant Executive Engineer (QC wing)** : Assistant Executive Engineer of the QC laboratories shall be responsible for implementing second-tier quality control tests in the projects executed by the department in the entire district of his jurisdiction. He shall inspect sites, monitor the quality control process and bring to the notice of field officers any shortfall in the quality of works carried out. He shall ensure that his subordinate officers will inspect the maximum number of project sites and carry out maximum number of quality tests in each project. He shall correspond with field engineers on issues related to quality control. He shall be responsible for approving the results of tests conducted in his laboratory and forwarding it to the Executive Engineer of the Regional Laboratory and the field engineers. He shall submit monthly reports on tests conducted to the Director (QC) with copy to Executive Engineer, QC wing within 10 days of the succeeding month. The Assistant Executive Engineer, QC wing shall prepare review notes for the quarterly review meeting by the Director (QC). The Assistant Executive Engineer shall monitor the timely repair, maintenance, and calibration of the Introduction 8 Kerala Public Works Department - Quality Control Manual laboratory equipment. Assistant Executive Engineer shall initiate action for providing additional equipment and facilities to the laboratory so that the performance of the QC activities is not hindered due to any reason.

viii. **Executive Engineer, (QC wing)** : Executive Engineer, QC wing shall monitor and review the second-tier QC system in the entire region of his jurisdiction. He shall inspect sites and bring to the notice of field officers any shortfall in quality of works done or the quality control process being followed. He shall take up quality control issues in a project with the Agreement Authority or the concerned Chief Engineer, wherever required. He shall review the monthly report of QC activities in each district submitted by the Assistant Executive Engineer and recommend action on the non-compliance reports. He shall submit quarterly reports to the Director (QC) regarding the implementation of QC in his region within 15 days after each quarter. He shall attend the State level review meetings on Quality Control.

PART B WATER SUPPLY

CHAPTER 1 INTAKE STRUCTURES

1.1. GENERAL

An intake is a structure constructed in a surface water to obtain water from the source. These structures arrange to draw water under wide variation of surface water levels or when it is desired to obtain water from a particular depth.

1.2. SELECTION OF SITE

The following points shall be kept in view.

(1) The inflow point of the intake drawing water from a stream or a lake should be well below the water surface to prevent hydraulically wasteful air entrainment but sufficiently high enough from the bed to avoid entrapping of suspended solids.

(2) The location should provide the most suitable quality of water available.

(3) The site should have firm strata for good foundations.

(4) Channels used for navigation should be avoided as they add to the danger of pollution through toilets and other refuse from ships.

(5) The location should not cause any danger from ice formation and thrust.

(6) The site should avoid the existence of currents that may endanger the safety of the structure or deposit silt against or on it.

(7) In very cold climates where ice formation are encountered, the inflow point shall be kept several metres below water surface to avoid the ice formation because of impact on the structure and clogging of the ports of the intake, and to keep the velocities down to 75mm to 100mm per second. This would avoid the entrainment of leaves, ice and debries etc in the flowing water and fish can also easily escape from intake current.

(8) The effect of floods at the proposed point should be studied and all precautions taken for the safety of the structure as well as safe working of the intake during floods.

(9) The distance from where the power is available should be considered.

(10) The distance of WTP from the proposed site of intake also deserves consideration. In case of impounding reservoir, the intake should be located at the deepest point in reservoir, which is generally near the dam site, in order to take the optimum utility of the reservoir capacity.

1.3. STRUCTURAL SAFETY OF INTAKES

A good factor of safety is considered in the design of the structure of intakes because the exact amount of forces to be resisted by the structure cannot be precisely assessed. Adequate measures are required to be adopted for the safety of structure likely damage due to blows from moving object for intakes located near the navigable channels. It should be considered that the strata where the foundations of structure are laid is sufficiently stable and water currents do not undermine the foundations.

In the case of open well construction minimum thickness of 200mm to 300mm and for scooping 400mm thickness desired for intake wells. The thickness shall also be sufficient to sink the well by its self weight.

1.4. INTAKE DESIGN

1.4.1. THE OBJECTIVES OF INTAKE DESIGN

Detailed consideration needs to be devoted to the intake design to serve various objectives, as follows:

(a) to prevent vortex formation

(b) to obtain uniform distribution of the inflow to all the operating pumps and to prevent starvation of any pump,

(c) to maintain sufficient depth of water to avoid air entry during draw down.

1.4.2. GUIDELINES FOR INTAKE DESIGN

Following points are to be noted in this respect. Note, D is the diameter of the suction bell mouth.

(a) Avoid mutual interference between two adjoining pumps by maintaining sufficiency clearance. The walls should have rounded or ogive ends.

(b) Avoid dead spots by keeping rear clearance, the dimension 'B' to about 5D/6 from the centre line of the pump. A dummy wall may be provided, if necessary3

(c) Provide tapered wall between the approach channel and the sump. By this the velocity should reduce gradually to about 0.3m/s near the pump. This is also helps to avoid sudden change in the direction of the flow.

(d) Avoid dead spots at the suction bell mouth by maintaining the bottom clearance dimension.

(e) Avoid sudden drop between eh approach channel and the sump. A slope of maximum 15^0 is recommended.

(f) Keep adequate submergence of the pump under the LWL

The Dimension D is generally the diameter of the suction bell measured at the inlet. This dimension may vary depending upon pump design. Refer to the pump manufacturer for specific dimensions.

1.4.3. RECOMMENDATIONS REGARDING INTAKE-DESIGN

Flow-rate in m^3/hr	Minimum submergence Dimension 'H', m	Position of trash-rack dimension 'A', m
1000	1.23	3.28
1600	1.50	5.20

2500	1.80	8.07
4000	2.17	12.87
6400	2.63	20.37
10000	3.15	31.61
16000	3.80	50.20
25000	4.56	77.91
40000	5.52	123.74

1.5. INTAKE PIPES

Intake pipes are laid at a grade to develop self-cleansing velocities ie. 0.90 to 1.20 m/sec. Intake conduits serve either as gravity or as suction pipes as the case may be. Intake pipes are laid on a gradual rising or falling grade to avoid accumulation of air pocket which would reduce the capacity of pipes.

PART B WATER SUPPLY

CHAPTER 2 PUMP HOUSES

2.1. GENERAL

Pump wells are generally located on the banks. The suction lift should remain within practical limits of 4.5m to 5.5m in case of centrifugal pumps. The pump houses can be located above roof slab of underground tanks or located adjoining a tank side wall as in the case of positive suction pump houses.

2.2. SPACE REQUIREMENT

Sufficient space should be available in the pumphouse to locate all the pumps, motors, valves, piping, control panels and cable trays in a rational manner with easy access and with sufficient space around each equipment for the maintenance and repairs. The minimum space between two adjoining pumps or motors should be 0.6m for small and medium units and 1 m for large units.

The space for control panels should be planned as per IE rules.

2.3. SERVICE BAY

A service bay should be provided in the pumping station with such space that the largest equipment can be accommodated for overhauling and repairs. For large installations the floors should be so planned that all piping and valves can be laid on the lower floor and the upper floor should permit free movement.

2.3 HEAD ROOM

In the case of VT pumps with hollow shaft motors, the clearance should be adequate to lift the motor clear off the face of the coupling and also carry the motor to the service bay without interference with any other apparatus.

The clearance should also be adequate to dismantle and lift the largest column assembly.

In the case of horizontal pumps (or vertical pumps with solid shaft motors) the head room should permit transport of the motor above the other apparatus with adequate clearance.

Pump houses must have minimum head room of 4.5m for centrifugal pumps and 6m for VT pumps.

PART B WATER SUPPLY

CHAPTER 3 AUTOMATION - QUALITY CONTROL AND QUALITY ASSURANCE

3.1. GENERAL

The water automation system and instrumentation are based on real-time operating systems and programming toolkit that solves the current global issues, such as potable water shortage, poor water quality, high processing monitors, energy savings, and supply costs. Automation describes a wide range of technologies that reduces human intervention in processes. The components cover the instruments, sensors and human interface terminal.

With automation KWA intends to supply the water at a consistent quantity and quality as and when required by the customers and to carry and treat waterborne wastes from return to the environment.

International Organisation for Standardisation (ISO), International Electrotechnical Commission (IEC), International Society for Automation (ISA) are the agencies that prepares and publish international standards for all electrical, electronics, automation and control and related technologies. Further for the devices we have Indian standards (IS) also.

Basic features

Some of the aims of good water resources management are:

- Improvement of water quality
- Improving energy efficiency while managing and treating water
- Minimizing leakage and wastage
- Conservation of resources
- Reducing downtime and operating costs

Use of dedicated Automated Control Systems effectively meets the above objectives, at a cost-effective price point.

All equipment and materials incorporated in the system shall be selected, designed and rated to operate under the defined performance duties and specified site conditions and to maintain a high level of operational reliability.

All equipment shall be designed for rapid and replacement of major subassemblies and components, which shall be mounted on printed-circuit boards or plug-in type bases with high-grade, non-ageing plugs and sockets with gold-plated contacts. Components on printed circuit boards shall be tropicalized and varnished.

All transformers shall be double wound with an earthed screen between primary and secondary windings. All transformers shall be vacuum-impregnated and all except power transformers shall be epoxy-resin encapsulated. Routine maintenance and repair shall, as far as possible, require neither highly skilled personnel nor soldering and wire-wrapping techniques.

Integrated circuits shall be used and, except in protection and circuits, solid-state devices shall be used in preference to moving-armature relays and electro-mechanical timers.

Relays shall be of the plug-in type and shall have polycarbonate covers used in tropical locations; the relays shall be hermetically sealed. The standards of reliability for moving armature relays and electro-mechanical timers shall not be less than specified in IEC 60947 . 4: 1999 or equivalent for medium-voltage contactors of Class 3 mechanical endurance. Operating coils shall be vacuum impregnated or epoxy-resin encapsulated.

Electronic units shall be fully solid state and the selection and installation of components shall give the maximum life possible. Wire-wound resistors shall be on ceramic formers and embedded in fire-proof and damp-proof material

Plant state indication systems shall be designed so that a failure of any component or circuit or power supply associated with the indication system cannot lead to the masking or inhibition of the indication of a potentially dangerous state.

Plant protection and control systems shall be designed so that their outputs are de-energized or neutralized whenever a failure occurs of any component or circuit or power supply associated with that protection or control circuit

No single equipment fault shall prevent the correct operation of any protection or shut-down circuit whenever necessitated by a plant fault condition or control action.

Under emergency, failure or shut-down circumstances, each regulating device shall move to the appropriate safe condition or stay-put in accordance with the relevant part of the Specification.

All instruments, gauges and control equipment which perform similar duties shall be of uniform type and manufacture throughout the Works in order to facilitate maintenance and the stocking of spare pans.

All equipment shall be fully tropicalized and suitable for the worst environmental operating conditions.

Panel-mounted instruments shall have damp-proof and dust-proof cases. Instruments mounted outside instrument panels shall have weatherproof and dust-proof cases. Instrument cases shall be of corrosion-resistant material or finish. Instrument screws (unless forming part of a magnetic circuit) shall be of brass or bronze. Access to terminal compartments of instruments mounted outside panels or other enclosures shall not expose any working part. Moving parts and contacts shall be adequately protected from the ingress of dust.

Plant-mounted indicators and gauges shall be sized to give full legibility when viewed from a position with convenient and easy access or from the point at which any operation requiring observation of the gauge is performed. The minimum diameter for any gauge shall be 100mm except where forming part of standard instruments and accessories such as air-sets.

Dials and bezels shall be of bronze and internal components shall be of stainless steel, bronze or other corrosion-resistant material.

Signal-transmission systems shall be in accordance with IEC 60381-1:1982 or equivalent and shall use a signal of 4mA to 20mA dc. Where possible, measuring systems shall be designed so that any necessary power supply is taken from the appropriate instrument panel.

Transmitting devices shall have integral indicators to monitor the output signal or connections suitable for use with a portable test meter, and shall be capable of meeting the performance requirements specified in the appropriate part of IEC 60770-1 : 2010 or equivalent.

Equipment mounted in enclosures shall be suitable for continuous operation at the maximum internal temperature possible in service, due account being taken of internally-generated heat and heat dissipated by other plant. All components shall be rated adequately and circuits shall be designed so that change of component characteristics within the manufacturers' tolerances shall not affect the performance of plant. All equipment shall be designed to operate without forced (or fan) cooling.

Equipment provided with anti-condensation heaters shall be capable of operating without damage if the heaters are left on continuously. Unless provided with unalterable factory configured ranges, measuring instruments shall have zero and span adjustment.

Instruments not mounted in panels shall be supplied complete with all brackets, stands, supporting steelwork and weatherproof enclosures (separate from the instrument cases) necessary for securing them in their working positions and affording complete protection at all times including periods of servicing, adjustment, calibration and maintenance.

3.2. INSTALLATION OF INSTRUMENTATION

3.2.1. Installation of instruments and sensing devices

Each instrument and sensing device shall be installed in accordance with the recommendations or instructions of the manufacturer for the particular application. Each mounting position shall be chosen to give correct operation of the equipment, faithful reproduction of the quantity to be measured, ease of operation, reading, maintenance and servicing, freedom from any condition which could have adverse effects and with particular regard to the safety of personnel and plant. Each item of plant shall be leveled and securely fixed to the surface, bracket or framework on which it is mounted.

Instruments to be installed in areas of high or low temperature or high humidity shall be provided with adequate protection from adverse effects.

Sensors shall be electrically, chemically and physically safe for the end user

3.2.2. Data transmission

Whatever instrumentation is done the device shall have the capability to send real time data and error logs to specified central database in the prescribed data format, by way of 3G/4G/WiFi/LoRa WAN or any other communication network.

The software being supplied as a part of solution shall be able to monitor the reading and give alerts and notifications to the concerned officials through mobile app/SMS/email when the reading crosses the threshold values

3.2.3. Inspection on delivery

The Observations shall be made for unusual conditions like weather beaten, frayed, rusted or stained parts, damp conditions indicating prolonged exposure to weather, damage due to rough handling indicated by splintered, torn or crushed packing, exposure to high temperature indicated by charred paper, wood or paint etc.

3.2.4. Observation and measurement during installation

Observation of motor/ generator vibration during operational testing.

Operational testing of relays,

Valve operation testing etc shall be done and recorded.

3.2.5. System Tests:

These tests shall be conducted as appropriate to demonstrate that the installed systems are free from damage due to shipment and installation, and that equipment performs in accordance with specifications.

3.2.6. Integrated Tests:

After completion of system tests, integrated tests shall be performed to demonstrate that the system performs satisfactorily when connected to its interfacing. These tests will be followed up by commissioning tests.

3.2.7. Commissioning

Commissioning Tests: These consist of a series of tests performed under service operating procedures to demonstrate compatibility of the physical plant with operating procedures.

3.2.8. Final Inspections

Final inspections shall be performed to ensure that all previously identified discrepancies have been resolved satisfactorily.

3.2.9. Documentation

As built drawing, equipment specification, date of installation, manuals for maintenance, calibration, fault diagnosis, repair and periodic testing shall be documented.

3.2.10. Drawings and Schedules

i. There shall be a process and instrumentation drawing which shall comply with BS 1646 (all parts) and BS1553-1
ii. General arrangement drawings of field-mounted instruments showing installation details
iii. General arrangement drawings of instruments and control panels fully dimensioned in plan and elevation views, showing foundation and fixing details, access doors, clearances, cable-entry positions, weight and lifting arrangements.
iv. Internal circuit and wiring diagrams for instrument and control panels
v. Schematic control diagrams
vi. Instrument loop diagrams
vii. Instrument wiring and piping diagrams
viii. Interconnection wiring diagrams
ix. Instrument system and panel power distribution diagrams
x. Schedule of inputs and outputs from programmable controllers and telemetry outstations

Annexure I

Instrumentation shall comply with relevant quality standards test procedures and latest version of codes of practice as below.

IEC 60381-1	Analogue signals for process control systems. Specification for direct current signals.
IEC 60947-4-1	Specification for low voltage switchgear and control gear. Contactors and motor-starters, electromechanical contactors and motor starters.
IEC 60947-4-2	Specification for low voltage switches gear and control gear. Contactors and motor starters. AC semiconductor motor controllers and starters.
IEC 60947-4-3	Specification for low voltage switches gear and control gear. Contactors and motor starters. AC semiconductor controllers and contactors for non-motor loads.
IEC 60770- 1	Transmitters for use in industrial process control systems. Methods for performance evaluation
BS ISO 1217	Displacement compressors. Acceptance tests.
ISO 2112	Specification for amino plastic molding materials
ISO 6817	Measurement of conductive liquid flow in closed conduits. Method using electromagnetic flow meters
BS EN 837-1	Pressure gauges. Bourdon tube pressure gauges. Dimensions, metrology, requirements and testing

BS EN 1057	Copper and copper alloys, Seamless, round copper tubes for water and gas in sanitary and heating applications
BS EN 1092-1	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges
BS EN 1563	Founding spheroid graphite cast iron
BS EN 60529	Specification for degrees of protection provided by enclosures (IP code)
IBS EN 60534-1	Industrial-process control valves. Industrial-process control valves. Control valve terminology and general considerations
BS EN 60546-1	Controllers with analogue signals for use in industrial-process control systems- Controllers with analogue signals for use in industrial-process control systems. Methods for evaluating performance.
BS EN 60584-2	Thermocouples. Tolerances
BS EN 60654	Operating conditions for industrial-process measurement and control equipment All relevant parts.
BS EN 60751	Industrial platinum resistance thermometer sensors
BS EN 60873	Methods of evaluating the performance of electrical and pneumatic analogue chart recorders for use in industrial-process control systems

BS EN 61000-6	Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments.
BS 89	Direct acting indicating analogue electrical measuring instruments and their accessories.
BS 90	Specification for direct-acting electrical recording instruments and their accessories
BS 7671	Requirements for electrical installations. IEE Wiring Regulations (sixteenth edition).
BS 476	Fire tests on building materials and structures.
BS 1042-1.4	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2.
BS 1041-2.1	Code for temperature measurement. Expansion thermometers. Guide to selection and use of liquid-in-glass thermometers.
BS 1041-2.2	Code for temperature measurement. Expansion thermometers. Guide to selection and use of dial-type expansion thermometers.
BS 1041-3	Temperature measurement. Guide to selection and use of industrial resistance thermometers.
BS 1041-4	Temperature measurement. Guide to the selection and use of thermocouples.
BS 1042-1.4	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2.
BS 1123-1	Safety valves, gauges and fusible plugs for compressed air or inert gas installations. Code of practice for installation.
BS 1203	Hot-setting phenolic and aminoplastic wood adhesives. Classification and test method.

BS 1553-1	Specification for graphical symbols for general engineering. Piping systems and plant.
BS 1571-2	Specification for testing of positive displacement compressors and exhausters. Methods for simplified acceptance testing for air compressors and exhausters.
BS 1646-1	Symbolic representation for process measurement control functions and instrumentation. Basic requirements.
BS 1646-2	Symbolic representation for process measurement control functions and instrumentation. Specification for additional basic requirements.
BS 1646-3	Symbolic representation for process measurement control functions and instrumentation. Specification for detailed symbols for instrument interconnection diagrams.
BS 1646-4	Symbolic representation for process measurement control functions and instrumentation. Specification for basic symbols for process computer, interface and shared display/control functions.
BS 1794	Specification for chart ranges for temperature recording instruments.
BS 2765	Specification for dimensions of temperature detecting elements and corresponding pockets.
BS 3680	Measurement of liquid flow in open channels. All relevant parts.
BS 3693	Recommendations for design of scales and indexes on analogue indicating instruments.
BS 4675-2	Mechanical vibration in rotating machinery. Requirements for instruments for measuring vibration severity.
BS 4999-142	General requirements for rotating electrical machines. Specification for mechanical performance: vibration.
BS 5169	Specification for fusion welded steel air receivers.
BS 5728-3	Measurement of flow of cold potable water in closed conduits. Methods for determining principal characteristics of single mechanical water meters (including test equipment)

BS 6004	Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal
BS 6739	Code of practice for instrumentation in process control systems:

PART B WATER SUPPLY

CHAPTER 4 WATER TREATMENT UNITS

4.1. GENERAL

The various units of conventional treatment plants and their purpose are tabulated below:

Sl. No.	Description	Purpose
1	In take works	For with drawl of water from surface source and to ensure entrance velocity of 0.60-0.90cm/sec.
2	Inlet channel	For conveyance of raw water to [illegible] it should [illegible]
3	Storage cum Sedimentation	It should be made water tight to reduce losses
4	Flash Mixer & Clariflocculator	The units should be tested for water [illegible]
5	Pump House	To house machinery and other equipment and shall be constructed as per standard departmental design.
6	Pumping plants	Centrifugal pumps are installed for pumping raw water to high level Tank and clear water to O H S R.
7	Wash Water Tank	For distribution of back wash water to filter units and should have scour and overflow arrangement. The structure should be tested for water tightness.
8	Slow sand filter/ Rapid sand filter	[illegible] inl [illegible] The structure should be tested for water tightness.
9	Clear water reservoir	For storage of clear water, and is provided with scour/over flow pipes. Structure should be tested for water tightness.
10	O H S R	[illegible]

4.2. POINTS TO BE NOTED:

1. All stipulations as per IS 456, IS 3370 Part I to IV, IS 1893, SP24 and other relevant codes shall be adhered to
2. Quality control of various items in this Work shall be governed by the provisions of Kerala PWD Quality Control (QC)Manual approved vide GO(Rt) No-1339/2015/PWD dated 10-9-2015 and Kerala PWD Quality Control laboratory Manual approved vide GO(Rt) No-1346/2015/PWD dated 11-9-2015 and subsequent modifications if any.
3. The intending bidders are expected to familiarize with the contents of QC manual before participating in the bid.
4. Technical audit as envisaged in clause 2406 of the revised PWD Manual-2012 shall be carried out for this Work. The contractor shall extend full cooperation to the agency entrusted with the technical audit.
5. The contractor shall extend full cooperation to the departmental officers of quality control wing for taking samples, curing and keeping them in safe custody whenever required. The contractor shall issue proper acknowledgement for samples so kept in his safe custody.
6. The contractor is to mobilize technical personnel who are well versed with quality control tests and other guidelines stipulated in the QC manual.
7. For Works or works costing more than Rs.200 lakhs, the selected Contractor shall establish site laboratories with required facilities as specified in PWD Laboratory Manual.
8. The contractor is responsible for ensuring quality of each item of work in this contract.
9. Being the agency entrusted with execution of the Contract, the primary responsibility for ensuring quality of each item of work in this Contract is vested with the Contractor. Engineer or his Representative shall issue guidelines as and when required for ensuring Quality Control, which the Contractor has to follow.
10. The Engineer and his Representative shall have the right to direct Contractor to remove materials supplied which do not conform to standards specified.
11. For works costing more than Rs.200 lakhs, the contractor shall conduct first tier quality control tests for all items of work at the site laboratory as per the procedure stipulated in the PWD Quality Control Manual at his own expense.

12. The Contractor is bound to carry out rectification works at his own cost, if results obtained during quality control tests either in the first tier or second-tier do not comply with the standards. He shall also carry out rectification works, if any pointed out during technical audit done after completion of work.

13. The decision of the Engineer-in-charge regarding compliance of test results and rectification works to be done shall be final and binding on the contractor.

14. Payment for works which are to be re-done or rectified will be made only after the Engineer-in charge, after inspection, certifies in writing that the rectifications have been done satisfactorily and the results of the tests conducted after the rectification comply with the specified values.

15. Third party testing shall be done in an independent approved laboratory, if there is dispute due to difference in the test results of first tier and second-tier testing or if any manipulated results are suspected. In case, certain specific tests cannot be carried out with the facilities available in the Contractor's site laboratory or the Department laboratories, third party testing shall be resorted to.

16. Engineer in charge shall decide whether third party testing is required to settle a dispute. His decision will be final and binding on the Contractor.

17. Third party tests, if approved by the Engineer-in charge shall be arranged by the Contractor in an approved laboratory as directed by the Engineer-in-charge. It is desirable that the test shall be done in the presence of the representatives of the Engineer-in charge and the Contractor to eliminate any further disputes. The expenses shall be met by the Contractor. The result obtained in the test shall be final and binding on both the Contractor and the Employer.

18. Wherever specified, the contractor shall also obtain manufacture‟s test certificate from the manufacturer/dealer and submit the same before executing the items listed in such certificates. Contractor shall be responsible for the genuineness of the Manufacturer's Test Certificate obtained and submitted by him. He shall record a statement in the Manufacturer’s Certificate that “This Certificate for supply of ....(Name of material with item no in BOQ) has been obtained by me from .. ..(Name and address of Manufacturer/Dealer) on ...... (date of receipt of certificate) for the actual materials supplied at site.

19. The rate quoted by the bidder shall include all expenses for carrying out the first tier quality control tests. Expenses for third party tests as detailed in clause 7.4 of the introduction to QC Manual, if required, shall also be borne by the Contractor.

20. All cutting and drilling of walls or other elements of the building or structure for the proper entry/installation of inserts, boxes, equipment, etc. shall be carried out using electrically operated tools only. Manual drilling, cutting, chiseling, etc. shall be permitted with the written approval of Agreement authority. No structural member shall be cut or chased without the written permission of the Engineer-in-Charge. Cutting and drilling of structural members shall be carried out using vibration free diamond wire sawing and diamond drilling only with prior permission from the Engineer-in-Charge. The costs for procurement and using such equipment are deemed to be included in the Contract and no extra costs will be paid.

21. Horizontal cutting of walls or other supporting structural elements for laying pipe conduits, water supply lines etc., shall be avoided as far as possible. Conduits shall be laid through lintels or slabs or similar elements without affecting the structural safety. The conduits shall be connected to the required locations though vertical cuts in the walls or the supporting elements.

22. Contractor shall make his own arrangement for electricity and water for construction purposes. The water used for construction purpose shall be potable and tested once in every 6 (six) months. The source of water shall be approved by the Engineer-in-charge.

23. The contractor shall arrange the water good for construction and personal use at his own cost and shall be responsible for all further connections, pumps, pipes, storage facilities and all other things necessary to distribute and use services from this distribution point.

24. The electricity required for Construction Work shall be arranged by the Contractor from the authorities and/ or generators provided at site at his own cost. Contractor shall be responsible for all distribution points as may be required for the Work. The Contractor shall also make arrangement for alternative standby services at his own cost in the form of additional Generators of adequate capacity (day and night) so that there is no delay in progress of Work as per construction schedule submitted by him and approved by the Engineer-in-Charge. Contractor shall ensure adequate capacity of generators to support such load sharing with other vendors.

25. The Contractor shall prepare schematic distribution diagrams of distribution of electricity and water for construction purposes incorporating all safeties and get them approved by the Engineer-in- Charge, the distribution at site shall be in accordance to the approved schematic. The contractor shall ensure incorporation and strict implementation of all safety parameters, equipments, instruments and directions given by the Engineer from time to time in this regard.

26. The contractor shall install the temporary distribution lines for water and electricity ensuring that work of other agencies / vendors is not interrupted or hampered. In case during the course of construction these lines foul or interrupt or hamper the work of other agencies / vendors, the contractor shall remove and relocate the service lines and relocate the same at his own cost within the time stipulated by the Engineer-in-Charge.

27. All statutory Fees, & miscellaneous expenses and costs for electric power and Water connection for construction purposes shall be borne by the Contractor.

28. Protection / preservation of trees: Contractor shall take all measures necessary to ensure the protection and preservation of existing trees within / outside the boundary of the site. Contractor shall be responsible of any damage / casualty to the trees happening as a result of his working at site and for 95 any action, claim, penalty or expenses imposed by the forest / any other department. No claim / payment shall be payable to the contractor on this account.

29. No subcontracting shall be done without prior written approval of Agreement Authority. Maximum value of works to be sub-contracted is limited to 25% of Contract value. The value of a sub-contract and Provisional Sums items as and when awarded, should be intimated by the Contractor to the Engineer-in charge and it should also be certified that the cumulative value of the sub-contracts awarded so far is within the aforesaid limit of 25%. A copy of the contract between the Contractor and Sub-Contractor shall be given to the Engineer within 15 days of signing and in any case 7 days before the Sub Contractor starts the Work and thereafter the Contractor shall not carry any modification without the consent in writing of the Engineer. The terms and conditions of sub-contracts and the payments that have to be made to the subcontractors shall be the sole responsibility of the Contractor. Payments to be made to such sub-contractors will be deemed to have been included in the Contract price. However, for major sub-contracts (each costing over Rs 50 lakhs), it will be obligatory on the part of the Contractor to obtain consent of the Engineer. The Engineer will give his consent after assessing and satisfying himself of the capability, experience and equipment resources of the sub-contractor. In case the Employer intends to withhold his consent, he should inform the Contractor within 15 days to enable him to make alternative arrangements to fulfill his programme.

30. The Contractor shall provide sufficient superintendence, whether on the site or elsewhere, to ensure that the work to be carried out by a sub-contractor complies with the requirements of the Contract.

31. The proposed sub-contract terms and conditions shall impose on the sub-contractor such terms of the Contract as are applicable and appropriate to the part of the Works to be sub-contracted, to enable the Contractor to comply with his obligations under the Contract.

32. Notwithstanding any consent to sub-contract given by the Engineer, if in his opinion it is considered necessary, the Engineer-in charge shall have full authority to order the removal of any subcontractor from the Site or off-Site place of manufacture or storage.

4.3 WATER TREATMENT UNITS : CHECKLIST

Sr. No	Material/ Equipment	Tests/ Frequency of test	Size of Sample	Authority to conduct test	Witness to test	Location of conducting test-manufacturer's place/ Site/ laboratory	Remark
1	Clarifier						
	Scraper drives	Running test	100%	Manufacturer	PHED	Manufacturers works / site	
	Agitators	Running test	100%	Manufacturer	PHED	Manufacturers works / site	
	Flocculates	Running test	100%	Manufacturer	PHED	Manufa¢tp rem wo	
	Dosing / transfer pumps	Performan ce test	100%	Manufacturer	PHED	Manufacturers works	
	Plates	Material test certificate	100%	Manufacturer	Record verification	Manufacturers works	
	Sluice gates	Leakage test	100%	Manufacturer	PHED	Manufacturers works	
2	Filter						
	Pumps	Performan ce test	100%	Manufacturer	PHED	Manufacturers works	
	Air blower	Performan ce test	100%	Manufacturer	PHED	Manufacturers works	
	Nozzles	Material test certificate	100%	Manufacturer	Record verification	Manufacturers works	
	Sand	Gradation test	100%	Manufacturer	Record verification	Manufacturers works	
	Wash water recirculation pump / plant	Performan ce test	100%	Manufacturer	PHED	Manufacturers works	
	Clarifier	Running	100%	Manufacturer	PHED	Manufactvrera	

Sr. No	Material/ Equipment	Tests/ Frequency of test	Size of Sample	Authority to conduct test	Witness to test	Location of conducting test-manufacturer's place/ Site/ laboratory	Remark
	sludge processing plant	test				works / site	
	Compressor	Performance test	100%	Manufacturer	PHED	Manufacturers works	
	Piping and valves	Material test certificate	100%	Manufacturer	Record verification	Manufacturers works	
3	Raw water/ Clear water / Back wash pumps	Material test certificate	100%	Manufacturer	Record verification	Manufacturers works/ Laboratory	
		Dynamic balancing	100%	Manufacturer	Record verification	Manufacturers works	
		NDT/Surface finish on shaft and impeller	100%	Manufacturer	PHED	Manufacturers works/ Laboratory	
		Hydro test of casing	100%	Manufacturer	Record verification	Manufacturers works	
		Performance test	100%	Manufacturer	PHED	Manufacturers works	BS 5316 Part 2
4	Pressure filters	Material test certificate	100%	Manufacturer	Record verification	Manufacturers works/ Laboratory	
		Welding qualification		Manufacturer	Record verification	Manufacturers works	
		Heat treatment	100%	Manufacturer	Record verification	Manufacturers works	
		Hydro test	100%	Manufacturer	PHED	Manufacturers works	IS 2825

All filter media shall be supplied in polytene bags.Care should be taken to protect the media from spillage or contamination.storage on site shall be on approved area,well drained and free of mud or silt.The media shall be carefully placed in the filter and shall not be dropped or machine handled so as to be detrimental to the floor media, nostrils or sealants.

Before filling the supporting layers and the sand of the filter beds the whole under drain system shall be thoroughly cleaned and tested for equal distribution of water. Each filter shall have central and lateral wash water troughs that shall be connected with adequate slope to the wash water outlet. The filter backwash water ultimately be discharged to Recycling (Buffer) tanks.

a. INSPECTION AND TESTING OF PLANT

4.4. A Off-Site inspection

A.1.1 General

The Contractor shall offer all items of Plant for inspection by the Engineer at all stages of manufacture and shall include for the testing of all Plant as required by the Specification. The Engineer/Employer/Third Party Inspection Agency may witness any test, at his sole discretion.

The off-Site tests shall normally be carried out at the manufacturer's works but if the tests are beyond the resources of the manufacturer, the Contractor shall make arrangements for tests to be carried out elsewhere. The off-site testing may be witnessed by the Engineer or by inspectors appointed by the Employer. All travel and out of pocket expenses, eg. air tickets, accommodation, allowances, professional charges, etc. incurred by the inspectors in attending any test will be paid by the Contractor and the same will be reimbursed to the Contractor at actuals out of the PROVISIONAL SUM included in the Price Schedule. Details of Inspection Agency and the details of agreement between Third Party Inspection Agency and the Employer will be notified to the successful Contractor.

No Plant or materials for inclusion in the Works shall be despatched from any manufacturer's works without the written permission of the Engineer. Any Plant or materials despatched without permission shall be returned and tested in accordance with the Specification at the Contractor's expense.

If during off-site testing, any Plant or materials fails to meet the requirements of the Specification, the defects shall be rectified forthwith. The rectified item shall be offered for re- inspection and witness testing, and all resulting additional costs incurred shall be borne by the Contractor.

The Contractor shall carry out all applicable tests required by the Specification and the Reference Standard, together with such tests as are necessary, in the opinion of the Engineer to demonstrate that the Plant or materials comply with the Specification.

When the Contractor is ready to carry out any off-Site test, he shall submit a detailed test procedure to the Engineer. The proposals shall give values, such as test parameters and make reference to Reference Standards, any other standards and manufacturer's literature. The proposed format for the test sheets shall be submitted at the same time. The testing shall not start until the Contractor's proposals and test sheets have been approved by the Engineer. After receiving approval, the Contractor shall notify the Engineer of the place and time of the proposed tests giving not less than fifteen working days notice.

The Contractor shall carry out every off-Site test at the time and place notified. If the Engineer does not attend any test, then the Contractor shall carry out the test in the absence of the Engineer and the certified copies of the test results shall be deemed to be a correct record. The Contractor shall provide the Engineer with three certified copies of the test results within two weeks of completing the tests. Enough information, including the Contract number and title, shall be given on each test certificate to enable the Engineer to check for compliance with the Specification.

No inspection or approval by the Engineer of the Plant or materials covered by the Contract

shall release the Contractor from any of his obligations under the Contract.

Where items of Plant are of identical size and duty the Engineer may elect not to witness all tests, but the Contractor shall assume that the performance tests on all items will be done prior to offering any Plant for witnessed testing.

A.1.2 Calibration of instruments

All instruments used for testing purposes shall have been calibrated by an independent accredited testing authority and shall have a valid calibration certificate.

The calibration validity period shall not be longer than 12 months. Instruments used for tests at site shall have been calibrated not more than 3 months before the start of testing.

The Contractor shall provide the Engineer with three copies of calibration certificates and correction graphs etc at the time of testing.

Any test instruments shall be recalibrated if requested by the Engineer.

A.1.3 Test procedure

The procedure and requirements for all tests off-Site on all Plant or materials shall be in accordance with the requirements of the Specification and shall in addition be in accordance with the requirements of the Reference Standards applicable to the item being tested.

A.1.4 Guaranteed performance

The figures entered in the Schedule of Technical Particulars or stated in the Contract for performance and efficiency shall be guaranteed by the Contractor in respect of the Plant offered at the duties specified. These figures will be binding and may not be varied except with the written approval of the Employer. No tolerances are permitted on these figures. Testing to the relevant standards and to prove guarantees given will be required for all Plant and materials and the complete Works.

A.1.5 Test records

For any test required by the Contract, the Contractor shall produce a written record, in a form approved by the Engineer, certifying that the test has been completed. The Contractor's representative at the test shall sign the test record. The tests witnessed by the Engineer's Representative shall be certified by the Engineer's Representative on the same test record.

A.1.6 Certificates

Certificates of test in triplicate shall be provided by the Contractor for all off-Site tests. These shall incorporate all test results, calculations, performance graphs and curves and shall be signed by representatives of the manufacturer, Contractor and Inspector. These certificates shall be provided within two weeks after completing the test. Copies of all test certificates shall be included in the operating and maintenance manual.

A.1.7 Notification

Following any inspection or testing of Plant or materials, the Engineer shall notify the Contractor in writing either that:

- the item has passed the tests;
- the item on any part thereof is defective;
- the item is not in compliance with the Specification; or
- the item has not met guaranteed performance or efficiency requirements not in compliance with the Specification.

The Engineer shall state the grounds on which the decision is based.

A.2. Site inspection and testing

A.2.1 Inspection

During erection of the Plant the Engineer will inspect the installation from time to time in the presence of the Contractor to establish conformity with the Specification. Any deviations found shall be corrected forthwith to the satisfaction of the Engineer.

As soon as the Engineer is satisfied that the erection of the Plant in an installation has been completed and the Plant found to be in good working order and that the associated civil works have been substantially completed to an extent permitting the proper operation of the plant, the Contractor shall start testing at Site.

A.2.2 Testing - general

Stages of testing at the Site shall be as follows:-

- Individual tests (also called pre-commissioning tests) which shall be at the first opportunity after installation of the Plant;
- Commissioning tests which shall be on whole systems to demonstrate to

the Engineer that a section of the Works is ready to undergo trial operation;

- Trial operation.

Before any testing involving water entering supply, disinfection of all Plant items in contact with water to be supplied shall be undertaken by the Contractor. The disinfection of structure and pipework shall be generally in accordance with clause A10.5 and subject to the approval of the Engineer.

When water is discharged to waste, the Contractor may, subject to such conditions as the Engineer and Employer may lay down, operate and adjust the Plant as necessary in order to test the operation of the Plant. No water shall be put into supply except with the prior authorisation of the Engineer and Employer and under such conditions as they may lay down.

No part of the Plant shall be set to work until it has been inspected and accepted by the Engineer.

A.2.3 Testing programme

The Contractor shall submit to the Engineer for his approval a programme for testing up to the issue of the Taking-Over certificate, at least 28 days in advance of the proposed start of testing and shall agree the timing with the Engineer and Employer not less than one week before the start of testing.

The programme shall show the quantities of raw water, chemicals and power required. Details of the proposed test procedures shall be submitted by the Contractor, including the manner and order in which each item of Plant and process will be tested. Associated flow rates and durations shall be submitted, and log sheets shall be prepared for recording plant information and other operating, water quality parameters, and presentation and interpretation of test data.

The programme shall be subject to approval by the Engineer and shall take into consideration

the extent of progress on other contracts, the availability of water, chemicals and power, and the Employer's requirements for disinfection and discharges either to supply or to waste.

The Contractor and any specialist sub-contractor shall be available to attend meetings at the Site to discuss the testing programme, the test details and the test results.

A.2.4 Labour, materials and sundry items for tests

For individual tests, commissioning tests and trial operation, the Contractor shall provide all necessary labour, materials, chemicals, electricity, fuel, stores, apparatus, instruments and indicators necessary to carry out the tests. Water and electricity used for the tests shall be recorded on suitable meters provided by the Contractor, which shall be read by the Engineer in the presence of the Contractor at appropriate times. Water and electricity consumed as a result of testing activities shall be paid for by the Contractor. The Engineer will from time to time deduct the cost of supplying water and electricity to the Contractor from the Contractor's monthly progress claims.

During testing of the Plant, until the issue of the Taking-Over Certificate, the Contractor shall be responsible for all work, plant and costs in connection with the commissioning of the Works.

All measuring instruments used for testing purposes shall comply with clause A9.1.2.

The Contractor shall prepare test record sheets for recording of all test results for the approval of the Engineer at least one month before the programmed date for the tests. Three copies of each approved sheet shall be provided to the Engineer not less than one week before the start of testing.

A.2.5 Individual tests

Individual tests shall be in the presence of the Engineer and shall include the following:-

- Leakage tests for structures and tanks;
- Leakage tests for pipework.

Leakage tests shall be carried out on all pipework. Where pipework is to be built in, these tests shall be carried out after erection and before concreting. The Contractor shall ensure that the pipework is suitably anchored and supported to sustain the pressure in the not-built-in condition.

Pipelines and valves shall be pressure tested to one and a half times working pressure unless otherwise specified.

Pipework and valves through which oil or gas is to be conveyed shall be thoroughly inspected then tested with the oil with which they are to be used or an inert gas and the whole checked for leakage. Hydraulic tests using water shall NOT be applied to this pipework.

Tests on all items of Plant and materials in accordance with the requirements of the Specification shall also be in accordance with the requirements of the Reference Standard applicable to the item being tested.

- Electrical tests to demonstrate compliance of the electrical installation

with specified and statutory requirements;
- Operational test for all valves;
- Running test for all pumps, blowers, compressors, etc.;
- Noise and vibration levels measurements shall be carried out for all rotating equipment.

A.2.6 Functional test of all protective devices.

All individual tests on items of plant or equipment making up a complete system shall be completed to the satisfaction of the Engineer, before starting the commissioning tests on that system.

A.3 Commissioning tests

The Contractor shall carry out such tests and retests on complete systems as are required to demonstrate to the satisfaction of the Engineer that substantial portions of the Works are ready to undergo the trial operation with a minimum of interruption in regular operation.

The commissioning tests shall demonstrate satisfactory performance of the items of Plant under normal operation and their response to abnormal and emergency conditions.

Each process system shall be set to work under manual control and commissioning tests shall be carried out for such time as is agreed by the Engineer as being appropriate. Subsequently the automatic control equipment shall be set to work and further commissioning tests shall be done.

The tests shall include simulation of the full ranges of alarm conditions over the full ranges of operation and include tests of emergency shutdown procedures including electricity power failure.

The period of commissioning tests shall finish after the Plant has been satisfactorily operated by the Contractor, as certified by the Engineer, for a continuous period of fourteen days or for such extended period in excess of 14 days as may be required by the Engineer to make up for interruptions in operation. However, the Contractor will not be required to run the Plant under the provisions of this clause more than once for one continuous fourteen day period.

The Contractor shall use the 14 day period to optimise the water treatment process.

During the 14 day period or after the Trial Operation as decided by the Engineer, the Contractor shall demonstrate the hydraulic capacity of the works and overflows at the maximum works throughput with:

- all process units in service
- one clarifier out of service,
- two filters out of service,
- one compartment of contact tank of service, and
- one compartment of treated water reservoir out of service.
- one thickener out of service.

During the hydraulic capacity tests, the Contractor shall measure water levels at various points corresponding to the points where levels are identified on the approved hydraulic profile drawing and shall also measure the free board at these points and at overflow points.

A.4 Trial operation

A.4.1 General

The Contractor shall start the trial operation when the following conditions have all been completed:

- commissioning tests have been successfully completed;
- the Plant is ready;
- draft operating and maintenance manuals have been submitted; and
- the Employer's staff have received full training as specified.

Trial operation shall be carried out on Sections of the Works and on the Works as a whole, as appropriate.

In addition, certain tests to demonstrate compliance with guaranteed or specified performance of particular items of Plant or parts of the Works shall be carried out independently from the Trial operation for the Works or Section of Works. These independent tests shall also be a condition precedent to the issue of the Taking-Over Certificate for the whole of the Works.

The trial operation shall demonstrate that the Works can fulfil all the mechanical, electrical, instrumentation, control and automation and process requirements of the Specification in the ambient conditions prevailing, using the raw water available at the time.

The Works shall be tested for performance for a continuous period of ten days, of which at least the last seven days shall be uninterrupted by other tests. During the seven day tests the Works shall be operated at the maximum output for at least 4 days as instructed by the Engineer. The object of the tests shall be to obtain a comprehensive set of data to show that treatment performance meets the Specification and performance guarantees specified over a range of flows within the design capacity limits. Following each flow change and after a period of plant stabilisation all process and water quality parameters shall be measured and recorded for comparison against the Specification and performance guarantees relating to:-

- Works output;
- Clarified water quality;
- Filtered water quality;
- Treated water quality;
- Filter run duration;
- Clarifier sludge discharge;
- Filter washwater consumption;
- Thickener supernatant turbidity;
- Any other parameter.

During the 10 day performance trial period, the Contractor shall collect samples and carry out analyses for the parameters listed in accordance with the sampling schedule at the end of this section of the Specification.

Every sample taken shall be divided into three equal portions; one portion shall be used for analysis by the Contractor's chemist, in accordance with the schedule. This analysis shall be witnessed by the Employer's chemist. The second portion may be used by the Employer for analysis at the discretion of the Employer. The third portion shall be retained as a check sample. The sample volume shall be at least 3 litres.

The Employer may, at its own discretion, carry out additional sampling and tests at its own laboratories or accredited laboratories as it deems necessary.

The methods to be used to analyse the listed parameters shall be as given in Standard Methods for the Examination of Water and Wastewater; APHA-

AWWA-WPCF, 20th Edition, 1998, as follows:-

Parameter	Method Reference
Turbidity	2130-B
Colour	2120-C
pH	4500-H^+ B
Alkalinity	2320-B
Aluminium	3500-Al E
Iron	3500-Fe D
Manganese	3500-Mn D
Chlorine residual	4500-Cl G
Bacteriological quality	9222-B and D

Any deficiencies or deviations from the guaranteed or specified performance of plant disclosed by the tests shall be corrected by the Contractor and tests shall be repeated as necessary until acceptable results are achieved to the satisfaction of the Engineer.

These tests shall require provision of facilities and man-power, organisation and a high degree of co-operation between the Contractor and the Employer and it shall be deemed that this has been taken into account in the rates and sums entered in the Schedules.

The Contractor shall be responsible for collecting and collating all data and test results and shall carry out all necessary calculations to confirm compliance with the Specification and Performance guarantees. A report comprising test data, results, calculations and conclusions shall be submitted within one week of the date of completion of the tests, or set of tests.

Satisfactory completion of the Tests on Completion is a prerequisite for the issue of the Taking over Certificate for the whole of the Works.

The test procedures to be used for the Tests on Completion during the specified periods shall be as follows:

(a) Works output

The Works output shall be the difference between the clarified water flow and the filter washwater flow. Clarified water flow shall be measured at the common clarifier outlet using the flowmeter in the pipe connecting the clarifiers and the filters totalised during the period when the works is operated at the maximum flow. Filter washwater flow shall be measured in the washwater outlet pipe from the washwater holding tank totalised during the period when the works is operated at maximum flow.

(b) Water quality

Samples of clarified water, filtered water and treated water shall be taken at the specified frequencies and tested by the methods listed in the Specification. Sampling at clarified water and filtered water shall be separated by about two hours and that between filtered water and treated water by about one hour to ensure that the same parcel of water is sampled in one sampling event. The failure of one or more of water quality parameters in filtered water and treated water shall be deemed to be a failure of the water quality test.

(c) Clarifier sludge discharge

Works input shall be monitored at the inlet flowmeter to the works and shall be totalised throughout the test. Losses due to clarifier desludging shall be the works input less the clarified water flow as defined above.

(d) Filter washwater consumption

The total quantity of washwater used during the test period measured at the washwater flowmeter divided by the total quantity of the Works input as defined above for the same period, multiplied by 100 shall be not greater than the filter washwater consumption as stated in the Schedule of Guarantees.

(e) Works chemical consumption

The chemical consumption on the plant to achieve the specified water quality guarantees during the test period shall be not greater than the chemical consumptions stated in the Schedule of Guarantees.

(f) Works energy consumption

The electrical energy consumption of the Works comprising raw water pumping plant, treatment plant and treated water pumping plant over the test period shall be evaluated on the basis of maximum demand and units used and shall be divided by the volume of raw water treated over the same period.

The electrical energy consumption of the Works shall not be greater than the electrical energy consumption stated in the Schedule of Guarantees.

A.4.2 Test failures

If the performance during the tests of the Works (or any parts thereof) fails to comply with the Specification or with the Contractor's performance guarantees, the Contractor shall submit his proposals for meeting the requirement of the Specification and the guarantees to the Engineer for his approval and shall carry out at his own expense, whichever measures may be necessary to achieve the specified requirements. Such measures may include improvements, alterations or additions to the plant and/or civil works and the Contractor shall bear the whole cost of such modification including any changes to the civil, electrical, instrumentation or mechanical works.

The tests shall be completely repeated and shall be continued until the Engineer is satisfied that the requirements of the Specification and the guarantees have been met.

Failure of any item of equipment or part of the Works which is tested for performance as a separate exercise during the Commissioning Tests will require the Contractor to repeat the complete Commissioning Test, as specified.

Failure of any one or more of the tests which forms part of the overall Works commissioning test will require the Contractor to repeat the complete commissioning test. The duration of repeat commissioning tests shall be not less than seven days.

In case of repeated failure, the Contractor shall continue to make adjustments to the Plant and repeat the tests until full compliance is reached, or until the Employer, at it’s sole discretion, decides to accept the Plant, despite the failure of the commissioning tests. In this event the Contractor shall pay delay damages to the Employer as specified.

A.4.3 Sampling Schedule

Parameters	Minimum sampling freq/24hrs
Raw water Turbidity Colour (true) Iron pH	 Every six hours Every six hours Every six hours Every six hours
Parameters	**Minimum sampling freq/24hrs**
Conductivity Alkalinity Manganese Total coliforms	Every six hours Every six hours Every twenty four hours Every twenty four hours
Aerated water (where applicable) Iron pH Alkalinity	 Every four hours Every four hours Every four hours
Clarified water Turbidity Aluminium pH Alkalinity	 Every one hour Every four hours Every four hours Every four hours
Filtered water Turbidity	 Every two hours Every

Aluminium Iron	four hours Every four hours
Treated water Turbidity Colour pH PHs Aluminium Iron Manganese Chlorine residual - total - free Bacteriological quality	 Every two hours Every eight hours Every two hours Every twelve hours Every eight hours Every eight hours Every twenty four hours Every two hours Every two hours Every twenty four hours
Thickener supernatant Turbidity	 Every twelve hours

A.5 Cleaning and sterilisation of structures

The greatest care shall be taken to ensure that all process unit tanks are kept free from contamination.

In addition the following structures shall be sterilised in accordance with the procedure set out below: -

- Pipes, channels and mixers from filter outlets to treated water reservoir;
- Chlorine contact tank and treated water reservoir;

- Pipe feed to treated water pumping station (where applicable);
- Treated water pumping station pipework (where applicable);
- Treated water surge vessels (where applicable);
- Treated water pumping or gravity main as applicable up to a point 1 m outside the site boundary;
- Balancing reservoir, balancing tank or service reservoir as applicable and the outlet main up to a point 1 m outside the site boundary;

The Contractor shall subject all workmen who will be engaged in sterilising structures to a medical examination by a doctor Approved by the Employer. Only workmen considered fit by the examining doctor shall be permitted to enter the structure for carrying out any work associated with the sterilisation procedure. The Contractor shall keep a separate register of all such labour and shall forward a copy to the Engineer prior to commencing such work. The Contractor shall maintain strict supervision over all workmen entering the tanks. The Contractor shall provide rubber boots and means for the workmen to wash their boots clean and sterilise them before entering the structure.

The Contractor's sterilisation procedure shall strictly adhere to Chlorination Method 3 as set out in Section 4.3 of AWWA Standard C652-92, 'Disinfection of water-storage facilities' and C651-99 'Disinfection of water mains'. The Employer will carry out the necessary sampling in the presence of the Contractor, and the subsequent physical and bacteriological analysis. The Engineer will advise the Contractor of the results. Should the tests fail the procedure shall be repeated as many times as may be necessary to achieve satisfactory results.

The Contractor shall make all arrangements necessary for conveying the water from the source to the point of filling and such arrangements shall be subject to the approval of the Engineer. The Contractor shall provide all hoses, pumps and other equipment necessary to carry out the tests. The Contractor shall also provide all water and chemicals necessary to sterilise structures, which shall be of a type and from a source Approved by the Engineer.

The Contractor shall note that these structures are Confined Spaces as defined in the Specification and that during the sterilisation process the levels of chlorine in the atmosphere may exceed acceptable occupational exposure limits. The work shall be subject to the specified requirements for entry and working in Confined Spaces, and the Contractor shall provide all necessary trained personnel and equipment as specified.

A.6 TESTING OF PLANT

A.6.1 General

The requirements for testing shall be as specified below.

A.6.2 Pumps, valves and pipework and general purpose machinery

A11.2.1 Off-site inspection and testing

(a) Pumps

Pumps shall be individually tested in accordance with BS EN ISO 5198 Part 2 (Class B) and the tests shall be with clean water. Site conditions shall be simulated as nearby as possible including the NPSH condition. Pumps shall be tested with their own prime movers. Where it is impracticable to include the full length of the connecting shaft, the Contractor shall state the allowances to be made for the losses incurred by its omission and shall demonstrate the accuracy of the allowances to the satisfaction of the Engineer.

Pumps shall be tested at the guaranteed duty point and over the full working range from the closed valve condition to 20 percent in excess of the quantity when a single pump runs alone at minimum head. The tests shall provide information for performance curves to be drawn for head/quantity, efficiency/quantity, power absorbed/quantity and nett positive suction head/quantity. Readings shall be taken at a minimum of seven points in addition to shut-off condition. Each pump shall also be run at its duty point for at least 30 minutes.

Positive displacement pumps shall be tested in accordance with BS EN ISO 9906.

For eccentric helical rotor pumps the tests shall provide information for performance curves to be drawn for pump speed/flow, input power absorbed/flow differential pressure/flow and pump efficiency/flow.

Pump casings shall be subject to a pressure test at 1.5 times the pressure obtained with the delivery valve closed. The positive suction head when installed shall be taken into account in determining this pressure. During the test, the casing and joints shall show no signs of leakage, distortion or defect.

In addition to confirming the specified hydraulic performance of the pumpset, the test shall demonstrate that vibration is within the specified limits, the mechanical performance is satisfactory and the noise level is within the specified limit.

Additionally chemical dosing pumps shall be tested in accordance with API standard 675 and the specified flow linearity, steady state accuracy and flow rate shall be demonstrated.

(b) Valves and Penstocks – General

Valves and penstocks specified as operated by actuators shall be tested with their own actuator. For valves and penstocks fitted with power operated mechanisms, the test shall be carried out to demonstrate correct manual and power operation.

(c) Gate valves

Gate valves shall be tested in accordance with BS EN 1171 or BS 5163 and BS 6755 Part 1 as relevant. Whichever applies, valve seat tests shall be made under open-end conditions, the test pressure being applied to each face of the valve in turn.

(d) Butterfly valves

Butterfly valves shall be tested in accordance with BS EN 593 and BS 6755 Part 1. The seat test shall be for tight shut-off and low leakage. Valves shall be tested under maximum unbalanced water test pressure in either direction.

(e) Air valves

Air valves shall be water tested for drop-tightness at all pressures from 0.2 bar in steps of 2 bar up to the specified pressure. The valve body shall be water tested at 1.5 times the specified pressure, at which pressure no damage or permanent deformation of the valve body, ball or seat shall occur.

Two valves of each type and size incorporating large orifices shall be tested for exhaust of air at a differential pressure up to 1 bar in steps of 0.1 bar and for inflow of air at a differential pressure up to 0.5 bar in steps of 0.1 bar. During the tests the air flow rates shall be measured by orifice plates in accordance with BS 1042. Pressures (positive or vacuum) shall be measured by Bourdon tube gauges or by mercury-in-glass manometers. The temperature of the flowing air shall be measured in accordance with relevant parts of BS

1041. The barometric pressure shall also be measured.

If the manufacturer provides results of independently witnessed air flow tests similar to those specified and these are accepted by the Engineer, the specified airflow tests shall be deemed to be completed.

(f) Check valves

Check valves shall be tested in accordance with the requirements of BS EN 12334 and BS 6755 Part 1.

(g) Pressure and flow control valves

Pressure and flow control valves shall be tested hydrostatically as follows:-

Body strength: closed-end test, valve open, test pressure 1.5 times working pressure;

Valve element strength: open-end test, valve closed, test pressure of 1.5 times working pressure applied to each end;

Leak tightness: open-end test, valve closed, test pressure of the working pressure applied to inlet end, no visible leakage permitted.

(h) Ball float valves

Ball float valves shall be tested hydrostatically in the closed position and a pressure of 1.5 times the working pressure applied to the inlet end.

Valves shall be tested for drop-tightness at the working pressure.

(i) Plug valves

Plug valves shall be subject to hydrostatic shell and seat tests in accordance with BS 5158 and BS 6755 Part 1.

(j) Diaphragm valves

Diaphragm valves shall be tested in accordance with BS EN 13397 and BS 6755 Part 1.

(k) Ball valves

Ball valves shall be tested in accordance with BS 5159 and BS 6755 Part 1.

(l) Globe valves

Globe valves shall be tested in accordance with BS EN 13789 and BS 6755 Part 1. Seating shall be tested hydrostatically at 2400 kN/m^2 and the valve shall be tested for 1500 kN/m^2 working pressure.

(m) Penstocks

Penstocks shall be operated from fully closed to fully open positions to verify correct operation.

Penstocks shall be tested in accordance with BS 7775 and AWWA C501 as relevant.

(n) Electric actuators

Electric actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

(o) Pneumatic actuators

Pneumatic actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

(p) Pipework

Pipework shall be tested in accordance with the appropriate Reference Standards.

(q) Castings

Castings shall be tested hydrostatically to 1.5 times the maximum working pressure for a minimum period of 1 hour.

(r) Surge vessels

Surge vessels shall be tested in accordance with the Reference Standards.

(s) Cranes

Cranes shall be completely assembled and tested for all operations in accordance with BS 466. All slings, ropes, shackles and other lifting equipment shall be tested at 1.25 x their Safe Working Load.

(t) Weighers

All weighing equipment shall be tested for accuracy with standard weights and shall be load tested at 1.25 times the safe working load.

(u) Automatic in-line strainers

Automatic in-line strainers shall be tested in accordance with the Reference Standards and with manufacturer's own requirements.

(v) Air supply plant

Tests shall be carried out on all items of plant, vessels, pipework and valves to demonstrate compliance with the criteria specified and with relevant standards. Unless otherwise specified the tests shall be in accordance with the Reference Standards including BS 6754 for dryers, BS 6759 Part 2 for safety valves, BS 1123 Part 1 for fusible plugs, BS 3274 for aftercoolers, BS 5169 for air receivers, BS 1571 for compressors and BS 5500 for pressure vessels and the manufacturer's own procedures.

Noise level of all the compressors and blowers shall be tested and shall not exceed the specified limit.

For package units' functional tests of the fully assembled system shall be carried out to demonstrate correct operation with respect to sequence and pressure.

A.6.2.1 Individual tests

The following Site inspections and tests shall be carried out as appropriate:

(a) Inspection to check the assembly of the Plant and conformity with the Specification and consented drawings;

(b) Rotational checking of all electric motors;

(c) Hydrostatic testing of all gravity flow pipework systems and penstocks at the maximum head or differential head that can occur in service. Leakage from penstocks shall be measured and recorded but shall not exceed the maximum value stated in the AWWA C501 or BS 7775 or otherwise required for safe operation;

(d) Hydrostatic testing of all pressurised pipework systems at 1.5 x maximum working pressure for a period of at least one hour; during this time the pressure shall not change;

(e) Functional testing of each pump, compressor and blower to prove correct operation, absence of fluid leaks, correct bearing temperatures and absence of undue vibration and noise for a period of not less than four hours;

(f) Functional testing of auxiliary items including automatic in-line strainers and valve actuators;

(g) Functional testing of valves to demonstrate correct orientation and operation;

(h) Overhead cranes and slings, ropes, shackles and other lifting equipment shall be tested with a load of 1.25 x Safe Working Load and results recorded in accordance with the Reference Standards. Additionally each complete system shall be tested for all functions including overload safety device;

(i) All weighers shall be tested with standard weights for accuracy and shall be load tested at 1.25 x the Safe Working Load;

(j) The following tests shall be carried out on the installed air supply systems:

- The air pipework system shall be tested for 1 hour at 1.5 x maximum working pressure using dry air or nitrogen;
- Pressure safety valve operation shall be demonstrated;
- Performance tests shall be carried out on all machinery, coolers and dryers for a minimum period of 48 hours with air demand simulated

by purging at measured rates downstream of all plant subject to testing; the purging rates shall correspond to zero demand, maximum demand and at least one intermediate value.

- The tests shall prove correct operation, absence of fluid leaks, correct operating pressures, temperatures and dew point and absence of excessive vibration and noise with due regard to any containment and attenuation provisions.

A.7 Mixers, flocculators and scrapers

A.7.1 Off-site inspection and testing

The complete mixer, flocculator and scraper system shall be checked for accuracy of dimensions against construction drawings and all welds inspected.

A.7.1.1 Individual tests

The following Site inspections and tests shall be carried out as appropriate:

(a) Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;

(b) Rotational checking of all electric motors;

(c) Tip speed and flight speed, as applicable;

(d) Rotation speed;

(e) Functional testing of the mixers, flocculators and scrapers;

(f) Scraper torque overload protection device;

(g) Head loss across static mixers at maximum works throughput.

A.7.1.2 Commissioning tests

The testing shall incorporate the following requirements.

The performance of the static mixers shall be tested for compliance over a 30 minutes period by dosing the chemical corresponding to each mixer at the specified doses and concentrations. Alternatively a solution of sodium chloride shall be injected continuously at a fixed dose in the range 10 to 20 mg/l or a fluoride solution at 1.0 mg/l as F. The injection velocity shall not be greater than that applicable to the specified chemical dosing. The mixer performance shall be determined by measuring either the conductivity or the chloride or the fluoride ion concentration. The background conductivity value or chloride or fluoride ion concentration shall be monitored during the test. The water shall be sampled continuously at the prescribed sampling points from at least four different positions along a diameter of the pipe using a sampling system specially designed for the purpose.

A.8 Filters

A.8.1 Off-site inspection and testing

Upon preliminary approval of sources of filter material supply and within two months of the award of Contract, the contractor shall submit to the Engineer a 10 kg of representative sample of each filter material for testing and approval as specified.
Filter material (sand and gravel) shall be tested by the Contractor before despatch from source in accordance with the following schedule. Certificates for all tests shall be delivered to the Engineer for approval or rejection before the material is despatched.

(a) For a volume equivalent to the volume in each filter Grading curve, effective size and uniformity coefficient.

(b) Additionally for a volume equivalent to the volume in 2 filters Specific gravity and losses of weight on acid washing and ignition..

(c) Additionally every 500 m^3 or every batch, whichever is the smaller

Loss due to abrasion.

A method of identification shall be employed to enable test certificates to be related to shipments of media delivered to Site.

A.8.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate :

(a) On delivery to Site, one kg of filter material shall be taken from a selection of bags until 12 kg is obtained. The samples shall then be mixed and quartered before testing as follows:-

(i) Gravel: a sample shall be taken from each delivery to Site as described above and graded. Samples shall be examined to ensure they are similar to the initial 10kg sample.

(ii) Sand: samples shall be taken from each delivery to Site as described above. Tests shall include a sieve analysis and preparation of grading curves, and shall give effective size, uniformity coefficient and specific gravity. A visual inspection shall also be carried out to ensure it is similar to the initial 10 kg sample.

In addition to the above tests, certificates for each load equal to one filter volume shall include tests to determine loss on acid washing and ignition as applicable to the filter material.

(b) Inspection to check the assembly of plant and conformity with the Specification and approved drawings;

(c) Pumps and valves shall be tested as specified;

(d) Functional testing of each air blower for correct operations, absence of fluid leaks, correct bearing and gearbox temperature and absence of undue noise and vibration;

(e) Relief valve operation and blower unloading device shall be demonstrated.

A.8.3 Commissioning tests

Testing shall incorporate the following requirements :

(a) Filter underdrain

Filters shall be tested as follows before any filter material is placed and additionally, in the case of pipes lateral system before placing concrete on the pipes:-

(i) Air distribution test

The empty filter bed shall be filled with water to a level 150mm above the top of the nozzles. Air shall then be passed into the underdrain system at such a rate that the system can be seen to pass air thorough the nozzles over the whole filter area. Any discrepancies in distribution shall be rectified and the test repeated.

(ii) Pressure test with water

All the nozzle outlets shall be plugged. The filter underdrain system shall then be filled with water and a pressure of (a-b+c) applied to the underside of the filter floor or to the piped lateral system as applicable where:

a = twice the normal peak pressure during a combined air and water filter wash, or

separate air and water filter wash as applicable to the design, measured under the filter floor or in the filter laterals;

b = the downwards pressure on the floor due to the weight of media and water which would be present during air scouring;

c = the pressure due to any water present in the filter above the floor during the test.

Any pressure relief pipe on the washwater supply pipework shall be blanked off during this test. The test pressure shall be maintained for one hour. Any leaks detected shall be corrected and the test repeated.

After placing the material in the filters and backwashing to remove fines the Contractor shall take samples of the material from each filter and carry out sieve analysis and the results along with grading curves shall be submitted to the Engineer. for approval. Only when the Engineer has given approval to the samples, shall the Contractor bring the filters into service.

(b) Manual and automatic backwashing sequence shall be demonstrated

The sampling of sand in the individual filters shall be repeated in the twelfth month of the Defects Notification Period for compliance with the

Specification. The results shall be submitted to the Engineer for approval.

A.9. Chlorine Plant

A.9.1 Off-site inspection and testing

Tests shall be carried out on all items of plant, pipework and valves to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards, the manufacturers' own tests and those set out below:-

(a) Welders of chlorine plant and pipework shall be tested and approved in accordance with the requirements of the appropriate part of BS 4871;

(b) Non-destructive tests including radiography and/or other methods as specified shall be carried out on all welds in plant and pipework;

(c) All gas isolating valves shall be tested in accordance with BS 6755 Part 1;

(d) All parts of the drum lifting system and suspended weigher shall be certified for a safe working load of 3.2 t and tested with a load of 4.0 t;

(e) Changeover control panels shall be tested in accordance with tests specified for instrumentation;

(f) Spray catcher shall be subjected to hydrostatic pressure hold test of 1.5 x design pressure for at least one hour;

(g) All gas handling plant shall be subjected to the following tests:-

   (i) Vacuum hold test for 1 hour where items normally operate under vacuum;

   (ii) Pressure hold test at 1.5 times the design pressure for at least one hour using air or nitrogen. Where items normally operate under vacuum, a pressure hold test at a pressure of at least 1.5 bar g or the highest pressure that can occur under fault conditions whichever is greater shall be carried out.

(h) Functional tests shall be carried out on all shut-off valves, vacuum regulators, pressure relief valves, gas control units, ejectors and related items which shall be temporarily rigged as systems to demonstrate correct operation and calibration. Water supply pressure and solution back-pressure for these tests shall be set to the limiting values anticipated at Site.

A.9.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:-

(a) Inspection to check assembly of the Plant and conformity with the Specification and approved drawings;

(b) The pressurised gas pipework system up to the vacuum regulator inlet connections shall be tested for at least one hour at 1.5 x maximum working pressure at 40°C using dry air or nitrogen; during this time the pressure shall not change. Where necessary, system pressure gauges may be removed prior to testing. On re-instatement of the gauges, the system shall be re-tested at the gauge maximum reading;

(c) The gas pipework system from the vacuum regulators including gas control units up to the ejector inlet connections shall be subjected to the following tests each for a period of at least one hour:

(i) Vacuum hold test for one hour;

(ii) Pressure hold test at a pressure of 1.5 bar g using dry air or nitrogen;

(d) Relief valve operating pressure shall be demonstrated;

(e) The chorine solution pipework including ejectors and all components up to the point of application shall be tested hydrostatically for at least one hour at 1.5 x maximum working pressure or 5 bar g whichever is greater. Manufacturers' recommended procedures shall be followed prior to execution of this test with particular reference to:

(i) Elimination of air on filling with cold water;

(ii) Temperature equilibration;

(iii) Stepwise application of test pressure starting at not more than 3 bar g for 10 minutes.

(f) The complete drum lifting system shall be tested with a load of 4.0 t and results recorded in accordance with the Reference Standards;

(g) Suspended weigher shall be tested for accuracy with standard weights and shall be load tested at 4 t;

(h) A functional test shall be carried out on the container changeover system using dry air or nitrogen at pressures up to the maximum working pressure of the system.

A.9.3 Commissioning tests

Testing shall incorporate the following requirements:-

(a) Functional tests shall be carried out using dry air or nitrogen on the vacuum regulators, pressure relief valves, gas control units, ejectors and related items as a system to demonstrate correct operation;

(b) Following satisfactory completion of the foregoing tests, functional testing with chlorine shall be carried out to demonstrate correct operation and calibration of the Plant.

A.10 Aluminium sulphate plant **A.10.1** Off-site inspection and testing

Tests shall be carried out on all items of plant, vessels, pipework and valves to demonstrate compliance with the criteria specified and with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and the manufacturers' own procedures.

A.10.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:-

- Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Functional testing of all auxiliary items including mixers;
- All tanks shall be filled to overflow level and inspected for absence of leaks;
- Hydrostatic testing of all pipework systems at 1.5 x maximum working pressure for a period of at least one hour; during this time the pressure shall not change;
- Relief valve operating pressure shall be demonstrated;
- Functional testing of each pump to prove correct operation, absence of fluid leaks, correct gearing and gearbox temperatures and absence of undue vibration and noise.

A.10.3 Commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing (without aluminium sulphate) of the batching system to demonstrate correct operation with respect to sequence, time, and levels;
- Functional testing of the batching system with aluminium sulphate to demonstrate correct operation and calibration;
- Dosing equipment calibration shall be demonstrated and specified

accuracies shall be confirmed.

A11. Hydrated lime plant

A11.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and manufacturers own procedures.

A11.2 Individual tests

The following Site tests shall be carried out as appropriate:-

- Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Functional testing of all ancillary items including mixers;
- The slurry tanks and saturators shall be filled with water to overflow level and inspected for absence of leakage;
- Water and slurry pipework and all components up to the point of application shall be tested hydrostatically for one hour at 1.5 x maximum working pressure;
- Relief valve operating pressure shall be demonstrated;
- Functional testing of each pump to prove correct operation, absence of fluid leaks, correct beaming and gearbox temperatures and absence of undue vibration and noise.

A11.3 Commissioning tests

Testing shall incorporate the following requirements:-

- Functional tests shall be performed on the solids handling systems with demonstration of correct operation of safety devices including silo pressure relief valves, all prior to charging with hydrated lime;
- Functional tests (without hydrated lime) shall be performed on the slurry batching systems and saturators demonstrate correct operation with respect to sequence, time and levels;
- Functional tests shall be performed on the solids handling and slurry batching systems with lime to demonstrate correct operation and calibration when handling hydrated lime;
- Functional tests shall be performed on the slurry dosing systems to demonstrate correct operation and calibration when handling hydrated lime and specified accuracies shall be confirmed in operation.

A12. Water sampling equipment A 12.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with relevant standards. Pumps shall be tested as specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards, the manufacturers' own tests where applicable.

A12.2 Individual tests

The following Site inspections and tests shall be carried as appropriate:-

- Inspection to check the assembly of the Plant and conformity with the Specification and approved drawings;
- Sample water pipework and components shall be tested hydrostatically for 1 hour at 1.5 x maximum working pressure or 5 bar g whichever is greater. During the test the pressure shall not change;
- Drain pipework shall be flushed and inspected visually for absence of leaks;
- Water quality monitoring instruments shall be tested as specified.

A12.3 Commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing of the sampling system (including water quality monitoring instruments);
- Sample lines shall be flushed and delivery rates checked for example by timing water into a calibrated vessel against a stop watch.

A13 Works water supply system A13.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and manufacturers own tests where applicable.

A13.2 Individual tests

The following Site inspection and tests shall be carried out as appropriate:-

- Inspection to check the assembly of the Plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Hydrostatic testing of all pipework systems at 1.5 x maximum working pressure for a period of at least one hour during which the pressure shall not change;
- Service water storage tank shall be filled to overflow level and inspected for absence of leaks;
- Testing of safety showers and eye baths for correct operation.

A13.3 Commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing of the hydropneumatic system to demonstrate correct operation with respect to sequence, pressure and level;
- Functional testing of the system including the elevated water storage tank with respect to sequence and level.

A14.

Miscellan
eous tests
A14.1
General

Miscellaneous tests shall include tests for hydraulic pallet trucks, safety equipment, and chlorine contact tank and access equipment.

A14.2 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified the tests shall be in accordance with the Reference Standards and the manufacturer's own procedures.

A14.3 Individual tests

The Site inspection and testing shall incorporate the following:-

- Pallet trucks shall be tested to 1.25 x Safe Working Load;
- Testing of access equipment for stability;
- Inspection of safety equipment to check sufficiency of supply and satisfactory installation.

A14.4 Commissioning tests

The testing shall incorporate the following requirements:-

- Chemical tracer tests using sodium chloride at a concentration of about 20 mg.l (with either conductivity or chloride concentration measurements) or fluoride at concentration less than 1.0 m/l as F (using specific ion electrode for concentration measurement) shall be carried out to demonstrate that the specified effective contact time in the chlorine contact tank has been satisfied at the maximum works throughput;
- Time to completely drain a clarifier from full.

A15 Switchgear and control gear A15.1 Off-site inspection and testing

Tests shall be carried out to demonstrate compliance with the Reference

Standards and the specified functional and performance criteria.

Unless otherwise specified, the tests shall be Routine Tests in accordance with the Reference Standards and the following additional tests as appropriate to demonstrate:-

(a) 400V switchboards and MCCs

(i) Power frequency test of busbars with circuit breaker connected;
(ii) The interchangeability of withdrawable equipment;
(iii) The correct operation of electrical and mechanical interlocks;
(iv) The correct and accurate functioning of current and voltage operated protection relays by primary and secondary current injection and voltage application;
(v) The correct polarity between current and voltage elements of power operated protective devices, instruments and metering;
(vi) Meters do not creep with the removal of either the current or voltage supply.
(vii) The correct operation of control circuits, indications and alarms;
(viii) Where necessary a suitable test panel shall be provided for simulation of external controls and signals during such tests;
(ix) The calibration of ammeters Voltmeter, KW meter, PF meter, H_z meter etc at 0.25, 0.5 and full scale deflection by secondary current injection;
(x) The calibration of tranducers;
(xi) Type and special tests shall be carried out when specified.

(b) 33/11/3.3kV switchboards

Power frequency voltage tests:-

(i) Power frequency high voltage pressure test with all breakers racked in and closed, between phases and from phase to earth;

(iii) Pressure test on secondary small wiring circuits;

(iv) Milli-volt drop tests - Milli-volt drop (Ductor) test across circuit breaker contacts and between extreme terminals on individual panels, (for comparison purposes, the manufacturer shall state design values for each size and rating of equipment);

(v) Operational closing tests - These tests are to ensure the operation of closing coil or spring release coil and satisfactory closing of the circuit-breaker with the voltage on the coil down to 80% of its rated voltage and to ensure that mal-operation does not occur, with a voltage at the coil of 120% of its rated voltage;

(vi) Operational opening tests - These tests are to ensure the satisfactory operation of the shunt trip circuit, and the tripping of the circuit-breaker at no load conditions with the trip coil energised at 50% of itsrated voltage;

(vii) Mechanical tests - All mechanical interlocks on the switchgear panels shall be thoroughly tested to ensure their correct operation, together with mechanical tripping, opening and isolating devices;

(viii) Interchangeability - Withdrawable circuit-breaker panels of identically equipped units shall be capable of inter-changing of circuit-breaker trucks. This facility shall be proved. A check shall also be carried out to ensure that the inter-changeability shall not be possible between incoming and outgoing feeder circuit-breaker trucks;

(ix) Heat run tests - Heat run tests will not be required on panels manufacturedunder this Contract provided type test figures for heat runs carried out on identical panel types are made available for inspection by the Engineer;

(x) General operation tests;

(xi) In addition to the tests given above, tests shall be conducted, where applicable, for the following purposes-

- to ensure satisfactory tripping of the circuit-breakers with the closing coil energised;
- to prove satisfactory mechanical behaviour of the circuit-breaker when the closing coil is energised with the tripping coil also energised;
- to prove that the operation of the power closing device when the circuit-breaker is already closed causes neither damage to the circuit-breaker nor danger to the operator;
- Protection and control circuits;
- For all forms of current transformer protection, the following information shall be made available to the Engineer prior to the time of inspection:-
- Current transformer magnetising curve;
- Recommended relay setting;
- Calculated primary operating current at this setting;
- Calculated through fault stability values, where applicable;
- Values of any stabilising and setting resistors employed in the scheme.

(xii) As far as possible, based on the completeness of the circuits in the final manufactured form within the manufacturer's premises, the satisfactory operation of associated control and protection circuits shall be proved by the following tests:-

- to ensure the correct operation of all current operated protection relays and direct acting coils at the recommended setting by current injection;
- to ensure the correct polarity between current and voltage elements of power relays, meters and instruments;
- to ensure the correct operation of control circuits at normal

operating voltage by operation of local control switches and simulation of operation from remote control positions.

Note: The checking of the operation of all protection relays and control circuits is to be carried out with all closing and tripping circuits energised at their normal rated voltage.

(xiii) Instrument and metering equipment-

- Indicating ammeters shall be checked for calibration at 0.25, 0.5, 0.75 and full scale deflection by primary current injection testing;
- Indicating voltmeters shall be checked for normal voltage readings by voltage application;
- Frequency, power factor and kilowatt meters shall be tested for accuracy of indication;
- Integrating kWh meters shall be tested for correct rotation. Creep tests shall be carried out to ensure that the meter is inoperative with voltage alone, if the secondaries of current transformers are left connected with the primary current interrupted;
- All transducers shall be tested for at least 5 different points in the complete working range of each unit.

(xiv) Current transformers;

(xv) Verification of terminal markings;

(xvi) High voltage power frequency withstand test on primary and secondary windings;

(xvii) Over-voltage inter-turn tests;

(xviii)Test for accuracy;

(xix) Voltage transformers ;

(xx) Verification of terminal markings;

(xxi) High voltage power frequency dry withstand test on primary windings;

(xxii) Test for accuracy;

(xxiii) Visual inspection;

(xxiv) Inspection of paintwork and measurement of paint thickness shall be carried out. Dimensional checks shall be also carried out.

A15.2 Individual Tests

The following Site inspections and tests shall be carried out as appropriate:-

(a) 400V Switchboard and MCC

(i) Insulation resistance of main connections and secondary wiring using an approved insulation tester. The test shall be carried out between phases and phase to earth. All circuit-breakers, switches and contactors shall be in circuit and closed;

(ii) The correct operation of electrical and mechanical interlocks shall be demonstrated;

(iii) The correct and accurate operation of current and voltage operated protection relays shall be demonstrated by primary and secondary current injection and voltage application. At least two points shall be demonstrated for each relays. Simulation test on the operation of thermal overload relay for motor shall not be acceptable. Actual test on thermal overload relay for motor shall be carried out;

(iv) The stability of unit protection systems shall be demonstrated by primary current injection;

(v) The correct operation of control circuits, indications and alarms shall be demonstrated;

(vi) The continuity of all protective conductors shall be checked;

(vii) The correct operation of intertripping circuits shall be demonstrated;

(viii) Demonstration of accurate operation at 50% and 10% of working range on all measuring devices, meters and transducers;

(ix) Any tests required by the electricity supply company.

(b) 33/11/3.3 kV Switchboard

(i) Pressure testing - Power frequency pressure test shall be carried out on equipment for use on systems above 1000 volts. For systems up to 1000 volts the insulation resistance of the equipment shall be tested with a 500 volt Megger hand generator. These tests shall be carried out with all circuit phases and phase to earth. All secondary small wiring circuits shall be similarly tested;

(ii) Mechanical tests - All mechanical tests specified and carried out at Manufacturer's premises are to be re-checked to ensure satisfactory operation of the Works in the final erected state;

(iii) Interchangeability - On withdrawable circuit-breaker panels identically equipped units such as incoming and outgoing panels shall be capable of inter-changing of circuit-breaker trucks. This facility is to be proved;

(iv) Protection and control circuits - The satisfactory operation of all current operated protection circuits over their whole operating range and correct connection of CT wiring shall be tested by primary current injection;

(v) The checking of the operation of all protection relays and control circuits shall be carried out with all tripping circuits energised;

(vi) The satisfactory operation of all inter-tripping circuits shall be tested;

(vii) The satisfactory operation of control circuits shall be tested from local and from remote positions;

(viii) Indicating ammeters - Indicating ammeters shall be checked for calibration at 0.25, 0.5, 0.75 and full scale deflection by primary current injection testing;

(ix) Indicating voltmeters - Indicating voltmeters shall be checked for normal voltage

reading by voltage application;

(x) Integrating kWh meters - Where possible kWh meters shall be tested for correct rotation. Creep tests shall be carried out to ensure that the meter is in-operative with voltage alone, if the secondaries of current transformers are left connected with the primary current interrupted;

(xi) Other indicating meters - Other indicating meters including frequency, power factor and kilowatt meters shall be tested for accuracy of indication;

(xii) Transducers - All transducers shall be tested for at least 5 different points in the complete working range for each unit;

(xiii) Current transformers - Current transformers shall be tested for the following:-

- verification of terminal markings;
- high voltage power frequency withstand test on primary windings;
- test for accuracy;

(xiv) For all forms of current transformer protection the following information shall be made available to the Engineer prior to the time of testing:-

- current transformer magnetising curve;
- recommended relay testing;
- calculated primary operating current at this setting;
- calculated through fault stability values where applicable;
- values of stabilising and setting resistors;

(xv) Voltage transformers - Voltage transformers shall be tested for the following:-

- verification of terminal markings;

- high voltage power frequency withstand test on primary windings;
- test for accuracy;

(xvi) Operational sequence tests - Tests shall be carried out on all starter panels to test operational sequence and operation of protection devices. Sequential tests for pump- motor shall be able to carry out when putting the VCB at "Test" position without required to modify any control circuit;

(xvii) Continuity of earth conductors - Continuity tests shall be carried out on the earth conductor of the switchboard, such tests being by current injection;

(xviii) This does not include the earth resistance test of the station earthing system which shall be tested as detailed elsewhere in the Specification.

A.16 Electric motors

A16.1 Off-site inspection and testing

Motors shall be inspected and tested to show that they are compliant with the Specification and approved drawings.

Tests shall be in accordance with BS 4999:Part 143. For low voltage standard production motors for general use, the tests shall be routine checks. For high voltage and low voltage motors for main drive application, the tests shall be duplicate.

If the test to determine the locked rotor current of cage induction motors is carried out at reduced voltage, allowance shall be made for the effect of saturation when adjusting for rated voltage. The estimated value of locked rotor current at rated voltage shall be stated on the test certificate.

A Polarisation Index test shall be carried out for high voltage motors. The requirement for "basic" or "special" tests shall be as specified.

A16.2 Individual Tests

Each motor shall be inspected prior to site testing for:-

- Absence of damage during transportation and erection;
- Absence of moisture or other contamination;
- Ventilation openings and drain holes are free of debris;
- Cable glanding and core terminations for tightness and identification;
- Free rotor rotation;
- Free movement of brush gear;
- Remote start/stop/E.stop control box wirings and arrangement;
- Starting interlocks

Unless otherwise specified the following tests shall be carried out on each motor before energising:-

- Winding insulation resistance;
- Polarisation Index for high voltage motors;
- Insulation resistance between motor and heater windings and ancillary devices;
- Calibration of winding and bearing temperature monitoring devices and the operation of alarm and trip initiating contacts;
- Continuity and resistance of winding thermistors;
- Bearing insulation integrity;
- Brush pressure.

Any other tests recommended by the manufacturer or stipulated in the Reference Standards.

On the satisfactory completion of the inspection and tests listed above, motors shall be energised to check for correct direction of rotation, noise and the vibration levels are within the specified limits. The tests shall be carried out with the motor uncoupled from the driven plant.

A17 Transformers

A17.1 Off-site inspection and testing

Transformers shall be inspected and tested to show that they are fully compliant with the Specification and approved drawings and shall include the following tests as a minimum:-

- Routine tests;
- Measurement on winding resistance;
- Ratio, polarity and phase relationship;
- Impedance voltage;
- Load loss;
- No-load loss and current;
- Insulation resistance;
- Induced over voltage withstand;
- Separate source voltage withstand;
- Magnetic circuit voltage withstand
- Transformer tank oil leakage test (1 kg/cm^2 for 24 hours);
- Transformer noise level measured in accordance with methods and procedures detailed in IEC 551 -Noise level shall not exceed 65dBA;
- Tap changer switching, mechanical and electrical tests according to BS4571;
- Zero sequence impedance measurement;
- Type tests;
- Impulse voltage withstand test;

- Temperature rise test;
- On load tap changer panels;
- Operational tests;
- Sequence tests.

Unless otherwise stated by the Engineer at the time of placing the order, evidence of records of satisfactory type test carried out on identical transformers to those ordered will be accepted in lieu of actual tests on transformers manufactured under this Contract for impulse voltage withstand test. Temperature rise test shall be carried out on one transformer of each size and type. The guaranteed no-load and load losses of each transformer shall be verified at the manufacturer's works. The positive tolerances stipulated in BS 171 shall not be accepted. The Board reserves the right to reject any transformer which does not achieve its declared guaranteed values.

A17.2 Individual Tests

The Site inspections and tests to be carried out are as follows:-

- Ratio, polarity and phase relationship;
- Impedance voltage;
- Insulation resistance;
- Oil and winding temperature gauges shall be calibrated and tested;
- Pressure gauges and oil level indicator relays shall be tested with pilot cables connected by mechanical operation of contacts;
- Tap changer equipment including protective devices shall be tested to ensure correct operation;
- Oil tests;

Samples of insulating oil shall be taken and subjected to dielectric strength tests. If the insulating oil fails the site test, the Contractor shall carry out the drying of oil to remove the moisture content or replace the oil and then carry out the oil tests again to comply with BS 148.

A12 DC Supply Units

A12.1 Off-site inspection and testing

The correct operation of the charger in the float and boost modes and the alarm functions shall be checked.

The following tests shall also be carried out:-

- Insulation resistance test;
- Load stability test;
- Incoming supply line test;
- Ripple voltage measurement with battery disconnected;
- Noise level measurement;
- Dropper diodes functional test;
- Charger automatic changeover test;
- Charger manual changeover test;
- Battery discharge test;
- Burn-in test at 110% load for 8 hours;
- Visual inspection shall be carried out to check the dimensions, paintwork, paint thickness and components inside the enclosures.

A13 Instrumentation, Control & Automation A13.1 Tests at manufacturers' works

(a) PLC, SCADA, MMS, Historian, Data Communications

The Contractor shall conduct a full programme of tests of the system at the Contractor's testing facility. The tests shall be carried out in the presence of the Engineer/Employer/Third Party Inspection Agency to verify that all features of the system have been provided, are operating correctly and are in full compliance with the Specification. Unless otherwise specified or agreed by the Engineer, the entire system shall be assembled and tested together as an integrated system, including all servers, all operator's consoles, EICs, field and general access MMI’s, all PLC’s, data communications networks and telemetry equipment including modems, and uninterruptible power supplies included in this Specification.

Not less than 7 days before the scheduled Factory Acceptance Test (FAT) the Contractor shall give written notification to the Engineer that a complete dry-run of the FAT has been performed successfully, and that in the opinion of the Contractor the system exhibits stable operation and is ready for the formal FAT.

The FAT will be considered successfully completed only when the system has successfully passed all factory tests. The system shall not be delivered to Site until the successful completion of the FAT is certified by the Engineer or unless otherwise approved by the Engineer Delay in the delivery of the system due to failure of the FAT shall not constitute an unavoidable delay. If the system fails the FAT, the test shall be extended or rescheduled at the discretion of the Engineer

All hardware to be used in the testing of the system shall have passed an agreed preliminary hardware performance test to ensure known hardware operability before software testing begins.

After successful completion of the factory acceptance test, no software changes shall be made to the system without written authorisation by the Engineer. Any changes to the system which effect the system software documentation, such as input scale modifications or changes to the control logic, shall be entered into the system documentation before delivery of the system to Site.

The scope of the tests shall include the proving of every aspect of hardware and software operation and functions as detailed below:-

(i) Hardware tests

- Verify the correct inventory of hardware
- Demonstrate that all spare memory, disk capacity and system expansion requirements have been met.
- Demonstrate that all input and output expansion requirements have been met, including wiring and signal isolation, and verify that power supplies are capable of supporting the increased load for this expansion.
- Demonstrate all hardware and software diagnostics.
- Verify all power supply voltages are within tolerance.
- Verify proper earth connections and isolation of instrumentation earth for all equipment.
- Demonstrate operation of test simulation and indication equipment and its suitability for adequate functional testing of all system functions.

(ii) Software tests

- Demonstrate the editing of all system parameters including set points, timers, etc.
- Demonstrate system configuration capabilities including the

addition and deletion of input and output points, outstations, and all data base parameters.

- Demonstrate the addition, deletion and modification of mimic displays and report formats.
- Demonstrate modification of the communications network.
- Demonstrate the capabilities of the communications monitoring and diagnostic facilities.

(iii) Functional tests

The functional tests shall verify proper operation of every specified system function as an integrated system. These tests shall be conducted in conjunction with functional tests of instrumentation and control panels as specified elsewhere. All failures or discrepancies found shall be documented in the test manual.

Following a failure of any functional test, should software or hardware modifications be required it shall be the decision of the Engineer whether the FAT is to continue, restart or be aborted. If testing is allowed to continue any changes which are required shall be described on a system modification document, signed by both Contractor and Engineer and be incorporated into the final FAT documentation. The failed test shall be re- conducted and the Engineer may require the retest of functions which may be affected by the modification.

The functional tests shall include, as a minimum, the following:

- Verification of proper scanning and data acquisition from all PLCs using the actual communications hardware to be used on-site where possible;
- Demonstration that the system meets the requirements of the

Specification for response time and speed of screen update;

- Verification of the accuracy of all analogue input points in the system. The procedure shall include applying the appropriate signal to each analogue input at a minimum of three points within the range of the input, checking for expected numerical results, and verifying appropriate update of related mimic displays. Proper sensing and action by the system to high and low out-of-range inputs shall also be verified;
- Verification of the proper logic sense, pulse accumulation and rate computation where appropriate, of all digital inputs and verifying appropriate update of related mimic displays;
- Verification of all control and sequencing operations and proper operation of all digital and analogue outputs. The procedure shall include simulation of all related process variables for both normal and abnormal conditions, including instrument and component failure, and demonstration of fail-safe response of the system. System outputs shall be indicated with appropriate lamps and indicators;
- Simulation of PLCs communications errors and failures and demonstration of error detection and handling, failure detection and handling, and appropriate changes to control actions as designed and specified;
- Verification of fault detection and diagnostics by inducing a sufficient variety of fault conditions in the system to ensure that detection processes and fail-safe operation are adequately tested;
- Demonstration of proper operation of all mimic displays, help pages, reports, operator procedures and historical data accumulation;
- Demonstration of proper operation of maintenance management system;
- Demonstration of proper operation of note book dial-in;
- Demonstration of proper operation of plant historian system;
- Demonstration of proper operation of all servers;

- Demonstration of proper operation of all PLCs and local MMIs following a simulated failure of both SCADA servers;
- Demonstration of proper operation of all equipment during either a system-wide or isolated power failure, and following power restoration. The procedure shall include the demonstration of battery backup PLCs for the full length of time specified, and proper operation of power fail, low voltage warning and all associated alarms;
- Where redundant systems are specified, demonstration of switch-over to backup systems, including automatic switch-over where specified;
- Verification of the accuracy of all calculated variables and parameters;
- Demonstration of the proper operation of all approved changes to the specified system;

(iv) Reliability test

After successful completion of the functional tests a 48-hour continuous run of the system shall be performed. The test shall be passed if no system function is lost or no hardware or software failure occurs. Hardware failure is defined for this test as the loss of a major component such as the computer, a PLC, a VDU or a peripheral device. Non-repetitive mechanical failures of loggers, push buttons, etc are excluded.

During this test the system shall be exercised with simulated inputs and conditions in a manner which approximates the on-site operational environment. Unstructured testing by the Engineer shall be included during this test. Upon any system failure during this period it shall be the decision of the Engineer whether the reliability test is to continue or be aborted. If testing is allowed to continue any changes to the system which are required shall be described in a system modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final FAT documentation.

(b) Instrumentation

Instrumentation shall be subjected to the manufacturers' own inspection and testing procedures together with a demonstration that an increase or decrease of the measured value at several points over the range of the instrument produces a corresponding increase or decrease in the instrument output signal or reading within the accuracy specified or otherwise required for the application.

Flowmeters shall be factory calibrated and tested on a certified wet test rig. The calibration certificate shall be submitted to the Engineer

Instrument and control panels, electrical interface cabinets inspection and testing shall be carried out to determine that:

- From visual inspection, design and construction are in accordance with the Specification. The engraving, position and fixing of all labels shall be shown to be satisfactory and in accordance with the approval of drawings;
- Power distribution circuits are correctly rated, coordinated and identified;
- Insulation resistance of circuits normally energized at potentials exceeding 50V to earth shall be not less than 10 M between conductors and between conductors and earth using a 500V insulation tester. Any equipment liable to be damaged by the application of the test voltage shall be disconnected prior to testing;
- Each item of equipment within a particular loop and the complete loop function correctly. Each indicator, recorder and controller shall be checked over the whole scale range and

there shall be no interaction with any other circuit. Controllers shall be checked for correct operation of control action, auto-manual circuits, cascade circuits, proportional, integral and derivative actions and any special features;

- Alarms function as required. Those initiated from remote contacts shall be tested by opening and closing the circuit at the panel outgoing terminals. Those operated from analogue signals shall be tested by use of a signal injector. Each test shall verify that the correct alarm circuit is operated, the alarm sequence is correct and that there is no interaction with any other circuit;
- Sequence programmes operate as required and that all input and output responses are correct.

A13.2 Individual Site tests

(a) PLC, SCADA, MMS, Historian, Data Communications Network

(i) Pre-commissioning tests

The Contractor shall perform pre-commissioning testing of the plant control system in accordance with that specified for instrumentation. The purpose of pre-commissioning tests is to confirm readiness of the system for commissioning.

The scope of pre-commissioning tests shall be generally as specified for FATs but real field inputs and final control elements shall be used wherever practical to provide inputs to the system and to confirm proper outputs. Where this is impractical, simulation signals shall be injected as near as possible to their ultimate sources so as to include in the tests as much of the cabling system as possible.

Pre-commissioning tests for fibre-optic communications networks shall include optical power loss testing and optical time domain reflectometry (OTDR) testing.

Each process system shall be set to work under manual control and the system tested to confirm proper operation.

After proper operation of each manual control mode has be verified, tests of automatic controls for each process system shall be conducted wherever practical.

(ii) Commissioning tests

The Contractor shall submit all relevant draft operating manuals for the plant control system to the Engineer for approval prior to commissioning tests. Any faults or failures of the system detected during the previous tests shall be noted and corrected to the satisfaction of the Engineer before commissioning is allowed to commence.

The plant control system shall be commissioned in accordance with procedures described elsewhere in this Specification, and subject to routine tests as required by the Engineer

The entire control system including field instruments, panels, PLC’s, SCADA system, plant historian and maintenance management system shall be subjected to a comprehensive site acceptance test (SAT).

(iii) Availability test

As part of the commissioning tests prior to the trial operation, the plant control system shall be tested for availability for a continuous period of

30 days. During this period the system will perform the normal functions according to the procedures described in the

Contractor's documentation.

The system shall have passed the availability test if all major components have been free from fault or failure and exhibit full error-free functionality for 98% of the total duration of the test, unless otherwise agreed by the Engineer. Major components include all master station equipment, outstations, communications facilities and instrument panel components, excluding push buttons, switches and lamps and any equipment not supplied by the Contractor.

During the availability test, no modifications to the system shall be made by the Contractor without the written approval of the Engineer. Erroneous functioning which requires software modifications or re-configuration to correct, other than set point or parameter changes, shall constitute a failure of the availability test. Any changes to the system which are required and approved shall be described in a system modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final test documentation. The test shall be restarted after corrections have been completed.

During the availability test, a minimum of one power failure for each outstation and for the master station shall be simulated. Improper operation during power down or power recovery shall constitute a failure of 1% of the test duration.

During the availability test, a minimum of one failure for each component with redundant backup unit shall be simulated. Improper switch-over to the backup unit shall constitute a failure of 1% of the test duration.

If a situation arises during the availability test which renders the system unavailable but which, in the opinion of the Engineer, does not accurately reflect the true system availability, the unavailable period shall be ignored and the test extended for an identical time period.

After the availability test period is complete, if the test objectives have not been met the test shall be extended until the required system availability is achieved over a consecutive 14-day period. If the test is extended in this manner for over 8 weeks the Engineer, at his discretion, may discontinue the test and the issues be resolved in accordance with contractual terms.

In order to establish that all failures have been satisfactorily repaired no repeat failure shall have occurred within 72 hours of the failure. The test shall be extended if necessary to satisfy this requirement.

(b) Instrumentation

The following inspections and tests shall be carried out after installation at site:-

- All instrument piping shall be tested for continuity and freedom from leakage;
- All cables shall be tested for continuity and insulation resistance;
- Electrical supply voltages shall be checked;
- Instrument air supply pressure shall be checked;
- The common mode d.c. voltage at each signal input terminal shall be measured and recorded;
- The zero setting of each display instrument shall be checked;
- The correct calibration of each item in each loop shall be checked by introduction of appropriate signals at each source at five cardinal points of the range for increasing and decreasing signals;

- Recorders shall be fitted with the correct charts and drives set in motion, pens inked and check for clear marking. Multi-point recorders shall be checked to ensure they print at the correct stations;
- Every item shall be visually inspected and any damaged part or deficiency made good;
- All safety devices shall be tested for correct operation;
- Control sequences shall be checked with control inputs activated but outputs initially in a monitoring mode;
- The test methods to be used shall be as follows unless otherwise agreed with the Engineer;
- Pressure operated devices shall be tested with dead weight testers or portable calibrators;
- Level operated devices shall be tested by actual level variation or simulation thereof. Zero readings shall be checked against a benchmark where applicable;
- Flow devices of the pressure differential type shall be tested by application of differential pressures. Flow devices of the magnetic type shall be tested with a flow simulator. Where practicable, each flow device shall be checked by an actual displacement test;
- pH electrodes and monitors shall be calibrated by measuring the emf produced in solutions of known composition and strength. Glass pH electrodes shall be given at least 12 hours to stabilise before calibration. pH monitors shall be checked by use of at least three buffer solutions;
- Water quality analysers shall be calibrated using prepared solutions;
- Each control valve shall be checked by operation of the manual output control on the associated controller. Automatic controllers shall be set to the appropriate estimated values of the control terms;
- All systems shall be checked for fail-safe operation as appropriate by simulated failure, open circuiting, disconnection and so forth;
- Instrument and control panels, electrical interface cabinets;
- These shall be tested as part of the tests on the process plant equipment.

A17 Cabling

A17.1 Tests at manufacturers' works

Unless otherwise specified cables shall be subject to Routine Tests in accordance with the Reference Standards.

A17.2 Individual Site tests

The following inspection and tests shall be carried out on the completed cable installation as appropriate:-

- Insulation resistance between cores and core to earth using an approved insulation tester compatible with the voltage grade of the cable under test. For high voltage cables, the test shall be carried out at the highest voltage compatible with the voltage grade of the cable under test. Where cables are jointed, the test shall be repeated after each joint has been completed;
- For multicore and multipair cables, continuity of each core and correct identification and ferruling;
- Supports and cleating arrangements are fitted;
- For power cables, correct phasing and phase colouring;
- Correct bonding and earthing of cable metallic sheaths, core screens and armouring;
- Sealing of cable entries against water and vermin ingress;
- Mechanical glands have been correctly fitted;
- For high voltage cables pressure tests shall be carried out in accordance with the Reference Standards using high voltage d.c. Wherever possible cables shall be energised after the satisfactory completion of the pressure test;
- For high voltage cables, additional checks and tests to the manufacturers' specific instructions shall be carried out;

- For low voltage cables, additional tests as required by the Reference Standard;
- Loop resistance test for each pair of conductors in multipair instrumentation and telephone distribution cables;
- Attenuation test for each pair of conductors in telephone distribution cables;
- Measurement of cross talk across pairs of conductors in telephone distribution cables over a minimum frequency band of 0.5 to 20kHz. The conductors connected to a resistive load equal to that of their characteristic impedance. The injected signal shall have a sinusoidal waveform at a level equivalent to the intended operating level of the modems to be connected (-3dBm).

A18 Earthing

A18.1 Individual Site tests

On completion of the earthing installation tests shall be carried out in accordance with the Reference Standards and the following requirement:-

- Resistant of each earth point shall be measured;
- Resistant value of the overall earthing system after the connection of linking tapes;
- The earth contact resistance and the earth conductor continuity from each major piece of the Works, i.e. main switchboards and transformers etc., shall be measured by using an earth loop impedance tester and auxiliary return conductor.

A19. Building services

A19.1 Individual Site tests

The building services installations shall be inspected and tested in accordance with the Reference Standards.

A.19.1 Lightning protection

A11.19.1 Individual Site tests

The lightning protection installation shall be inspected and tested in accordance with the Reference Standards and the following requirement:-

- Resistant of each earth point shall be measured;
- Resistant value of the overall earthing system after the connection oflinking tapes.

PART B WATER SUPPLY

CHAPTER 5 WATER RETAINING STRUCTURES

5.1. RELEVANT IS CODES

(1) IS 456: Plain and Reinforced Concrete

(2) IS 3370 Part I : S 3370 (Part-I) Code of practice for concrete structures for storage of liquids : General Requirements

(3) IS 3370 Part II : S 3370 (Part-I) Code of practice for concrete structures for storage of liquids : Reinforced Concrete Structures

(4) IS 3370 Part IV : S 3370 (Part-I) Code of practice for concrete structures for storage of liquids : Design Tables

(5) IS 13920 : Ductile Detailing

(6) IS 516 : Testing Strength of Concrete

(7) IS 1893 : Criteria for EQ Resistant Structures

(8) IS 4326 : EQ Resistant Design and Construction

(9) IS 10262 Concrete Mix Design

(10) IS 11682 : RCC Staging for Overhead Water Tanks

(11) IS 9103 : Concrete Admixtures

(12) IS 4926 : Ready Made Concrete

The provisions in these codes shall be kept in general

5.2. RELEVANT SPECIAL PUBLICATIONS

(1) SP 23 : Concrete Mixes

(2) SP 34 : Reinforcement and Detailing

(3) SP 16 : Design Aids for RCC

The provisions in these publications shall be kept in general

5.3. MINIMUM GRADE OF CONCRETE MIX AND COVER

LOCATION	MINIMUM GRADE	MINIMUM COVER mm
WATER RETAINNING FACES	M 30	45
UNDER SIDE OF ROOF	M 30	45
FACES IN CONTACT WITH CHLORINE VAPOUR	M 30	45
OTHER FACES	AS PER TABLE 5 OF IS 456-2000	AS PER TABLE 5 OF IS 456-2000

MINIMUM REINFORCEMENT SHALL BE AS PER CALUSE 7.1 OF IS 3370 Part II

THE MAXIMUM CEMENT CONTENT FOR WATER RETAINING PARTS SHALL BE LIMITED TO 400 kg/m3

5.4. MATERIALS

The requirement for materials shall be governed by 4 of IS:456-1964* and 4 of IS: 1343-1960+ for reinforced concrete and prestressed concrete members, respectively, with the following additional requirements:

(a) *Porous aggregates*- Under no circumstances shall the use of porous aggregates, such as burnt clay and broken brick or tile, be allowed for parts of structure either in contact with the liquids on any face or enclosing the space above the liquid.

(b) *Prestressing steel* – The prestressing steel for prestressed concrete members of the structure shall comply with the requirements of either IS:1785-1961 or IS : 2090-1962 .

Joining Materials – Joint, fillers, joint sealing compounds, water bars and joint cover plates shall conform to the requirements of relevant Indian standards.

5.5. CONCRETE MIX

3.1 Provisions in 5 of IS : 456-1964* and 4.2.5 of IS : 1343-1960 + shall apply for reinforced concrete prestressed concrete members, respectively subject to the following further requirements:

a) Except in case of thick sections as described in & and parts of structure neither in contact with the liquid on any face not enclosing the space above the liquid, concrete mix weaker than M 200' shall not be used.

b) The minimum quantity of cement in the concrete mix shall be not less than 330kg/m^3 in reinforced concrete work, 360kg/m^3 in post tensioned prestressed work and 380kg/m^3 in pretensioned prestressed work. The maximum quantity of cement in the prestressed work. The maximum quantity of cement in the concrete mix shall preferably no exceed 530kg/m^3 of concrete.

c) The design of the mix shall such that the resultant concrete in sufficiently impervious. The mix obtained in accordance with the above, if fully compacted, will generally give a degree of impermeability adequate for all ordinary purposes. In special circumstances, the engineer-in-charge should satisfy himself that an adequate permeability is obtained by percolation tests.

Pneumatic Mortar

The grading of fine aggregates for pneumatic mortar should conform in general to grading zone I or II specified in Table 3 of IS :383-1963*

NOTE- Pneumatic mortar is mortar applied pneumatically through a suitable nozzle; it is used for example, as cover to external prestressing steel or as internal rendering.

The proportions of pneumatic mortar should be such that the ratio (by weight) of cement content to fine aggregate is neither less than 0.3 nor more than 0.5.

A suitable mix for final cover coat of pneumatic mortar is 50 Kg cement, 4.5 kg hydrated lime and 140kg of dry sand of such size that it will pass through 2.36mm IS Sieve.

Imperviousness of Concrete Mix – In the construction of concrete structure for the storage of liquids, the imperviousness of concrete is an important basic requirement. The permeability of any uniform and thoroughly compacted concrete of given mix proportions is very largely dependent on the water-cement ratio. While an increase in this ratio leads to an increase in inherent permeability, a very much reduced water-cement ratio of a mix with a given cement content may cause compaction difficulties and thus may prove equally harmful. For a given mix made with particular materials, there is a lower limit to the water-cement ratio which can be used economically on any job. It is essential to select a richness of mix compatible with available aggregates, whose particle shape and grading have an important bearing on workability which must be suited to the means of compaction selected. Efficient compaction preferably by vibration is essential. In practice, it is usually convenient, particularly when dealing with thin congested reinforced sections, to specify a cement content sufficiently high to ensure that thorough compaction is obtainable while maintaining a sufficiently low water-cement ratio. In thicker sections, where a reduction in cement content might be desirable to restrict the temperature rise due to cement hydration, a lower cement content is usually permissible, partly because the overall permeability of the section is reduced by the greater thickness and partly because less congested conditions may permit thorough compaction of a somewhat drier mix.

While proper attention just be paid in achieving a mix of inherently low permeability, it should be recognized that common and more serious causes of leakage in practice, other than cracking, are defects such as segregation and honey combing and in particular all joints are potential source of leakage. The mixes as specified in 3, if fully compacted, will give a degree of permeability adequate for all ordinary purposes. In special circumstances, where necessary, the engineer should satisfy himself by a percolation test, that an adequate degree of impermeability is obtained.

5.6. SITE CONDITIONS

The following conditions of the site in relation to the functional and structural requirements of the liquid retaining (storage) structure materially influence the methods of design and the cost of the structure.

a) Physical characteristics of soil in which the liquid retaining structure may be partly or wholly enclosed and also the physical and geological features of the supporting foundations,

b) Extent of water-logging at the site, and

c) Chemical properties of the soil and of the ground water.

In making the choice of the site and in the preparation of the design the factors mentioned in 4.1 should be taken into account generally as indicated below:

a) *External earth pressure* – Relief from external earth pressures either wholly or partially should not generally be relied upon, unless the operation of such pressures throughout the service life of the liquid retaining structure in ensured. On the other hand, walls of the liquid retaining structure shall be checked for external pressures under empty or partially-empty conditions.

b) *Water-logged ground* – If in the sitting of a liquid retaining structure, water-logged ground cannot be avoided, the dangers of the external water pressure shall be carefully guarded against by the following:

1) Designing the structure to resist such pressure under empty or partially-empty conditions and taking precautions to prevent floating and ensuring stable equilibrium under all conditions of internal and external loads. It is advisable to make the design such that the minimum gravity weight exceeds the uplift pressure by at least 20 percent.

2) Providing under floor drainage to reduce the level of the external water as far as local conditions permit.

3) Providing relief valves discharging into the liquid retaining structure, when the external pressure exceeds the internal pressure; this arrangement is feasible only in cases when the liquid retaining structure is not required for the storage of liquids which should not be contaminated.

4) Designing both internal and external faces of the walls and floor as water retaining faces, where the walls and floors of the liquid retaining structure are submerged in water or water bearing soils.

c)*Stability* – The equilibrium and safety of structure and parts of it against sliding and overturning especially when the structure is founded on a side long or sloping ground, shall also be checked.

d) *Settlement and subsidence-* Geological faults, mining, earthquakes, existence of subsoils of varying bearing capacities may give rise to movement or subsidence of supporting strata which may result in serious cracking of structure. Special considerations should be given in the preparation of the design, to the possible effect of subsidence or movement of the foundation strata.

e) *Injurious soils* – Chemical analysis of the soil and ground water is essential in cases where injurious soils are expected to exist, as concrete structure may suffer severe damage in contact with such soils. The use of sulphate resisting cement will increase the resistance to the action of certain injurious soils but may not afford complete safeguard. An isolating coat of bituminous or other suitable material may improve the protective measures.

5.7. PROTECTION AGAINST CORROSION

5.1 The type of liquid to be retained should be considered in relation to the possibility of corrosion of steel or attack on concrete with corrosion waters (as in the case with certain natural waters), it is desirable to use richer and denser concrete and provide increased cover to steel. Considerations may also given to the use of special cements, such as, sulphate-resisting cement or high alumina cement. Where attack is likely to be appreciable the provision of an impervious protective lining should be considered.

5.8. THICK SECTIONS

7.1 Thick sections shall be those parts of structure which have thickness greater than 450 mm. There is a likelihood of cracking in such sections as a consequence of temperature rise during hydration of the cement and subsequent cooling. Such cracking is not easy to control by reinforcement. The following are some of the measures that may be adopted for reducing the likelihood of cracking:

a)Magnitude of the temperature rise should be restricted by limiting the cement content, or by using a type of cement with a low rate of heat of evolution or adopting suitable construction methods, Portland cements with lower rates or strength development generally give lower rates of heat evolution. In such cases the permissible stresses shall conform to requirements of 3.3. Temperature rise may also be restricted by casting the concrete in shallow lifts at intervals of few days so as to allow the escape of part of heat from the exposed upper surface.

b) Steep temperature grading will occur by sudden chilling of the concrete surface. This should be avoided, for instance, some protection may be required when removal of heavy timber form work coincides with on set of cold weather.

c) Restraint to overall contraction may be limited by provisions of movement joints and by provision of suitable sliding layer (see 6.1.4.3 and 6.1.4.4). Another cause of restraint which may lead to cracking occurs when a substantial lift of concrete is cast upon a cold foundation. A better procedure is to avoid excessive disparity in temperature between successive lifts and where practicable to introduce shallow lifts when starting from or resuming work on cold foundation.

5.9. CONSTRUCTION

Unless otherwise specified in this code, and subject to the following additional recommendations, the provisions of IS: 456-1964* and IS : 1343-1960+ shall apply to the construction of reinforced concrete and prestressed concrete liquid retaining structures, respectively.

Thick Sections – The precautions necessary in the construction of thick sections shall be observed as per requirements of 7.

Joints – Joints shall be constructed in accordance with requirements of 8.

Mixing and Placing of Pneumatic Mortar

Mixing – The aggregate and cement should be mixed in an approved mechanical mixer and delivered from an approved mechanical digester. The minimum amount of water should be injected into the mixture as this will ensure maximum density of the mortar.

*Placin*g- The pneumatic mortar should be applied with an approved nozzle by a skilled operator. The velocity of the material leaving the nozzle should be maintained uniform and should be such as to produce minimum rebound of sand.

Curing- Immediately after pneumatic mortar has been placed it should be protected against premature drying by shading from strong sunshine and shielding from the wind. As soon as it has hardened just sufficiently to avoid damage it should be thoroughly wetted and thereafter kept wet continuously for at least seven days. Adequate protection against fluctuations in temperature by shading and shielding shall also be given.

Construction of Floors.

Floors founded on the Ground

The ground should be covered with an at least 75mm thick plain concrete screed of composition as described in 6.1.4.4. Floors cast on the ground should be in not less than two layers, the bottom later of which may comprise or replace the plain concrete screed. When the screed forms an integral part of the floor slab forming one of the two layers then the mix for screed shall conform to the requirements of 3.

9.4.1.2 A layer of building paper or other suitable material should be laid between successive layers.

9.4.1.3 The layers, other than the plain concrete screed, if used should be placed in panels, the sides of which should not exceed 7.5m in the case of reinforced slabs and 4.5m in the case of plain slabs.

The tendency for the development of cracks in the upper layer of paving slab or a reservoir floor is greatly diminished if the reinforcement is discontinuous through the joints and it is recommended that the floor panels be laid in chessboard fashion (all the 'black' or all the 'white' squares first). The edges of the panels in the bottom layer may be butt-jointed and the panels in the various layers should be arranged to break joint.

Suspended Floors – Floors which are not directly supported on the ground should be cast in panels, the sides of which should not exceed 7.5m. At joints in suspended floors, the surface of the panels for a width not less than the thickness of the panel on each side of the joint should be primed and painted with at least two coats of bituminous or other approved paint.

Junction of Floor and Walls – Where the wall is designed to be monolithic with the bottom slab, a suitable arrangement of reinforcement and form-work shall be made to facilitate the form-work to fit tightly and avoid leakage of cement paste from newly deposited concrete as such leakage if allowed to take place is very liable to cause porosity in the finished concrete. On such arrangement is by providing a continuous upstand section of the wall cast at the same time, as, and integrally with, the slab; the height of this upstand must be sufficient to enable the next lift of form-work to fit tightly and avoid leakage of the cement paste from the newly deposited concrete.

Construction of Walls

In all cases where the reinforcing steel is discontinuous at vertical contraction joints, the walls should be constructed in alternate panels with as long a pause as practicable before the concrete is placed in the intervening panels.

Where the reinforcement is continuous through vertical joins in walls, construction in alternate panels may result in a greater tendency to the development of cracks in those panels which are cast between two earlier placed panels, the existence of which increases restraint of the natural shrinkage of the intermediate panel.

9.5.3 The height of any lift should not exceed 2m unless special precautions are taken to ensure through compaction throughout by mechanical vibration or by other suitable means.

All vertical joints should extend the full height of the wall in unbroken alignment.

9.6 Surface Finish to Prestressed Concrete Cylindrical Tanks – The circumferential prestressing wires of a cylindrical tank should be covered with a protective coat, which may be pneumatic mortar, having a thickness that will provide a minimum cover of 40mm over the wires.

5.10. FORMWORK

Removal of Formwork – The requirements shall conform to 20.2.3 of IS: 456-1964*

Bolts passing completely through liquid-retaining slabs for the purpose of securing and aligning the form-work should not be used unless effective precautions are taken to ensure water-tightness after removal.

5.11. LINING OF TANKS

The type of liquid to be stored should be considered in relation to the possibility of corrosion of the steel or attack on the concrete. Provision of an impermeable protective lining should be considered for resistance to the effects of corrosive liquids. Certain natural waters exhibit corrosive characteristics and in such cases it is important to obtain a dense impermeable concrete and with a higher cement content. An increased coved to the steel is also desirable. Use of sulphate resisting Portland cement, pozzolana cement, or blast-furnace slag cement may in certain cases be advantageous.

5.12. TESTS ON STRUCTURE

10.1 In addition to the structural test of the structure as given in 21.3 of IS:456-1964*, the tanks shall also be tested for water tightness at full supply level as described in 10.1.1, 10.1.2 and 10.1.3

10.1.1 In the case of tanks whose external faces are exposed such as elevated tanks, the requirements of the test shall be deemed to be satisfied if the external faces show no signs of leakage and remain apparently dry over the period of observation of seven days after allowing a seven day period for absorption after filling.

10.1.2 In the case of tanks whose external faces are submerged and are not accessible for inspection, such as underground tanks, the tanks shall be filled with water and after the expiry of seven days, after the filling , the level of the surface of the water shall be recorded. The level of the water shall be recorded again at 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 watertightness of the tank. The engineer-in-charge shall decide on the actual permissible nature of this drop in the surface level, taking into account whether the tanks re open or closed and the corresponding effect it has on evaporation losses. For many purposes, however, underground tanks whose tope is covered may be deemed to be water-tight if the total drop in th surface level over a period of seven days does not exceed 40mm.

10.1.3 If the structure does not satisfy the conditions of test, and the daily drop in water level is decreasing, the period of test may be extended for a further seven days and if specified limit is ten reached, the structure may be considered as satisfactory.

5.13. GENERAL REQUIREMENTS

Design and construction of reinforced concrete liquid retaining structures shall comply with the requirements of IS:3370 (Part I)-1965*.

DESIGN

General – Provisions shall be made for conditions of stresses that may occur in accordance with principles of mechanies, recognized methods of design and sound engineering practice. In particular, adequate consideration shall be given to the effects of monolithic construction in the assessment of bending moment and shear.

Before taking up the detailed design, the designer should satisfy himself on the correct estimation of loads and on the adequate statical equilibrium of the structure, particularly in regard to safety against overturning of overhanging members; in the latter case the general arrangement should be such that statical equilibrium should be satisfied even when the overturning moment is doubled.

FLOORS

Provisions of Movement Joints – Movement joints shall be provided in accordance with 8 of IS:3370 (Part I) -1965*

Floors of Tanks Resting on Ground – If the tank is resting directly over ground, floor may be constructed of concrete with a nominal percentage of reinforcement (smaller than the minimum specified in 7) provided it is certain that the ground will carry the load without appreciable subsidence in any part and that the concrete floor is cast in panels with sides not more than 4.5 metres with contraction or expansion joints between. In such cases a screed or concrete layer not less than 75mm thick shall first be placed on the ground and covered with a sliding layer of bitumen paper or other suitable material to destroy the bond between the screed and floor concrete.

In normal circumstances the screed layer shall be of grade not weaker than M 100 specified in IS:456-1964, where injurious soils or aggressive water are expected, the screed layer shall be of grade not weaker than M150 specified in IS: 456-1964 and if necessary a sulphate resisting or other special cement should be used.

Floors of Tanks Resting on Supports – If the tank is supported on walls or other similar supports, the floor slab shall be designed as floors in buildings for bending moments due to water load and self weight. The 1964+, since water level extends over all spans in normal construction except in the case of multi-cell tanks, these will have to be determined by the designer in each particular case.

4.3.1 When the floor is rigidly connected to the walls (as is generally the case) the bending moments at the junction between the walls and floor shall be taken into account in the design of floor together with any direct forces transferred to the floor from the walls or from the floor to the wall due to the suspension of the floor from the wall.

If the walls are non-monolithic with the floor slab, such as in cases where movement joints have been provided between the floor slabs and walls, the floor shall be designed only for the vertical loads on the floor.

4.3.2 In continuous T-beams or L-beams with ribs on the side remote from the liquid, the tension in concrete on the liquid side at the face of the supports shall not exceed the permissible stresses for controlling cracks in concrete. The width of the slab given in 9.2.2 of IS :456-1964* shall be made the basis for calculation of the resistance to cracking of T-beam, L-beam sections at supports.

4.3.3 The floor slab may be suitably tied to the walls by reinforcement bars properly embedded in both the slab and the walls. In such cases no separate beam (curved or straight) is necessary under the wall, provided the wall of the tank itself is designed to act as a beam over the supports under it.

4.3.4 Sometimes it may be economical to provide the floors of circular tanks in the shape of dome. In such cases the dome shall be designed for the vertical load of the liquid over it and the ratio of its rise to its diameter shall be so adjusted that the stresses in the dome are, as far as possible, wholly compressive. The dome shall be supported at its bottom on the ring beam which shall be designed for resultant circumferential tension in addition to vertical loads.

WALLS

Provision of Joints

Sliding Joints at the Base of the Wall – Where it is desired to allow the walls to expand or contract separately from the floor, or to prevent moments at the base of the wall owing to fixity to the floor, sliding joints may be employed.

5.1.1.1 Considerations affecting the spacing of vertical movement joints are discussed in 8 of IS : 3370 (Part I) – 1695+ While the majority of these joints may be of the partial or complete contraction type, sufficient joints of the expansion type should be provided to satisfy the requirements of 8 of IS: 3370 (Part I) -1965.

ROOFS

Provisions of Movement Joints – To avoid the possibility of sympathetic cracking, it is important to ensure that movement joints in the roof correspond with those in walls if roof and walls are monolithic. If, however, provision is made by means of a sliding joint for movement between the roof and the wall, correspondence of joints is not so important.

Loading – Fixed covers of liquid retaining structures should be designed for gravity loads, such as the weight of roof slab, earth cover, if any, live roads, and mechanical equipment. They should also be designed for upward load if the liquid retaining structure is subjected to internal gas pressure.

6.2.1 A superficial load sufficient to ensure safety with the unequal intensity of loading which occurs during the placing of the earth cover should be allowed for in designing roofs. The engineer should specify a loading under these temporary conditions, which should not be exceeded. In designing the roof, allowance should be made for the temporary condition of some spans loaded and other spans unloaded, even though in the final state the load may be small and evenly distributed.

Water- Tightness – In case of tanks intended for the storage of water for domestic purposes, the roof must be made water-tight. This may be achieved by limiting the stresses as for the rest of the tank or by the use of the covering of water proof membrane or by providing slopes to ensure adequate drainage.

Protection Against Corrosion – Protective measures shall be provided to the underside of the roof to prevent it from corrosion due to condensation.

5.14. TESTI NG CONCRETE STRUCTURES FOR LEAKAGE

The Conrrarror shall take special care for concrete fpr liquid retaining structures, underground structures and those others specifically called for to guarantee the finish and water tightness. The Contractor shall make all arrangements for hydro-testing of structure.

The Contractor shall also make all temporary arrangements that may have to be made to ensure stability of the structures during construction. Any leakage that may occur during the hrdro-test shall be effectively stopped either by cement/epoxy pressure grouting, guniting or such other methods as may be approved by the engineer in charge.

Tanks shall be tested for water tightness at full supply 1evet as described in Clause 22.1.1. and 12.1.2 of IS:3370 Part I.

Testlng Concrete Stru¢tures for Leakage

Hydro-static test for water tightness shall be done at full supply level, as may be directed by the Eng ineer in-C harge

The tanks shall be filled with water and after the expiry of seven days after the f illing, the level of the surface of the water shall be recorded. The level of water shall be recorded again at subsequent intervals of 24 hrs. over a period of seven days. The total drop in surface 1evel over a period for seven days shall be taken as an indication of water tightness of the structure. The actual permissible nature of this drop in the surface level, shall be decided by taking into account r whether the structures are open or closed and the corresponding effect it has on evaporation /losses and/or on amount of rainfall.

For above ground srructures, the permissible loss may be adopted as per provisions in the respective contract agreement or as may be directed by Engineer -in charge.

However, underground tanks whose top is covered may be deemed to be water tight if the total drop in surface level over a period of seven days does not exceed 20 mm.

In the case of structures whose external faces are exposed, such as elevated tanks, the requirements of the test shall be deemed to be satisfied if the external faces show no sign of leakage and remain apparently dry over the period of observation of seven days after allowing a seyen day period for absorption after filling.

If the structure does not satisfy the conditions of test, and the daily drop in water level is decreasing, the period of test may be extended for further seven days and if specified limit is then reached, the structure may be considered as satisfactory.
The roofs of liquid retaining structures should be water tight and should be tested on completion by flooding of roof with water to a minimum depth of 25 mm for 24 hours or longer, if so specified. Where it is impracticable, because of roof slopes or otherwise, to contain a 25 mm depth of water, the roof should have continuous water applied by a hose or sprinkler system to provide a sheet of water over the entire area of roof for not less than 6 hours. In either case the roof should be considered satisfactory if no leaks or damp patches show on the soffit. Should the structure not satisfy either of these
tests then after completion of the remedial work it should be retested in arcordance with relevant clauses of 1S.3370 Part I.

5.15. WATER RETAINNING CONCRETE STRUCTURES : EXTRA POINTS TO ENSURE QUALITY

1 Ensure adequacy of quantity of materials before starting a concreting work

2 Check quality of materials including water.

3 Check Mixer, Vibrator (min two no.).

4 Check Form work for Strength, lines and levels.

5 Check Shuttering for Dimensions and leak proof-ness.

6 Reinforcement Detailing – Check, record and get it check measured before starting concreting (including chairs).

7 Ensure cover blocks properly placed.

8 Keep wooden planks ready for walking over fresh concrete and also for placing vibrators.

9 Ensure Wiring cables, boxes, wall castings etc. are placed properly.

10 Ensure Proper Access for inspection.

11 Plan Construction joints in Advance.

12 Plan Curing Arrangements before starting Concreting.

13 Take Precautionary arrangements in case of an expected rain.

14 In sunny weather keep Sheets or bags/paper ready for covering slabs to avoid drying after casting.

15 Ensure Adequate through Slump Tests

16 Use Design Mixes only.

17 Maintain specified cover through out.

18 Turn the end of binding wires inward, without allowing to encroach cover region.

19 Ensure Sufficient Anchorage and Development lengths for reinforcing bars.

20 Do not substitute lower diameter bars with higher diameter bars.

21 Avoid plain bars.

22 Ensure Proper curing.

23 Do not use rapid hardening cement for water retaining portions (shrinkage is more).

24 Prefer thin, steel shuttering than thick, wooden shuttering (Easy escape of heat).

25 Adopt lesser cement content in case of thicker sections.

26 Cast the haunches between side wall and base slab monolithically with base.

27 Cast the sidewall within 48 hours of casting base slab (Especially in summer).

28 Do not go for slab sections thicker than 450 mm.

29 Never refill excavated earth under the base slab in case of ground level reservoirs. If becomes necessary to adjust levels, use lean concrete.

30 For water retaining portions prefer rounded Aggregates to angular ones.

PART B WATER SUPPLY

CHAPTER 6 PIPE LAYING WORKS

6.1. EXCAVATION AND FILLING

6.1.1. ROUTING

6.1.1.1. General: The choice of route for a pipeline is governed by economic considerations and other factors such as overhead and underground cables, existing pipelines and traffic flow.

6.1.1.2. Final Field Survey Plans - Field surveys for strip width representing about 500 m along the proposed alignments should be carried out. Any vertical section or profile along the pipeline route should be shown to a scale appropriate to the variations in ground elevation. Special crossings which require permission from authority should be detailed on separate drawings and cross referenced to the appropriate strip plan; the scale should be between 1:100 and 1:125 depending on the complexity of the work. In built up areas, consideration should be given to the use of plans of 1:1250 scale. In urban areas, trail trenches at suitable intervals will be necessary to locate the utilities which may affect the laying of pipes.

6.1.2. SITE PREPARATION/ CLEARING THE SITE

6.1.2.1. Preliminary work required to be done before laying of pipelines includes pegging out, clearing and disposal of all shrubs, grasses, large and small bushes, trees, hedges, fences, gates, portions of old masonry, boulders, and debris from the route.

6.1.2.2. Before the earthwork is started, the area coming under cutting and filling shall be cleared of shrubs, vegetation, grass, brushwood, trees and saplings of girth up to 30 cm measured at a height of one metre above ground level and rubbish removed up to a distance of 50 metres outside the periphery of the area under clearance. The roots of trees and saplings shall be removed to a depth of 60 cm below ground level. The holes or hollows due to removal of old foundation shall be filled up with the earth, well consolidated to the required compaction and levelled.

6.1.2.3. The trees of girth above 30 cm measured at a height of one metre above ground shall be cut only after obtaining written permission of the Engineer. The roots of trees shall also be removed. Existing structures and services such as old buildings, culverts, fencing, water supply pipe lines, sewers, power cables, communication cables, drainage pipes etc. within or adjacent to the area if required to be diverted/removed, shall be diverted/dismantled as per directions of the Engineer.

6.1.2.4. Where trees have been felled, the resulting timber shall be stacked properly and disposed of as directed by the authority. Tree roots within a distance of about 0.5 metre from either side of the pipeline should be completely removed before laying pipelines.

6.1.2.5. All other serviceable materials, such as wood, bricks and stones, recovered during the operation of clearing the site, shall be separately stacked and disposed of as directed by the authority.

6.1.2.6. If the site is such that surface water shall drain towards it, land may be dressed or drains laid out to divert the water away from the site.

6.1.2.7. Before pipeline is laid, proper formation shall be prepared. For buried pipeline, suitable trenches should be excavated, pipeline above ground may be laid in cutting or on embankments or be supported by pillars as the cast may be.

6.1.3. EXCAVATION AND PREPARATION OF TRENCH

6.1.3.1.**General :**

6.1.3.1.1. The trench shall be so dug that the pipe may be laid to the required alignment and at the required depth.

6.1.3.1.2. Limits of Excavation Relative to Gradients: Except where special foundations are to be provided for the reasons given in 3.1.3, the trench shall be excavated in accordance with one of the following alternatives as may be considered appropriate by the Authority:

a. The trench shall be excavated to the exact gradient specified so that no making of the sub-grade by backfilling is required and the pipe rests on solid and undisturbed ground when laid;

b. When the bottom of the trench at the specified gradient is found to be unstable or to include ashes and cinders, all types of refuse, vegetable or other organic material, or large pieces or fragments of inorganic material, they shall be removed to the satisfaction of the Authority; and

c. Where the excavation is in rock or boulders, the clearance specified in 3.2.1.1. shall be provided.

6.1.3.1.3. 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 Authority, it cannot be removed and replaced with an approved material thoroughly compacted in place to support the pipe properly, a suitable foundation for the pipe, consisting of piling, timbers or other materials, in accordance with plans prepared by the Authority shall be constructed.

6.1.3.1.4. The trench shall be excavated only so far in advance of pipe laying as specified by the Authority.

6.1.3.1.5. The trench shall be so braced and drained that the workmen may work therein safely and efficiently.

6.1.3.1.6. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains and shall not be allowed to be spread in the vicinity of the work site.

6.1.3.1.7. Trenching by Machine or by Hand: Hand methods for excavation shall be employed in locations shown on the drawings given by the Authority. In other places excavation may be done by hand or by machine.

6.1.3.2.**Trench Dimensions And Minimum Clearance**

6.1.3.2.1. General:

6.1.3.2.1.1. Pipe Clearance in Rocks: Ledge rock, boulders and large stones shall be removed to provide a clearance of at least 150 mm below and on each side of pipes, valves and fittings for pipes 600 mm in diameter or less, and 200 mm for pipes larger than 600 mm in diameter.

6.1.3.2.1.2. The specified minimum clearances are the minimum clear distances which will be permitted between any part of the pipe or appurtenance being laid and any part, projection or point of such rock, boulder or stone.

6.1.3.2.1.3. A minimum cover of 1.20m, measured from crown of the pipe may be provided when heavy vehicular traffic is expected and 0.90m in all other cases.

6.1.3.2.1.4. Special consideration should be given to the depth of the trench. In agricultural land, the depth should be sufficient to provide a cover of not less than 900 mm so that the pipeline will not interfere with the cultivation of the land. In rocky ground, rough grazing or swamps, the cover may be reduced provided the water in the pipeline is not likely to freeze due to frost.

6.1.3.2.1.5. It may be necessary to increase the depth of pipeline to avoid land drains or in the vicinity of roads, railways or other crossings.

6.1.3.2.1.6. Horizontal Separation: A water main should be laid such that there is at least 3m separation, horizontally from existing or proposed drain or sewer line. If local conditions prevent this lateral separate water main may be laid closer to a storm or sanitary sewer, provided that the main is laid in separate trench or on an undisturbed earth shelf located on one side of the sewer at an elevation that the bottom of the water main is at least 0.5m above the top of the sewer.

6.1.3.2.1.7. Where a pipeline runs parallel to other pipelines or cables, the distance between them should not be less than 0.4 m. At points of congestion, a distance of 0.2 m should be maintained unless steps are taken to prevent direct contact.

6.1.3.2.1.8. Vertical Separation: In situations where water mains have to cross house sewer, storm drain, or sanitary sewer should be laid at such an elevation that the bottom of water main is 0.5m above the drain or sewer with the joints as remote from the sewer as possible. This vertical separation should be maintained for a distance of 3m on both sides measured normal to the sewer where it crosses.

6.1.3.2.1.9. Provisions for Joints: Additional width shall be provided at positions of sockets and flanges for jointing to be made properly. Depths of pits at such places shall also be sufficient to permit finishing of joints.

6.1.3.2.2. Metal Pipes (Cast Iron/ Ductile Iron/ MS Pipes):

6.1.3.2.2.1. The width of the trench at bottom between faces of sheeting shall be such as to provide not less than 200 mm clearance on either side of the pipe except where rock excavation is involved. Trenches shall be of such extra width, when required as will permit the convenient placing of timber supports, strutting and planking, and handling of specials.

6.1.3.2.2.2. When welding is to be carried out with the pipe in the trench, additional excavation of not more than 600 mm in depth and 900 mm in length should be provided all-round the pipe at the position of the joints for facilities of welding.

6.1.3.2.3. uPVC Pipes

6.1.3.2.3.1. Width: Trenches should be of adequate width to allow the burial of pipe, while being as narrow as practical. If expansion and contraction are not problems and snaking of pipe is not required, minimum trench widths may be obtained by joining the pipe outside the trench and then lowering the piping into the trench after the testing.

6.1.3.2.3.2. See Tables 6.3.2.3.1 and 6.3.2.3.2.for narrow (unsupported) and supported trench widths. For PVC pipes of diameter below 63mm, a minimum trench width of 30cm may be adopted.

6.1.3.2.3.3. Minimum Cover : The following guidelines should be followed:

a) If frost is anticipated, locate the pipeline below the frost line.

b) A minimum cover of 0.9 m when truck traffic is expected.

c) A minimum cover of 1.8 m when heavy truck or locomotive traffic (dynamic loads) is expected. Usually pipe below 2.0 m of cover are not affected significantly by dynamic loads. If the application prevents deep burial of the pipe and heavy traffic passing over the pipe is expected, it would be advisable to use steel or reinforced concrete casing to prevent damage to the pipe.

d) For high static and/or surcharge loads, it is important to use pipes of an appropriate stiffness in order to ensure the initial deformation of the pipe is maintained within a limit of 5 percent, maximum.

Table 6.1.3.2.3.1. Unsupported Narrow Trench Width - Minimum

Sl. No.	Nominal Pipe Size (Diameter in mm)	Trench Width	
		Number of Pipe Diameters (Approx.)	Width (mm)
1	63	7.1	450
2	75	6.0	450
3	90	5.0	450
4	110	4.0	450
5	125	4.0	500

6	140	3.9	550
7	160	3.5	560
8	180	3.2	580
9	200	3.0	600
10	225	2.8	630
11	280	2.4	680
12	315	2.25	710
13	355	2.1	760
14	400	1.9	760

Table 6.1.3.2.3.2. Supported Narrow Trench Width - Minimum

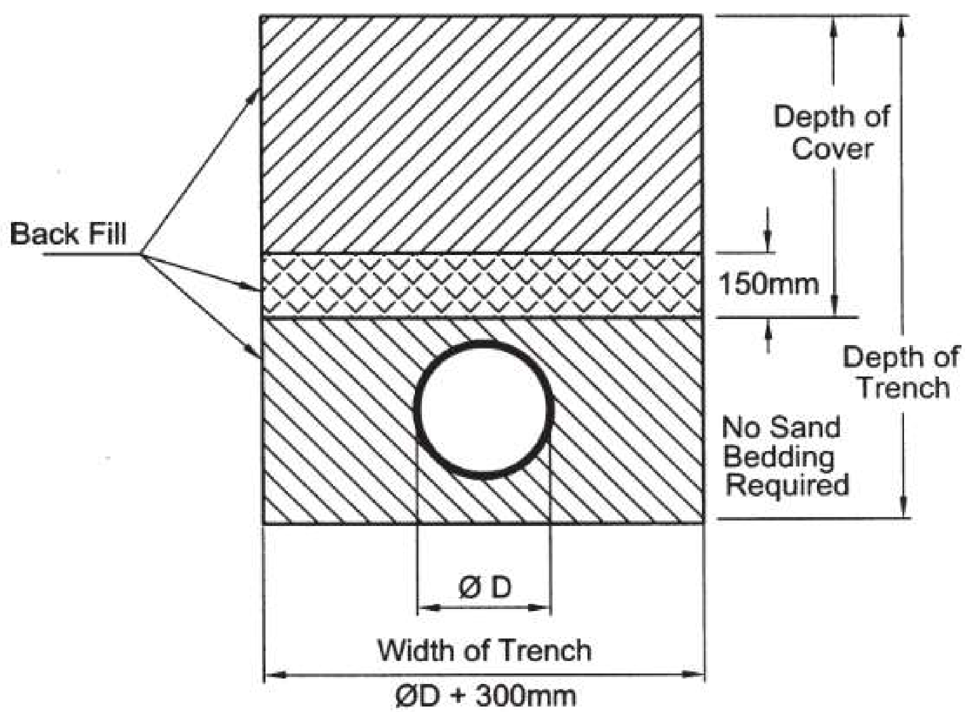
Sl. No.	Nominal Pipe Size (Diameter in mm)	Trench Width	
		Number of Pipe Diameters (Approx.)	Width (mm)
1	63	14.2	900
2	75	12.0	900
3	90	10.0	900
4	110	8.2	900
5	125	7.2	900
6	140	6.4	900
7	160	5.6	900
8	180	5.0	900
9	200	4.5	900
10	225	4.2	940
11	280	3.5	990
12	315	3.1	1040
13	355	3.1	1090
14	400	2.85	1140

6.1.3.2.4. PE Pipes

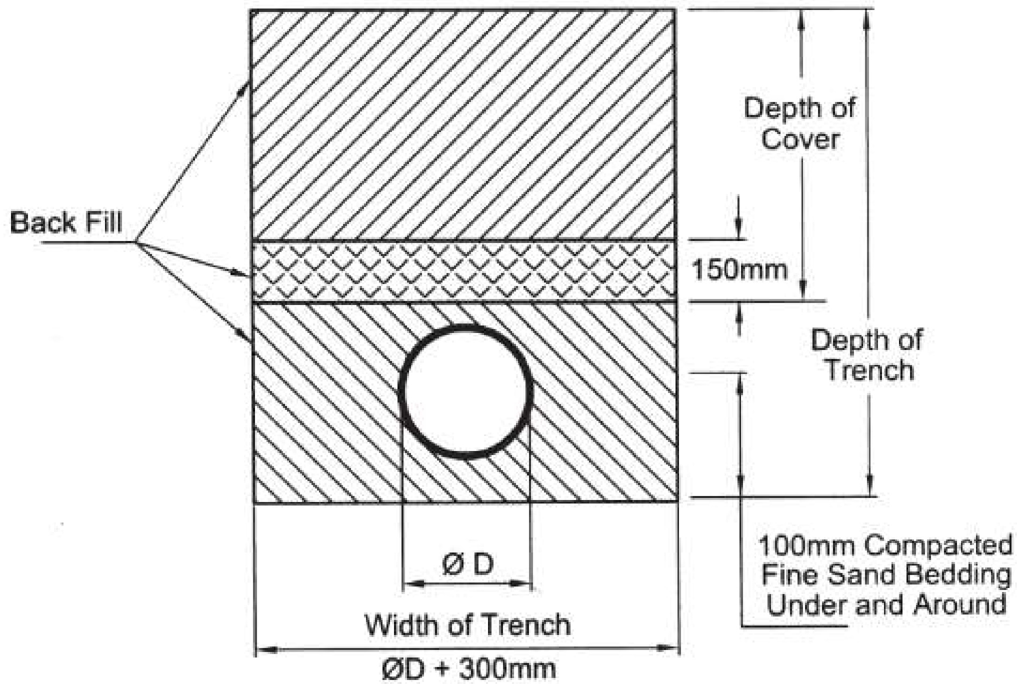
6.1.3.2.4.1. Trench width and depth shall be as per Fig. 6.1.3.2.4.1 and Table 6.1.3.2.4.1.

6.1.3.2.4.2. Polyethylene pipes can be jointed inside or outside the trench, as per site conditions. However, in case of jointing inside the trench, the width of the trench may be suitably increased to ensure work space.

6.1.3.2.4.3. The trench depth shall be as per Table 6.3.2.4.1.



For Soil having no Rocks and Natural Aggregate Comprised Primarily of Rounded Particles Created by Mechanical Erosion



For Soil having Sharp Rocks and Unconsolidated Material that are Made Up of Rocks Fragments > 20 mm Diameter

Fig: 6.1.3.2.4.1. Trench Layout

Table 6.1.3.2.4.1. Trench Dimensions

All Dimensions in Millimeters

Sl. No	Size of Pipe	Width	Initial Back Fill	Range of Depth of Cover
1	20-110	300	150	900 – 1100
2	125	425	150	900 – 1100
3	140	440	150	900 – 1100
4	160	460	150	900 – 1100
5	180	480	150	900 – 1100

6	200	500	150	900 – 1100
7	225	525	150	900 – 1100
8	250	550	150	900 – 1100
9	315	615	150	900 – 1100
10	355	655	150	900 – 1100
11	400	700	150	900 – 1100
12	450	750	150	900 – 1100
13	500	800	150	900 – 1100
14	560	860	150	900 – 1100
15	630	930	150	900 – 1100
16	710	1010	150	900 – 1100
17	800	1100	150	900 – 1100
18	900	1200	150	900 – 1100
19	1000	1300	150	900 – 1100
Notes				
Width may be increased where jointing inside trench becomes necessary because of site conditions.				
Under National/State Highways, a concrete/hume pipe shall be covered over the pipe.				
Depth is to be measured over the crown of the pipe.				
In case of mole plough technique of pushing the coils of diameter 20-100mm in a narrow trench the width of 300mm is not mandatory.				
Initial back fill material shall be as per IS 7634 (Part 2) – 2012				

For gravity lines SDR more than 22, manufacturers should be consulted for allowable deformation calculations under dynamic traffic load.

6.1.3.3.**Trench –Preparation/Protection/Finishing - Bedding and Side**

6.1.3.3.1. General (CPHEEO)

6.1.3.3.1.1. The trench bed must be free from any rock projections.

6.1.3.3.1.2. The trench bottom should be carefully examined for the presence of hard objects such as flints, rock, projections or tree roots. In uniform, relatively soft fine grained soils found to be free of such objects and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their lengths, the pipes may normally be laid directly on the trench bottom. In other cases, the trench should be cut correspondingly deeper and the pipes laid on a prepared under bedding, which may be drawn from the excavated material if suitable.

6.1.3.3.1.3. Previous Excavations: Where the trench passes over a sewer or other previous excavation, the trench bottom shall be sufficiently compacted to provide support equal to that of the native soil or conform to other regulatory requirements in a manner that will prevent damage to the existing installation.

6.1.3.3.1.4. Rock Excavation: The term 'rock' wherever used in this chapter shall have the same meaning as given under terminology in IS 1200 (Part 1): 1992

6.1.3.3.1.5. Blasting: Blasting for excavation shall be permitted only after securing the approval of the Authority and only when proper precautions are taken for the protection of persons or property. The hours of blasting shall be fixed by the Authority. The procedure of blasting shall conform to the requirements of local controlling Authority.

6.1.3.3.1.6. The trench shall be shored, wherever necessary, and kept dry so that the workman may work therein safely, and efficiently. The discharge of the trench dewatering pumps shall he conveyed &her to drainage channels or to natural drains, and shall not be allowed to be spread in the vicinity of the worksite.

6.1.3.3.1.7. Braced and Sheeted Trenches: Open-cut trenches shall be sheeted and braced as required by any governing state laws and municipal regulations and as may be necessary to protect life, property or the work. When close sheeting is required, it shall be so driven so as to prevent adjacent soil from entering the trench either below or through such sheeting.

6.1.3.3.1.8. The Authority shall have the right to order the sheeting to be driven to the full depth of the trench or to such additional depths as may be required for the protection of the work. Where the soil in the lower limits of a trench has the necessary stability, the Authority at discretion, may permit stopping of the driving of sheeting at some designated elevation above the trench bottom.

6.1.3.3.1.9. Sheeting and bracing which have been ordered to be left in place should be removed for a distance of 900 mm below the established street level or the existing surface of the street, whichever is lower. Trench bracing, except that which should be left in place, may be removed when the back filling has reached the respective levels of such bracing. Sheeting, except that which has been left in place, may be removed after the backfilling has been completed or has been brought up to such an elevation as to permit its safe removal. Sheeting and bracing may be removed before filling the trench, but only in such manner as will ensure the adequate protection of the completed work and adjacent structures.

6.1.3.3.2. Cast Iron

6.1.3.3.2.1. Trimming of Trench Bottoms: Where rock and large stone or boulders are encountered, the trench shall be trimmed to a depth of at least 150 mm below the level at which the bottom of the barrel of the pipe is to be laid, and filled to a like depth with granular material to pass through a sieve of 12.5 mm aperture size and well rammed to form a fair and clean bed for pipe.

6.1.3.3.2.2. Finish of Surfaces: In all cases there shall be a uniform and continuous bearing and support for the pipe at every point between the sockets or flanges except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 450 mm near the middle of each pipe length by the withdrawal of pipes lings or other lifting tackle. The finished sub-grade shall be prepared accurately by means of hand tools.

6.1.3.3.2.3. The sub-grade beneath the center line of the pipe shall be finished to within one cm of a straight line between the pipe joints or batten boards.

6.1.3.3.3. Ductile Iron/MS Pipes

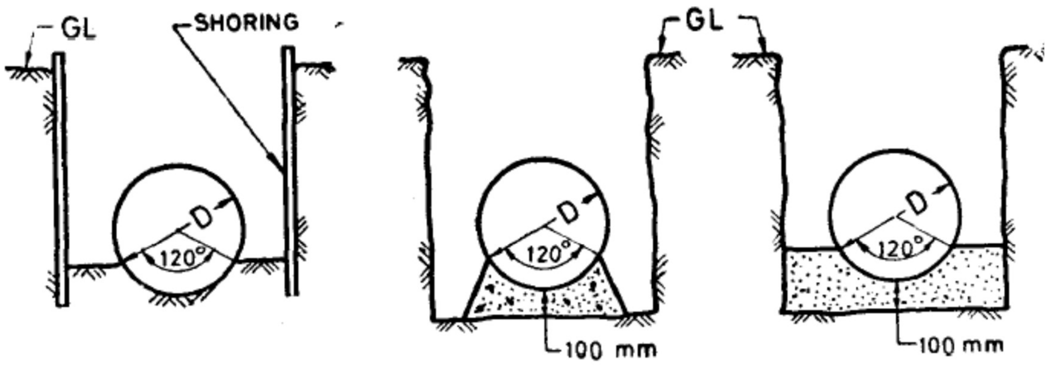
6.1.3.3.3.1. Care should be taken to avoid the spoil bank causing an accumulation of rainwater. (PWD 204.1.d & Fig may be added)

6.1.3.3.3.2. The bottom of the trench shall be properly trimmed to permit even bedding of the pipeline.

6.1.3.3.3.3. For MS pipes larger than 1200 mm diameter in earth and murum and for DI pipes, the curvature of the bottom of the trench should match the curvature of the pipe as far as possible, subtending an angle of about 120o at the centre of the pipe, as shown in (Fig. 3.3.3.1.(1 A)). The trench surface should be trimmed and leveled to permit even bedding of the pipeline and should be free from all extraneous matter which may damage the pipe or the pipe coating. Additional excavation should be made at the joints of the pipes so that the water main is supported along its entire length.

6.1.3.3.3.4. Where rock or boulders are encountered, the trench shall be trimmed to a depth of at least 100 mm below the level at which the bottom of the barrel of the pipe is to be laid and filled to a like depth with lean non-compressible material like sand of adequate depth to give the curved seating, as shown in (Fig.6.3.3.3.1.(1 B))and Fig. (Fig. 6.3.3.3.1.(1 C)).Material harmful to the pipeline should not be used.

6.1.3.3.3.5. Temporary under pining, supports and other protective measures for building structures or apparatus in or adjacent to the trench should be of proper design and sound construction.



1A Trench in Earth or Murum

1B Trench in Hard Rock with Cement Concrete Bedding.

1C Trench in Hard R with Sand Beddin

Fig: 3.3.3.1. Trenching of DI/ Steel Pipes

6.1.3.3.4. PVC Pipes

6.1.3.3.4.1. Where necessary to prevent cave-ins, trench excavations in unstable soil shall be adequately supported. As backfill is placed and sheeting withdrawn, the void left by the withdrawn sheeting shall be filled and compacted before withdrawing the next increment.

6.1.3.3.4.2. Trench Bottom: The trench bottom shall be constructed to provide a firm stable and uniform support for the full length of the pipeline. There should be no sharp objects that may cause point loading. Any large rocks, hard pan, or stones larger than 20 mm should be removed to permit a minimum bedding thickness of 100-150 mm under the pipe. For pipes of diameters 100 mm or greater, bell holes in the bedding, under each socket joint, shall be provided by removing some of the bedding material, to accommodate the larger diameter of the joint and to permit the joint to be made properly.

6.1.3.3.4.3. Bedding and backfill material may be available by selection from 'as dug' excavated material. –Such soils as free draining coarse sand, gravel and soils of a friable nature, that is soils which crumble easily, are considered suitable.

6.1.3.3.4.4. Excavated Material: Excavated material should be deposited at a sufficient distance away from the trench to prevent damage to the pipeline through falling stones or debris.

6.1.3.3.4.5. Soil: The type of soil and the amount of compaction of the pipe embedment directly affect the performance of the pipeline. With proper embedment soil and compaction, greater burial depths are possible and higher external pressure capability and less pipe deflection will occur.

6.1.3.3.4.6. 'As dug' material must be free from boulders, sharp stones, flints, lumps of clay or chalk. Contaminated soil and any organic material should be discarded. Where excavated material is not suitable, suitable imported material must be used.

6.1.3.3.4.7. Prepare the bedding by laying on soft soil and alternatively compacting and watering sparingly until an effective thickness of 100 to 150 mm is achieved.

6.1.3.3.5. PE Pipes

6.1.3.3.5.1. Flexibility: For rigid pipes such as concrete, etc, the pipe alone has to take the main vertical forces acting on the pipe, while flexible PE pipe makes use of the horizontally acting soil support accumulating as a result of the deflection of the pipe. This aspect improves the load bearing capacity of PE pipe especially useful property in gravity pipe design where there is no internal pressure to ensure the pipe circularity.

6.1.3.3.5.2. Trench Bedding: Polyethylene pipe requires no special bed preparation for laying the pipe underground, except that there shall be no sharp objects around the pipe. However, while laying in rocky areas suitable sand bedding should be provided around the pipe and compacted.

6.1.3.3.5.3. Water in the Trench (see Fig. 3.3.5.1.): The pipe shall be laid on a stable foundation. Where water is present or where the trench bottom is unstable, excess water should be removed before laying the pipe. In case there is a chance of floatation because of likely flood, the pipe shall be encased with concrete weights as per the buoyancy calculations.

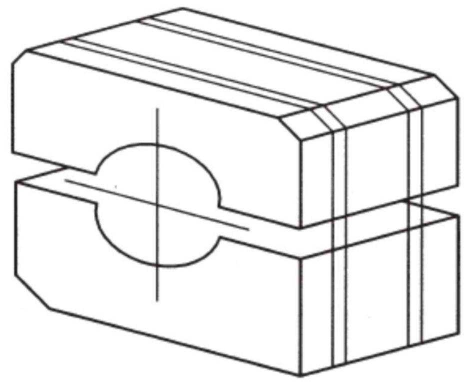


Fig. 6.1.3.3.5.1. Typical Anti-buoyancy Weight – Concrete Block

6.1.3.3.5.4. Under Water Installations (see Fig. 3.3.5.2): Polyethylene pipes are frequently used for carrying potable water across rivers/canals/lakes. Even water filled PE pipe is lighter than water. Thus the pipe can be aligned along the recommended route over the water surface and then submerged with suitable weights (see Fig.3.3.5.1.). Submerged installations require permanent concrete ballast rings attached around thepipe to ensure submergence and stable system once it is submerged. Concrete block design depends on type of installation, tidal flows and wave actions.

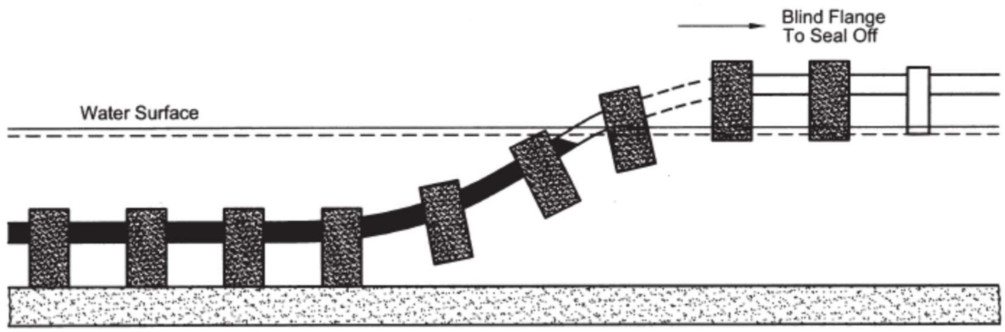


Fig.6.3.3.5.2. Under Water Installation

6.1.4. BACK FILLING

6.1.4.1.**General**

6.1.4.1.1. Surface Material for Re-use - All surface materials which, in the opinion of the authority, are suitable for re-use in restoring the surface shall be kept separate from the general excavated material as directed by the authority.

6.1.4.1.2. Stacking Excavated Material - All excavated material shall be stacked in such a manner that it will not endanger the work or workmen and it will avoid obstructing footpaths, roads and driveways. Hydrants under pressure, surface boxes, fire or other utility controls shall be left unobstructed and accessible during the construction work. Gutters shall be kept clear or other satisfactory provisions made for street drainage, and natural water-courses shall not be obstructed.

6.1.4.2. **Cast Iron/ Ductile Iron**

6.1.4.2.1. Back-Filling - For the purpose of backfilling, the depth of the trench shall be considered as divided into the following three zones from the bottom of the trench to its top:

a) Zone A: From the bottom of the trench to the level of center line of the pipe.

b) Zone B: From the level of center line of the pipe to a level 300mm above the top of the pipe.

c) Zone C: From the level 300mm above the top of the pipe to the top of the trench.

6.1.4.2.2. Back-Fill Material –

6.1.4.2.2.1. Back-fill material shall be free from cinders, ashes, slag, refuse, rubbish, vegetable or organic material, lumpy or frozen material, boulders, rocks or stone or other material, which in the opinion of the authority, is unsuitable or deleterious. However, material containing stones up to 200 mm as their greatest dimension may be used in Zone C, unless specified otherwise herein.

6.1.4.2.2.2. Back-Fill sand- Sand used for back-fill shall be a natural sand complying with 4.2.2.1., graded from fine to coarse. The total weight of loam and clay in it shall not exceed 10 percent. All material shall pass through a sieve or aperture size 2.00 mm and not more than 5 percent shall remain on IS Sieve or aperture size 0.63 mm.

6.1.4.2.2.3. Back-Filling gravel - Gravel used for back-fill shall be natural gravel, complying with 4.2.2.1. and having durable particles graded from fine to coarse in a reasonably uniform combination with no boulders or stones larger than 50 mm in size. It shall not contain excessive amount of loam and clay and not more than 15 percent shall remain on a sieve of aperture size 75 micron.

6.1.4.2.3. Back-Filling in Freezing Weather – Backfilling shall not be done in freezing weather except by permission of the authority, and it shall not be made with frozen material. No fill shall be made where the material already in the trench is frozen.

6.1.4.2.4. Back-filling in Zone A shall be done by hand with sand, fine gravel or other approved material laced in layers of 150 mm and compacted by tamping. The back-filling material shall be deposited in the trench for its full width of each side of the pipe, fitting and appurtenances simultaneously.

6.1.4.2.5. Back-filling in Zone B shall be done by hand or approved mechanical methods in layers of 150 mm, special care being taken to avoid injuring or moving the pipe. The type of backfill material to be used and the method of placing and consolidating shall be prescribed by the authority to suit individual locations.

6.1.4.2.6. Back-filling in Zone C shall be done by hand or approved mechanical methods. The types of back-fill material and method of filling ‘shall be as prescribed by the authority.

6.1.4.2.7. Back-Fill Under Permanent Pavement - Where the excavation is made through permanent pavements, curbs, paved footpaths, or where such structures are undercut by the excavation, the entire back-fill to the subgrade of the structures shall be made with sand in accordance with 4.2.2.1.

6.1.4.2.8. Paved footpaths and pavements consisting of stone, gravel, slag or cinders shall not be considered as being of a permanent construction. Method of placing and consolidating the backfill material shall be prescribed by the authority.

6.1.4.2.9. Back-Fill With Excavated Material - The excavated material may be used for backfilling the following cases, provided it complies with 4.2.2.1.

a) In Zone C, in cases where settlement is unimportant and when shown on the drawings or specified, the back-fill shall be neatly rounded over the trench to a sufficient height to allow for settlement to the required level.

b) In any zone, when the type of back-fill material is not indicated or specified, provided that such material consists of loam, clay, sand, fine gravel or other materials which are suitable for backfilling in the opinion of the authority.

6.1.4.3.**Steel Pipes**

6.1.4.3.1. Backfilling should closely follow the welding of joints of the pipe so that the protective coating should not be subsequently damaged. Material harmful to the pipeline shall not be used for backfilling. Refilling shall be done in layers not exceeding 300 mm. Each layer shall be consolidated-by watering and ramming, care being taken to prevent damage to the pipeline. The filling on the two sides of the pipeline should be carried out simultaneously.

6.1.4.3.2. The spiders provided during assembly and welding shall be retained until the trench is refilled and consolidated. Where timbers are placed under the pipeline to aid alignment, these shall be removed before backfilling. For further precautions and use of material in backfilling, reference should be made to clause 4.2. above.

6.1.4.4.**PE Pipes**

6.1.4.4.1. The initial back fill up to 150 mm above the crown of the pipe should be compacted with screened excavated material free of sharp stones or objects or with fine sand where no such material is available.

6.1.4.4.2. The excavated soil from the trenches should be placed such that it shall not interfere with stringing and jointing of the pipes.

6.1.4.4.3. In all cases, 150 mm above the top of the crown of the pipe is to be compacted either by mechanical or manual means. Wherever road crossing with heavy traffic is likely to be encountered — a concrete pipe encasing is recommended.

6.1.5. FINISHING WORKS

6.1.5.1. Concrete Slabs Over Pipes - When pipes are laid under roads and pavement subjected to heavy traffic loads, the trenches may be covered with reinforced concrete slabs of suitable dimensions.

6.1.5.2. Pipeline Markers - Distinctive markers should be erected at all roads, railways, river and canal crossings, and elsewhere as required to identify the pipeline and to indicate its position. Markers should be placed at field boundaries, preferably in such a way that they are not obscured by vegetation. At all valve installations, plates should be provided to give the same information as on the makers. Markers should not be treated with any substance likely to be harmful to livestock.

6.1.6. QUALITY CONTROL

6.1.6.1. The dry density/moisture content relationship will be determined by the heavy compaction test as per IS: 2720 (Part-8) for ensuring compaction of fill material at optimum moisture content.

6.1.6.2. The Contractor shall carry out moisture content determinations at frequent intervals or when there is a change in the material on the soils undergoing compaction so as to ensure that the moisture content of the soil is within the optimum range for the field compaction determined from compaction trials.

6.1.6.3. Density of the compacted layers shall be determined regularly or as and when required by the Engineer in accordance with IS: 2720 (Part-28) or by any appropriate method.

6.1.6.4. The control tests shall be carried out if the quantity of filling to be done is more than 50 m

6.1.7. REFERENCES

1.	IS 3114:1994	Laying of Cast Iron Pipes
2.	IS 12288:1987	Use and laying of Ductile Iron Pipes
3.	IS 5822:1994	Laying of Electrically Welded Steel Pipes for Water Supply
4.	IS 7634 (Part 3): 2003	Plastics Pipes Selection, Handling, Storage and Installation for Potable Water Supplies. (Part 3:Laying and jointing of uPVC Pipes)
5.	IS 7634 (Part 2): 2003	Plastics Pipes Selection, Handling, Storage and Installation for Potable Water Supplies. (Part 3:Laying and jointing of Polyethylene (PE) Pipes)
6.	IS 1200 (Part 1): 1992	Methods of measurement of building and civil engineering works
7.	PWD Quality Control Manual	
8.	CPHEEO Manual on Water Supply and Treatment	

6.2. INSTALLATION OF PVC PIPES

6.2.1. JOINTING TECHNIQUES

6.2.1.1. **General :**

6.2.1.1.1. Unplasticized PVC pipes are made by a continuous extrusion process and are generally available as rigid (hard), in-factory cut lengths. Pipes are supplied with one of the following four end conditions:

(a) Plain end, for jointing by means of separate couplers, including mechanical joints,
(b) Integral socket on one end, fir solvent cement jointing,
(c) Integral socket on one end for jointing with elastomeric sealing rings,
(d) Threaded, for jointing with threaded coupler.

6.2.1.1.2. Satisfactory jointing plays an important role in successful performance of these pipes. Commonly used joints are as follows:

(a) Solvent welded joints,
(b) Integral elastomeric sealing ring joints,
(c) Mechanical compression joints,
(d) Flanged joints,
(e) Screwed or threaded joints, and
(f) Union coupled joints.

6.2.1.2. **Solvent welded joints**

6.2.1.2.1. These are permanent in nature and can withstand axial thrust (end-load bearing). This technique is used with plain ended pipes with couplers, for pipes with integral sockets as well as with injection moulded fittings (see Fig. 1)

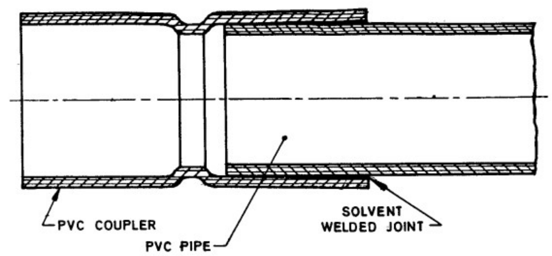


Fig. 1 PVC Solvent Welded Joint

6.2.1.2.2. Pipes and fittings are manufactured to certain tolerances to provide for small variations in the extrusion, moulding and socket processes and are not exact in size.

6.2.1.2.3. ***Solvent Cement***: Consists essentially of a solution of vinyl chloride polymer or copolymer dissolved in a suitable volatile mixture of organic solvents. The solvent constituents soften the mating surfaces, which diffuse into one another to form a ‘cold weld’

6.2.1.2.3.1. Specification: Solvent cement shall conform to all the requirements of IS 14182

6.2.1.2.3.2. Selection: Solvent cement is available in three grades of viscosity as given below to cover a range of pipe sizes from 20 mm to 630 mm. Sufficient solvent cement shall be applied so that a wet-film thickness adequate enough to fill a gap in a pipe joint is formed. Selection is also dependent on the climatic conditions prevalent at the site.

Pipe Size (mm)	Cement Type	Minimum Viscosity (MPas)	Minimum wet film thickness (mm)
Up to 50	Regular bodied	90	0.15
63 to 160	Medium bodied	500	0.3

Above 200	Heavy bodied	1600	0.6

Medium bodied and heavy bodied cements may be used for smaller pipe sizes than that shown in the table above. The reverse does not hold good.

6.2.1.2.3.3. Storage : PVC solvent cement should be stored in a cool place except when actually in-use at the site. The cement has a limited shelf life when not stored in hermetically sealed containers. HDPE screw top containers are not considered hermetically sealed. The cement is not suitable for use if it exhibits an appreciable change from the original viscosity, or if a sign of gelation is apparent. Addition of thinners is not recommended for restoring the original viscosity.

6.2.1.2.4. Procedure:

6.2.1.2.4.1. Cutting : Pipes are supplied with square-cut and de-burned ends. However, if pipes need to be cut to smaller lengths, use a fine-toothed hand saw and a mitre box or a power saw with wood-working blades, with a Suitable guide. The cutting must not raise a burr or ridge on the cut end of the pipe. Failure to remove the ridge will result in cement in the fitting or socket being scraped away from the jointing surfaces, leading to a dry joint with probability of join; failure, Remove-all bums ‘and ridges with a deburring knife, file, or abrasive paper (see Fig. 2).

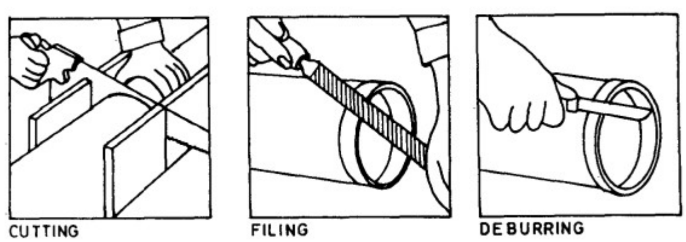


Fig. 2 Pipe Cutting at Site

6.2.1.2.4.2. Chamfering : Provide an approximately 2 mm wide, 15° chamfer on pipe ends. A chamfer prevents the cement film from being wiped off into the interior of the socket during assembly.

6.2.1.2.4.3. Dry fit test : Before applying cement, insert the pipe end into the socket of the next pipe or fitting to check that interference occurs at about 1/3 to 2/3 of the socket depth. When the pipe and the socket are at their extreme tolerances, the pipe can bottom (travel fully into) in the socket. In such a case, it should be a snug fit. A loose or wobbly fit will result in joint failure. Another pipe end or the socket should be selected until these conditions are fulfilled. Mark the insertion depth on the pipe end with a felt tip pen or marker.

6.2.1.2.4.4. Cleaning : Surfaces to be joined must be free of dust, dirt, oil, moisture and other foreign material. Wipe clean with a dry cloth. If this is not sufficient, use a chemical (such as dichloro-methane, methyl ethyl-ketone or mechanical cleaner). With chemical cleaners, observe safety precautions. Ketones are inflammable.

6.2.1.2.4.5. Application of cement : PVC solvent cement is quick drying, therefore it shall be applied as quickly and carefully .as possible and in consistence with good workmanship. For larger sizes, it is advisable for two workers to work simultaneously on the pipe and socket. The surface temperature of the mating surfaces should be above O"C but should not exceed 45°C. Water can be used to cool the surfaces, but these should be wiped thoroughly dry before application of cement.

Dip the applicator brush in the solvent cement and apply a liberal coat of cement to the end of the pipe up to the insertion depth.

Apply a uniform thin coat of cement inside the socket, working axially from the inside of the socket to the outside. Do not apply any cement on the shoulders of the socket (socket-to-pipe transition area). Care should be taken not to apply excess cement inside the socket. Excess cement m the socket will be pushed further into the pipe during assembly and cause the pipe to soften and weaken at that point. Hot and dry climates generally require slightly thicker coatings of solvent cement.

In climates with large differences between day and night temperatures, it is advisable to make joints early in the morning or in the evening when it is cooler. Thus, the joints are prevented from being pulled apart if the pipes contract.

6.2.1.2.4.6. Within 20s after the last application of solvent cement, insert the pipe into socket in a single steady and every controlled but forceful action. Press it in fully until it bottoms. No hammer blows should be used. If there is any sign of drying of the cement coat before insertion; the surface should be re-coated, avoiding application of excess cement in the socket. Once the insertion is complete, hold in place for 1 min without shifting the pipe in the socket.

6.2.1.2.4.7. For large diameter pipes, two or more workers may be needed for this operation. Mechanical equipment such as levers and winches maybe used. Care shall be taken to ensure that force is not transmitted to previously made joints. Until the cement is set, the pipe must be prevented from backing out of the socket.

6.2.1.2.4.8. Immediately after assembly, wipe the excess solvent cement from the pipe at the end of the socket. A properly made joint will have a uniform bead around its entire perimeter. Any gaps in this bead may be indicative of an improper joint due to insufficient cement or the use of a lighter-bodied cement than the one recommended.

6.2.1.2.4.9. Setting times : Joints should not be handled until the requisite setting time has elapsed. Recommended setting times are a function of the ambient temperature at the job site as given below:

Temperature (^{0}C)	Recommended setting time (h)
15 to 40	1
5 to 15	2
-5 to 5	4
-20 to -5	6

6.2.1.2.4.10. Installation and commissioning : After the setting time has elapsed, the pipe may be handled carefully for installation. Pressure testing may be carried out only after a curing period of 24 h.

6.2.1.3. **Integral Elastomeric Sealing Ring Joints**

6.2.1.3.1. Pipes are cut to length and bell socket in-line, to form a groove for the elastomeric sealing ring, and supplied in nominal lengths. Couplers and bends fabricated out of UPVC pressure pipes are likewise socket.

6.2.1.3.2. Elastomeric sealing ring joint consists of an elastomeric sealing element located in the groove in the socket formed integrally with the pipe or fitting. The sealing element (sealing ring) is automatically compressed to form a pressure tight seal when the spigot of the pipe is inserted into the socket.

6.2.1.3.3. These joints are non-end load bearing and it is essential to ensure the probability of joint separation due to axial thrust. Joint separation can be prevented in below ground applications by incorporating concrete anchor blocks at appropriate places. In above ground applications, anchor blocks must be provided (see 6.4). Where large diameter pipes operating at high pressures are involved, axial thrusts of several tonnes can be developed.

6.2.1.3.4. In order to meet water quality and bio-degradation requirements, elastomeric sealing rings are usually made from synthetic materials like ethylene-propylene-diene (EPDM) copolymer, styrene-butadiene rubber (SBR) or a combination of synthetic and natural rubber. The material should conform to IS 5382.

6.2.1.3.5. ***Procedure***

6.2.1.3.5.1. Pipes are supplied with the spigot end chamfered. However, if pipes have to be shortened for any reason, preparation of the ends will be necessary before assembly.

6.2.1.3.5.2. Cutting of pipes, if required, must be done on a jig to ensure that the cut is square to the axis of the pipe. It is recommended that the pipe be marked around the entire circumference prior to cutting. The pipe ends must be chamfered at an angle of 15° with a medium grade tile and de-burred. (see Fig. 2)

6.2.1.3.5.3. Clean the spigot end of the pipe up to the insertion depth (depth of the corresponding socket). Remove all traces of mud, dirt, grease and gravel. Do not use any chemicals or solvents for cleaning. For stubborn areas of dirt. a very fine grade of emery or sand paper can be used lightly. Wipe the pipe with a clean cloth moistened with water and allow to dry completely.

6.2.1.3.5.4. Clean the inside of the socket. Remove all traces of mud, dirt, grease and gravel. Do not use any chemicals or solvents for cleaning. For stubborn areas of dirt, a very fine grade of emery or sand paper can be used lightly. Wipe the inside of the groove with a damp cloth and allow to dry completely.

6.2.1.3.5.5. Mark the insertion depth on the spigot of the pipe, if not already applied by the manufacturer. The insertion depth is equal to the depth of the socket of the pipe, measured up to the end of the parallel portion of the socket (excluding the shoulder). This distance is marked on the spigot (excluding the chamfer) with an indelible felt-tip marking pen.

6.2.1.3.5.6. Insert the elastomeric sealing ring into the groove. Rings to be used are system specific and shall be those supplied by the manufacturer for his own system. Form the ring into a heart shape by pinching a portion of the ring from the inside (see Fig. 3). Insert into the socket and release to seat into the groove. Ensure proper seating of the ring in the groove. If the ring is wrongly inserted it will lead to leakage. It may also dislocate completely during assembly. Follow instructions of the manufacturer.

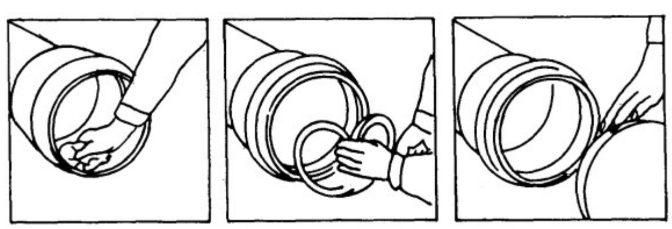


Fig. 3 Sealing Ring Joint Assembly

6.2.1.3.5.7. Apply lubricant to the outside of the spigot (consult the manufacturer). The lubricant should cover the entire surface of the spigot for at least half the insertion depth, starting from the end of the pipe. The lubricant used should not have any detrimental effect on the pipe, fittings or the elastomeric sealing ring and shall not be toxic, shall not impart any taste or odour to the water or encourage growth of bacteria. Do not use oil-based or solvent-based lubricants

6.2.1.3.5.8. Align the socket and spigot correctly in the horizontal and vertical planes. Ensure that no sand or dirt adheres to the lubricated surfaces of the pipe.

6.2.1.3.5.9. Insert the spigot end carefully into the socket. Place a firm wooden block against the other end of the pipe and, using a crow-bar as a lever, push home the spigot up to the insertion depth mark (see Fig. 4). For larger sizes of pipe, the use of a jointing jack may be helpful. The jack can also be used to extricate a pipe from a socket.

6.2.1.4.**Mechanical Compression Joints**

These are commonly separate fittings made from UPVC or metal and can be in the form of a coupler for connecting pipes and tittings of the same material and of the same dimensions, or as an adaptor for connecting components of different materials andlor dimensions. Generally compression fittings consist of four main elements: body, elastomeric scaling rings, backing (compression) rings and bolts. Both pipe ends should bc clean and free from damage before assembly is begun. Each element is positioned on the pipe separately, centred over the joint and the sealing rings compressed between the body of the fitting and the pipe by tightening the backing rings. Bolts should not be over tightened and the manufacturer's recommendations followed at all times (see Fig. 5)

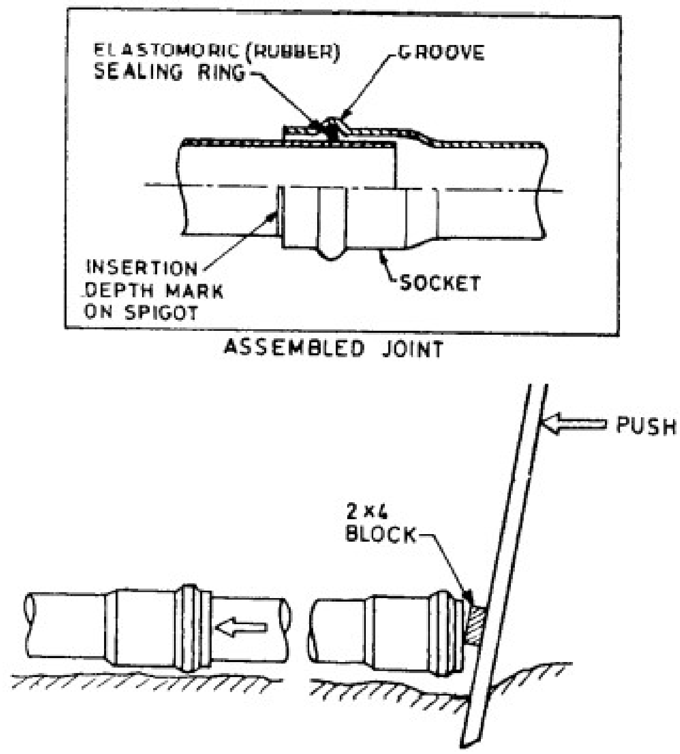


Fig. 4 Bar and Block Assembly

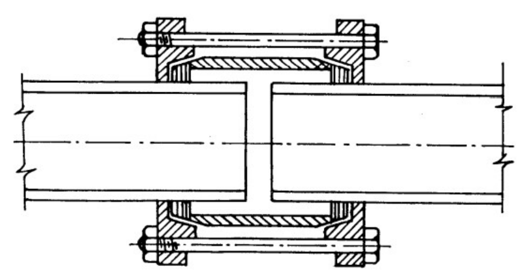


Fig. 5 Mechanical Compression Joint

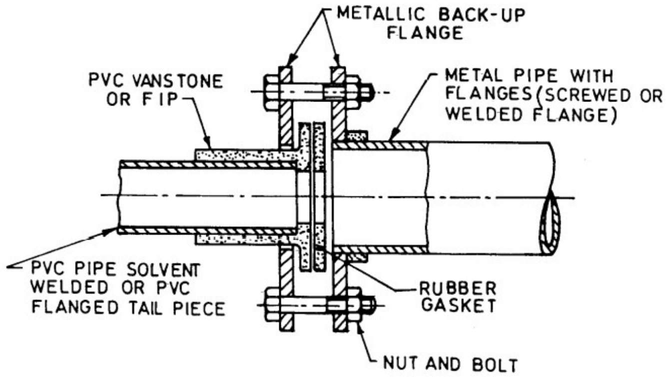


Fig. 6 Flanged Joints with PVC

6.2.1.5.**Flanged Joints**

These are used for jointing of UPVC pipes to other pipes, fittings, valves and vessels made from dissimilar materials, for example metals. The joint is made by compressing a gasket or elastomeric sealing ring between the mating surfaces of the flanges. Detailed flange designs can vary considerably. Figure 6 and Fig. 7 show two types of flanged joints.

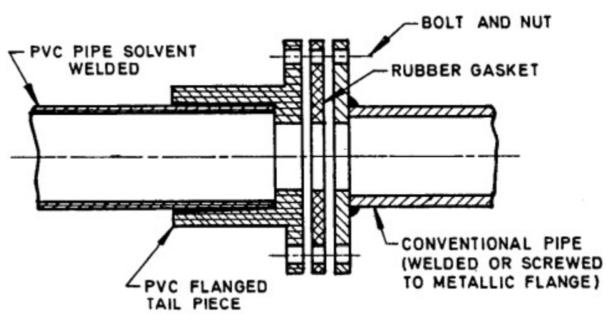


Fig. 7 Flange Joints (Jointing PVC Pipes and other Conventional Pipes using PVC Flanged Tail Piece)

6.2.1.6.**Screwed or Threaded Joints**

These are similar to the joints used with metal pipes. If the pipe has to be joined by screw threads, only thick walled pipe should be used and cut with taper threads. Some manufacturers supply pipes with factory cut threads. Threaded pipes shall not be subjected to a pressures exceeding two-thirds of the rating for unthreaded pipes.

6.2.1.6.1. To obtain a good thread, it is essential to ensure that:

a) Die holder is fitted with a guide of the correct size. The guide must be properly screwed down so that the two halves of the die are flush with the face of the holder.
b) Die is not blunt.
c) Two halves of the die are adjusted so that they are seated squarely in the holder and are equidistant from the sides of the holder. Observe the gaps on either side.
d) There are no sharp edges on the end of the pipe. Provide a light chamfer with the edge of a sharp knife.
e) Die holder is carefully slid over the pipe and the two halves of the die adjusted with the fingers so that the first threads seat lightly on the pipe. Pipe must be properly centered. Now tighten the adjusting screws ¼ turn with a spanner.
f) Thread is cut slowly and that after every ½ turn, the die is turned back ¼ turn.
g) Entire thread is cut in four equal passes

   Automatic threading machines may also be used. Follow the instructions of the manufacturer.

6.2.1.6.2. Short pieces of thick-walled pipe maybe threaded at one end and solvent cemented onto normal walled pipe at the other to make the connector pieces to screwed metal fittings. This system may be used for pipes up to 50 mm outside diameter.

6.2.1.6.3. No tape or paste shall be used for jointing. The joint shall be made to firm hand tightness using only strap wrenches.

6.2.1.6.4. There is no well-defined increase in tightness at assembly as there is with metal fittings. These joints can therefore very easily be overstrained.

6.2.1.6.5. Injection moulded threaded joints are used for jointing PVC to metal pipes. Injection moulded threads are less notch sensitive than cut threads.

6.2.1.6.6. PVC to metal connections with threaded joints should be made with the PVC as the male components of the joint. PVC as the female component may be used only when specific arrangements are made to prevent over tightening or where both the threads are of parallel form and the fluid seal is made by a separate ring or gasket. A typical illustration of this is shown in Fig. 8.

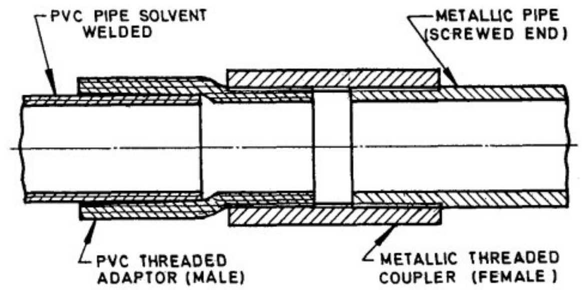


Fig. 8 Jointing PVC Pipe to Conventional Pipe using Threaded Joints

6.2.1.6.7. While connecting metallic water taps to the PVC pipes in domestic plumbing, it is recommended to use a metallic coupler to the tap and then connect the same to the PVC pipe using injection moulded threaded joints. The metallic part alone is supported and not the PVC. The unsupported length from the face of the wall should not be more than 100 mm for satisfactory operation and a strong coupling should be provided on the face of the wall at the point of overhang. For any repairs on the tap, the tap should be removed from the metal coupler to avoid working on it *in-situ*. A typical illustration of such a connection is shown in Fig. 9.

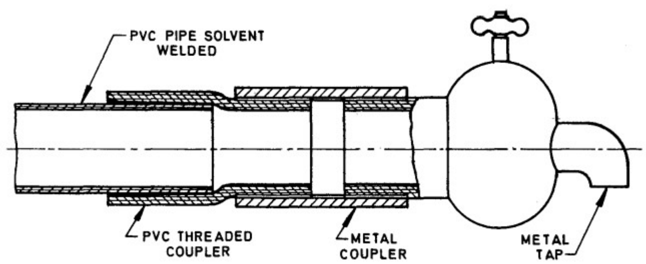


Fig. 9 Connection of PVC Pipe to Metallic Water Taps

6.2.1.7.**Union Joints**

This is a form of flanged joint, but the faces are held together by a screwed connection. A composite metal and PVC socket union is a very satisfactory method of jointing PVC to screwed metallic fittings. A typical illustration of union is shown in Fig. 10.

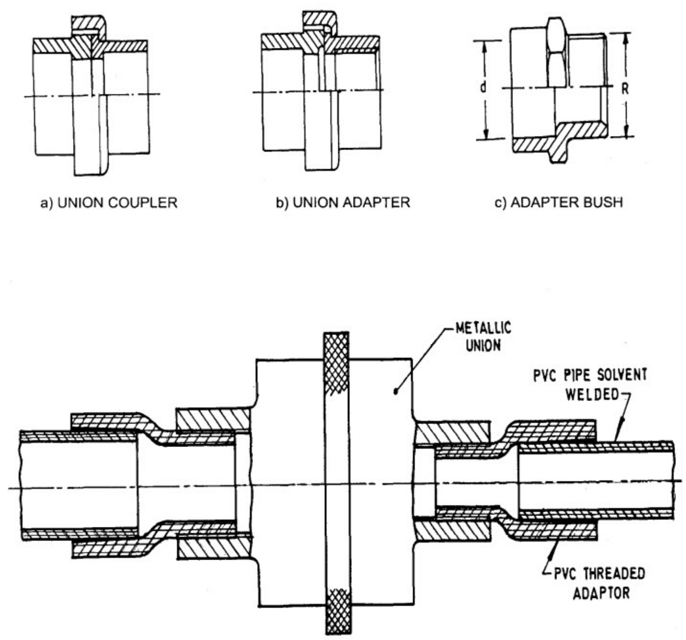


Fig. 10 Types of Union Joints

6.2.2. LAYING

6.2.2.1. Lay the pipes in the trench after ensuring that bell holes have been provided for at the appropriate places in the bedding (pipes of diameter 110 mm or less, with no live load application, do not require bell holes in the trench bottom). These have to be refilled carefully after testing of the pipeline and prior to complete backfilling of the trench. Though not essential, the pipes should be laid with the spigots entered into the sockets in the same direction as the intended flow of water.

6.2.3. ANCHORING

6.2.3.1. To sustain ‘thrust caused by internal pressure, concrete anchor blocks should be provided at all changes of direction, tees, blank ends, large reductions in diameter and valves. The purpose of the anchor block is to transfer the total thrust to the trench sides.

It is therefore important to take account of the load-bearing capacity of the surrounding ground (see Fig. 11).

6.2.3.2. Recommended mixture for concrete is one part cement, two parts washed sand and two parts gravel.

6.2.3.3. Where concrete would be in direct contact with the pipe or fittings, these should be wrapped with a compressible material, for example rubber sheet or foamed polyethylene sheet, to accommodate creep and prevent the occurrence of high local stress concentrations. The compressible material should not contain substances which could attack the pipe, for example plasticizers.

6.2.3.4. Typical thrusts generated are given in Table 3. Thrust forces on reducers need only be considered where the reduction in diameter is large (315 to 90 mm). In such cases, the thrust is the product of test pressure and annulus area:

$$F = 2p.\pi.\frac{D_i^2 - D_e^2}{4}$$

Where;

F = thrust force;

P = test pressure;

D_i = inside diameter of the larger pipe; and

D_e = outer diameter of the smaller pipe.

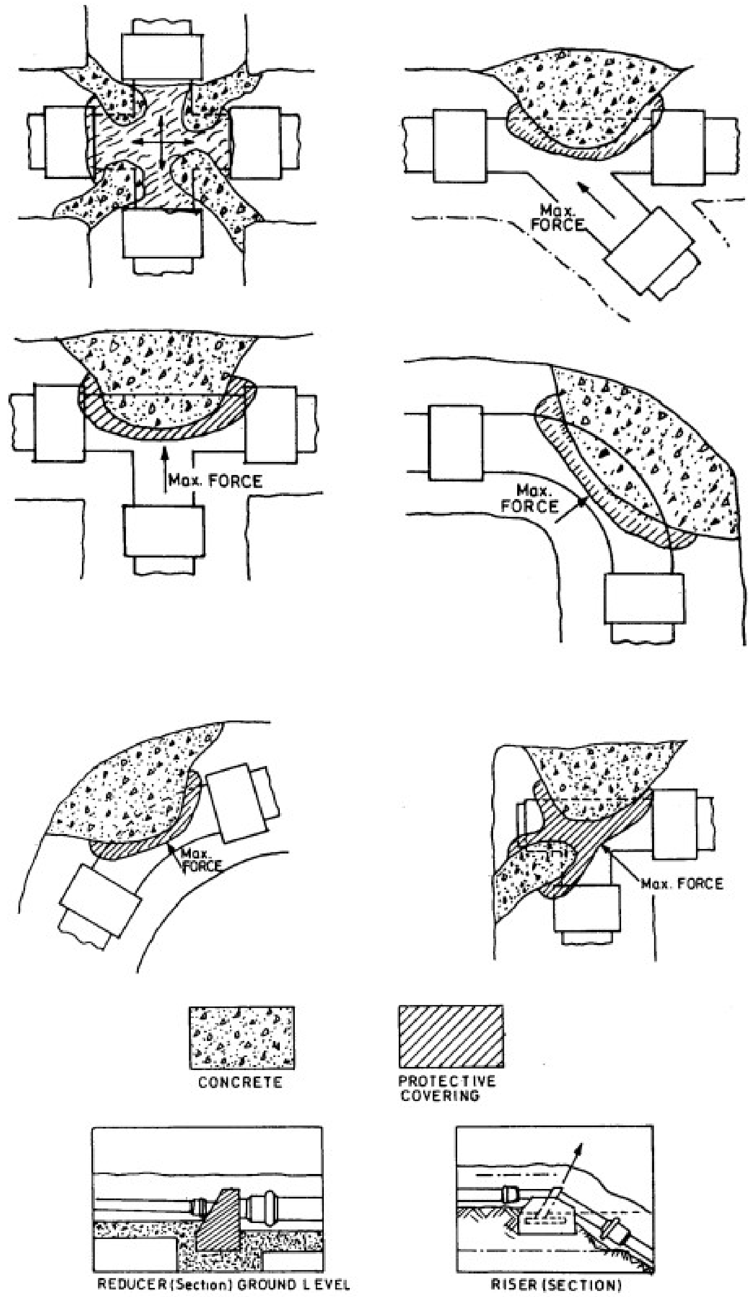


Fig. 11 Various Types of Poured Concrete Anchoring

Table 3 Thrust Forces for Blank Ends and Bends (Clause 3.4)

Sl No.	Nominal Diameter d_n mm	Thrust on Blank End (kN/bar)[1]	Radial Thrust on Bends kN/bar of Various Angles (kN/bar)[1]			
			90°	45°	22. 5°	11.25°
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	63	0.31	0.44	0.24	0.12	0.06
ii)	75	0.44	0.62	0.3	0.17	0.09
iii)	90	0.64	0.90	0.49	0.25	0.12
iv)	110	0.95	1.34	0.73	0.37	0.19
v)	125	1.23	1.74	0.94	0.48	0.24
vi)	140	1.54	2.18	1.18	0.68	0.30
vii)	160	2.01	2.84	1.54	0.78	0.39
viii)	180	2.54	3.60	1.95	0.99	0.50
ix)	200	3.14	4.44	2.40	1.23	0.62
x)	225	3.98	5.62	3.04	1.55	0.78
xi)	250	4.91	6.94	3.76	1.92	0.96
xii)	280	6.16	8.71	4.71	2.40	1.12
xiii)	315	7.79	11.02	5.96	3.04	1.53
xiv)	355	9.90	14.00	7.58	3.86	1.94
xv)	400	12.57	17.77	9.62	4.90	2.46
xvi)	450	15.90	22.49	12.71	6.21	3.12
xvii)	500	19.63	27.77	15.03	7.66	3.85
xviii)	560	24.63	34.83	18.85	9.61	4.83
xix)	630	31.17	44.08	23.86	12.16	6.11

[1] The values in the table are per bar of internal pressure.

6.2.4. ABOVE GROUND INSTALLATION

6.2.4.1. Since solvent cemented joints will sustain axial thrust caused by internal pressure, it is strongly recommended that UPVC pipes and fittings systems installed above ground or in service ducts constructed below ground are jointed by the solvent cement method. In certain circumstances the manufacturer's advice should be considered. Other forms of end-load bearing joints are also acceptable for inclusion in above ground installations.

6.2.4.2. UPVC pipes may fracture if fluids contained within the pipes are allowed to freeze. Sections which are likely to freeze should be isolated and drained, or insulation provided to prevent damage.

6.2.4.3. Pipes should be installed in such a way as to ensure that the minimum amount of stress is induced in the system from movement caused by expansion/ contraction or any other forces (see Fig. 12).

6.2.4.4. UPVC pipes should not be restrained in the hoop direction by straps or clamps made from unyielding material. The use of a compressible material such as rubber of foamed polyethylene between clamp and pipe is recommended. Pipes should be free to move in the longitudinal direction unless otherwise fixed for expansion contraction control

6.2.4.5. UPVC pipes should be installed at sufficient distances from sources of heat to prevent damage due to radiant heat.

6.2.4.6. All control devices (such as valves) should be correctly supported so that the pipe is not subjected to any operational torsion strain. In addition, the support provided should be sufficiently robust to prevent bending and direct stresses being induced by the weight of the device.

6.2.4.7. UPVC pipes and fittings installed above ground should be protected from direct sunlight.

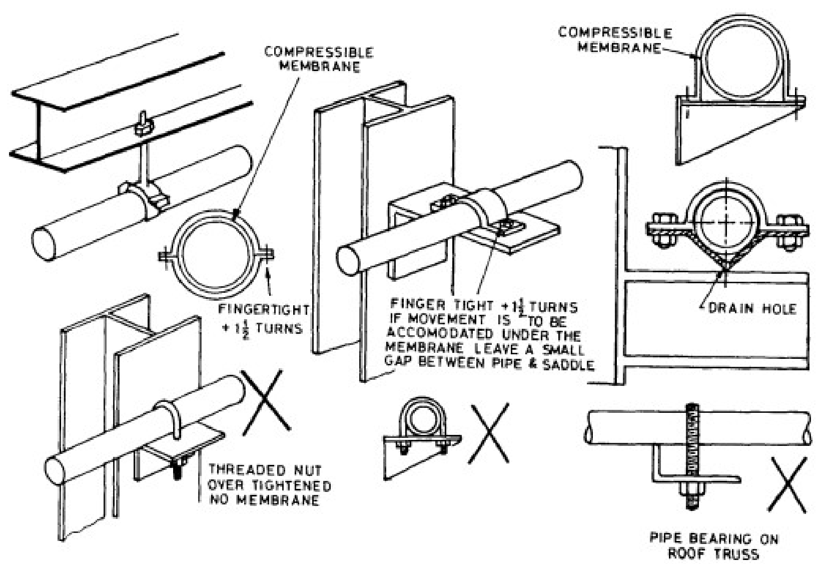


Fig. 12 Correct and Incorrect Installation

6.2.5. INSTALLATION IN DUCTS

6.2.5.1. Where possible, pipes with end-load bearing joints should be used for installation inside inaccessible ducts. In addition, rings should be fitted to the pipe to provide optimum support and to facilitate the withdrawal of the pipe in the event of rupture (see Fig. 13 for typical detail). For large diameter pipes, or where the duct is large compared to the pipe but not large enough to be accessible, other methods of securing the pipe maybe necessary (see Fig. 14). The opening between the pipes and the ducting system should be sealed at the ends.

6.2.5.2. Installation of pipes inaccessible ducts should be as described for above ground installation under 4.

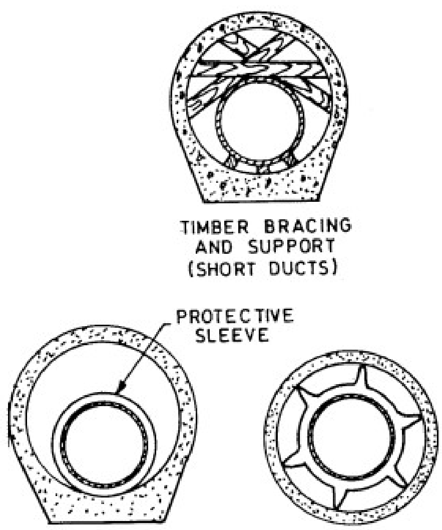


Fig. 13 Typical Details of Pipes Installed in Small Ducts

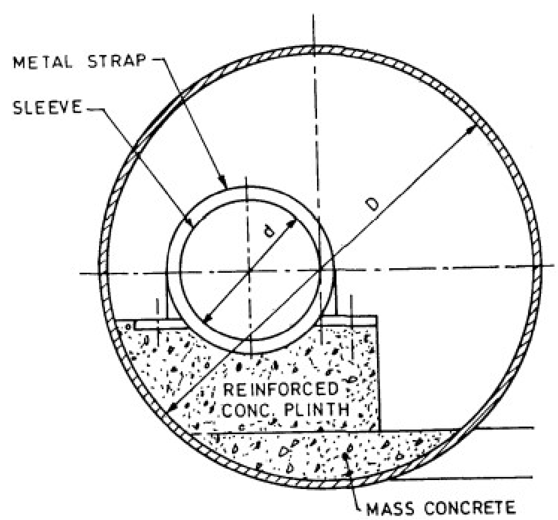


Fig. 14 Typical Details of Pipes Installed in Large Duct

6.2.6. TESTING

6.2.6.1. WARNING: Pressure tests should never be carried out using compressed air or gasses.

6.2.6.2. Procedure

6.2.6.2.1. Pipe systems should be hydraulically tested in lengths appropriate to the diameters and site conditions. Pipelines longer than 800 m may require testing in sections. Preferably, the length selected for test is between 300 m and 500 m.

6.2.6.2.2. Preferably, the test should be carried out between blank flanges (see Fig. 15). Testing against closed valves is not recommended, unless there is no alternative.

6.2.6.2.3. Do not support the end pieces of the test section against the already laid pipes of the proceeding section.

6.2.6.2.4. Testing should not take place until any concrete used for anchoring has fully cured (normally 72 h) and attained its required strength. Solvent cemented joints must be allowed to harden for a minimum of 24 h before being subjected to test condition.

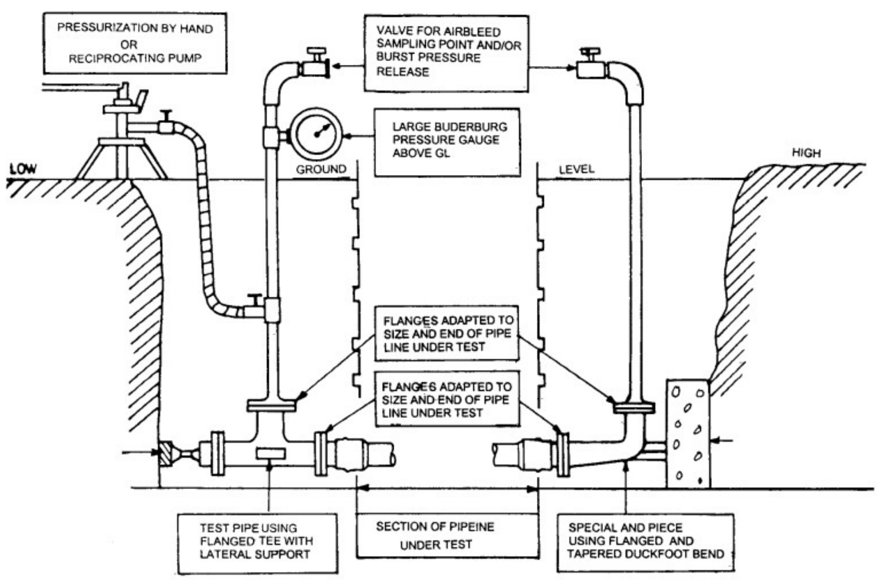


Fig. 15A Typical Layout Details for Test Ends

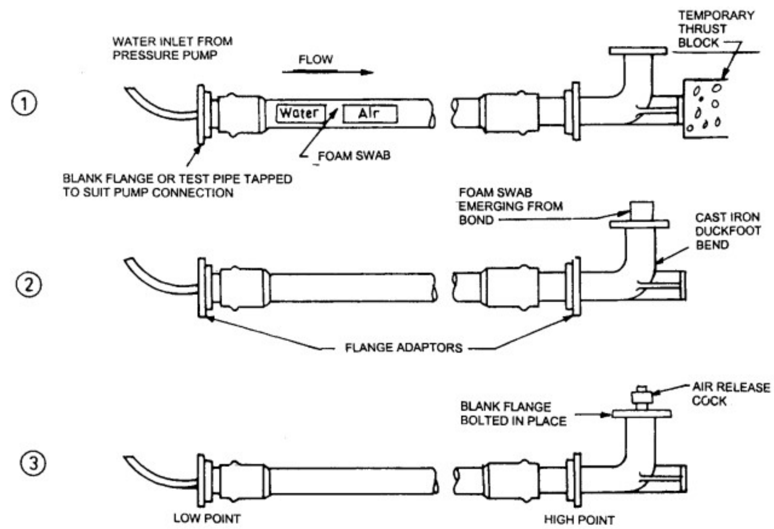


Fig. 15B Filling Behind a Form Swab

Fig. 15 Pressure Testing of Installed Pipeline

6.2.6.2.5. It is important to provide sufficient backfill over the main barrel of the pipe, to prevent displacement and to maintain stable temperature conditions. Leave joints free for inspection.

6.2.6.2.6. The test position should be located at the lowest point of the pipeline profile to encourage expulsion of air as the pipe is being filled with water. Adequate air release mechanisms should be located at all high points along the line.

6.2.6.2.7. Test-ends should be designed to enable the measured filling and subsequent emptying of the pipeline. Air bleed should also be incorporated at each end.

6.2.6.2.8. Pressurizing equipment should be adequately sized. Check all seals and non-return valves prior to the test. Pressure gauges should have an accuracy of + 0.2 bar. Automatic pressure recording equipment is recommended.

6.2.6.2.9. Before filling the pipeline, all line valves and air venting systems should be checked open. All air must be removed from the system.

6.2.6.2.10. Fill the system slowly. Water velocity must not exceed 0.6 m/s. Potable water pipelines should be tested with potable water only. After charging, close all air valves and check proper action of automatic valves.

6.2.6.2.11. During filling, a number of movements will be seen in the pipeline. Allow the pipeline to stabilize under a nominal pressure for a minimum of 2 h.

6.2.6.3.Test Pressure

6.2.6.3.1. The test should conform to the following conditions.

a) be carried out at ambient temperature;
b) be applied for at least 1 h, but not more than 24 h; and
c) not exceed 1.5 times the maximum rated pressure of the lowest rated component.

6.2.6.4.Applying the Test

6.2.6.4.1. Allow the system to stabilize for 2 h after filling. Apply pressure steadily. Observe pressure gauges throughout and record the rates of pressure increase recorded.

6.2.6.4.2. The pressure should be increased till the specified pressure is reached at the lowest part of the section. Maintain test pressure at this level, by additional pumping if necessary, for a period of 1 h.

6.2.6.4.3. Close all valves and disconnect the pressurizing unit. No further water should be allowed to enter the system for a further period of 1 h.

6.2.6.4.4. During the test period, carry out a visual examination of all joints and exposed connections.

6.2.6.5.Interpretation of the Results

6.2.6.5.1. There should be no leakage in any part of the section.

6.2.6.5.2. If there has been a decrease in pressure during this period other than due to leakage, the original pressure is re-established by injecting a measured quantity of water into the section.

6.2.6.5.3. The test is considered to be satisfactory if:

a) there is no decrease in pressure (a slight rise in pressure is also, possible due to changes in ambient temperatures),
b) the measured quantity of water required to reinstate the pressure to the original test pressure is less than the ‘permissible maximum’ Q,

where Q = 4.5 litres per 1.6 km per 25 mm of nominal bore per 30 m head of test pressure per 24 h

The volume of water added is an allowance made to compensate for the natural expansion/movement of the pipe and flexible joints under pressure and for the inevitable entrapment of small amounts of air within the test length. In bubble form, this air compresses and may pass in and out of solution at test pressures.

6.2.6.5.4. On completion of any test, the residual pressure should be released slowly and in a carefully controlled manner.

WARNING: The rapid decompression of any entrained air may cause surge conditions which are potentially dangerous both to the pipeline and to personnel.

6.2.6.5.5. All defects revealed in the test should be rectified and the procedure repeated until a satisfactory result is obtained.

6.3. INSTALLATION OF PVC PIPES

6.3.1. JOINTING TECHNIQUES

6.3.1.1.General :

6.3.1.1.1 Polyethylene pipes are made by continuous extrusion process and are generally available in factory cut lengths and in form of coils. PE pipes conforming to IS 4984, as they are UV protected (due to carbon black content in the pipe), may be stored either in open or covered.

6.3.1.1.2 The commonly used joints are as follows:

a) Fusion Welding

i. Butt fusion welding,

ii. Socket fusion welding, and

iii. Electro fusion welding

b) Insert type joints,

c) Compression fittings/push fit joints,

d) Flanged joints,

e) Spigot and socket joints

6.3.1.2.Fusion welded joints

The principle of fusion welding is to heat the two pipe surfaces to a designated temperature and then fuse them together by application of sufficient force. This force causes the melted materials to flow and mix, there by resulting in fusion.

Fusion welding of PE pipes must be carried out with welding equipment having temperature and pressure (where applicable) display arrangements. PE pipes and PE fittings, to be joined by face-to-face (butt fusion) welding must be of the same wall thickness and the ends must be cut square. However, in some cases of fusion, where face-to-face contact is not involved the jointing pipes/fittings wall thicknesses need not be same.

The integrity of the fusion joint is dependent on the cleanliness, temperature control and designated equipment that has been properly maintained.

The pipe ends shall be dry and free of dust. Mating surfaces shall be planed/scraped before fusion to remove surface material as polyethylene (PE) oxidizes on exposure to air. These prepared (scraped) surfaces should not be touched, as there is a risk of contamination of the surface, which may affect the weld efficiency. The site conditions must be protected against bad weather influences such as moisture and temperatures below 5°C.

The fusion welding procedure described here is suitable for welding polyethylene pipes and fittings falling in melt flow rate (MFR) range of 0.1–1.2 g/10 min at 190°C with nominal load of 5 kgf.

6.3.1.2.1. Butt Fusion Welding: See Fig. 1

6.3.1.2.1.1. Butt fusion equipment

Basic welding machine shall be self-supporting such as guides and clamps to suit the stability of the basic machine and with sleeves as per the size requirement along with the following accessories:

a) Non-stick coated with poly tetra flouro ethylene (PTFE), heating plate with thermostat and temperature indicator,

b) Chamfering (Planing) tool — electrical/ manual as appropriate, and

c) Electro-hydraulic power pack (for sizes greater than 125 mm) unit with pressure indicator, bypass arrangement and accumulator.

The butt fusion equipment shall incorporate a facility for supporting the heating plate and planing tool (necessary to square cut the pipe end) when in use. The machine shall be robust enough to withstand normal field use.

Butt welding machines can be manual (for diameters up to 125 mm), hydraulic or pneumatic. However, a locking system to hold the fusion force is to be ensured in all the systems, and the equipment shall be protected against exerting over-pressure on the pipe. It shall be able to maintain the required interface force on the pipe or fittings end as long as necessary.

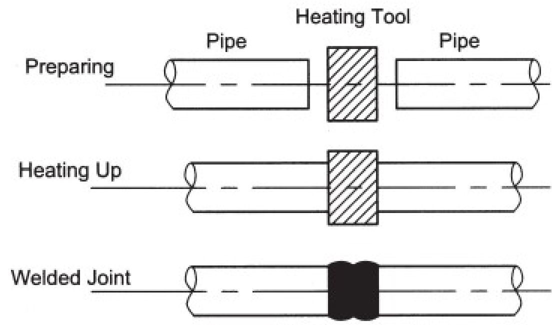


Fig. 1 Butt Welding Procedure of PE Pipes

6.3.1.2.1.2. Butt welding procedure (see Fig. 1)

a) Clamp the pipes/fitting in the butt fusion machine.

b) Wipe the ends to be welded, inside and out, with a clean cloth to remove water, dirt, mud, etc.

c) Welding ends should be squared. In case of pipe, plane both ends by a planer (mechanical/ electrical for pipe diameters greater than 160 mm) until they are perfectly square. Fittings' ends can be re-cut square, where necessary.

d) Remove the plastic shavings from the vicinity of the ends without touching the prepared surface as any contamination will be detrimental to the welding process. Re-clean the surface with proper solvent.

e) Bring together the two ends and ensure they are aligned.

f) Check the hot plate (mirror) temperature (range 200-230°C) and make certain the plate surfaces are clean. It is good practice to make 'dummy' welds daily, prior to welding sessions as a means of cleaning the mirror. That is, the weld procedure should be taken to the heat soak stage, when the process can be aborted. The hot plate surface must not be touched with hand, metal implements or tools. A damaged or dirty hot plate will result in a poor joint. Heating mirror is nothing but a metallic plate heated up to the required temperature by electrical coil embedded inside. The word 'mirror' has come into vogue because the heating plate radiates heat.

g) Prior to heating, levelling of the pipes/fittings is essential to ensure square plane face over the heat surface [see 1.2.1.2 (c)].

h) Move the pipe/fitting ends into contact with hot plate and a steady pressure of 0.15 ± 0.01 MPa shall be applied while a uniform bead forms around the circumference of the both ends. This procedure is to ensure that the entire face of the weldable portion heats uniformly through the surface contact with the mirror.

j) After the bead height is formed as per Table 1 relieve the pressure but maintain contact pressure between the plate and the ends of the heated surfaces as per pressure build up time mentioned in Table 1.

k) Push back the pipe/fitting ends away from the mirror after the above operation. When removing the mirror, make sure it is not brushed across the molten pipe ends.

m) Bring the molten ends together and follow the recommended pressure as per the requirement of the pipe/fitting wall thickness (see Table 1). This pressure should be applied by building up gradually to avoid squeezing out too much of the melt. Do not disturb the joint during the required cooling time. Follow the pressure-time diagram as given in Fig. 2.

n) Relax the pressure and carefully remove the clamps only after ensuring that cooling time has elapsed.

p) Inside or outside bead removal after the weld joint cools, shall have no affect on the weld performance.

6.3.1.2.1.3. Caution

It is essential to ensure the pressure-temperature chart and the corresponding timing table is followed.

While jointing, the pressure should be maintained as mentioned in Table 1. After the pressure is relieved, the joint is allowed to cool to ambient temperature. Under no circumstance the weld should be forcibly cooled (no quenching).

Table 1 Values of the Recommended Bead Width and Timing for Butt Fusion Welding

(Clauses 1.2.1.2 and 1.2.1.3)

Sl No.	Nominal Wall Thickness	Bead Height on the Heated Tool	Heating Up	Change Over	Jointing and Cooling		
					Pressure Build-up Time	Cooling Time Under Pressure	Cooling Time During Pressure Relaxation
	mm	mm	s	s	s	s	S
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Up to 4.5	0.5	45	5	5	6	300
ii)	4.5-7	1.0	45-70	5-6	5-6	6-10	600
iii)	7-12	1.5	70-120	6-8	6-8	10-16	900
iv)	12-19	2.0	120-190	8-10	8-11	16-24	1 200
v)	19-26	2.5	190-260	10-12	11-14	24-32	1 500
vi)	26-37	3.0	260-370	12-16	14-19	32-45	1 800
vii)	37-50	3.5	370-500	16-20	19-25	45-60	2 100
viii)	50-70	4.0	500-700	20-25	25-35	60-80	2 700

NOTE — Bend strap testing is suggested on a test sample to verify fusion joint integrity and to qualify the welding technicians. The specimen shall be made by the cutting the pipe longitudinally into strips of 1 or 1.5 times the wall thickness wide and by about 300 mm or 30 times the wall thickness in length with the fusion centred strip (*see* Fig. 3). The fusion sample should be bent till the ends meet and visually inspected. The sample should be free of cracks and breaks and shall have seamless joint surface. Testing shall be done on the each size of the pipe being used at the site, to qualify various machines and the technicians that are likely to be employed at the site.

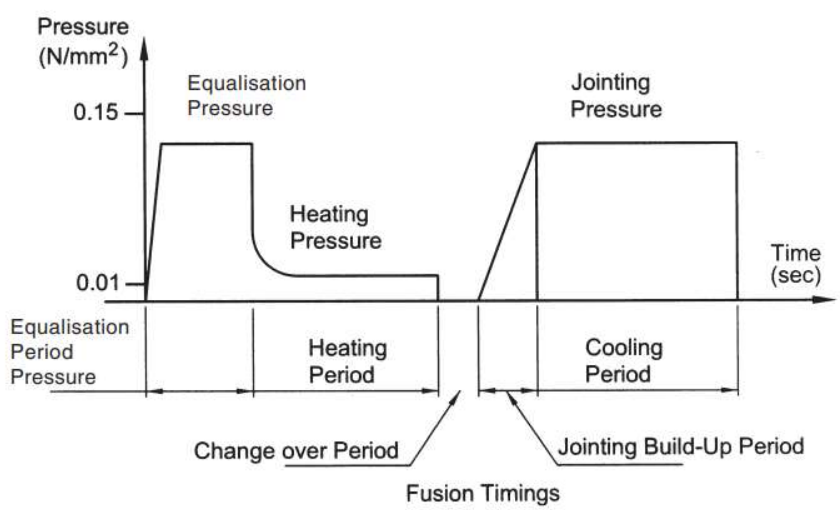


Fig. 2 Pressure-Time Diagram

Fig. 3 Bend Strap Test — Welded Pipe Portion Cut Longitudinally and Bent

6.3.1.2.2. Socket Fusion (see Fig. 4)

This technique consists of simultaneously heating the external surface of the pipe and the internal surface of the socket fitting until the material reaches fusion temperature; inspecting the melt pattern; inserting the pipe end into the socket; and holding it in place until the joints cools.

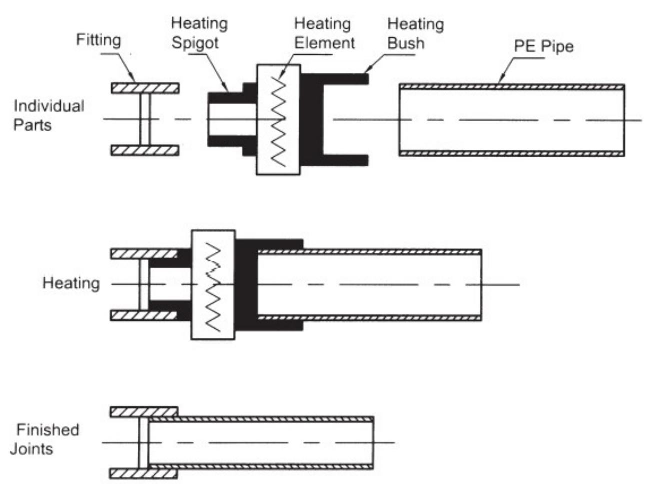


Fig. 4 Socket Fusion Jointing Procedure

6.3.1.2.2.1. Socket fusion procedure

a) Prepare the pipe — cut at right angles and trim;

b) Chamfer pipe end. Remove burrs and chips from inside pipe ends;

c) Utilize proper depth gauge to ensure correct insertion depth and pipe roundness;

d) Clean pipe and fitting with cloth to remove all the contaminants;

e) Verify proper heater plate temperature. Temperature should be 200-230°C;

f) Force fitting and pipe onto a heater surface. Be sure to insert pipe completely into female socket and the fitting completely onto the male socket;

g) Apply the heat on the surface of the pipe;

h) Remove the pipe and fitting from the heater. Care should be taken for not to apply torque or twist the pipe or fitting;

j) Quickly insert heated portion of the pipe into the heated socket of the fitting and ensure coaxial alignment of the pipe and fitting;

k) Allow joint to cool for proper cooling time. Be sure to maintain pressure while cooling;

m) Allow joint to cool to room temperature before moving the joint; and

n) Inspect joint for weld integrity.

6.3.1.2.3. Electro fusion (see Fig. 5)

Electro fusion is a heat fusion process where a coupling or fitting containing an integral heating source (resistance wire) is used to join the pipes and fittings. The jointing areas, that meets the pipe surface and the inside the fittings are overlapped and the resistance wires inside the fitting are heated by electric current. During heating, fitting and pipe materials melt, expand and fuse together. Heating and cooling cycles are automatically controlled by the bar code arrangement on the fittings and machinery used.

The welding equipment or its accessory shall be able to supply the required voltage for the electro fusion joint. The device must switch off as soon as the necessary heat has been fed to the welding zone. The welding machine must be calibrated and timing adjusted to the electro fusion fitting's bar code data (the fitting and machinery manufacturer recommendations shall be followed).

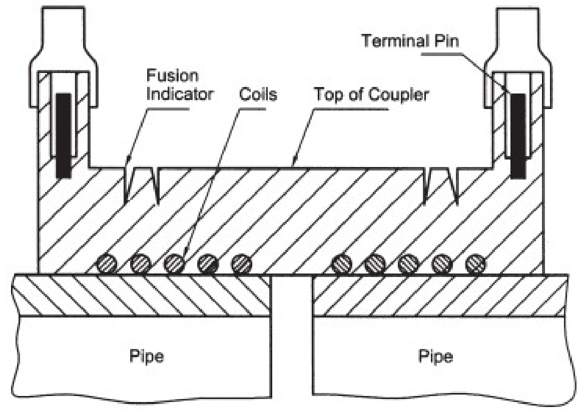


Fig. 5 Electro Fusion Process

Electro fusion is the only heat fusion procedure that does not require longitudinal movement of the joinable surfaces. It is frequently used where both pipes lengths are constrained, such as for repairs or tie-in joints in the trench. Joints between dissimilar polyethylene grades and different wall thicknesses can also be made using electro fusion, as the procedure readily accommodates polyethylene grades with different melt flow rates and is independent of the pipe wall thickness.

6.3.1.2.3.1. Electro fusion welding procedure

a) Prepare the pipe — Cut at right angles and trim;

b) Remove the outer film of pipes using scraper;

c) Clean pipe surfaces with cleaner (as recommended by the electro fusion fittings supplier);

d) Mark the insertion depth on the pipe;

e) Remove the fittings from the packaging without touching the fusion surface;

f) Firmly push-in the pipe until the centre stop or marking;

g) Mount and fix assembly attachment;

h) Slide in the second pipe up into the fitting to centre stop or marking;

i) Firmly fasten the integrated clamp to ensure no movement while welding;

j) Follow operating instructions of the machine and fitting manufacturer or read the bar code;

k) Check the fusion indicator on the fittings and then remove cable; and

l) Wait for cooling to remove the assembly (follow the fusion guidelines of the fusion fittings supplier or what is given in the bar code data).

6.3.1.3.Insert type joint (see Fig. 6)

6.3.1.3.1. Insert type of fittings are available in both plastic and metal for use with PE pipes. These are commonly used for the delivery pipe connections of bore/tube well pumps.

6.3.1.3.2. In corrosive locations plastic/stainless steel insert fittings are preferred. In less corrosion conditions gunmetal fittings may be used and in normal or slightly corrosive environments, brass fittings may be employed. The insert moulding plastic fittings with metallic inserts are also available. The outer serrations of PE/metal insert type fittings — slightly over sized — lock into the pipes to prevent their coming out under sudden pressure surge. The pipe bore is expanded by immersion in oil bath (130°C) where the heat of the oil bath would soften the pipe to enable insertion of fitting.

6.3.1.3.3. The insertion of these fittings into the bore of the pipe is done with by hand pressure only. A worm driven type clip while the surface of the pipe is relatively warm should be tightened over the pipe to ensure the grip. Bolting or riveting the inserted fitting onto the pipe wall is also recommended for carrying heavy weight, such as submersible pump.

6.3.1.3.4. This type of jointing is used normally for diameter pipes up to 110 mm and internal pressure below 0.4 MPa. Load carrying capacity of this assembly depends on the pull force applied by the weight of the total assembly including the weight of the hung item (say a submersible pump) and media weight inside the pipe. The pipe manufacturers' recommendations are to be followed for allowable total pull force on a given pipe with insert type connection. The elongation of PE pipe is very high (over 600 percent), hence these recommendations attain significance. More so, if the load on to the assembly is very high such as in the case of submersible pump lowered with PE pipe as a delivery pipe with this type of connection.

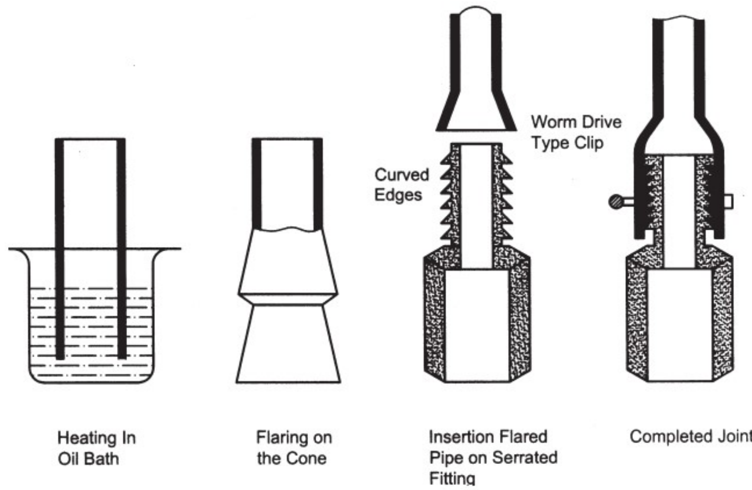


Fig. 6 Typical Illustration of Making Insert Type Joints for PE Pipes

6.3.1.4.**Compression fittings (see Fig. 7 and 8)**

6.3.1.4.1. Compression fittings are detachable joints and are made of metal or plastics [polypropylene (PP)] or a combination of both. Compression fittings form a tight seal by applying a compressive force to the pipe and pipe fitting. The fitting is compressed against the pipe with a force sufficient to eliminate all space remaining in the joint, thus preventing the fluid from leaking.

6.3.1.4.2. It is critically important to the integrity of the fitting that excessive force is avoided in tightening the nut. If the fitting is over tightened, the gripper (clip ring) will deform and cause leaks. Over tightening is the most common cause of leaks in compression fittings. As a general rule, a compression fitting should be ‘finger tight’ and then tightened one turn with a wrench. The fitting should then be tested, and if slight weeping is observed, the fitting should be slowly tightened a bit more until the weeping stops.

6.3.1.4.3. Compression fittings are also available as metal fitting such as the type of fitting commonly used for copper tubes. In this type of joint the dimensions of the pipe are generally not altered. The joint is affected by an internal liner and a compression ring or sleeve which shrinks and therefore compresses the pipe wall on the liner, thus gripping to the wall of the pipe. The liner and compression sleeve may also be an integral unit.

6.3.1.4.4. Compression fittings with collar/pipe ends and flat gaskets

Aluminum alloy or brass fitting with male and female coupling parts may also be used for jointing with metallic fittings. The male and female ends of the coupling are welded face to face on two ends with hot plate or electric coil. The two collars are brought together and the female end of the coupling is tightened on the male end. A water tight seal is made between the flanges. This is the detachable type of jointing and is practicable up to 50 mm diameter pipes (see Fig. 8).

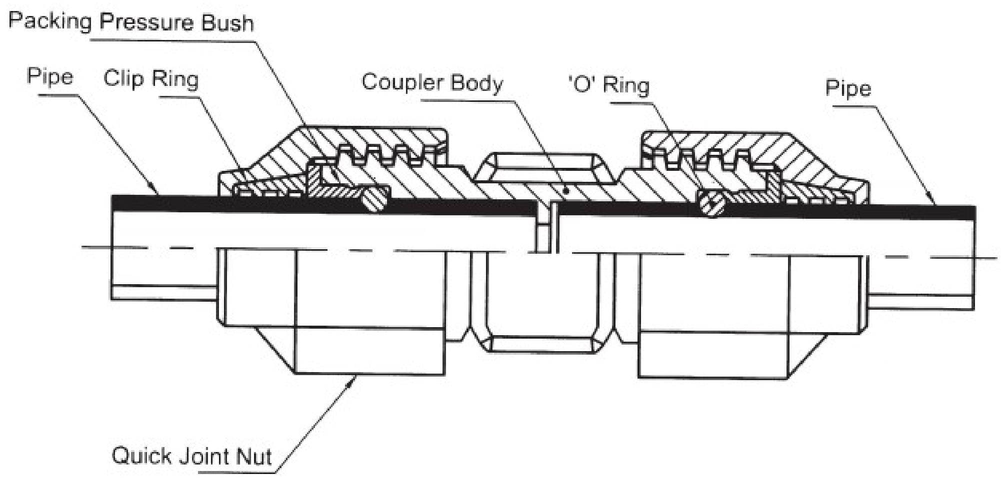


Fig. 7 Polypropylene Compression Coupler (Socket)

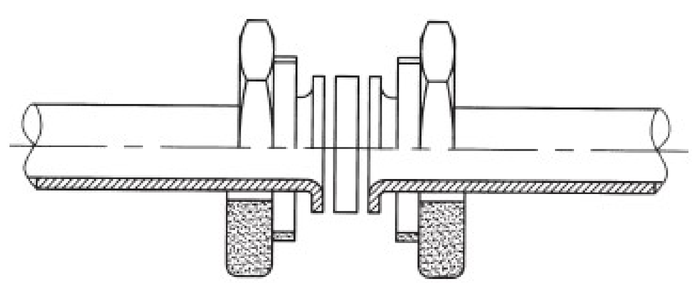


Fig. 8 Metallic Compression Fitting

6.3.1.4.5. Compression fittings do not require fusion. They work at higher pressures and even with toxic media. Compression fittings are especially useful in installations that may require occasional disassembly or partial removal for maintenance, etc, since these joints can be detached and re-joined without affecting the integrity of the joint. They are also used in situations where a heat source, in particular a heating plate, is prohibited and inside bead formation by butt fusion is not preferred.

6.3.1.4.6. For coiled polyethylene pipes, of small diameters (<110mm) where the working pressure do not exceed 1.6 MPa, jointing by polypropylene (PP) compression fittings is generally recommended over fusion jointing.

6.3.1.4.7. Various varieties of PP compression fittings such as couplers, bends, tees, reducers and threaded/flanged adapters to connect to valves /tanks/ non-PE pipes are available.

6.3.1.4.8. Polypropylene compression fittings are easy to fit requiring no special skills, have no possibility of infiltration (seepage) from outside or leaks from inside and therefore, are most ideal for domestic service connections enabling easy threaded connections to the ductile/cast iron/PVC-U/PE pipe ferrules/saddles of the main lines.

6.3.1.5.**Flanged Joints (see Fig. 9)**

6.3.1.5.1. These are used for jointing the PE pipes particularly of larger size to valves and vessels and large size metal pipes, and where non-PE pipes are to be joined with PE pipes.

6.3.1.5.2. It contains slip-on metallic/polyethylene flanges with collar/stub ends. The collar/stub end is welded by butt, socket or electro fusion, as per procedures (see 1.2.1.2, 1.2.2.1 and 1.2.3.1) to the pipe. In case polyethylene flanges are used a suitable metallic backing plates shall be used to support the polyethylene flanges so that the bolt force does not deform the plastic flange. Injection moulded polyethylene flanges without backing flanges conforming to IS 8008 (Part 7) may also be used. Sealing is improved by incorporating a natural or synthetic rubber gasket between flanges.

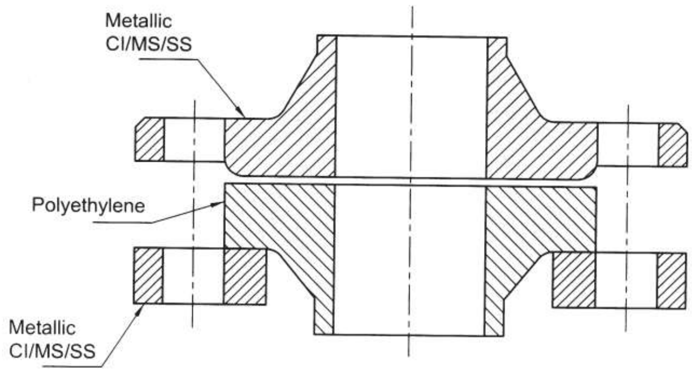


Fig. 9 Typical Flanged Joint

6.3.1.6.**Spigot and Socket Joint (see Fig. 10)**

6.3.1.6.1. Any joint that permits sliding of the free end (spigot end) inside the socket with a rubber or suitable gasket, without leakage is called a spigot and socket joint.

6.3.1.6.2. The socket (bell) could be an integral part of the pipe at one end or a special coupler, into which the free ends (spigot ends) of the pipes are pushed to achieve a water tight joint. Various types of ‘O’ rings are available in the market and the user may check with the manufacturer about the suitability of the same as per site conditions.

6.3.1.6.3. These joints are normally weak in longitudinal pull and hence need anchoring wherever such a tendency of longitudinal pull is likely in the pipe line. The supports of the side connection should ensure that excessive lateral bending does not occur. In small diameter, the coupler itself could be modified to have a split, threaded, grip type gasket of hard materials in addition to ‘O’ ring to prevent loosening because of longitudinal pull. Special type of rubber gasket (for water tightness) to prevent any slipping out of the free end of the pipe shall be used.

6.3.1.6.4. This type of joint is best used for non-pressure applications, such as gravity lines and for encasing cables or smaller diameter pipes.

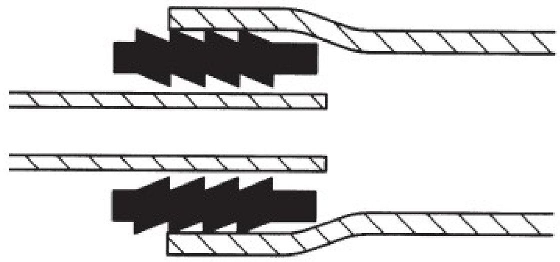


Fig. 10 Spigot and Socket Joint

6.3.2. BENDING

6.3.2.1.Cold Bending

Polyethylene pipes have a degree of flexibility such that a substantial radius may be set up within a length of pipe itself without heating and causing residual stress. This enables gradual curves to be negotiated without the need for special bends or flexible couplings. However the radius of the bend shall be as per Table 2. Cold bending should only be used on pipes at ambient temperature.

Table 2 Allowable Bend Radius for Various SDRs
(Clause 4.1)

Sl No. (1)	**Pipe SDR** (2)	**Minimum Bending Radius** *R* (3)
i)	SDR ≤ 9	10 times diameter
ii)	9 < SDR ≤ 13.6	13 times diameter
iii)	13.6 < SDR ≤ 21	17 times diameter
iv)	SDR > 21	20 times diameter

NOTE — SDR (Standard Dimension Ratio) is defined as:

$$SDR = \frac{\text{Outside diameter, mm}}{\text{Minimum wallthickness, mm}}$$

6.3.2.2.**Hot Bending**

6.3.2.2.1. Forming of small radius bend may easily be done by the application of heat either by hot air oven or by immersion in a suitable liquid at an appropriate temperature.

For lower density polyethylene pipe, the temperature range is 100 to 110°C and suitable liquids are water, glycerol or a solution of calcium chloride. Higher density polyethylene pipe should be heated in an inert liquid, such as glycerol at a temperature of 130°C. Electrical heating coils or plates may be used only by experienced technicians.

6.3.2.2.2. In preheating operations, the low thermal conductivity of PE should be kept in mind. Over heating can usually be recognized by surface discolouration and distortion. On the other hand bending operations should not be performed at too low a temperature.

6.3.2.2.3. At higher temperature, the bore of the pipe tends to collapse and therefore requires support during the bending operation. Internal support should be affected before heating by packing the bore of the pipe with warm fine dry sand or by inserting rubber pressure hose, rubber rod or a flexible spring. After the pipe is uniformity heated it should be bent around a sample jig and held in the correct position until the form is cooled.

6.3.2.2.4. It is recommended that radius of the bend for pipe up to 50 mm size should not be less than three times the outside diameter of the pipe for lower density PE and five times the outside diameter for higher density PE. Pipes of large diameter will require an increase in radius. General recommendations of the bend radius given in Table 2 are to be followed. The pressure compatibility of the bend is to be tested before using the same in the field.

6.3.3. LAYING

6.3.3.1. The pipe line may be laid along side of the trench and jointed there. There after the jointed pipeline shall be lowered into the trench carefully without causing undue bending. The pipeline shall be laid inside the trench with a slack of up to 2 m/100 m of pipe line.

6.3.3.2. Polyethylene pipes conforming to IS 4984, being black in colour, when subjected to direct sunlight or warm ambient temperature may become warmer than the ground temperature. When placed inside the trench, the pipe will contract in length as it cools to the surrounding soil temperature. If the pipe is connected to sub-surface structures (such as preset valve, etc) before it is cooled sufficiently, excessive pull forces could develop. Allow the pipe to cool to ambient temperature prior to making a connection to an anchored joint.

6.3.3.3. Polyethylene pressure piping systems jointed by butt welding, electro fusion and flanges do not require external joint restraints or thrust block joint anchors.

6.3.3.4. Polyethylene pipes are non-metallic, so once buried, metal detector type locators are ineffective. To facilitate locating a buried PE pipe, metallic locating tapes or copper wires can be placed alongside the pipe. Locating tapes/wires are placed slightly above the crown of the above before the final back fill.

6.3.3.5. Because of high integrity of properly made fusion joints, PE pipes can be used with special installation techniques such as horizontal directional drilling, pipe bursting, micro tunnelling methods of trench less technologies.

6.3.4. INSTALLATION

6.3.4.1. ***Lowering:*** When jointed outside of the trench the jointed pipeline shall be lowered into the trench (for underground installations) carefully (preferably with mechanical handling equipment for sizes greater than 160 mm) without causing undue bending that can cause kinking. The pipeline shall be laid inside the trench with a slack of up to 2 m/100 m of the pipeline (pipe line to be laid in a sinuous alignment).

6.3.4.2. Bending of pipe inside the trench involves excavating the trench to the desired bend radius. Exposed black PE pipe to ambient temperature greater than 30°C will have very high surface temperature that makes it difficult to handle. Proper precautions shall be taken to ensure safety at work site.

6.3.5. FIELD TESTING

The pipeline to be tested shall be filled with water slowly allowing for splurging the entrapped air. Air valves at high points should be open to allow air to escape while water is being filled. Before pressure is applied, the pipeline section under test shall be restrained against movement.

The following procedure is recommended for PE pipe testing:

a) Polyethylene pipelines shall be pressure tested at ambient temperature. After filling with water the pipeline shall be left to stabilize for a period of 1 h.

b) Fusion joints may be covered during testing. Flanged joints shall be kept open for visual inspection. The pipeline shall be filled with water and pressure tested from the lowest point.

c) During the test period, make-up water is continuously added to maintain the pressure.

d) The test pressure shall be 1.5 times the rated pressure of pipes or of the proposed maximum design pressure of the section. Apply the pressure by continuously pumping at a constant rate.

e) Under no circumstance, air is to be used instead of water for testing.

f) Tests should be performed on reasonable lengths of pipelines. Long lengths more than 2000 m may make leak detection more difficult.

g) Acceptance criteria — If the pressure remains steady (within 5 percent of the target value) for 1½ h, leakage is not indicated. Flanged connections shall be visually inspected.

h) If the test is not complete because of leakage or equipment failures, the test section shall be depressurized and allowed to relax for at least 8 h, before starting the next testing sequence.

j) Testing outside the trench is to be avoided, as pipe rupture may involve safety issues.

6.4. INSTALLATION OF DI PIPES

6.4.1. JOINTS AND JOINTING

6.4.1.1. General :

6.4.1.1.1. Two main types of joints are used with ductile iron pipes and fittings:

(a) Socket and spigot flexible joints:

i. Push on joints; and

ii. Mechanical joints;

(b) Rigid flanged joint

6.4.1.2. Flexible Joint

The spigot and socket flexible joint should be designed to permit angular deflection in direction and axial movement to compensate for ground movement and thermal expansion and contraction. They incorporate gasket of elastomeric materials and the joints may be of the simple push-on-type or the type where the seal is effected by the compression of a rubber gasket between a seating on the inside of the socket and the external surface of spigot. Joints of the latter type are referred to as mechanical joints. Both push-in (Fig. 1A) and mechanical joints are flexible joints. Flexible joints require to be externally anchored at all changes in direction such as at bends, etc, and at blank end to resist the thrust created by internal pressure and to prevent the withdrawal of spigots.

6.4.1.3. Flanged Joint

Flanged joints are made on pipes having a machined flange at each end of the pipe. The seal is usually effected by means of a flat rubber gasket compressed between two flanges by means of bolts which also serve to connect the pipe rigidly (see Fig. 1B). Gaskets of other materials, both metallic and non-metallic, are used for special applications.

6.4.1.4. Jointing Procedure

Procedure for jointing will vary according to the type of joint being used. Basic requirements for all types are:

a) Cleanliness of all parts,

b) Correct location of components,

c) Centralization of spigot within socket, and

d) Strict compliance with manufacturer's jointing instructions.

The inside of sockets and the outside of spigots should be cleaned and wirebrushed for a distance of 150 to 225 mm. Glands and gaskets should be wiped clean and inspected for damage. When lifting gear is used to place the pipe in the trench, it should also be used to assist in centralizing the spigot in the socket. Where the pipeline is likely to be subjected to movement due to subsidence or temperature variations, the use of flexible joints is recommended. A gap should be left between the end of the spigot and the back of the socket to accommodate such movement.

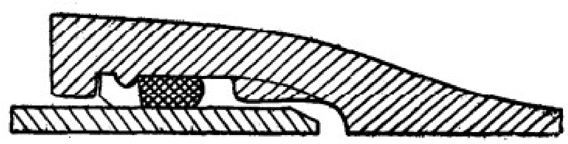


Fig. 1A Flexible Joint (push in type)

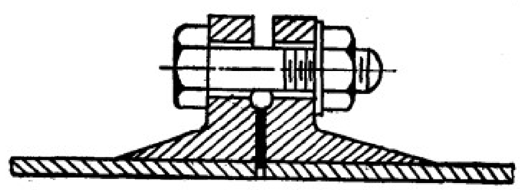


Fig. 1B Flanged Joint

Fig. 1 Typical Types of Joints

6.4.2. LAYING

6.4.2.1. Laying underground

6.4.2.1.1. Pipes should be lowered into the trench with tackle suitable for the weight of pipes. For smaller sizes, up to 250 mm nominal bore, the pipe may be lowered by the use of ropes but for heavier pipes, either a well-designed set of shear legs or mobile crane should be used. When lifting gear is used, the positioning of the sling to ensure a proper balance, should be checked when the pipe is just clear of the ground. If sheathed pipes are being laid, suitable wide slings or scissor dogs should be used.

6.4.2.1.2. All construction debris should be cleared from the inside of the pipe either before or just after a joint is made. This is done by passing a pull-through in the pipe, or by hand, depending on the size of the pipe. When laying is not in progress, a temporary end closure should be securely fitted to the open end of the pipeline. This may make the pipe buoyant in the event of the trench becoming flooded, in which case the pipes should be held down either by partial re-filling of the trench or by temporary strutting. All persons should vacate any section of trench into which the pipe is being lowered.

6.4.2.1.3. On gradients of 1:15 or steeper, precautions should be taken to ensure that the spigot of the pipe being laid does not move into or out of the socket of the laid pipe during the jointing operations. As soon as the joint assembly has been completed, the pipe should be held firmly in position while the trench is backfilled over the barrel of the pipe. The backfill should be well compacted.

6.4.2.2. Laying above ground

6.4.2.2.1. The ground should be dressed to match the curvature of the pipe shell for an arch length subtending an angle of 120^0 at the centre of the pipes. Alternatively, the pipeline should be laid either on saddle, roller or rocker supports as specified by authority. The pipes may be allowed to rest on ground if the soil is non-aggressive.

6.4.2.3. Supporting Pipes above ground

The following recommendations assume that no additional bending moments above those due to the self weight of the pipe and its contents are present.

6.4.2.3.1. *With Spigot and Socket Pipes* - It is recommended that above ground installations of spigot and socket pipes be provided with one support per pipe, the supports being positioned behind the socket of each pipe.

This results in a normal distance between supports of 4 m as shown in Fig. 2A.

Pipes should be fixed to the supports with mild steel straps so that axial movement due to expansion or contraction resulting from temperature fluctuation, is taken up at individual joints in the pipeline. In addition, joints should be assembled with the spigot end withdrawn 5 to 10 mm from the bottom of the socket to accommodate these thermal movements.

Pipes supported in this way are capable of free deflection and axial movement at the joints which accommodate small movements of the pipe supports.

The designed anchorage shall be provided to resist the thrusts developed by internal pressure at bends, tees, etc.

Where a pipeline crosses a watercourse, the design and method of construction should take into account the characteristics of the water course. The concerned authorities may be consulted to ascertain the nature of bed, scour levels, maximum velocities, high flood levels, seasonal variation, etc, which affect the design and laying of pipeline. Early consultation with river authorities will assist in evaluating the effect of river characteristics (for example, nature of bed, scour levels, maximum velocities, high flood levels, seasonal variations, etc), on design and construction.

If necessary, unsupported spans between 4 and 6 m may be obtained by positioning the pipe supports relative to the pipe joints as shown in Fig. 2B

6.4.2.3.2. *With flanged Pipes* - The recommended maximum unsupported span is 8 m. The supports shall be located at the centre of every second pipe as shown in Fig. 3A.

The recommended maximum unsupported span at water course is 8 m. The relative positions of pipe joints and pipe supports should be as shown in Fig. 3B.

The supports of all flanged pipework spans should be stable and unyielding due to movements in the pipeline.

The straps should prevent any lateral movement or lifting of the pipelines but not restrict expansions and constructions caused by temperature fluctuations.

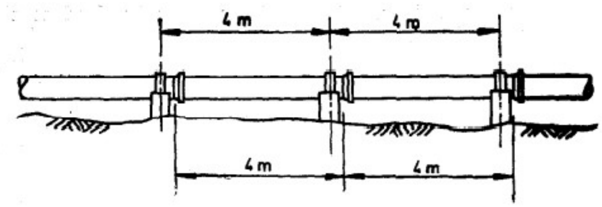


Fig. 2A Pipes over normal ground

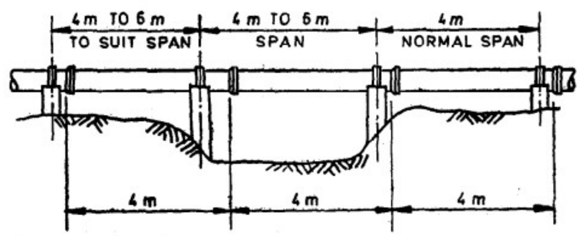


Fig. 2B Pipes crossing over water course

Fig. 2 Spigot and Socket Pipes Laying Above Ground

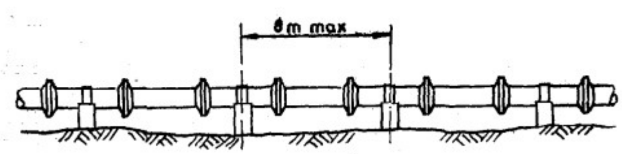


Fig. 3A Pipes above normal ground

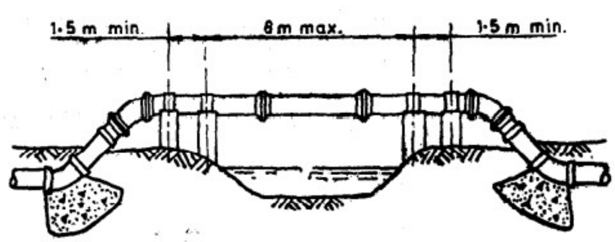


Fig. 3B Pipes crossing over water course

Fig. 3 Flanged Pipes Laying Above Ground

6.4.2.4. Cutting of pipes - The cutting of pipe for inserting valves, fittings, etc, shall be done in a neat and workman like manner without damage to the pipe or lining so as to leave a smooth end at right angles to the axis of the pipe. Methods of cutting ductile iron pipes are given in 2.4.1 to 2.4.3.

6.4.2.4.1. *By Hacksaw* - Hand or power operated hacksaw should be used with blades having teeth at a pitch of 1 mm.

6.4.2.4.2. *By Manually Operated Wheel Cutter* - The type of cutting wheel used for cast iron pipes is not suitable for ductile iron pipe. Special wheels, as used for cutting steel pipes, shall be used and cut ends are trimmed with a file.

6.4.2.4.3. *By Pipe Cutting Machine* - Machines with cutter heads or abrasive wheels shall be used. Cutter head should have a front rake angle of 7” as used for steel pipes.

6.4.2.5. End Preparation of Cut Pipes for Jointing - The burr left after cutting should be trimmed off by light grinding or by filling.

6.4.2.6. Wrapping - When ductile iron pipes are to be laid in aggressive soils, the pipes should be wrapped externally with protective coatings, such as bitumen or coaltar sheathing protective tapes or by loose polythene sleeving, or in certain circumstances, concrete before laying. At joints, bends and valves, precautions should be taken to provide sufficient overlap of the wrapping sleeve so that no pipeline is exposed to the aggressive soil.

6.4.2.7. Pipeline Markers - Distinctive markers should be erected at all roads, railways, river and canal crossings, and elsewhere as required to identify the pipeline and to indicate its position. Markers should be placed at field boundaries, preferably in such a way that they are not obscured by vegetation. At all valve installations, plates should be provided to give the same information as on the makers. Markers should not be treated with any substance likely to be harmful to livestock.

6.4.2.8. Pipeline Anchorage - All pipelines having unanchored flexible joints require anchorage at changes of direction and at dead ends to resist the static thrusts developed by internal pressure. Dynamic thrusts caused by flowing water act in the same direction as static thrusts. This thrust is of sufficient magnitude at high velocities to warrant safety consideration.

Anchorages to resist the thrust should be designed taking into account the maximum pressure the main is to carry in service or on test, and the safe bearing pressure of the surrounding soil.

Where possible, concrete anchor blocks should be of such a shape as to allow sufficient space for the remaking of the joints. Figure 4 shows typical anchorages using concrete anchor blocks.

Pipeline should be securely anchored at dead ends, tees, bends, tapers and valves to resist thrust arising from internal pressure. Anchors and thrust blocks should be designed in accordance with IS: 5330-1984. Steeply inclined pipelines should be secured, by transverse anchors spaced as shown below:

Gradient	Spacing (m)
1 in 2 and steeper	5.5
Below 1 in 2 to 1 in 4	11.0
Below 1 in 4 to 1 in 5	16.5
Below 1 in 5 to 1 in 6	22.0
Flatter than 1 in 6	Not usually reuired

Typical anchor blocks to resist horizontal thrust, vertical thrust and gradient thrust for buried mains are shown in Fig. 4.

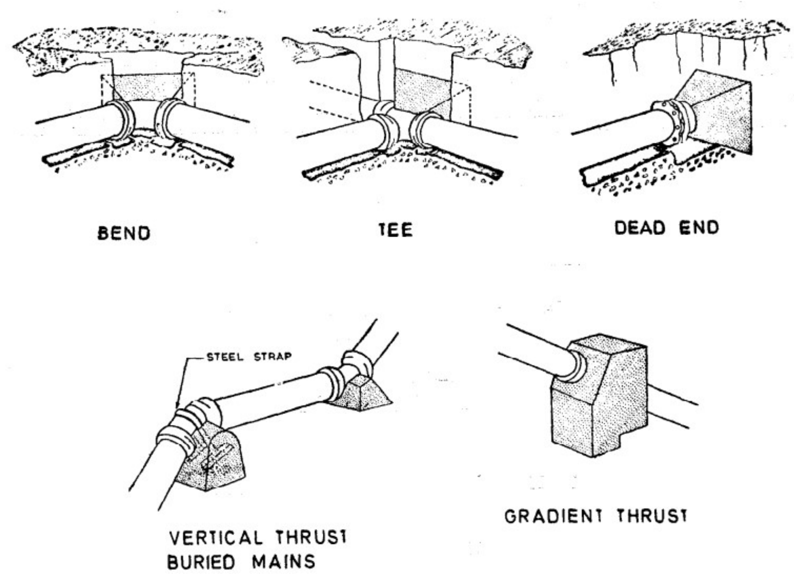


Fig. 4 Typical Thrust Blocks

6.4.3. HYDRAULIC TESTING

6.4.3.1.After a new pipeline is laid and jointed, testing shall be done for:

a) mechanical soundness and leak tightness of pipes and fittings;

b) leak tightness of joints; and

c) soundness of any construction work, in particular that of the anchorages.

6.4.3.2. **Hydrostatic Testing -** The completed pipe line may be tested either in one length or in sections; the length of section depending upon :

1) availability of suitable water,

2) number of joints to be inspected, and

3) difference in elevation between one part of the pipeline and another

Where the joints are left uncovered until after testing, sufficient material should be backfilled over the centre of each pipe to prevent movement under the test pressure.

It is prudent to begin testing in comparatively short length of test section. Progressively as experience is gained, lengths of about 1.5 km or more, are tested in one section, subject to consideration of length of trench which can be left open in particular circumstances.

Each section should be properly sealed-off, preferably with special stop ends secured by adequate temporary anchors. The thrust on the stop ends should be calculated and the anchors designed to resist it. All permanent anchors (see 2.8) should be in position and, if of concrete, should have developed adequate strength before testing begins. The section under test should be filled with water, taking care that all the air is displaced either through vents at the high points or by using a pig or a sphere.

6.4.3.3.The test pressure to be applied should be not less than any of the following:

a) The maximum sustained operating pressure,
b) The maximum static pressure plus 5 N/mm2, and
c) The sum of the maximum sustained operating pressure (or the maximum static pressure) and the maximum calculated surge pressure.

After filling, the pipeline should be pressurized to the specified operating pressure and left for a period of time to achieve stable conditions.

The length of this period of time depends on many factors such as slight movement of the pipeline under pressure whether air is trapped in the pipeline or whether the pipeline has a concrete lining which absorbs water.

The pipeline is then pressurized up to the full test pressure and the section under test completely closed off. The test should be maintained for a period of not less than 10 minutes to reveal any defects in the pipes, joints or anchorages.

The test pressure should be measured at the lowest point of the section under test or alternatively, an allowance should be made for the static head between the lowest point and the point of measurement, to ensure that the required test pressure is not exceeded at the lowest point.

6.4.3.4. In case of extreme temperature conditions, there may be a tendency of hydraulic pressure building up inside the pipeline because of expansion of water during the high day time. This should normally not be of any major concern as the joints and the pipes are manufactured to resist a much high pressure. However, sufficient care should be taken to prevent floating bulging of the pipeline because of building up of such high pressure during the temperature rise.

6.4.3.5. If the test is not satisfactory, the fault should be found and rectified. Where there is difficulty in locating a fault, the section under test should be sub-divided and each part tested separately.

Methods employed for finding leaks include:

a) Visual inspection of each joint if, not covered by the backfill;

b) Use of a bar probe to detect signs of water in the vicinity of joints, if backfilled;

c) Aural inspection using a stethoscope or listening stick in contact with the pipeline;

d) Use of electronic listening device which detects and amplifies the sound or vibrations due to escaping of water, actual contact between the probe and the pipe is not essential;

e) Injection of a dye into the test water-particularly suitable in water-logged ground; and

f) Introduction of nitrous oxide in solution into the test water and using an infra-red gas concentration indicator to detect the presence of any nitrous oxide that has escaped through the leak.

6.4.3.6. After all sections have been joined together on completion of section testing, a test on the complete pipeline should be carried out. This test should be carried out at a pressure not less than the maximum sustained operating pressure or the maximum static pressure of the pipeline and, during the test, inspection made of all work which has not been subject to section tests. During the test, the pressure at the lowest point in the pipeline should not exceed the maximum given below.

Maximum Field Hydrostatic Test Pressure for Ductile Iron Pipelines with Flexible Joints

Nominal Bore mm	Maximum Field Hydrostatic Test Pressure N/mm^2
Up to 300	4·5
350 to 600	3·0
700 to 1200	2·1

NOTE 1 — The above pressures are 0·5 N/mm^2 higher than the pressure ratings for ductile iron pipes and fittings with flexible joints. It is not considered necessary to field test ductile iron pipelines to 1½ times the design operating pressure as is often the practice with grey iron pipelines.

NOTE 2 — The field test pressures is applied to ductile iron pipelines only when the pipeline and its fittings are properly anchored.

6.4.3.7. It is important to ensure that proper arrangements are made for the disposal of water from the pipeline after completion of hydrostatic testing and that all consents which may be required from authorities have been obtained. In some cases, for example, heavily chlorinated water, some treatment may be necessary before final disposal.

6.4.4. FINISHING WORKS

6.4.4.1. **Allowable Removal of Pavement -** Pavement and road surfaces may be removed as a part of the trench excavation, and the amount removed shall depend upon the width of trench specified for the installation of the pipe and the width and length of the pavement area required to be removed for the installation of gate valves, specials, manholes or other structures. The width of pavement removed along the normal trench for the installation of the pipe shall not exceed the width of the trench specified by more than 150 mm on each side of trench. The width and the lengths of the area of pavement removed from the installation of gate valves, specials, manholes or other structures should not exceed the maximum linear dimensions of such structures by more than 150 mm on each side. Wherever, in the opinion of the authority, existing conditions make it necessary or advisable to remove additional pavement, it shall be removed as directed by the authority.

6.4.4.2. **Restoration of Damaged Surface and Property -** Where any pavement, shrubbery, fences poles or other property and surface structures have been damaged, removed or disturbed during the course of work, such property and surface structures shall be replaced or repaired after completion-of work. All pavements, paved footpaths, curbing, gutters, shrubbery, fences, poles, sod or other property and surface structures removed or disturbed as a part of the work shall be restored to a condition equal to that before the work began, furnishing all labour and materials incidental thereto. In restoring the pavement, sound stone blocks, sound brick or asphalt paving blocks may be re-used. No permanent pavement shall be restored unless and until, in the opinion of the authority, the condition of the back-fill is such as to properly support the pavement.

6.4.4.3. **Cleaning-up -** All surplus materials, and all tools and temporary structures shall be removed from the site as directed by the authority. All dirt, rubbish and excess earth from the excavation shall be hauled to a dump and the construction site left clean to the satisfaction of the authority.

PART B WATER SUPPLY

CHAPTER 7 ELECTROMECHANICAL ITEMS

7.1. GENERAL

Quality Control is a series of activities systematically carried out to fulfil requirements of quality for the procurement of materials and works. Quality control is used to verify that the product delivered are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, close review of the product and the testing process. Quality Control is an essential part of any production. Quality control is required in infrastructure development also, such as in water supply sector.

This section is prepared to provide a base document to effect quality control in the electro-mechanical works / such component in various works carried out by Kerala Water Authority. This is intended to enable the engineers and supervisory staff to check the different activities of electro-mechanical works with reference to the quality aspects and ensure that standards envisaged are achieved.

7.2. GOALS OF QUALITY CONTROL IN ELECTRO-MECHANICAL WORKS.

a. Quality control aims to ensure quality of the installed products as per the standards.

b. The activities or techniques used to achieve and maintain the product quality, process and service comes under quality control.

c. Quality control is exercised by finding and eliminating causes of quality problems through tools and equipment so that user requirements are satisfied.

7.3. QUALITY CONTROL SYSTEM FOR ELECTRO-MECHANICAL WORKS

KWA shall follow a three-tier quality control system for ensuring quality of electro-mechanical works executed. This includes technical audit after completion of construction. The system envisaged is as below:

7.3.1. FIRST TIER QUALITY TESTING.

In first-tier Quality Control testing, the Contractor has to carry out the required tests at his own cost during the course of a work. First tier quality control tests are mandatory for all projects including maintenance and repair works. If any test cannot be carried out with the facilities available with the Contractor, it shall be got done in an approved laboratory by the Contractor at his own cost.

If the QC test is done in the field laboratory established at site, the test results shall be signed by the Overseer/Assistant Engineer, whoever is supervising the work. It shall also be signed by the Contractor. Copy of test results shall be forwarded by the Assistant Engineer to the Assistant Executive Engineer/Executive Engineer concerned for review.

7.3.2. SECOND TIER QUALITY TESTING

Second-tier Quality Control checks / tests are to be done by the Electrical and Mechanical quality control units of KWA on a random basis. However, it is desirable that the Quality Control unit does quality control tests for all major and important items of electro-mechanical installation. The frequency of tests shall be as given in this Manual or as specified in the Contract. The electrical and mechanical quality control unit is authorized to inspect all projects of electro-mechanical works undertaken by KWA, including maintenance and repair works, irrespective of the estimated cost and conduct quality tests.

7.3.3. THIRD TIER QUALITY TESTING.

In the third tier of quality testing, technical audit shall be done by an external agency/expert empaneled for the purpose after the electro-mechanical work is completed.

All tests carried out in the first tier and second-tier quality control testing shall be reviewed during technical audit. Technical Audit shall be completed within six months from the date of installation of electro-mechanical component.

7.3.4. MANDATORY TWO-TIER QUALITY CONTROL.

7.3.4.1. Two-tier design and document quality control is mandatory for all pumps / replacement of pumps for which the power capacity calculated based on design duty conditions and specified pump efficiency exceeds 50HP.

7.3.4.2. Two-tier quality control including design and document control is mandatory for all pumps / replacement of pumps for which the power capacity calculated based on design duty conditions and specified pump efficiency exceeds 100HP.

7.3.4.3. Two-tier quality control including design and document control is mandatory for all the electro-mechanical components of the water treatment plants for which the capacity exceeds 50mld.

7.3.4.4. Two-tier quality control including design and document control is mandatory for all the electrical sub-stations / sub-systems of electrical substations.

7.3.4.5. Two-tier quality control including design and document control is mandatory for all replacement of transformers.

7.3.5. THIRD PARTY TESTING.

Third party testing is carried out by an independent agency other than KWA or the Contractor. This is required when the Contractor raise a dispute due to difference in the test results of first tier and second-tier testing or certain specific tests cannot be carried out with the facilities available in the Contractor’s or Department laboratories or existence of manipulated results are suspected.

The Executive Engineer (Electrical / Mechanical – Quality Control) shall decide whether a third part testing is required to settle the dispute. If so, he shall issue a written direction to carry out a test by another approved agency. The test shall be arranged to be done in the presence of the Assistant Executive Engineer/Assistant Engineer and the Contractor. The result obtained in this test shall be final and binding on both the Contractor and the Department. The expenses for third party testing shall be met by the Contractor. Third-party testing is expected to provide a nonbiased view and thus a better confidence in the test results.

With respect to the methodology of independent testing, the following aspects are important in order to achieve the right quality:

- **i.** The agency must be able to choose and apply the test method that provides a technically correct answer to the problem.
- **ii.** The testing must be performed efficiently, also in such a way that delivery times can be met and costs and charges minimized.
- **iii.** The agency must be able to provide reliable results with accuracy appropriate to the needs.
- **iv.** The testing agency must have the necessary expertise available to be able to assist in the evaluation of the test results and to provide other relevant technical services of an advisory nature.
- **v.** The reports and presentations of the results must be clear and complete.

7.4. ORGANIZATIONAL SET-UP FOR IMPLEMENTATION OF QUALITY CONTROL OF ELECTRO-MECHANICAL SYSTEMS.

7.4.1. MECHANICAL

Mechanical Quality Control Lab shall be set up for the ensuring quality of the mechanical installations in KWA. The labs shall have amenities like building, testing equipment, vehicles, computers, and software etc. The activities of the lab shall be monitored by the Executive Engineer (Mechanical – Quality Control). Two Assistant Executive Engineers (Mechanical – Quality Control) and four Assistant Engineers (Mechanical – Quality Control) shall be appointed for assisting the Executive Engineer (Mechanical). All the Engineers should have relevant qualification in the Mechanical branch of Engineering.

The Executive Engineer (Mechanical – Quality Control) shall conduct quarterly review the Quality Control activities and submit a report, including recommendations for the betterment of quality control activities, to the Technical Member.

7.4.2. ELECTRICAL

Electrical Quality Control Lab shall be set up for the ensuring quality of the electrical installations in KWA. The labs shall have amenities like building, testing equipment, vehicles, computers, and software etc. The activities of the lab shall be monitored by the Executive Engineer (Electrical – Quality Control). Two Assistant Executive Engineers (Electrical – Quality Control) and four Assistant Engineers (Electrical – Quality Control) shall be appointed for assisting the Executive Engineer (Electrical). All the Engineers should have relevant qualification in the Electrical branch of Engineering.

The Executive Engineer (Electrical – Quality Control) shall conduct quarterly review the Quality Control activities and submit a report, including recommendations for the betterment of quality control activities, to the Technical Member.

7.5. INTIMATION TO THE MECHANICAL / ELECTRICAL QUALITY CONTROL UNIT

Agreement Authority shall forward copy of contract documents to the concerned Executive Engineer, quality control unit within 10 days of executing agreement. The Assistant Executive Engineer in charge of the work shall ensure that the date of commencement of each item of work is intimated in a timely manner to the concerned Executive Engineer of the quality control unit for arranging second-tier quality control testing.

7.6. TECHNICAL COMMITTEE

7.6.1. The Technical Committee, chaired by the Technical Member, and all the Chief Engineers of KWA as members, shall give timely instructions for effective implementation of the quality control system in KWA. The Technical Committee shall also consider the reports / recommendations submitted by the Executive Engineer

(Electrical / Mechanical – Quality Control), scrutinize the same and recommend suitable action to the Managing Director / Authority for the effective implementation of quality control / betterment of quality control activities of electro-mechanical works in KWA.

7.6.2. The Technical Committee shall also consider the electro-mechanical quality control formats / checklist newly prepared / modified and submitted by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

7.6.3. The Technical Committee shall consider the recommendations submitted by the Executive Engineer (Electrical / Mechanical – Quality Control) regarding blacklisting of manufacturers of poorly performing material / equipment component and recommend the Managing Director / Authority for suitable action.

7.6.4. The Technical Committee shall consider the lists of electromechanical materials / equipment components for which manufacture certificate / KWA team or third-party inspection is required, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

7.6.5. The Technical Committee shall consider the methodology to be adopted for the random selection / frequency of quality assurance activities for the procurement of materials / works for which the two-tier quality control is not mandatory as per clause no. 3.4, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

7.6.6. The Technical Committee shall consider the list of agency / experts / laboratories to be empaneled for third tier quality testing, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

7.7. TECHNICAL SPECIFICATIONS AND SPECIAL CONDITIONS OF CONTRACT DOCUMENT

7.7.1. DUTY CONDITIONS / TECHNICAL SPECIFICATIONS.

The quality of the electro-mechanical works in KWA shall be ensured based on the technical specification as per contract requirements and as per the latest edition of the relevant Indian / International Standards. The duty conditions / technical specification shall be finalized as per the design requirement for each individual work and a detailed account of the same shall be incorporated into the contract document, including drawings.

7.7.2. TECHNICAL SPECIFICATIONS / SPECIAL CONDITIONS.

The Technical Specification / Special Conditions of Contract Document shall be prepared in accordance with the Indian Electricity Act / Indian Electricity Rules / Central Electricity Authority Regulations / Guidelines of Department of the Electrical Inspectorate, Government of Kerala and other applicable Acts, Rules, Regulations and Guidelines.

7.8. INSPECTIONS AND TESTS

Materials and components to be incorporated into electro-mechanical works shall be inspected as soon as they are delivered, to ensure that they meet the specifications and design requirements, are in agreement with shipping documentation, and are accompanied by manufacturers certifications or third-party inspection certificates, as applicable. Accepted materials and equipment shall be properly stored until needed. If manufacturers installation instructions conflict with design or contract requirements, installation shall proceed only after the conflict has been resolved.

A series of inspections and tests during installation and at the completion of electro-mechanical works shall be performed as follows:

- **Preparatory Inspections:** Prior to installation, the Civil and Structural works where electro-mechanical equipment is to be installed shall be inspected to ensure conformance with designs and equipment installation requirements.
- **Installation Inspections and Tests:** A system of inspections and tests, as specified in the contract or recommended by the equipment manufacturer, shall be employed throughout movement to position and installation of equipment and systems. Inspections shall be performed at critical points during installation. Surveillance shall be provided throughout the progress of the work to ensure that installation is performed in accordance with the requirements and specifications, approved drawings, acceptable workmanship standards and configuration control requirements. All field modifications and retrofit work shall be performed under strict surveillance.
- **Installation Verification Inspections:** Prior to all mechanical and electrical testing, verification inspections shall be performed to ensure that equipment has been satisfactorily installed.
- **System Tests:** These tests shall be conducted as appropriate to demonstrate that the installed systems are free from damage due to shipment and installation, and that equipment performs in accordance with specifications.
- **Integrated Tests:** After completion of system tests, integrated tests shall be performed to demonstrate that the system performs satisfactorily when connected to its interfacing systems or sub-systems. These tests will be followed by commissioning tests.
- **Commissioning Tests:** These consists of a series of tests performed under service operating procedures to demonstrate compatibility of the physical plant with operating procedures.
- **Final Inspections:** Final Inspections shall be performed to ensure that the completed work is in accordance with the requirements and specifications, and that all previously identified discrepancies have been resolved satisfactorily.

7.9. CONTROL OF ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENTS

This article provides and overview of control requirements for electro-mechanical materials and equipment components, including manufacturer's certification and KWA team / third-party inspection.

7.9.1. QUALITY ASSURANCE ELECTRO-MECHANICAL MATERIAL / EQUIPMENT COMPONENT.

The Quality assurance process is needed to ensure process quality during manufacturing and inspection stage in order to satisfy the standards of quality laid down and to meet the purpose for which it is being procured.

7.9.1.1. The Engineer in charge shall ensure that the materials / equipment which are intended to be procured have been manufactured as per the relevant BIS/International standards & technical specifications and as per the contract requirement. To achieve the same, the bid document should specify the standards, details of inspection and tests to be carried and stages and manner for carrying out the same.

7.9.1.2. Inspection has to be resorted to wherever necessary to ensure that the quality, functions etc. of the materials and equipment to be procured comply with specifications as per the contract requirement. The Inspecting Engineer shall be conversant with the materials / equipment, its specifications & Standards.

7.9.1.3. The Engineer authorized to receive materials and equipment should satisfy himself that the materials / equipment is in conformity with the specifications as per the contract requirement. Any materials / equipment which do not conform to specification or not as per approved samples or which is damaged or defective in any respect should summarily be rejected.

7.9.2. INSPECTION.

Inspection has to be resorted to wherever necessary to ensure that the quality, functions etc. of the materials / equipment to be procured comply with specifications as per the contract requirement. Any discrepancy, defects, deviations etc. noticed during testing shall be duly notified to the Manufacturer in writing in order to attend the same as per the conditions in the contract document.

Depending on the nature of materials / equipment being procured, usually, the following types of inspection may be adopted.

7.9.2.1. Stage Inspection:

This type of inspection has to be conducted for materials / equipment having long manufacturing process and for which quality of each component has to be ensured during manufacturing process such as Power Transformers, Circuit Breakers etc. These inspections may be carried out as many times as required for the materials / equipment.

7.9.2.2. Prototype Inspection:

In a contract containing bulk quantity for particular materials / equipment of major equipment / items, a prototype inspection shall be conducted as per approved drawings and guaranteed technical specifications before issuing sanction for bulk manufacturing. This procedure is preferred for all new designs proposed by manufacturers.

7.9.2.3. Pre-Dispatch Inspection:

When the materials / equipment to be procured are ready for Factory inspection the purchaser will witness the various factory acceptance tests as per approved Factory Acceptance Test procedures. Only after successful completion of the factory acceptance test, the clearance for dispatch of materials / equipment shall be issued.

7.9.2.4. Inspection of materials and equipment components on receipt at consignee's / user's premises:

Such inspection is done on receipt of materials / equipment at site before accepting the same against the quantity and quality ordered as per the specification and standards. Also, samples will be taken and sent for Site Acceptance Tests, if required, as per the Site

Acceptance Test procedures. Only materials / equipment accepted as above shall be utilized for works.

7.9.2.5. Post installation Inspection:

The inspection of the materials / equipment installed at site shall be carried out by competent authority for checking its readiness for commissioning and discrepancies noticed shall be recorded and brought to the notice of contractor / manufacturer.

7.9.2.6. Testing & Commissioning of the materials and equipment components:

The functional performance and output of the materials / equipment shall be ascertained during the testing and commissioning of the same as per the Guaranteed Technical Particulars specified as per contract requirements.

7.9.2.7. Inspection Test procedures and Formats:

All Test procedures as per relevant standards shall be submitted by the contractor / manufacturer to the Engineer in charge in advance along with the inspection call letter for approval.

Complete lot of the materials / equipment or designated batches of materials / equipment as per contract shall be offered for inspection, as per the delivery schedule in the contract. All cost of testing equipment, tools, manpower, goods etc. used during any of the above inspection/testing shall be the responsibility of the contractor as a part of the contract.

7.9.2.8. Outside Testing Laboratories:

If necessary to conduct type test, acceptance test or special test at outside laboratories, when facilities for these tests are not available in-house with the contractor or KWA, he may obtain prior approval of the testing lab from the Engineer in charge along with required Test procedures and formats. Cost of such tests also would be borne by the contractor.

7.9.3. INSPECTION AND DISPATCH

The Inspecting Engineer after inspection of the materials / equipment should submit a sealed Inspection Report along with inspection summary with specific recommendation for acceptance / rejection immediately after satisfactory completion of inspection and witnessing tests. Representatives of both contractor / Manufacturer and the Authorized Engineer shall sign the test/inspection reports in proof of the testing/inspection carried out. The inspected materials / equipment, if required as per the contract requirement, shall be stamped, labelled, marked, or sealed, in such a way as to make subsequent identification of accepted lots. Rejection notes shall be issued by the Engineer in charge immediately for the materials / equipment not meeting the contract requirements.

7.9.4. ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENTS TO BE CERTIFIED BY MANUFACTURER.

Acceptance of certain manufactured materials and equipment components, as stipulated in the contract, shall be based on test certificates from the manufacturer conforming to relevant Indian / International Standards. Materials and equipment components conforming to Indian standards shall invariably bear ISI mark. The Engineer in charge of the work shall review the manufacturer's certificates for conformance to contract requirements before these items are delivered to the site. Upon their delivery and before their installation or otherwise incorporation in the works, the Engineer in charge of the works shall inspect the condition of these items. It may be decided to test the delivered items by another agency or laboratory. The cost of such tests shall be borne by the contractor.

Following is a sample list of materials and equipment component subject to be certified by the manufacturer. The sample list is only for guidance purpose.

- Flow-measuring devices – General.
- Batteries.
- Firefighting equipment.
- All other electro-mechanical items as required by the contract.

7.9.5. ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENT TO BE INSPECTED BY THE KWA TEAM / THIRD PARTY.

Materials and equipment to be inspected by KWA team / third party may vary from work to wok and package to package, as required by the contract. KWA team / third party inspection should normally take place at factory during or upon completion of manufacture. Before site delivery, the Engineer in charge shall review the KWA team / third-party inspection certificates for conformance to the contract requirements. Upon delivery and before installation or incorporation in the works, the Engineer in charge shall inspect the physical condition of these items, and if necessary, test them on site. Inspection criteria should be stipulated in the contract document.

Following is a sample list of materials and equipment to be inspected by KWA team / third party, normally done at the manufacturing facility, during or upon completion of manufacture. The sample list is only for guidance purpose.

- Flow-measuring devices – Special.
- Cranes and lifting tackles.
- Electrical Cables – Special.
- Butterfly Valves.
- Sluice Valves.
- Reflux Valves.
- Air Valves.
- Control Valves.
- Vertical Turbine Pumps / Centrifugal Pumps / Other Pumps.
- Motors.
- Electrical Starters.
- Power Transformers.
- Switch Boards (HV/MV/LV)
- Battery Chargers.
- Motor Control Center.
- Indication-cum-enunciation panel.

- Capacitors.
- Sluice Gates.
- All other electro-mechanical items as required by the contract.

7.10. DESIGN QUALITY CONTROL.

The duty conditions and technical specification of the material / equipment component shall be arrived at after collecting all the relevant data and proper analysis and shall be in agreement with related specifications of other components of the system. The same shall be finalized only after detailed design based on results of the analysis of the all the relevant data. Detailed drawings and technical specifications shall be prepared to describe the proper assembly / installation of the material / equipment component.

7.11. MATERIAL / EQUIPMENT COMPONENT / SYSTEMS IN WHICH SCOPES OF BOTH THE ELECTRICAL AND MECHANICAL QUALITY CONTROL UNITS ARE INVOLVED.

Material / equipment component / systems for which scope of both the electrical and mechanical quality control units are involved, a committee of Executive Engineer (Electrical – Quality Control) and Executive Engineer (Mechanical – Quality Control) shall be responsible for the quality control activities.

7.12. PERFORMANCE QUALITY.

The performance of the electro-mechanical materials shall be monitored by the Engineer in charge for the warranty period or for two years after installation / commissioning, whichever is maximum. The Executive Engineer (Electrical / Mechanical – Quality Control) shall keep a track of such reports / checklists and recommend the manufacturers whose material / equipment component has frequent unsatisfactory performance, for blacklisting. Such recommendations of blacklisting of manufacturers with poorly performing material / equipment component shall be submitted to the Technical Member.

7.13. QUALITY CONTROL METHODS.

7.13.1. The quality of electro-mechanical works shall be ensured through, but not limited to, the following methods.

- Obtaining manufacturer certificates.
- KWA team / Third party inspection.
- Random inspection by Electrical / Mechanical quality control units.
- Maintaining quality assurance check lists for procurement of electro-mechanical materials / equipment.
- Maintaining quality assurance check lists for installation / maintenance of electro-mechanical material / equipment works.

7.13.2. The formats / check lists for procurement / installation / maintenance of various electro-mechanical materials / equipment shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The formats / check lists shall be updated, revised, and documented whenever found necessary. The formats / check lists thus prepared shall be submitted to the Technical Member for concurrence / approval.

7.13.2. Lists of electromechanical materials / equipment components for which manufacture certificate / KWA team or third-party inspection is required, shall be prepared, and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The lists shall be updated, revised, and documented whenever found necessary. The lists thus prepared shall be submitted to the Technical Member for concurrence / approval.

7.13.3. The methodology to be adopted for the random selection / frequency of quality assurance activities for the procurement of materials / works for which the two-tier quality control is not mandatory as per clause no.3.4, shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The methodology / frequency of activities shall be updated, revised, and documented whenever found necessary. The methodology / frequency of activities thus prepared shall be submitted to the Technical Member for concurrence / approval.

7.13.4. The list of agency / experts / laboratories to be empaneled for third tier quality testing shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The list shall be updated, revised, and documented whenever found necessary. The lists such prepared shall be submitted to the Technical Member for concurrence / approval.

7.13.5. The Executive Engineer (Electrical / Mechanical – Quality Control) shall ensure that all the necessary formats / check lists / data entry modules / report generation facility related to quality control are incorporated into the software.

7.14. SAMPLE CHECK LISTS FOR ELECTROMECHANICAL WORKS.

Sample checklist for electrical and mechanical works are given below. The sample checklists are only for guidance purpose.

7.14.1. SAMPLE CHECK LIST FOR ELECTRO-MECHANICAL WORKS WHICH INVOLVES PROCUREMENT OF MATERIALS / EQUIPMENT COMPONENT WHICH REQUIRES MANUFACTURER CERTIFICATE.

Sl. No.	**Particulars.**	**Conformity.**	**Remarks.**
1.	The material / equipment component was packed and forwarded properly.	Yes / No / Not Applicable.	
2.	The material / equipment component was received at site in good condition.	Yes / No / Not Applicable.	
3.	The manufacturer has provided certification regarding the quality	Yes / No / Not Applicable.	

	/ conformity of the material / equipment with the relevant standards / conformity of factory acceptance tests.		
4.	The certificate provided by the manufacturer is in the prescribed format and acceptable.	Yes / No / Not Applicable.	
5.	The material / equipment satisfies all the parameters of the site acceptance tests.	Yes / No / Not Applicable.	
6.	The results of preparatory inspections carried out at place of installation were satisfactory.	Yes / No / Not Applicable.	
7.	The results of installation inspections and tests carried out during the installation were satisfactory.	Yes / No / Not Applicable.	
8.	The results of installation verification inspections carried out after the installation were satisfactory.	Yes / No / Not Applicable.	
9.	The results of system tests carried out were satisfactory.	Yes / No / Not Applicable.	
10.	The results of integrated tests carried out were satisfactory.	Yes / No / Not Applicable.	
11.	The results of commissioning tests carried out were satisfactory.	Yes / No / Not Applicable.	
12.	The results of final inspections carried out were satisfactory.	Yes / No / Not Applicable.	
13.	The work was carried out in	Yes / No / Not	

	accordance with the relevant Acts / Rules / Regulations / Guidelines.	Applicable.	
14.	The material / equipment was successfully / satisfactorily commissioned.	Yes / No / Not Applicable.	

7.14.2. SAMPLE CHECK LIST FOR ELECTRO-MECHANICAL WORKS WHICH INVOLVES PROCUREMENT OF MATERIALS / EQUIPMENT COMPONENT WHICH REQUIRES KWA TEAM / THIRD PARTY INSPECTION.

Sl. No.	**Particulars.**	**Conformity.**	**Remarks.**
1.	The material / equipment satisfies all the parameters of Factory Acceptance Test during the tests at the manufacturer facility.	Yes / No / Not Applicable.	
2.	The material / equipment was packed and forwarded properly.	Yes / No / Not Applicable.	
3.	The material / equipment was received at site in good condition.	Yes / No / Not Applicable.	
4.	The technical specification / performance curves of the material / equipment provided by the manufacturer agrees with the duty conditions specified in the contract.	Yes / No / Not Applicable.	
5.	The material / equipment satisfies all the parameters of the site acceptance tests.	Yes / No / Not Applicable.	

6.	The results of preparatory inspections carried out were satisfactory.	Yes / No / Not Applicable.	
7.	The results of installation inspections and tests carried out during the installation were satisfactory.	Yes / No / Not Applicable.	
8.	The results of installation verification inspections carried out after the installation were satisfactory.	Yes / No / Not Applicable.	
9.	The results of system tests carried out were satisfactory?	Yes / No / Not Applicable.	
10.	The results of integrated tests carried out were satisfactory.	Yes / No / Not Applicable.	
11.	The results of commissioning tests carried out were satisfactory.	Yes / No / Not Applicable.	
12.	The results of final inspections carried out were satisfactory.	Yes / No / Not Applicable.	
13.	The work was carried out in accordance with the relevant Acts / Rules / Regulations / Guidelines.	Yes / No / Not Applicable.	
14.	The material / equipment was successfully / satisfactorily commissioned.	Yes / No / Not Applicable.	

7.14.3. SAMPLE CHECK LIST FOR DESIGN QUALITY CONTROL.

Sl. No.	**Particulars.**	**Conformity.**	**Remarks.**

1.	Sufficient data for the design / determination of technical specifications / duty conditions was collected.	Yes / No / Not Applicable.	
2.	Proper analysis of the collected data was carried out.	Yes / No / Not Applicable.	
3.	Design / drawings were prepared in accordance with the relevant Indian / International standards / accepted norms / guidelines / manuals.	Yes / No / Not Applicable.	
4.	Duty conditions / technical specifications were finalized after carrying out the analysis of the collected data and / or after the design.	Yes / No / Not Applicable.	

7.14.4. SAMPLE CHECKLIST FOR PERFORMANCE QUALITY.

Sl. No.	**Particulars.**	**Conformity.**	**Remarks.**
1.	The material / equipment component performed satisfactorily during the warranty period / first two years after installation / commissioning.	Yes / No.	
2.	If No, whether the manufacturer may be considered for blacklisting?	Yes / No / Not Applicable.	

7.14.5. SAMPLE CHECKLIST FOR DOCUMENT CONTROL.

Sl. No.	Particulars.	Conformity.	Remarks.
1.	The duty conditions / technical specifications were finalized as per the design quality control requirement for each individual work and a detailed account of the same were incorporated into the contract document, including drawings.	Yes / No / Not Applicable.	
2.	The Technical Specification / Special Conditions of contract document were prepared in accordance with the Indian Electricity Act / Indian Electricity Rules / Central Electricity Authority Regulations / Guidelines of Department of the Electrical Inspectorate, Government of Kerala and other applicable Acts, Rules, Regulations and Guidelines.	Yes / No / Not Applicable.	

7.15. SOFTWARE AND REPOSITORY OF QUALITY CONTROL RECORDS.

7.15.1. The Software 'Project Status Alert System of KWA' (PASK) shall act as a monitoring tool for quality control for electro-mechanical works in KWA. It shall also act as a repository of records of quality control such as formats, certificates, reports, checklists etc. The software shall be enabled for all quality control activities. New modules for the above purpose shall be incorporated into the software.

7.15.2. A module for recording the performance of electrical / mechanical component and for generating manufacturer-wise abstract with good performance / bad performance shall also be incorporated into the software.

7.15.3. Provision for three-tier quality control and related document upload / facility for data entry shall also be incorporated into the software.

7.15.4. The Executive Engineer (Mechanical / Electrical – Quality Control) shall be responsible for incorporating new / modified formats / checklists into the software.

7.15.5. The Engineer in charge of the works shall enter each electro-mechanical work in the PASK. The formats / check lists integrated into the software shall be updated upon each event in the format / check list. All the manufacturer certificates, test certificates, inspection reports etc. related to the quality control activity shall be uploaded in the software.

7.15.6. For quality control activities of collective responsibility of Electrical and Mechanical quality control units, dual approval facility shall be incorporated into the software.

7.15.7. Facility for necessary report generation on various quality control activities including reports on insufficient data entry shall be incorporated into the software.

PART B WATER SUPPLY

CHAPTER 8 SERVICE CONNECTIONS

8.1. GENERAL

Providing house connection including fixing water meter from existing distribution lines up using Indian Standard Pipes and specials viz. ferrule, full way wheel valve, Elbow, MTA, FTA, couplers, Service Saddle of suitable size etc. and connecting with the distribution lines, testing the joints etc. complete including trenching and refilling in all kinds of soil up to the specified depth , lighting, watching, providing caution boards , controlling traffic ; and restoring the road surface by providing PCC using 20mm metal to the tar/concrete cut portion etc. complete as per the direction of the departmental officers.

8.2. QUALITY STANDARDS

8.2.1. Class 6 uPVC pipes conforming to IS 4985 and uPVC specials conforming to IS 13593 shall be used for water connections with uPVC pipes.

8.2.2. PE pipes, PE80, PN16 conforming to IS 4984 and PE specials shall be used for water connections with PE pipes.

8.2.3. Ferrule conforming to IS 2692 shall be used in all water connections.

8.2.4. Air valves [conforming to IS 14845] shall be used only in locations where the problems related to the entry of air into the water meter assembly is reported and where the use of air valves are recommended by the Sub-Divisional officer concerned.

8.2.5. Air valves shall be sealed by suitable means wherever it is used, to prevent theft of water.

8.2.6. GM check valves shall be as per IS 778

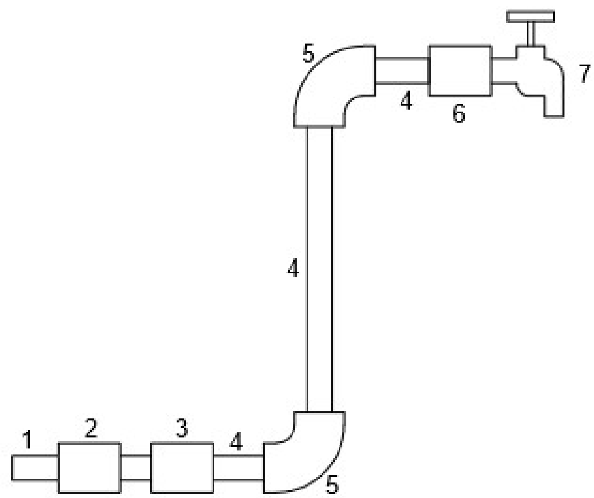
8.2.7. In case, the site conditions prevent the use of uPVC pipes such as in rocky terrains, GI pipes conforming to IS 1239 and fittings can be used for water connections.

8.2.8. Water meters shall be confirming to IS 779

8.2.9. All IS Standards as per latest revision to be adopted

PVC TAP

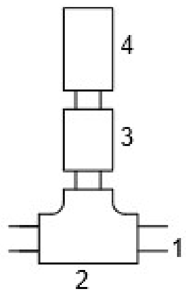
15mm ($\frac{1}{2}$") PVC Tap in 25mm ($\frac{3}{4}$") Indian Standard PE Service Pipe



1. Pipe, PE, PE80, PN16, Conforming to IS 4984: 2016 or later edition, 25mm ($\frac{3}{4}$").
2. Compression FTA, PP, PN16, 25mm ($\frac{3}{4}$").
3. MTA, uPVC, 12.5 kg/cm2, 25mm x $\frac{3}{4}$".
4. Pipe, uPVC, Indian Standard, Class 6, 25mm ($\frac{3}{4}$").
5. Elbow, uPVC, Indian Standard, Class 6, 25mm ($\frac{3}{4}$").
6. Reducer FTA, uPVC, 12.5 kg/cm^2, 25mm x $\frac{1}{2}$".
7. Tap, PVC, 15mm ($\frac{1}{2}$").

AIR VALVE

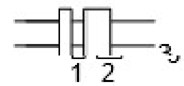
15mm ($\frac{1}{2}$") GM Air Valve in
25mm ($\frac{3}{4}$") PE Servie Pipe.



1. Pipe, PE, PE80, PN16, Conforming to IS 4984: 2016 or later edition, 25mm ($\frac{3}{4}$").
2. Compression Tee MTA, PP, PN16, 25mm ($\frac{3}{4}$").
3. Reducer Threaded Coupling, Brass, 20mm x 15mm ($\frac{3}{4}$" x $\frac{1}{2}$").
4. Air Valve, GM, Indian Standard, Class 2, 15mm ($\frac{1}{2}$").

CHECK VALVE

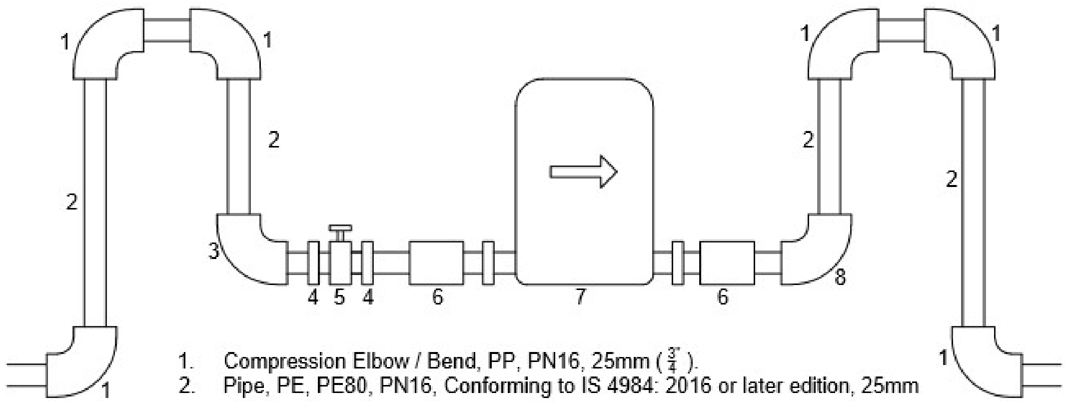
15mm ($\frac{1}{2}$") GM Check Valve in
20mm ($\frac{1}{2}$") PE Servie Pipe.



1. Hexagonal Nipple, Brass, 15mm ($\frac{1}{2}$").
2. Check Valve, GM, Indian Standard, Class 2, 15mm ($\frac{1}{2}$").
3. Pipe, PE, PE80, PN16, Conforming to IS 4984: 2016 or later edition, 20mm ($\frac{1}{2}$").

SERVICE PIPE WITH METER ASSEMBLY

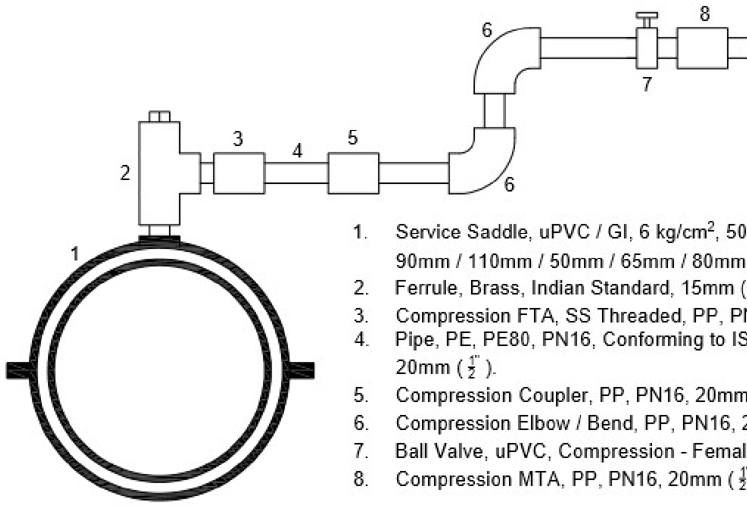
25mm Indian Standard PE Service Pipe with 15mm ($\frac{1}{2}''$) Water Meter for 20mm ($\frac{3}{4}''$) Connection.



1. Compression Elbow / Bend, PP, PN16, 25mm ($\frac{3}{4}''$).
2. Pipe, PE, PE80, PN16, Conforming to IS 4984: 2016 or later edition, 25mm ($\frac{3}{4}''$).
3. Compression FTA Elbow / Bend, SS Threaded, PP, PN16, 25mm ($\frac{3}{4}''$).
4. Hexagonal Nipple, Brass, 20mm ($\frac{3}{4}''$).
5. Gate Valve with Wheel, GM, Indian Standard, Class 2, 20mm ($\frac{3}{4}''$).
6. Reducer Threaded Coupling, Brass, 20mm x 15mm ($\frac{3}{4}'' \times \frac{1}{2}''$).
7. Water Meter, Indian Standard, Class B, Multijet, 15mm ($\frac{1}{2}''$).
8. Compression MTA Elbow / Bend, SS Threaded, PP, PN16, 25mm ($\frac{3}{4}''$).

CONNECTION PIPE for PVC/HDPE/AC/GI Mains

For 15mm ($\frac{1}{2}''$) Connection Using Indian Standard 20mm PE Pipe (Using Service Saddle)



1. Service Saddle, uPVC / GI, 6 kg/cm^2, 50mm / 63mm / 75mm / 90mm / 110mm / 50mm / 65mm / 80mm / 100mm / 125mm x $\frac{1}{2}''$.
2. Ferrule, Brass, Indian Standard, 15mm ($\frac{1}{2}''$).
3. Compression FTA, SS Threaded, PP, PN 16, 20mm ($\frac{1}{2}''$).
4. Pipe, PE, PE80, PN16, Conforming to IS4984: 2016 or later edition, 20mm ($\frac{1}{2}''$).
5. Compression Coupler, PP, PN16, 20mm ($\frac{1}{2}''$).
6. Compression Elbow / Bend, PP, PN16, 20mm ($\frac{1}{2}''$).
7. Ball Valve, uPVC, Compression - Female Threaded, 20mm ($\frac{1}{2}''$).
8. Compression MTA, PP, PN16, 20mm ($\frac{1}{2}''$).

Notes:
1. PVC Service Saddle shall be used for PVC / HDPE Mains.
2. GI / SS Service Saddle shall be used for AC / GI Mains.
3. Size of Water Connection is the size of Ferrule.

PART C WASTE WATER MANAGEMENT

CHAPTER 1 SEWER LAYING WORKS

1.1. GENERAL

The most common type of sewer construction practice involves the use of open trenches and prefabricated pipes. However, larger sewer systems, and unusual situations may require micro tunnelling, jacking of pipes through the soil, or cast-in-situ concrete sewers. On all excavation work, safety precautions for the protection of life and property are essential; and measures to avoid too great inconveniences to the public are desirable. Such measures and precautions include the erection and maintenance of signboards (to forewarn public), barricades, bridges and detours; placing and maintenance of lights both for illumination and as danger signals; provision of watchmen to exclude unauthorized persons, particularly children from trespassing on the work. Computation of the safe load carrying capacity of the pipe when installed and bedded in the manner to be specified using a suitable factor of safety and making certain the design supporting strength thus obtained is greater than the maximum load to be applied. Sewers may be laid in trenches or under embankment in areas which may be temporarily or permanently submerged in water. The fill load in such cases will be reduced and will correspond to the buoyant weight of the fill material. However, effect of submergence could be ignored which provides an additional factor of safety, but it may be necessary to check whether a pipe is subject to flotation. Under submergence, the minimum height of the fill material that will be required to prevent flotation ignoring the frictional forces in the fill can be determined. Wherever sufficient height of fill material is not available, anti-flotation blocks should be provided. All rigid pipes may be tested for strength in the laboratory by the three-edge bearing test (ultimate load). Width of the trench specified for a particular job should be minimum in consonance with the requirements of adequate working space to allow access to all parts and joints of pipe.

The Field Engineer should keep the approved shop drawings prepared by the Design Engineer throughout the duration of the Project and any deviation from the shop drawings due to the exigencies of work, should be immediately investigated and corrective measures taken in time. All pipes used on the work should be tested as per the IS specifications and test certificates of the manufacturers should be furnished for every consignment brought to the site. Proper backfilling methods both as regards to selection of materials, methods of placing and proper compaction should be in general agreement with the design parameters. The back filling should be done layer by layer not exceeding 20cm and field test to be conducted at regular intervals to get a compaction of more than 90%. In quicksand conditions, it is necessary to anchor the sewer to the ground and hold it at the grade as laid in the face of soil sinkage. The line (horizontal alignment) and grade layout of a sewer line as per design must be carried out meticulously. The horizontal layout determines the location as well as direction of the sewer line, while slope (grade) of the line provides the necessary hydraulic carrying capacity of the sewerage system.

The location of the trench is generally laid out first as an offset line running parallel to the proposed sewer centre line. This offset line is demarcated by wooden stakes driven into the ground surface at intervals of 20m. The offset line, as is clear, is quite away from the sewer centre line with a view not to allow it being disturbed during construction; however, it must be proximate enough so that the transfer of measurements to the actual trench can readily be done. Two procedures are available to lay pipe sections in the open trench, namely, by batter boards, and by laser beams. Better boards are placed across the trench at uniform intervals. The tops of these boards can be set at some even height above the designed sewer invert elevation. In the laser method, advantage is taken of an intense, narrow beam of light that is projected by the laser instrument, over a long distance. This beam is aligned through a sewer pipe to strike a target held at the other end of the pipe. A transit that is placed above a manhole helps establish the alignment of the sewer with reference to field survey points and transfer it down to the laser instrument that is mounted inside the manhole. Lasers can achieve an accuracy of 0.01 per cent over up to 300 m.

A cross connection between water main and sewer main seldom occurs because of the sizes of these mains. However, where the location is complicated, the water mains shall be either blue coloured pipes or painted with blue florescent coloured paint. A minimum offset of equal to half the width of the manhole plus 30 cm shall be the lateral offset between water mains and sewer lines. It is advisable to encase the sewer than the water main. Gravity sewers shall not be laid closer to water retaining structures and the effort should be to detour as far as possible. In case of leakages in sewer joints, the leakage may gain access to the sidewalls of the water retaining structures.

Excavation for sewer trenches for laying sewers shall be in straight lines and to the correct depths and gradients required for the pipes as specified in the shop drawings. The material excavated from the trench shall not be deposited very close to the trench to prevent the weight of the materials from causing the sides of the trench to slip or fail. The sides of the trench shall, however, be supported by shoring where necessary to ensure proper and speedy excavation. In case, the width of the road or lane where the work of excavation is to be carried out is so narrow as to warrant the stacking of materials near the trench, the same shall be taken away to a place to be decided by the Engineer-in-Charge. This excavated material shall be brought back to the site of work for filling the trench.

In case the presence of water is likely to create unstable soil conditions, a well point system shall be employed to drain the immediate area of the sewer trench prior to excavation operation. A well point system consists of a series of perforated pipes driven or jetted into the water bearing strata on either side of a sewer trench and connected with a header pipe leading to a pump, In the event of excavation being made deeper than necessary, the same shall be filled and stabilized.

The shoring shall be adequate to prevent caving in of the trench walls of subsidence of areas adjacent to the trench. In narrow trenches of limited depth, a simple form of shoring shall consist of a pair of 40 to 50 mm thick, and 30 cm wide planks set vertically at intervals and firmly strutted. Necessary Timber shoring/Steel Shoring/ Aluminium hydraulic shoring/Interlock sheet pipling for trenches shall be provided according to the soil and site conditions where ever found required. The shoring shall be adequate to prevent caving in of the trench walls of subsidence of areas adjacent to the trench.

All pipes, ducts, cables, mains and other services exposed due to the excavation shall be effectively supported. Trenches for sewer construction shall be dewatered for the placement of concrete and laying of pipe sewer or construction of concrete or brick sewer and kept dewatered until the concrete foundations, pipe joints or brick work or concrete have cured. Where a sewer must be laid in a soft underground stratum or in a reclaimed land, the trench shall be excavated deeper than what is ordinarily required. The trench bottom shall be stabilized by the addition of coarse gravel or sand. In case of very bad soil the trench bottom shall be filled in with cement concrete of appropriate grade. In the areas subject to subsidence, the pipe sewer should be laid on suitable supports, sleepers or concrete cradle supported on piles.

In the case of cast-in-situ sewers, an RCC section with both transverse and longitudinal steel 4140 reinforcement shall be provided when intermittent variations in soil bearing capacity are encountered. In case of long stretches of very soft trench bottom, soil stabilization shall be done either by rubble, concrete or wooden crib.

Micro tunnels are employed in sewer systems when it becomes economical, considering the nature of soil to be excavated and surface conditions with reference to the depth at which the sewer is to be laid. Generally, in soft soils the minimum depth is about 10 m. In rocks, however, tunnels may be adopted at lesser depths. In busy and high activity zones crowded condition of the surface, expensive pavements or presence of other service facilities near the surface sometimes make it advantageous to tunnel at shallower depths.

1.2. METHODOLOGY-OPEN CUT PIPE LAYING WORKS:

1.2.1. Pre-commencement Works:

The pre-commencement period will include Survey, Design, Preparation of Shop Drawings and Approvals prior to commencement of the Excavations.

Within this period following has to be ensured for carrying out the works;

- Surveys of existing services, meeting with Client representatives and Service providers.
- Trial pits to facilitate above works.
- Correlation of Project and Existing Services drawings and planning for rerouting / removal / protection of existing services.
- Development of Traffic Management Plan.

- Prepare Shop drawings specific to the location with all the details & shall be approved by the Engineer Representative.
- Development of Construction Methodology that will best suit the location.
- Approval for Excavation from Statutory Bodies and Engineers Approval.
- Identify and obtain approvals from Municipality for dumping spoils from excavation.
- Pre-condition survey for the existing structures to be conducted & Photographic records to be prepared.
- Carryout activities pertaining to KWA. A notification prior to excavation shall be distributed among public so that the public is well aware of the works in progress.
- Approval from the concerned authorities for dumping the Excavated Material shall be obtained prior to Excavation works.
- Deliver & Store the Material used for Construction such as Pipes etc., in a safe manner to the approved adjacent location of the site execution according to Specifications/Manufacturer's instructions.

1.2.2. Method of sewer laying works:

Before commencement of the excavation the method statement shall be submitted to the Engineer for approval.

1.2.2.1 General:

Survey & Route Approval:

The line and level of trenches shall be as shown on the drawings or as may be directed by the Engineer. The route of the trench shall be pegged out accurately and the natural ground level shall be agreed with the Engineer. Strong sight rails shall then be fixed and maintained at each change of gradient, and at as many intermediate points as may be necessary. On these rails shall be marked the centre line and the level to which the excavation is to be carried out, such rails being not more than 20 m apart. Alternative methods to maintain line and level of pipelines shall be to the approval of the Engineer.

Trial Holes:

Trial holes shall be excavated by hand to the required depth necessary to determine and confirm the alignment for the trench, soil conditions & services. Refilling & reinstatement of the trial holes shall be carried out immediately after the required information is obtained. The reinstatement of trial holes shall be carried out to the approval of the Engineer. Shop drawings of the trial pit excavations shall be submitted to the Engineer for information. Prior to Starting excavation obtain Approval from the Engineer. All trees, bushes, hedges, or other obstacles shall be removed at the excavation location to ensure a safe working area. Necessary approvals from the local authorities shall be obtained prior to cutting any trees. Necessary dewatering system will be installed where ever found required.

1.2.2.2. Trench Excavation:

Trench excavation shall be carried out by such methods and to such lines, dimension and depths as shall allow for the proper construction of the works, provided always that, unless the Engineer permits otherwise, no trench excavation shall be less than 600 mm in width. Excavation shall be carried out by hand methods where ever required to ensure the stability of utilities encountered during excavation work. Notwithstanding the foregoing, any rock in trench excavation shall be so excavated that the clearance between the pipe, when laid, and the rock sides and bottom of the trench is kept to the minimum limits necessary to provide for the specified thickness of bedding and concrete protection of the pipe. The bottom of the trenches shall be properly trimmed off and a compacted granular bed of thickness as shown on the drawings shall be placed and prepared to provide a firm and uniform bearing throughout the length of the pipe.

The bedding shall be lightly raked prior to placing the pipes on it. Bell holes and holes and depressions for couplings, valves and the like shall be excavated the same distance below these installations. The materials excavated shall be used in the backfill if suitable, or removed and disposed off, as required by the Engineer and as specified. The trench shall be dug only so far in advance of pipe laying as the Engineer shall permit.

Trenches shall have vertical sides unless otherwise authorized by the Engineer. No trench shall remain open for longer than 15 days.

Trench excavation in Roads:

Main Roads, City roads or utility crossings shall be carried out using non-disruptive construction techniques when specified or otherwise. If open excavation is allowed, all trench excavation and other works carried out within the limits of any existing road or highway shall be completed as rapidly as possible.

In case of roads capable of carrying two or more lanes of traffic, not more than half of the width of the carriageway shall be obstructed at any one time. In single lane roads, works shall be programmed in such a manner that the minimum inconvenience is caused to the public. Obstruction of the Road shall not begin until Engineer's Permission in writing is obtained. Road drains and channels shall be free from obstructions at all times. Where trench excavation or any other part of the works obstructs any footpath or right-of-way, a temporary footpath around the obstruction shall be provided to the satisfaction of the Engineer. Where applicable, this temporary footpath shall include bridges of wooden planks or other approved construction across any open trenches. Trenches will not be excavated in more than one location in any one road at a given time without the Engineer's permission. A Proper traffic management plan to be prepared and approved by the concerned authority.

Supporting Trench Excavations:

The trench shall have required shoring and escape routes. Trenches shall be maintained in a safe condition at all the times. The trenches shall have vertical sides unless otherwise authorized by the Engineer. Sides of the trench excavation shall be well and effectively supported with adequate supports. Trenches shall be sloped back as specified in the project specifications. The trench support equipment used shall be in good condition and be approved by the Engineer. If permitted by the Engineer to execute trench excavation with battered sides, stable slopes shall be excavated from 300 mm above the top of pipe.

Shoring of Trenches:

Necessary Timber shoring/Steel Shoring/ Aluminium hydraulic shoring for trenches shall be provided according to the soil and site conditions where ever found required. The shoring shall be adequate to prevent caving in of the trench walls of subsidence of areas adjacent to the trench. In narrow trenches of limited depth, a simple form of shoring shall consist of a pair of 40 to 50 mm thick, and 30 cm wide planks set vertically at intervals and firmly strutted. For wider and deeper trenches, a system of wall plates (Wales) and struts of heavy timber section is commonly used. Continuous steel sheet piling or interlocking sheet piling shall be provided outside the wall plates to maintain the stability of the trench walls. The thickness, size, type of the wall plates shall be fixed considering the depth of trench, type of soil & existing water table. In non-cohesive soils combined with considerable ground water, it may be necessary to use continuous interlocking steel sheet piling to prevent excessive soil movements due to ground water percolation. Such sheet piling shall extend at least 0.5 m below the bottom of the trench and as per requirement based on soil conditions. In case of deep trenches, if conditions demand, excavation and shoring may be done in stages.

1.2.2.3. Pipe Surrounds & Bedding:

Pipe bed and surround shall be depending on the pipe properties. As soon as the excavation is complete to normal grade of the bottom of the trench, bedding shall be placed, compacted and graded to provide firm, uniform and continuous support for the pipe. Bell holes shall be excavated so that only the barrel of the pipe bears upon the bedding. The pipe shall be laid accurately to the lines and grades indicated on the Drawings. Blocking under the pipe will not be permitted. Bedding shall be placed evenly on each side of the pipe to mid-diameter and hand tools shall be used to force the bedding under the haunches of the pipe and into the bell holes to give firm continuous support for the pipe. Surround shall then be placed to 30 cm above the top of the pipe.

The remainder of the trench shall then be refilled in compacted layers not exceeding 200 mm in thickness, each layer being well compacted with power rammers, vibrating plate compactors or other mechanical means of a type to be approved until the ground is thoroughly consolidated up to the required level for surface reinstatement. Each layer shall be compacted to 90% of its maximum dry density. Test to be taken for same and the level of compaction for each layer should be done in the presence of the Engineer.

For pipelines located beneath the permanent groundwater level pipes any granular bedding material , surround shall be laid on and enclosed within a geo-textile filter fabric membrane. All bedding & surround material by Geo textile Fabric shall be subject to prior approval of the Engineer.

1.2.2.4. Pipe Laying:

To prevent contamination of pipes all open ends shall be closed by means of a temporary watertight stopper or cap whenever the pipe laying work is not carried out.

uPVC Pipe & Fittings: Maximum buried depth for uPVC pipes shall be 6 meters, unless approved otherwise by the Engineer. All joints shall be spigot and socket type with flexible elastomeric sealing rings, unless approved otherwise by the Engineer. Pipes, fittings and specials shall be delivered, handled and stored according to the manufacturer's recommendations

Transportation, handling and storage shall at all times be performed in a manner to avoid product damage. Only nylon slings shall be allowed for lifting pipes and fittings. Steel chains, clamps or cables shall not be allowed for lifting purposes. Steel chains or cables may be allowed for securing pipes during transport or storage provided protective padding or timber blocking is utilized. Do not store pipes on rough or rocky ground. Do not stack pipes with timber blocking; lay directly on pipe barrels by alternating socket ends. Cover pipes to prevent UV degradation. Elastomeric sealing rings (rubber gaskets) shall be stored in closed containers or out of direct sunlight until needed.

No piece of pipe shall be laid unless it is straight. The centreline of the pipe shall not deviate from a straight line drawn between the centres of the openings at the ends of the pipe by more than 5mm/metre of length. If a piece of pipe fails to meet this requirement check for straightness, it shall be rejected and removed from the site. Laying instructions of the manufacturer shall be explicitly followed.

If any defective pipe is discovered after it has been installed, it shall be removed and replaced with a sound pipe in a satisfactory manner. All pipe and fittings shall be thoroughly cleaned before installation, shall be kept clean until they are used in the work and when laid, shall conform to the lines and grades required. PVC pipe and fittings shall be installed in accordance with requirements of the manufacturer.

All pipes shall be sound and clean before installation. When installation is not in progress, including lunchtime, the open ends of the pipe shall be closed by watertight plug or other approved means. Good alignment shall be preserved during installation. The deflection at joints shall not exceed than that recommended by the manufacturer.

When cutting pipe is required, the cutting shall be done by machine, leaving a smooth cut at right angles to the axis of the pipe. Cut ends of pipe to be used with a socket shall be bevelled to conform to the manufactured spigot end. Each length of the pipe shall have the assembly mark aligned with the pipe previously laid and held securely until enough backfill has been placed to hold the pipe in place. Joints shall not be “pulled” or “cramped”. Any Pipe having defective joint surfaces shall be rejected, marked as such and immediately removed from the job site. Before any joint is made, the pipe shall be checked to assure that a close joint with the next adjoining pipe has been maintained and that the inverts are matched and conform to the required grade. The pipe shall not be driven down to grade by striking it.

Precautions shall be taken to prevent floatation of the pipe in the trench. Concrete thrust blocks shall be installed at all fittings and other locations as directed by the Engineer. Minimum bearing area shall be as shown on the Shop Drawings. Concrete shall be placed against undisturbed material and shall not cover joints, bolts or nuts, or interfere with the removal of any joint. Wooden side forms shall be provided for thrust blocks.

Jointing (Push-on type)

Joints shall be made in strict accordance with the manufacturer’s instructions. Pipe shall be laid with bell ends looking ahead. A rubber gasket shall be inserted in the groove of the bell end of the pipe and the joint surfaces cleaned and lubricated. The plain end of the pipe to be entered shall then be inserted in alignment with the bell of the pipe to which it is to be joined and pushed home with a come-along or by other means. Check that the reference mark on the spigot end is flush with the end of the bell. Pipe and fittings shall be jointed in accordance with the recommendations of the detailed instructions of the manufacturer.

All manhole connections shall be as shown on the Shop Drawings except concrete and other mortared connections shall be equipped with an integral O-ring or other sealant such that a positive watertight seal is established.

HDPE Pipe & Fittings:

Handling of pipe & fittings shall be in accordance with the manufacturer's Recommendations. Care shall be taken in loading, transporting and unloading of pipes, to prevent any cuts/gauges/scratches, Nylon Belts/ropes or rubber-protected slings/straps shall only be used for handling the pipes. Use of steel chains, steel wire ropes and steel hooks inserted into pipe ends shall not be permitted. Pipes shall be stored on clean, dry, level ground, free of sharp protrusions.

Stacking of pipes shall be limited to a height that will not cause excessive deformation of the bottom layer of pipes. Where necessary, due to ground conditions, the pipe shall be stored on wooden sleepers, spaced suitably, as not to allow deformation of the pipe at the point of contact with the sleeper or between supports.

Pipes and fittings shall be examined before installation and any damage to pipes/fittings shall be repaired as directed by the Engineer. All joints between PE pipes and /or fittings for sizes 75mm OD & larger for force main shall be welded by butt fusion or Electro Fusion methods as the case may be. For gravity sewers extrusion welding shall be followed which will reduce the internal flow obstruction caused by the projected butt fusion joint. PE pipes 63mm OD & smaller may be joined with butt fusion welding or approved compression fittings.

All pipes, fittings, valves etc. shall be carefully lowered into the trench with suitable equipment in a manner that will prevent damage. All foreign matter shall be removed from inside the pipe or fitting before being lowered into position. At the close of a day or whenever pipe laying is not in progress the open ends of the installed pipe shall be closed by an approved cap or blank to prevent the entrance of ground water or any other foreign matter. Under no circumstances shall pipes be used for the storage of tools etc. Ensure that the pipeline is clear and free of all foreign matter at all times.

1.2.2.5 Backfilling:

Excavations in roads and streets shall be filled with approved backfilling material above the level of any pipe surround required, in accordance with the regulations set out by KWA or any statutory body such as PWD, NH, KRFB, Local Bodies, Etc., and according to standard specifications and approved drawings issued for construction.

Approval of Engineer to be sought before screening excavated trench material on site.Soil utilized for landscaping or agricultural purposes shall be stockpiled separately. Unsuitable materials shall be removed and disposed off. Any soils utilized for landscaping shall be replaced in their original position and condition. Trenches shall not be backfilled until all required tests are performed and until the Engineer has verified that the pipes cables, other service have been installed in accordance with the Specifications and Drawings. Lumps and clods shall be broken up before use. Materials shall not be dropped from a height and where directed water shall be added to assist in adequate consolidation

Where cover to pipes cables/ducts is less than 400 mm, or where ordered by the Engineer, protection in the form of concrete encasing shall be provided according to the approved drawing or as directed by the Engineer. Backfilling of trenches shall commence as soon as practicable after the pipe line works have been completed, tested and approved by the Engineer.

Compaction test for fill materials will be carried out as per specifications. Unless directed otherwise on site Compaction test of in-situ soils shall be at the minimum rate of :

a) One test per backfill layer to a maximum stretch of 100 m.

b) One test per backfill layer should determine maximum dry density (MDD).

Selected Material:

When required, approved selected/ filter material shall be placed in backfilling structures in accordance with the details shown on the shop drawings.

Warning Tape:

Detectable Warning tape shall be installed above sewage pumping mains, ducts and cables as per approved drawings. The Warning tape shall be laid in the pipe trench after partial backfilling and compaction is complete.

1.2.3. HDPE manhole erection:

1.2.3.1. General

Ensure that the relevant drawings for the intended location are in possession and the area to be excavated has the required NOC/permissions. Centre line will be marked and checked against the alignment drawing to ensure that there is enough space. Marking will be done by keeping minimum 2 to 3 meters distance from the centre of the existing line using steel bars and tape. Initial marking shall be carried out by Surveyor. Trial holes shall be excavated by hand to the required depth necessary to determine and confirm the alignment for the trench, soil conditions & services. Refilling & reinstatement of the trial holes shall be carried out immediately after the required information is obtained. The reinstatement of trial holes shall be carried out to the approval of the Engineer. Shop drawings of the trial pit excavations shall be submitted to the Engineer for information. Prior to starting excavations, the Site Supervisor shall carryout daily inspections of the work site, the adjacent areas, and protective systems for evidence of a situation that could result in possible accidents, indications of failure of protective systems, hazardous atmospheres, or other hazardous conditions. All trees, brush, hedges, or other obstacles shall be removed at the excavation location to ensure a safe working area with prior Permission. Ascertain the level of water table at Manhole Installation location. Where possible, excavated spoil will be heaped near the location. When it is not possible to store the excavated spoil nearby, the spoil will be transported away to a location acceptable to the Municipality. Permissions from the relevant authorities will be taken in this case.

1.2.3.2. Setting out

The setting out for the installation of manhole with its outlet and inlet elevations shall be carried out by Surveyor as per the AFC/ Shop drawings.

1.2.3.3. Excavation works

Excavation and preparation of trenches for installation of HDPE manhole shall be done to required invert levels in accordance with the specification and approved shop drawings. The final 150mm depth of all excavations shall be taken out by hand and the bottom leveled & rammed immediately prior to placing concrete. The sides of excavation may be sloped as required by soil condition to stabilize the sides for safe working condition. Such excavation shall be limited to the amount considered necessary for safety. If dewatering is required for trench preparation, installation of piping or trench filling this shall be performed and water shall be disposed in designated area. If rock excavation is found it may require use of pneumatic hammers to remove in hand excavation or the use of ripper fitted to JCB for mechanical excavation. Mechanical excavation shall be carried out keeping the equipment at a safe distance from the edge of the excavation as per the prevailing soil type and condition. Set spoils and equipment at least 1 m back from the excavation. Where the site does not permit a 1 m set back, spoils to be temporarily hauled to another location. Depth of excavation will be as per the approved for construction drawing/ Shop Drawing.

1.2.3.4. Installation and construction of HDPE Manhole:

The bottom of excavation shall be blinded with class ‘C’ (20/20) concrete as specified in the Tender drawing/shop drawings. Provide 200mm layer of 10mm Natural Aggregate and then place 1000-gauge polyethylene sheet. Blinding concrete shall be placed. Then the concrete base slab (C45/20) will be laid as specified and as per drawings. Two coatings of Bituminous paint will be applied for the outer surfaces of the concrete in contact with earth in accordance with the specification. HDPE manhole shall be carefully lifted transported and lowered into the excavated location without causing any damage to the material. Approved belt / ropes shall only be used during above operation & Installation of HDPE manhole.

1.2.3.5. The connection pipes to HDPE manholes:

The inlet and outlet shall be duly welded with approved HDPE fusion welding procedure to the benching of the manhole. In case of manholes with branch connections for pipes upto and below 250mm OD, inlets shall be socket and the outlet shall be spigot and so jointing shall be done by push fit method. For branch size 300mm and above, jointing of both inlet & outlet shall be formed by extrusion butt welding. Extended drop connection shall be by push-fit method for pipes up to 400mm and formed by extrusion butt welding for 450mm and above.

1.2.3.6. Backfilling of manhole trench shall commence in layers after approval of manhole installation of connection is over. Each layer of backfill shall be compacted to 90% of its max. dry density.

1.2.3.7. Construction of Manhole cover slab

The manhole cover slab (C45 concrete) shall be constructed as indicated in the tender/shop drawing. The cover slab shall be surmounted by ductile iron / equivalent manhole cover and frames of the quality specified and in accordance with KWA standards. The cover on roads and paved areas shall be set on precast concrete brickwork to the level and slopes of the roads or pavements. The manhole covers and frames shall be of class D400 and in accordance with BSEN: 1240 and KWA standard drawings. In the case of shallow manholes, the cover and frame may be cast directly with reinforced concrete cover slab as in the shop drawings.

1.2.3.8. Inspections and Testing

In accordance of the standard specification, all HDPE manholes shall be free from all defects and subject to approval of Engineer. As per project specification and quality requirement, applicable tests shall be conducted for concrete elements of the manholes. The water test shall be carried out for pipe jointing with HDPE manhole for any leakage, by filling water to upstream manhole to the downstream manhole in between the sewer pipes laid. A level should be marked in the shafts of the up shown and down shown manholes. The water level should be checked for reduction in level marked from original level. If there is no visible leakage through joints the pipe connection shall be treated as passed. Otherwise, in accordance of standard specification shall be followed for the above water test. On satisfactory completion of the inspection by the Engineer, clearance shall be obtained for the next activity.

1.2.4. Precast RCC Manhole Erection:

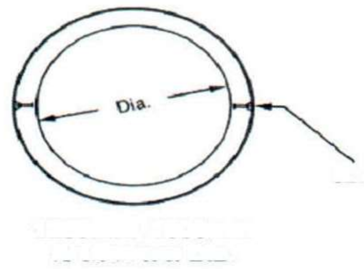
Scope of works covers the installation of precast RCC Manhole/ access chamber components for Kerala water Authority.

1.2.4.1. Inspection of Material

When Components and accessories are delivered to the site, these should be checked for damage and omissions, to ensure that installation can proceed successfully. Check to ensure that all the components are available to enable finishing to the designed cover level. Correct lifting apparatus must be on hand before work can commence.

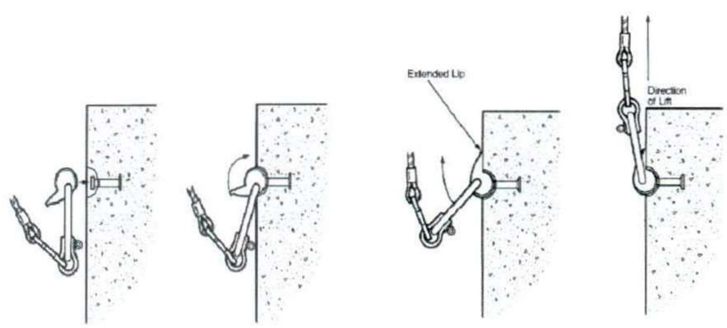
1.2.4.2. Excavation & Installation

The excavation all around the Manhole and ground support shall be minimum 200 mm clear of the outside of the component subject to site requirement based on depth of Manhole. In manhole products, lifting anchors are placed on the sides of the product. Manholes have one or more anchors on either side of the product for stability during installation and stacking.

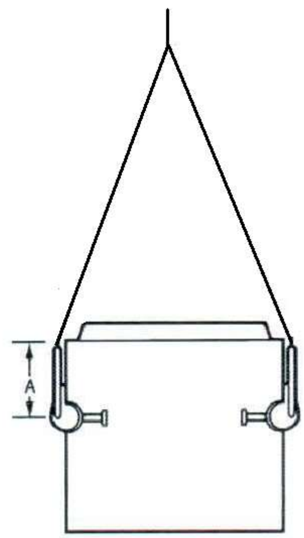


1500mm & 1800mm dia SL ANCHORS

Lifting anchors are sized and located specifically for each Manhole component to be lifted individually. No attempt shall be done to lift more than one concrete Manhole component at a time, and must be ensured that the load is applied to all lifting anchors simultaneously in order to safely lift the product. The MAXIMUM safe working load is clearly visible on the head of the anchor for easy recognition of the appropriate hardware and accessories for-use with the lift anchor.



Using short lifting cables or chains that results in sling angle greater than 60 degree can greatly increase the possibility of damaging the top shoulders of the Manhole riser and potentially cause the Manhole riser to fail structurally. When risers have multiple openings, extra care must be taken to reduce the inward force from the rigging by use of longer cables.



A=minimum edge distance

Precast Base Erection

Concrete used in blinding below the base construction shall be minimum grade M 20. Flexible joints shall be provided on all pipeline connections to manhole /access chamber in accordance with the drawing. Precast base components may incorporate factory formed holes or alternatively holes may be core drilled on site using a core drill. Precast bases may be supported on the blinding concrete to a minimum thickness of 75 mm. Jointing of pipeline with or without drops to the precast base shall be using rubber rings provided by the Manufacturer.

Assembly of components

The components shall be assembled and jointed in accordance with the drawings. Jointing surface shall be clean and free of unacceptable defects and damage before making the joint.

Care shall be taken to ensure that:

• Correct lifting gear and procedures are used.
• Jointing mastic or rubber sealing rings are placed correctly in accordance with manufacturer's instruction.

The component to be joined should be lowered into position slowly and deliberately, ensuring uniform contact is made all around. It is useful to hold the components to be joined slightly above the one in position, to allow steadying prior to placement. After placement, it should be checked that the components have joined evenly and in accordance with manufacturer's specifications.

The rubber ring shall be clean and free of damage such as cuts, gouges etc.

- Place the ring around the spigot with the ribbed side of the ring against the concrete spigot.
- Insert a smooth rounded object such as a screwdriver shaft under the ring and run along the concrete spigot.
- Push the ring down to ensure it rests firmly against the spigot step.
- Align the components to be joined and lower the socketed component ensuring the correct alignment is maintained to engage the rubber ring lead-in of the socket profile.
- The lighter components, such as small diameter shaft units, may require downward push to close the joint.
- Subsequent component shall not be installed on top of any joint that is not fully closed.

Assembly of top components

Top slab must be placed at the required level and slope as specified in the drawing or as directed by the Engineer. "Make up" ring to be used to control the level and slope at which the cover is finished.

Jointing of liners

The precast manholes are manufactured with HDPE liners as per requirement. The jointing of liners between two components shall be carried out by hot air welding with flat sheet.

Handling of precast manhole sections shall be carried out with due care so as to avoid damage to the external coating, wherever applicable. Any damage to external coating shall be repaired according to the type of external coat and as directed by the Engineer.

1.2.4.3. Backfilling

The material used for backfilling around the manhole/access chamber may be the same as that is used for backfilling of the pipeline or as directed by the Engineer. The backfilling material shall be placed evenly around the circumference of the access chamber and compacted ensuring that the components and joints are not displaced. Care must be taken to ensure uniform compaction is achieved around the access chamber. Uneven side loads or construction traffic loads shall be avoided. The backfilling operation should be completed with the aim of minimal or no subsidence of the fill material after completion of the works.

1.2.4.4. Tolerances

The maximum allowable tolerance for installation shall be;

- The invert levels for inlet and outlet pipes shall be within the tolerances specified for pipe laying.
- The variation from plumb shall not exceed 10 mm in any 3 meters or 20 mm in any 6 meters.
- The level of the cover shall be within 5 mm of the level specified on the drawings or as directed by the Engineer

1.2.4.5. Testing

All manholes/access chambers shall be capable of passing water test as specified. The water test may be carried out prior to backfilling. After plugging all pipe opening, the manhole/access chamber shall be filled with clean water to the lowest point in the top of the access cover frame. Plugs should be positioned in the pipes as near as practicable to the internal face of the manhole/access chamber. After allowing an interval for internal absorption of not less than 15 min, the manhole/access chamber passes the test if the drop in water level is less than 3mm for each 1 meter depth of Manhole/access chamber, when measured from the bottom of the access cover recess in the frame to the invert of the outlet from the manhole/access chamber. Manhole/ Access chamber that fails to meet the requirements of the specified test shall be remedied.

1.2.4.5. Summary

Summary of critical steps to be observed while installation:

- Ensure that the components are not damaged when delivered.
- Replace over-excavation with correct filling.
- Ensure correct starting level
- Jointing of Manhole/chamber components is carried out uniformly and positively.

- Channel is correctly aligned.
- Comply with all tolerances.

1.2.4.6. Manpower, Tools & Equipment

- The manpower requirement include Foreman/Charge-hand, Rigger, Banks man, Welder (HDPE liner), Masons & Helpers.
- The tools and plant requirement includes Slings/Lifting belts, Lifting hooks, Crane, JCB/Shovel, Plate Compactor & Pedestal compactor.

1.2.5. Quality Assurance of sewers during laying

For Solid Wall UPVC Pipes, the single most important precaution is to ensure that the excavated trench is not waterlogged. Where situations imply water logging, it is mandatory to employ a well point dewatering system running 24 hours, 7 days a week to hold the subsoil water at least 50 cm below the bedding elevation. Thereafter, the grade of the trench having been checked, lower the pipe with socket ends facing up gradient. When a pipe needs to be cut to suit a given distance, the pipe shall be cut perpendicular to its axis using a firm handheld saw and bevel the cut end by a beveling tool or power tool to the same angle as in the original uncut pipe and mark the insertion line freshly using an indelible black paint to retain the guide limit for insertion. Carefully remove any loose soil from the socket and do not remove the O ring from its housing. Check by hand whether the O ring is seated uniformly. Thereafter place the pipe spigot end near the socket. The standard EN 13476 “Plastics piping systems for non-pressure underground drainage and sewerage - Structured wall piping systems of PVC-U, PP and PE” covers the performance requirements for high quality Structured Wall Pipes (SWP). These pipes are manufactured with externally corrugated wall or with I beam type of wall with hollows between the webs of the I beams. These are laid in almost the same way as the UPVC pipes. Double Walled Corrugated Polyethylene (DWCPE) pipes are produced globally and in India following the EN 13476-3 standard which is holistically adopted from the ISO 21138-3 standard. This standard is currently being reviewed by BIS and this will take some more time to be published. It has a corrugated profiled outer surface wall and a smooth inner wall.

Other than the metallic and concrete pipe sewers, the uplift during high groundwater conditions above the pipe level is a problem specifically in high ground water locations, waterlogged locations and coastal areas. The concrete surrounds or venteak piles shall be used to hold these in place in such conditions, where ground water can rise above the sewer. Each section of sewer shall be mirror tested and also tested for water tightness preferably between manholes. To prevent change in alignment and disturbance after the pipes have been laid, it is desirable to backfill the pipes up to the top keeping at least 90 cm length of the pipe open at the joints. However, this may not be feasible in the case of pipes of shorter length, such as stoneware and RCC pipes. As soon as a stretch of sewer is laid and tested, manual inspection or CCTV inspection has to be done to check for any obstruction in the pipe line and the open ends of the pipe need to be closed.

No trench shall be filled in unless the sewer stretches have been tested and approved for water tightness of joints. However, partial filling may be done keeping the joints open to avoid disturbance. In the design of sewer systems, consideration should be given to the desirability of maintaining velocities sufficient to avoid sulphide build up and of minimizing pressure lines and points of high turbulence. The designer should take into consideration topography, grades of sewers, ventilation, materials of construction, sewage temperature and strength, etc.

Any protective coating used should possess the following qualities: (i) it should be resistant to acid attack, (ii) it should bond securely to the concrete, (iii) it should be economical and durable, (iv) it should be resistant to abrasive action by flow of sewage, and (v) when applied, it should be thin enough to fill all pores and irregularities in the surface. The coating should be continuous with no pin holes or other breaks.

1.2.5. Service Connections.

The house service sewer connections shall be effected only to manholes. In case of old sewers, a new manhole shall be inserted for this purpose. A block property chamber should be constructed inside the consumer property and connection should be made between the BPC and the manhole on road. The material of the House Service Sewer shall be either conventional salt glazed stoneware or UPVC rigid straight pipes of 8 kg/cm2 pressure class in manufacture and as per IS: 15328 with solvent cement joints. The minimum earth cover above the crown shall be 90 cm and where this becomes impossible, the property owner shall be directed to depress his terminal chamber to comply with the above especially as the public sewer manhole shall start at its crown at 90 cm below ground level. Where such sewers cross the electricity power cables, the specifications of IS: 1255 of 1983 reaffirmed in 2001 in clauses 6.3.3 and 6.3.3.1 shall be followed without any exception that all such house service sewers shall be only above the power cable and the minimum clearance shall be 30 cm over the cable which itself shall be covered all around by 15 cm riddled soil and further protected on top by tiles, bricks or slabs. The house owner shall be mandated to possess a “kraite” a type of non-corroding sufficiently flexible but rigid type of less than 10 mm diameter rod, which he/she shall use to rod the house service sewer freely up to the manhole/ Inspection Chamber on road and the labour of the local body shall not be deployed for any removal of obstructions in the house service sewer. Typically, it is possible to effect six service connections to a manhole. Pre designed & pre-fabricated manholes/ ICs are to be used as far as possible to avoid any additional puncturing or distrusting portion of the manholes already in position. It is recommended to install collection chambers/ rider main with shallow depth Inspection Chambers outside a group of houses and collect sewer load through pipes and connect inspection chamber with manholes using pipes with backdrops previously designed.

1.2.5. Lifting stations in gravity sewers

When there are situations restricting depth of cutting which are very exceptional the depth of sewers to a practicable limit can be made by diverting the flow into a pavement submersible pump station with a lockable control panel there itself and the delivery main can lift the flow to the downstream manhole at the conventional 0.9 m depth to invert. This can also be suitably used in settlement clusters and low-lying area settlements. These submersible pump stations can be operated by mercury float switches and powered by dedicated feeder lines from the local electrical authority like the lines given to the hospitals, etc. These pump sets can also be connected to solar panels. The pump pit can be covered with pedestrian grade walkway slabs which are of RCC and with adequate lifting arrangements to permit the lowering and lifting the submersible pump sets. With the advancement in technology, the IoT enabled sensors can be installed in these lift manholes and connected to a remote-control station using cloud data transfer.

1.2.6. Sewer network management

Sewer network system can be made efficient in operation using huge volume data obtained from individual sensors installed in the manholes and lifting points. This historical data will provide backbone for emergency routing plans for failure of a link or obstructions. Sewer network system must be carefully examined using digital data for potential nodes of weakness or redundancies and specially addressed periodically.

There must be continuous coordination between the designer of the sewer network and the engineer in charge of the operation and maintenance of sewer system for addressing issues during repair, expansion of network and diagnostics of blocks. The engineer in charge should prepare Shop drawings based on design parameters & should allow to follow only the approved shop drawings while construction. Any modifications during execution have to be in consultation with the designer/ consultant.

A computer simulation model of the sewer network system must be constantly upgraded with data obtained from sensors for real time monitoring and future predictions of the versatility of the sewer carriage system. Similarly, all lifting manholes must also be continuously monitored in digital platform for performance appraisal and future modifications.

There must be continuous coordination between the designer of the sewer network and the engineer in charge of the operation and maintenance of sewer system for addressing issues during repair, expansion of network and diagnostics of blocks.

1.2.6. Health safety & Environment

During site induction all personnel will be made aware of the Project Safety Requirements, Accident Reporting and Site Emergency procedures. These will be adhered to at all times. Key personnel of the project shall be familiar with the policies and procedures in place on projects of the same type, with knowledge gained from previous projects. All personnel shall be issued with the necessary PPE and is expected to wear it at all times on site. Special PPE shall be issued as necessary in the hazardous locations following site induction. As each new area of work is approached, the Site Supervisor will hold regular Tool Box Talk meetings with key personnel and, in particular, machine operators in respect of the works to be executed, in which areas, and most importantly the factor of risk likely to be encountered during each specific operation.

All areas of work will be supervised at all times. It will be the responsibility of each Supervisor to constantly assess the ability of each operative both before and during with regard to the individual's capabilities in respect of the work he has been assigned to do in both experience, competence and most importantly, his ability to complete the work in a safe manner without incurring risks to himself or third parties. Supervisory charge-hands will be in possession of a set of documents relating to method of work. A suitable first aid box shall be made available and a qualified first aider shall be supplied.

1.2.6. 1. Public & Employee Protection:

Services:

Services which are known to exist adjacent to footpaths/roads and entry of site, services within the curtilage of the site which are to remain live, etc., should be assessed and protected as necessary. Carefully controlled hand excavated trial pits shall be carried out as necessary to prove and verify exact location and nature of recorded services.

Site perimeter:

Warning notices and restricted area notices will be positioned at vantage points. The permanent working area is to be protected and barricaded as per requirement prior to work commencing. Barriers will be in place to all site boundaries through the provision of either earth bund, timber hoarding, solid fencing or utilization of existing boundary walls. As a general practice, solid water-filled barriers will be in place at locations that are next to the roads. Locations where the public rights of way are affected, will have sentries in attendance when needed. During plant movement the management of pedestrians and traffic will be implemented jointly with the Police / Local Authority.

Access and egress to the workforce will be via designated routes. The existing road system is to be followed in accordance with the traffic management scheme to be adopted. All plant will be delivered to site by road using low loader, with no plant movements carried out on existing roadway to ensure that the road surface and also existing below ground services are not damaged through displacement.

Workforce protection:

Areas of risk directly at the excavation area will be cordoned off and clearly segregated from third parties. Barriers are to be erected complete with warning signs. All temporary barriers and signs etc. will be constantly checked and maintained before and during each working day by the Site Supervisors. All areas of safety will be constantly evaluated with attention to detail being given the utmost concern at all times. Any secondary lighting required within the site shall be provided in a safe and secure manner. The positioning of any lights will be in liaison with KWA. The position of any lighting will be such that there is no risk imported to the adjacent operational properties.

Personal protective equipment: All site personnel will be issued with standard personal protective equipment. Each person will have general protection issued by the Site Supervisor dependent upon the work in hand. Safety wear will comprise of the following: Hard hats, ear and eye defenders, nasal protection against high volume of dust, dermal protection to exposed vulnerable areas and footwear against risk of penetration and impact, high visibility vests/jackets.

Accident procedure:

In the event of any accident occurring, a standard procedure will be adopted. For all injuries a detailed record will be maintained on site. Minor injuries will be treated in situ, if possible, by utilizing a standard first aid kit available on site. More serious injuries will be treated by a suitably qualified off-site party. In either event all parties requiring notification will receive it.

Dust & noise reduction strategy:

It is accepted that noise cannot be eliminated entirely, but reasonable steps will be taken to reduce any adverse effects of noise generated by the works. The nature and capability of the plant proposed to be used is such that all operations will be carried out with the minimum of noise and emissions generated on the site. As a matter of course all plant and machinery will have the engines turned off when idling.

For sites within an existing city limit and the creation of dust is a potential cause for concern. This has to be taken into consideration and a dust suppressive method has to be adopted. The main objectives are to minimize the production of dust and also to suppress any dust that is generated at source. Given the requirement to 'damp down' dust generated both at the workplace and access roads, water tankers are to be deployed to spray regularly or whenever required.

Tidal Influence Area:

Tides are change in Sea levels which results from the gravitational force between the Earth, Sun and Moon .Tides are extreme during periods of full and new moon. Experienced Banks man will present to monitor the tides. Tide prediction will be done by Banksman. Tides guide book will be issued to Site representative. Rescue procedures will be implemented according to the site conditions. Communication system will be implemented at site to communicate with Coastal guards/Rescue team. Awareness of Self- Rescue for high tide will be given to site personnel. Routine Training Program to site personnel working will be given nearby tidal influence areas to avoid panic situation. Lifesaving jackets shall be provide if necessary.

Water Logged Area:

Hazard Analysis/Risk Assessment will be carried out for water logged areas for the installation of pipelines, according to the site conditions. Safety Measures for the installed dewatering system will be carried out either on or off the construction right of way. Sediment barriers shall be installed across the entire construction right of way for pipelines at all water-logged areas. Site personnel should be given awareness program and toolbox talk regarding the Hazardous materials of water bodies. Substances such as chemicals, fuels and lubricating oils used for installation of pipelines are not stored within 100 ft of a wet land, water body or designated Municipal area. Safety procedures will be followed for crossing the General water bodies. Trained Banksman will be present at all time where construction equipment operates at the waterlogged areas. Strict Safety measures shall be followed regarding the Electrocution in water logged areas.

Safety Precautions:

Following safety precautions shall be explained and implemented at site while carryout the Open Cut Pipe Laying works. During site induction all personnel shall be made aware of the Project Safety Requirements, Accident Reporting and Site Emergency procedures. These shall be adhered to at all times. All workers shall use approved PPE while working at the trench area.

- Proper stair and ladder accesses shall be provided for Access / exit to the excavated trenches.

- Existing underground cables / pipes shall be properly supported to protect these services from any damages.
- Protection barriers shall be provided at both sides 2m away from the excavated trench with proper signboards.
- Excavated Materials shall be kept minimum 2m away from the excavated line.
- Excavation shall be carried out with proper side slopes with proper benching.
- Stairs or Ladder shall be provided for the personnel access / exit of the trench. Never use support services for entry/exit purposes.
- Ramps shall be provided for the equipment / vehicle access /exit of the trench.
- Frequent toxic gases free checks shall be carried out if trench depth is more than 1.2m. Gas monitor should have valid calibration certificate.
- Keep all the plants and equipment movement away from the edge of the trench excavation line.
- High visibility cloths shall be worn while working in vicinity of plant and equipment.
- Daily inspection by supervisor shall be carried out to detect evidence of possible sliding or cracks on slope to avoid trench collapse. In case of rain necessary protections shall be provided to protect the sliding or collapse.
- Service roads shall be provided to suit with the site condition for the vehicle movements at both sides of the pipe trench. Prior to that, Approved Service Layout drawing shall be provided by the concern HSE Personnel.

1.2.7. Quality Control Inspections & Testing:

All Pipelines shall be inspected and tested according to the approved inspection procedures/Manufacturer's instructions and according to standard specifications. Quality control of the works shall be supervised by the QA/QC Engineer and the QC Inspector of the related functions in accordance with the Quality Control Plan (QCP). Procedures and all such inspections and records shall be maintained by them as per the contract requirements.

PART C WASTE WATER MANAGEMENT

CHAPTER 2 PUMP HOUSE

2.1. SCOPE

This chapter intends to provide necessary guidelines for ensuring quality of work with regard to sewerage pumping stations, location selection, design, construction, equipment and safety precautions.

2.2. LOCATION OF PUMPING STATIONS

While selecting the location of pumping station due consideration to the following may be given:

- Location should be in such a way that location may be fixed only after a comprehensive study of the area to be served
- Should Ensure that the location is feasible to serve the entire area that can be adequately drained
- Local topography of the area, as slope of the ground, above and below ground obstructions such as other utilities, structures, soil nature, etc
- Should preferably located near a natural disposal unit such as a stream, a river, etc. But at the same time, the site should be such that it is not liable to get flooded with river water or seepage from the ground.
- The location should be easily accessible under all weather conditions.
- Proposed layout of the particular development and of future developments
- Proximity of proposed and/or existing sewerage infrastructure
- Size and type of the pumping station
- Access considerations for O&M needs including operators health and safety issues
- Visual impact, particularly the vent tube, odours, noise problems, etc.,
- Availability of power, water etc.

- Compatibility to neighbouring residences by suitable dialogues.

Special consideration should be taken to avoid site's vulnerable **to inundation**. The designer shall establish the levels of the top of the wet well wall, top of valve chamber walls and top of the plinth supporting the electrical cubicle, so that those structures cannot be inundated by a flood of a 1 in 100-year recurrence interval.

Preferred method will be the formed ground level to be at the 1 in 100 -year flood level and building plinth and top of wet wells etc. shall be at 0.45 m above.

2.3. NATURE OF GROUND

Investigations of the nature of ground to be made before a site is selected and if the station involves deep excavation trial holes should be dug or boreholes drilled for the purpose.

The level of ground water should be recorded as a high standing water level may require specialconstructional methods. Study of floatation forces are to be made in the selected location for the designing of the under ground structures to be constructed

2.4. PUMPING STATION – TYPES AND SELECTION

Pumping stations are either as in-line for lifting the sewage from a deeper sewer to a shallow sewer or for pumping to the STP or the out fall. They are required where low lying development areas cannot be drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity. The type of pumping station can be based on the selection of pumping system proposed:-

1. In dry pit Pumping System
    a. Horizontal pumps in dry pit,
    b. Vertical pumps in dry pit,
2. In wet pit Pumping System

a. Vertical pumps in suction well

b. Submersible pumps in suction sump

The above pump arrangements are shown in figure 3.1. below.

Where suction lifts are about 3 m to 5 m only, the horizontal foot mounted centrifugal pump stations should be explored in view of the ease of repairs from local resources and the fact that motors and pumps can be independently taken out for repairs. In addition, where space limitations are constricting, submersible pump stations could be preferred.

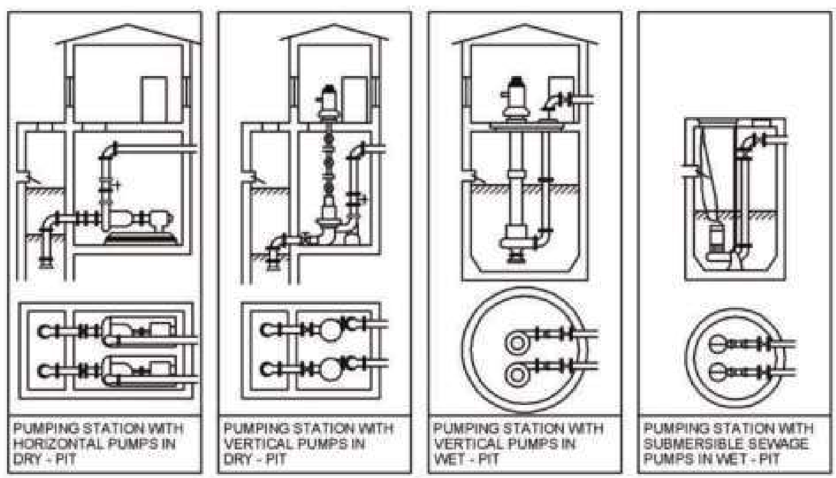


Fig.3.1. Typical Dry well and Wet well installations (Source: CPHEEOManual)

2.5. CAPACITY/DESIGN PARAMETERS OF PUMPING STATIONS

2.5.1. RATES OF FLOW

2.5.1.1.Pumping station should be capable of dealing with the daily and seasonal variations of the inflow.

2.5.1.2.If a pumping station is to be added to an existing system, past records of flow for as long a period as available should be obtained and the conditions to be anticipated in the future estimated therefrom.

2.5.2. DESIGN SUCTION WATER LEVEL

2.5.2.1. The suction elevation should be preferably below the invert of the incoming sewer to facilitate air passage through the sewer in the reaches closer to the pump station.

2.5.2.2. A preferable drop of 50 cm to 100 cm below the invert of the incoming seweris desirable to safeguard against problems of choking of sediments in sewers due to stagnations.

2.5.3. DESIGN DISCHARGE LEVEL

The water surface elevation in the receiving structure decides the static lift when compared to the suction level. However, friction losses and free-fall at receiving chamber are to be added to this to get at the design discharge level. As a rule, if needed this has to be increased such that the hydraulic grade line does not cut the longitudinal section of the ground level along the pumping main. This is achieved by raising the discharge elevation by means of a raised delivery line ending up ina goose-neck before dropping the flow into the receiving chamber such that the hydraulic grade line moves upwards in its terminal end and thus becomes free of the ground level. The hydraulic grade line shall be at least 1 m above the highest ground level or the top most crown of the pumping main.

2.5.4. PUMPING CAPACITY

2.5.4.1. Number and capacity of pumping units should be chosen so that fluctuations in the pumping rates are not considerable and also under normal conditions frequent cutting in and cutting out is avoided.

2.5.4.2. Number of different sized units should be selected after studying the overall economy and should be kept as low as possible to facilitate repairs and to reducethe number of necessary spares to a minimum.

2.5.4.3. Stand by pumps should be installed of sufficient capacity that with any one pump out of service, the remainder may deal with the peak flow.

2.6. POWER SOURCE AND AUXILIARY POWER DEVICES

A dedicated feeder from the nearby substation is recommended and in large pumping stations ***two such independent dedicated feeders*** from two different substations is to be considered. Drawing off a nearby power cable is permissible for small pumping stations handling lessthan 1 MLD of DWF.

In order to minimize the chance of sewage overflow or by pass due to prolonged power failure, interruption to and fluctuation of supply causing stoppage of equipment, the securityof power could be upgraded by duplicating the supply feeders to the pumping station or by the provision of a ***standby Generator***.

2.7. ELECTRICAL SYSTEM

The arrangement for providing the electricity supply to pumping station should be determined in liaison with KSEB.

Special consideration should be given to maximum demand and the estimated load profile, maximum instantaneous load, supply voltage, power transformer, security and reliability of power supply, starting equipment, statutory regulations, energy efficiency and power quality, renewable energy equipment.

2.8. SUB STRUCTURE

2.8.1. GATE

- A penstock gate is to be inserted at the entry of the sewer into the wet well.
- Either hand driven or motorised gear wheel mechanism may be employed for operating the gate.

2.8.2. SCREEN

- Travelling mechanized endless screen is recommended so that man entry is totally avoided.
- Are to be properly designed based on DWF and peak flow values.
- In large pumping stations, it is recommended to provide two successive screens: one coarse and other fine, the idea being to have a backup, in case one of them is in downtime.
- In small stations where the depth of incoming sewer is just about 3m or so, a hand operated screen facility can be provided.

2.8.3. GRIT CHAMBER

- Grit channel should have a minimum capacity of one percent of the daily Dry Weather Flow.
- The compact mechanical systems shall be an enclosed for eliminating human contact.
- There should be two similar units, each of which can be used, allowing the other to be cleaned.
- In small installations, grit removal shall be once in a week whereas in large installations the removal may be a continuous daily process.
- Proper measures are to be taken to dispose of the grit collected based on its nature viz., biodegradable, plastic, non-biodegradable etc.

2.8.4. WET WELL

2.8.4.1. CAPACITY :

Wet well size and depth shall be adequate to accommodate the influent sewer, provide for adequate pump suction pipe or pump submergence and to provide adequate volume to prevent the frequent start and stop of pumps. The sizing of wet well shall be determined based on the minimum and maximum rates of flow. The size of the wet well shall be determined such that, with any combination of inflow and pumping, the cycle of operation for each pump will not be less than 5 minutes and a maximum retention time in the wet well not exceeding 30 minutes.

2.8.4.2. DESIGN :

In respect of civil structural design, all wet wells shall be designed to withstand soil water pressure as though it is at ground level itself irrespective of actual waterlevel, to take care of contingencies of flooding and marooning of the stations.

In addition, the stability of the base slab shall be checked for resisting moment by considering the weight of the slab alone and neglecting the weight of the sidewalls.

Pressure relief valves for soil water uplift should not be encouraged in wet wells and IS: 456 & IS: 3370 shall be followed.

All civil works in contact with sewage shall be constructed with either brick work or RCC and in both cases sulphate resistant cement alone shall be used.

In RCC, Fusion Bonded Epoxy coated reinforcement steel having not less than 175 to 300 microns shall be used for reinforcement.

Epoxy coating over the inner face of the screen well / grit well 1 m above the maximum sewage water level is recommended.

Following points should be considered while designing the wet well pumping system: -

- Normal operating volume shall prevent any one pump from starting morethan 3 times per hour.
- Level control is to be provided by ultrasonic level controller or submersible transducer.
- Provide high water and low water alarm activated by ultrasonic or submersible level control system and backup float switches.
- Locate level switch where flow from the inlet pipe will not interfere withthe float.
- Design electrical service to handle the ultimate capacity of the pump station.

2.8.4.3. NUMBER :

There shall be 2 parallel wells, each catering to 50% of the volume or in case of large flows, a single well with two compartments which can be hydraulically connected by a penstock in the partition wall.

2.8.4.4. CONSTRUCTION:

Sewage pumping-station wet wells shall be constructed of brickwork duly plastered or reinforced concrete and shall be circular.

Wet wells that are installed below the groundwater table shall be adequately designed to prevent uplift pressure without the use of hydrostatic pressure relief valves.

Wet well interior shall be lined with material that is completely resistant tohydrogen sulphide and sulphuric acid, easily cleanable and sufficiently durable.

2.8.4.5. FLOOR SLOPE :

In the case of separate wet and dry well arrangement with horizontal foot mountedCF pumps, the floor should have benching like a hopper with a minimum slopeof 1 vertical to 1 horizontal to enable suspended solids to drain into the hopperand pumped out without depositing on the entire flow.

In the case of submersible pump / immersible pump, the floor shall be horizontal to permit easy installation of present and future pumps.

2.8.5. DRY WELL

- Shall be designed in accordance with IS: 456 and IS: 3370 and the precautions stipulated in Subsection 3.8.1.2. shall apply here also.
- For easy access to the dry wells they have to be provided with separate entrance and suitable stairways preferably not less than 90 cm in width shall be provided along with 90 cm high railings, wherever required.
- Provision should be made to facilitate easy removal of pumps and motors for

periodic repairs, overhauls or replacements. This shall be done by providing a gantry of suitable capacity and with suitable travelling type chain and pulley blocks

- The dry well floor should be graded to a sump and a dewatering pump of the non clog type shall be provided to pump such water to the wet well. The delivery discharge should be installed above pumping station flood level to ensure that water cannot siphon back to the dry well.

2.9. SUPER STRUCTURE

2.9.1. ENGINE OR MOTOR ROOM:

Sufficient floor space at both motor and pump level should be provided for dismantling and overhaul.

2.9.2. TRAVELLING GANTRIES FOR HANDLING PUMPS AND MOTORS

- An average travelling crane should be included in the machinery to be installed particularly in large station and arrangements made for its installation before that of the pumps.
- Chain controls for such a crane shall be of sufficient length to permit operation at both motor and pump floor level.
- A hatch in the roof should be provided where necessary in case of vertical spindle driven pumps.

2.9.3. LIGTHING

The interior of pump stations, whether at grade or below grade, shall have a lighting system specifically designed to provide illumination best suited for the station layout, which may include suspended, wall, or ceiling mounted. Energy efficient fluorescent fixtures are preferred. Lighting shall be at levels adequate for routine service inspections and maintenance activities.

2.9.4. VENTILATION

Pump stations shall be provided with a separate ventilating system and shall be sized to provide a minimum of 10 air changes per hour. Ventilation systems shall be capableof matching inside air temperature to outside air and shall be automatic. Ventilation shall be accomplished by the introduction of fresh air into the pump station under positive pressure. The air shall be filtered to remove particulates inside the pumping station.

2.9.5. AESTHETICS

The superstructure of the pumping station should have a pleasing and attractive architectural treatment and a good landscaping for the surrounding is recommended.

A buffer of 5m width with good aromatic plants may be provided around the pump house.

2.10. PIPING AND OTHER APPURTENANCES

- The suction and delivery piping of pumping stations are to be chosen between ductile iron and cast iron and the inside lining shall be with either high alumina cement mortar or polyurea and outside coated with epoxy.
- Air release and air/vacuum release valves shall be specifically designed for sewerage services and be sized as per the manufacturer’s recommendations.
- A manually controlled isolation valve shall be installed between the force main and the air release or air / vacuum release valves.
- There should be provision of at least one force main dewatering connection at the pumping station and dewatering connections at other major force main low points.
- Drains shall generally include a plug valve installed on a tee and drain pipingto an existing sewer manhole or to a separate manhole that can then be pumped out.
- Proper devices for alarm, flow measurement and automatic operation shouldbe available.

2.11. SAFETY AND ENVIRONMENT PROTECTION

- Railings shall be provided around man holes, openings etc.
- Guards around all mechanical equipment, other moving parts etc.
- Stair cases shall be preferred to ladders (particularly in dry well)
- Communication facility
- Fire extinguishers, first aid boxes and other safety devices etc.
- Following system of colours for pipe to minimise possibility of cross connections
- No direct connection between wet and dry well should be made to prevent leakageof explosive gases
- Electrical installations should be properly insulated and of non sparking/explosionproof.
- Fencing to prevent trespassing
- Adequate lighting should be provided
- Hoisting equipment/ gantries of adequate capacities for handling equipment during breakdown.
- Ditch drain shall be mandatorily provided all around, if it is not possible to drain by gravity to the nearby natural drain. However, this should not pollute any water course used for drinking water purpose.
- Drain pump sets shall be installed with 100% standby to pump out rain water and connected to the standby power.
- Rain-water harvesting shall not be provided in sewage pumping stations to avoid ground water pollution by raw sewage due to accidental spillage.
- Necessary Trees to be planted in the yard for odour control

PART C WASTE WATER MANAGEMENT

CHAPTER 3 SEWAGE/ SEPTAGE TREATMENPLANT

3.1. DETAILED PROJECT REPORT PREPARATION

3.1.1. DETAILED SURVEY AND INVESTIGATION.

The presence of rock or underground obstacles such as existing sewers, water lines, electrical or telephone wires, tunnels, foundations, etc., have significant effect upon the cost of construction. Therefore, before selecting the final lines and grades for sewers necessary information regarding such constructions is collected from various central and state engineering departments. Besides the location of underground structure, a detailed survey regarding the paving characteristics of the streets, the location of all existing underground structures, the location and basement elevations of all buildings, profile of all streets through which the sewer will run, elevations of all streams, culverts and ditches, and maximum water elevations therein are also made. The above details are noted on the map. The scale of the map may vary depending upon the details desired.

Drawing up the plan and implementing the project requires a great deal of information, necessitating detailed investigations and surveys. Generally, information at three levels is required: at the reconnaissance, feasibility, and post-authorization level.

3.1.1.1. AT RECONNAISSANCE LEVEL

When drainage problems have to be tackled, the first step is to conduct a reconnaissance study. Its main objective is to make an inventory of the problems andto formulate possible alternative solutions. The feasibility of the proposed project should be identified on its technical and economic merits.

3.1.1.2. AT FEASIBILITY LEVEL

This phase comprises the additional activities required to select one preliminary planfrom among the possible options. The feasibility study should enable financing agencies to appraise the project and to decide whether or not to execute it. Field surveys and investigations are needed to prepare the drainage plan in more detail.

3.1.1.3. AT POST-AUTHORIZATION LEVEL

The post-authorization phase comprises the final design of the project and the preparation of tender documents.

3.1.1.4. ZONAL PLANS

Broadly, the drain area of each STP defines zone area of that STP. As such no. and location of STPs proposed should be decided judiciously. Each zone can be further divided in sub zones as per main physical features, phasing of development of sewerage system, topography etc.Zonal plans with contours of minimum 1m interval may be used.

Working drawings with detailed calculation and longitudinal sections- It is recommended to adopt the following scales for various plans and drawings depending upon the detailed information desired.

(a) Index Plan	-	1 : 100,000 or 1 : 200,000
(b) Key Plan and general layout	-	1 : 10,000 or 1 : 20,000
(c) Zonal Plans	-	1 : 2,500 or 1 : 5,000
(d) Longitudinal sections of sewers	-	1 : 500 or 1 : 2,250 or 1 : 2,500
(e) Structural drawings		1 : 20 or 1 : 50 or 1 : 100 or 1 : 200

3.2. DESIGN OF SEWER NETWORK

The major roles of a sewer system can be listed as follows:

– Improvement in the environment by removing the sewage as it originates

– Preventing inundation of low lying areas that may be otherwise caused by not providing sewers

– Prevention of vector propagation by sewage stagnations

– Avoiding cross connections with freshwater sources by seepage

In addition, there is a strong emphasis on:

3.2.1 Avoiding sewer impacts on groundwater quality by infiltration of soil water into sewers and exfiltration of sewage into soil water, occurring rather as a cycle depending on the flow conditions in leaky sewers, and

3.2.2 Moving away from the mind-set that a sewer system shall necessarily be an underground sewer right in the middle of the road with costly construction, upkeep and remediation and making the objective realizable if necessary in an incremental sewerage commensurate with optimizing the area coverage in the available financial and human resources to create and sustain the system.

The design work includes the followingn process.

Part - 1 Estimation of Design Flows

Part - 2 Types and Hydraulics of Sewers

Part - 3 Design of Sewer Networks

Part - 4 Types and Construction of Manholes

Part - 5 Laying, Jointing and Construction of Sewers

3.3. SEWER APPURTENANCES

The structures, which are constructed at suitable intervals along the sewerage system to help its efficient operation and maintenance, are called as sewer appurtenances. These include: (1) Manholes, (2) Drop manholes, (3) Lamp holes, (4) Clean-outs, (5) Street inlets called Gullies, (6) Catch basins, (7) Flushing Tanks, (8) Grease & Oil traps, (9) Inverted Siphons, and (10) Storm Regulators.

3.3.1. MANHOLES

The manhole is masonry or R.C.C. chamber constructed at suitable intervals along the sewer lines, for providing access into them. Thus, the manhole helps in inspection, cleaning and maintenance of sewer. These are provided at every bend, junction, change of gradient or change of diameter of the sewer. The sewer line between the two manholes is laid straight with even gradient. For straight sewer line manholes are provided at regular interval depending upon the diameter of the sewer. The spacing of manhole is recommended in IS 1742-1960. For sewer up to 0.3 m diameter or sewers which cannot be entered for cleaning or inspection the maximum spacing between the manholes recommended is 30 m, and 300 m spacing for pipe greater than 2.0 m diameter . A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers (CPHEEO, 1993). The internal dimensions required for the manholes are provided in Table (CPHEEO, 1993). The minimum width of the manhole should not be less than internal diameter of the sewer pipe plus 150 mm benching on both the sides.

Spacing of Manholes	
Pipe Diameter	Spacing
Small sewers	45 m
0.9 to 1.5 m	90 to 150 m
1.5 to 2.0 m	150 to 200 m
Greater than 2.0 m	300 m

The minimum internal dimensions for manhole chambers	
Depth of sewer	Internal dimensions
0.9 m or less depth	0.90 m x 0.80 m
For depth between 0.9 m and 2.5 m	1.20 m x 0.90 m, 1.2 m dia. for circular
For depth above 2.5 m and up to 9.0 m	For circular chamber 1.5 m dia.
For depth above 9.0 m and up to 14.0 m	For circular chamber 1.8 m dia.

3.3.1.1. Materials for construction-

3.3.1.1. Brick • Used particularly for large diameter sewers • Advantage- – Can be constructed to any required shape and size • Disadvantage- – higher cost – Slow work progress – Larger space requirement • Cement concrete or stone invert • To prevent ground water infiltration: – plaster outside surface with mortar using sulphate resistant cement – inside surface mortar + high alumina cement (IS 6452) or polyurea coating.

3.3.1.2. Concrete • Advantages – Relative ease with which required strength may be provided – Wide range of pipe sizes – Rapid trench backfill • Disadvantages – crown corrosion by sulphide gas – mid depth water line corrosion by sulphate – outside deterioration by sulphate from soil water.

3.3.1.3. Precast concrete • Commonly used for branch and main sewers • Two types – Non-pressure pipes • used for gravity flow (sewers running partially full) • Plain (I.D. 80mm-450mm; thickness: 25mm-35mm) (NP1) • Reinforced (I.D. 80mm-2600mm; thickness: 25mm-215mm) (NP2, NP3 & NP4) – Pressure pipes (P1, P2 & P3) • used for force mains, submerged outfalls, inverted siphons and for gravity sewers where absolute water-tight joints are required. • Reinforced (I.D. 80mm-1200mm; thickness: 25mm-120mm) • Length : 2-3m • These pipes have plain ends or spigot and socket ends.

3.3.1.4. Cast-in-situ Reinforced Concrete • constructed where they are more economical • when non-standard sections are required • when a special shape is required • when the headroom and working space are limited.

3.3.1.5. Stoneware or Vitrified Clay • normally available in lengths of 90 cm • Skilled labour required for caulking the joints with yarn soaked in cement mortar and packing in the spigot and socket joints • Classes – AA: 100% hydraulic testing of pipes to be carried out in manufacturing stage – A: 5% of the pipes to be tested by following IS 651 • Resistant to most acids and to erosion due to grit and high velocities • A minimum crushing strength of 1,600 kg/m is adopted for all sizes • Special bedding or concrete cradling required to improve field supportive strength.

3.3.1.6. Asbestos Cement • usually used in sizes ranging from 80 mm to 1000 mm in diameter • Advantages – Non corrosiveness to most natural soil conditions, – freedom from electrolytic corrosion, – good flow characteristics, – light weight, – ease in cutting, drilling, threading and fitting with specials, – allowance of greater deflection up to 12 degrees with mechanical joints, – ease of handling, – tight joints and – quick laying and backfilling are to be considered • Disadvantages – subject to corrosion by acids, highly septic sewage and by highly acidic or high sulphate soils – Cannot stand high super imposed loads and may be broken easily.

3.3.1.7. Cast Iron • Available in diameters from 80 mm to 1050 mm and are covered with protective coatings • supplied in 3.66 m and 5.5 m lengths • A variety of joints are available including socket, spigot, and flanged joints. • Classified as LA, A and B according to their thickness. Class LA pipes have been taken as the basis for evolving the series of pipes. • Application: Cast iron pipes with a variety of jointing methods are used for pressure sewers, sewers above ground surface, submerged outfalls, piping in sewage treatment plants and occasionally on gravity sewers where absolutely water-tight joints are essential or where special considerations require their use. • Advantage: long laying lengths with tight joints, ability when properly designed to withstand relatively high internal pressure and external loads and corrosion resistance in most natural soils. • Disadvantage: – corrosion by acids or highly septic sewage and acidic soils – the amount of deflection allowed should not normally exceed 2.5 degrees for lead caulked joints. • Inside coating shall be by Cement mortar and outer coating shall be coal tar

3.3.1.8. Steel • Pressure sewer mains, under water river crossings, bridge crossings, necessary connections for pumping stations, self- supporting spans, railway crossing and penstocks are some of the situations where steel pipes are preferred • Advantages –

withstand internal pressure, impact load and vibrations much better than CI pipe. – more ductile and withstand water hammer better. • Disadvantage – cannot withstand high external load – main is likely to collapse when it is subjected to negative pressure – susceptible to various types of corrosion • Inside coating by high alumina cement mortar or polyurea and outside by epoxy. • Steel pipes shall conform to IS 3589. Electrically welded steel pipes of 200 mm to 2,000 mm diameter should conform to IS 5822.

3.3.1.9. Ductile Iron Pipes • made by a metallurgical process, which involves the addition of magnesium into molten iron of low sulphur content. • The ductile iron pipes are usually provided with cement mortar lining at the factory by centrifugal process to ensure a uniform thickness throughout its length • available in the range of 80 mm to 1000 mm diameter, in lengths of 5.5 to 6 m • Advantages – excellent properties of machinability, – impact resistance, – high wear and tear resistance, – high tensile strength and ductility and – corrosion resistance. – strong, both inner and outer surfaces are smooth, – These pipes are approximately 30 % lighter than conventional cast iron pipes

3.3.1.10. UPVC Pipe (unplasticized polyvinylchloride) • Advantages – resistance to corrosion, – light weight for transportation, – toughness, rigidity, – economical in laying, jointing, and maintenance and – easy to fabricate • IS 15328 deals with non-pressure unplasticized polyvinylchloride (PVC) for use in underground sewerage system. IS 9271 deals with the unplasticized polyvinyl chloride (UPVC) single wall corrugated pipes for drainage.

3.3.1.11. High Density Polyethylene (HDPE) Pipes • Advantages – Offer smooth interior surfaces and – relatively higher resistance to corrosion – they are available in solid wall – When laid in straight gradients without humps or depressions, they can easily offer longer life cycle • joints are usually fusion welded or flange jointed depending on straight runs or fittings

3.3.1.12. Structured Wall Piping • These pipes can be manufactured in PVC-U, PP and PE as per EN 13476-3 / IS 16098 • These pipes are either double walled or ribbed walled • The Type B pipes are generally known as Double Walled Corrugated (DWC) pipes. • In India, DWC pipes are produced in sizes 75 mm ID to 1,000 mm ID with a standard length of 6 m for easy transportation and handling and to reduce the number of joints required.

3.3.1.13. Glass Fibre Reinforced Plastic Pipes (GRP) • widely used in countries where corrosion resistant pipes are required at reasonable costs • GRP can be used as a lining material for conventional pipes which are subject to corrosion. • Fibre glass can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical in nature.

3.3.1.14. Fibre Glass Reinforced Plastic Pipes (FRP) • FRP is a matrix or composite of glass fibre, polyester resin and filters. • These pipes possess better strength, durability, high tensile strength, low density and are highly corrosion resistant. • Fibre-glass pressure pipes are manufactured in diameters up to 2,400 mm and length up to 18 m.

3.3.1.15. Pitch Fibre Pipes • These are pitch impregnated fibre pipes • Advantages – light in weight – Durable – pipes can be easily jointed in any weather condition as internally tapered couplings join the pipes without the use of jointing compound – flexible, – resistant to heat, freezing and thawing and earth currents, which cause electrolytic action. – unaffected by acids and other chemicals, water softeners, sewer gases, oils and greases and laundry detergents. – can be cut to required length on the site • Application – septic tanks and house connection to sewers, farm drainage, down pipes, storm drains, industrial waste drainage • Available sizes: 50 to 225 mm nominal diameter and length varying from 1.5 to 3.5 m • Disadvantage – susceptible to the delamination of their inner surface (blistering) – susceptible to collapse under applied loading sooner than other pipes

3.3.1.16. References for pipes required for sewers: Sewer material and corresponding standard specification Material Standard specification Code: Brick (Inside plaster with mortar using high alumina cement) IS 6452 Concrete Pre-cast concrete (Non-Pressure pipes) IS 458 Cast in-situ reinforced concrete (Concrete) IS 456 Stoneware or vitrified clay (hydraulic testing) IS 651 Asbestos cement IS 6908 Cast Iron IS 1536 (spun pipe) and IS 1537 (vertically cast pipe) Steel IS 3589 DI pipes IS 8329 (centrifugally cast DI pipes); manufactured with ISO 9002 accreditation ; IS 9523 (DI fittings); UPVC IS 15328 (Non-pressurized); IS 9271 (single walled corrugated pipe for drainage) HDPE IS 14333 Structured wall pipe EN 13476-3 / IS 16098 GRP IS 14402 FRP -

3.4. SPECIAL BEDDING/CONCRETE CRADLING-

The bedding surface shall provide a firm foundation of uniform density throughout the length of sewer pipe trenching. It shall confirm to specified levels, grades and alignment. The manual of Sewerage and Sewage Treatment Plant published by ministry of Housing and Urban Development, Government of India provides mainly two types of beddings. One specifies that the sewer pipe trench shall be evenly bedded with continuous layer of well compacted approved granular material shall concentrically to bit the lower part of the sewer pipe. The bedding material shall be well graded sand or granular materials pass. Through 5.6 mm sieve and suitably compacted/ rammed. The compacted bedding layer shall be as per the provision made in this article. The thickness of bedding shall in no case be less than 7.5 mm. Second type is concrete cradle bedding. At certain places taking the poor soil condition into consideration, concrete cradles of M-15 minimum is to be provided for obtaining firm foundation for the sewer pipe which shall be laid over the concrete bedding before the concrete is set. Where the sewer pipe crosses road and pipe is subjected to damage due to this load of passing Vehicles, concrete arch bedding shall be provided. However, the type of bedding to be provided shall be decided by the design Engineer considering the soil condition and excepted load over the pipe. It is to be seen that the supporting strength of sewer pipe denuded by the factor of safety should be equal to or greater than the imposed load on the sewer pipe (i.e, weight of earth over the pipe and excepted superimposed load on the pipe). Hence design of the bedding for laying the sewer pipe is one of the essential aspects.

3.4.1. EARTH BEDDING : The excavation of earth in the trench shall be carried out up to 1501mm below the sewer pipe and back filled with compacted earth . Filling and removing earth or similar materials beneath the sewer pipes to the allowable depth, so as to adjust with the grade, will not be permitted except filling with compacted granular bedding .

3.4.2. GRAVEL BEDDING- In case of all kind of soil met with in the trench 150 mm below the bottom level of sewer pipe to a maximum width of the trench. The resulting space shall be filled up with good quality compactable granular material (i.e, gravel). The granular materials shall be filled in the trench upto the level one forth of outer diameter of the sewer pipe above the bedding well compacted. The rock excavation should progress at least 20m in advance of the pipe laid. The graded granular bedding materials shall be used in class B bedding and so round shall consist of durable gravel, crushed stone and disintegrated rock. Any important bed and surrounding materials shall be as per specification of relevant IS: 460 (Part-I). The granular bedding materials shall not exceed 0.5% and 0.6% of by weight respectively. All graded materials shall pass through test sieve confirming to 15.460 (Part-I).

3.4.3. SAND BEDDING -is generally used below sewer pipe where hard rock is not during excavation. The graded sand shall be clean, hard, and strong. In place of sand durable pieces of crushed stone, crushed gravel or combination of both can be use. Graded sand shall confirm to IS: 383 which shall pass through tested sieve confirming to IS: 2386 (Part I to VIII) in preparation of mass.

3.4.3. CONCRETE ARCH/ CRADLE BEDDING- If slushy earth is encountered during excavation of trench, concrete bedding is suggested. The sub grade shall be provided to the exact dimensions. In the bottom, a layer of sand is provided and compacted with the help of mechanical rammer. Over this sand layer concrete bedding is provided. The bottom of trench should be sloped towards side or kerbed. The sand should be clean and of medium grained free of impurities. The sand in layers not exceeding 150mm shall be compacted by hard compacted by watering. The concrete mix shall be of 1:3:6. The maximum thickness of the concrete for the arch portion shall be as per the specification provided in the approved drawing. The slum of the concrete as arch portion shall not be more than 25mm. The unfiltered ground water in the portion shall be bailed out prior to taking up the concrete bedding work. The concrete is to be placed most carefully so that it should not cause any damage or injury to the jointly or displace the pipes

3.4.4. SPECIAL BEDDING FOR VERY POOR SUB-GRADE -When sub-grade is observed to be of very poor quality, special case should be taken for providing the bedding. The soft and spongy materials are to be removed for a depth of minimum 300mm below the pipe bedding and the same shall be replaced by crushed stone, local time stone free of dry and vegetable and impact and graded in size from 25m to 30mm in general. The sand filling shall be made for preparing the sub-grade. If the soft soil cannot be removed and replaced with approved bedding materials and compacted thoroughly then the suitable foundation for the pipes, then concrete or wooden piles shall be provided.

3.5. PROTECTIVE BARRIERS

3.5.1. GENERAL

The persons engaged in the operation and maintenance of sewerage systems are exposed to different types of occupational hazards like physical injuries, injuries caused by chemicals and radioactive wastes, infections caused by pathogenic organism present in the sewage and dangers inherent with explosive or noxious vapours and oxygen deficiency.

The health and safety of personnel can be safeguarded to a great extent by taking the likely hazards into consideration at the time of designing the sewers, sewers appurtenances and pumping stations. During maintenance the still possible hazards can be reduced by using safety equipment and precautions appropriate for each hazardous condition. Even then the maintenance work should be supervised by the competent personnel for preventing accidents.

‘Sewer gas’ is a mixture of gases in sewers and manholes containing abnormally high percentage of carbon-dioxide, varying amount of methane, hydrogen, hydrogen sulphide and low percentage of oxygen caused by septic action through the accumulation of organic matter inside the sewer.

The main hazard is due to the presence of high levels of methane forming an explosive mixture or the oxygen deficiency or hydrogen sulphide in excess of permissible levels.

Some trade wastes also contribute to other gases like chlorine, ammonia, sulphur dioxide etc.

A noxious gas or vapour which is directly or indirectly injurious or harmful to the health or life. It can be a simple asphyxiant, chemical asphyxiant, irritant, volatile solvent or the combustible gas.

Simple asphyxiants are the physiologically inert gases like nitrogen, methane and hydrogen which when breathed in high concentration act mechanically by excluding oxygen. Chemical asphyxiants are substances like carbon monoxide which by combining with the hemoglobin of the blood or with some constituents of the tissues either prevent oxygen from reaching the tissues or prevent the tissues from using it.

Irritants are the substances like chlorine which injure the air passage and lungs and induce inflammation in the surface of the respiratory tract. Volatile solvents and drug like substances exert little or no effect on the lungs but affect the nervous system including anaesthesia.

Combustible vapours burn as long as they are in contact with a flame, spark or a heated material having a temperature equal to or greater than ignition temperature of the vapour, provided there is sufficient oxygen present for combustion.

3.5.2. PRECAUTION:

When the sewer or a manhole has to be entered for cleaning or clearing an obstruction, it is advisable to go in for efficient ventilation either natural or forced and get assured that the atmosphere inside the manhole or sewer is free from oxygen deficiency and noxious gases or vapours.

When clearance of the inside atmosphere is not possible, or time-consuming, following precautions should be taken before entering the sewer:

(i) Traffic warning signs should be placed on road.

(ii) No smoking or open flames should be allowed and sparks should be guarded.

(iii) Only safety, explosion-proof electric lighting equipment or mirrors for reflection of light should be used.

(iv) The atmosphere should be tested for the presence of noxious gases and oxygen deficiency.

(v) When atmosphere is normal, the worker may enter in the manhole or sewer, with safety harness attached with two men available at the top.

(vi) In case oxygen deficiency or noxious gas is detected, forced ventilation should be resorted to using a portable blower.

(vii) Frequent tests for oxygen deficiency and noxious gas should be done, even if the initial tests are satisfactory, because conditions may change during the working period inside the manhole and sewers.

(viii) If forced ventilation is not possible or not satisfactory and men have to enter urgently, such as in case of saving the life of fallen persons, a gas mask should be worn and extreme care should be taken to avoid all sources of ignition if inflammable gas is present. Only permissible safety lights, rubbers or non-sparking shoes and non-sparking tools should be used.

(ix) Only experienced personnel having experience of working under such conditions and fully equipped with the proper protective safety equipment should be allowed to enter the sewers.

Following precautions should be taken for the personnel working in sewerage maintenance system which are prone to infections:

(i) Emergency first aid kit should be provided to take care of all minor injuries, cuts and burns, to the gang.

(ii) In case of emergency the services of a doctor should be available.

(iii) All the concerned workers should be educated about the hazards of water-borne diseases through sewage and tetanus through cuts and wounds.

(iv) The importance of personal hygiene should be emphasized and the workers should be instructed to keep finger nails short and well-trimmed, not to brush fingers when they are sore, wash hands with soap and hot water before taking food, keep the fingers away from nose, mouth and eye.

(v) Rubber gloves should be used so that sewage may not come in direct contact of the hands.

(vi) Workers should be provided with complete change of work clothes to be worn during working. Workers should also use gum-boots.

3.6. SAFETY EQUIPMENT:

Following are the common safety equipment's, which are used by the workers connected with sewer maintenance works:

3.6.1. GAS MASKS**:** In general purpose gas masks are used for respiratory protection from low and moderately high concentrations of all types of toxic gases and vapours present in the atmosphere in which there is sufficient oxygen to support life.

Masks afford necessary respiratory protection under many circumstances, but the various limitations of these gas masks should be known to the workers using them. In the general purpose gas masks provide protection against organic vapours, acid gases, carbon monoxide upto 2% concentration, toxic dusts, fumes and smoke.

The gas mask mainly consists of a face piece, a canister containing purifying chemicals, a timer for showing duration of service and a harness for support. Protection against specific contamination can be achieved by the selection of the appropriate canisters. Gas masks cannot be used in oxygen deficient atmosphere or in unventilated location or areas.

3.6.2. OXYGEN BREATHING APPARATUS**:**

This apparatus is used for respiratory protection from atmosphere containing high percentage of toxic gases and vapour which are deficient in oxygen. This apparatus fully protects the workers against all gases, vapours, dusts, fumes, smokes and oxygen deficiencies in atmosphere including petroleum vapours. This is a dependable device. The apparatus may be of air hose respirator type or a pure oxygen respirator.

3.6.3. PORTABLE LIGHTING EQUIPMENT**:**

Portable electric hand lamps of permissible type, electric cap lamps and explosion proof flash lights are used while doing work inside sewer lines.

3.6.4. PORTABLE AIR BLOWERS**:**

Forced ventilation of manholes, pits and tanks can be provided by portable air blowers powered by enclosed explosion proof electric motors. Special precautions are required to check that blowers do not become the source of ignition for inflammable gases. Trailer mounted blower having a capacity of 210 m2/min can easily ventilate many metres of medium sized sewer.

3.6.5. NON-SPARKING TOOLS**:**

Non-sparking tools to be used during sewage maintenance works are made of an alloy (containing at least 80% of copper) that will not spark, when struck against other objects and metals and yet have the required strength and resistance to wear and tear.

3.6.6. INHALATORS:

Approved inhalators employing a mixture of oxygen and carbon dioxide are used for resuscitating victims of collapse, drowning or electric shock. Artificial respiration should be started at once on the patient and an inhalator face piece attached to the victim's mouth as soon as the equipment can be made ready.

The carbon dioxide used in small percentages stimulates deep breathing so that more oxygen may be inhaled. Pure oxygen should be used only when irritant gases such as hydrogen sulphide or chlorine have caused the victim's collapse.

3.6.7. SAFETY BELT**:**

This belt consists of a body belt with a buckle and a shoulder harness. The life line is of high grade spliced manila rope or a steel cable anchored with rings, on each side of the belt and provided with safety straps for anchoring or securing to a stable support.

The life line should be 15 m in length and the overall assembly should be capable of withstanding a tensile load of 2000 kg. The safety belt and life line should be daily tested before use.

3.6.8. PREVENTIVE MAINTENANCE:

The clogging of the sewers can be prevented by periodic cleaning and removal of silt accumulations from sewer lines, including manhole repairing, during the functioning of the sewerage system.

Each sewer maintenance gang should be under the supervision of a competent person well trained in the use of all the necessary tools, machines, safety equipment's and qualified to give first-aid-service also.

The covers of all manholes immediately upstream and downstream of the particular manholes into which men are to enter should be removed and kept open for at least half an hour, for natural ventilation. Necessary protective barricades and boards should be provided on the road to prevent entry of the traffic in the area.

When the foul atmosphere is cleared from the sewers, the workers may enter the sewer. If the natural ventilation is not sufficient and the foul atmosphere is not cleared, forced ventilation should be provided. Ordinarily the flexible sewer rod with manila rope is used for sewer cleaning.

The composite flexible rod composed of rope tied together with bamboo strips is lowered inside the manhole by a person on top, while another worker inside the manhole thrusts the same into the sewer in the direction of flow.

The worker inside the next downstream manhole receives the rod and pushes it out of the manhole. As soon as the end of the 60 m rod is thrust into the sewer, it is connected to a thick manila rope which is dragged and kept coiled on the surface near the downstream manhole.

When the rope is dragged through the sewer, the silt is drawn out into the downstream manhole from where it is taken out by buckets. Now this process is repeated for the next section of the sewer. This process is continued till the sewer line is cleaned. With the cleaning of the sewer other repairs, if any, to the inside of the manhole, the footsteps, cover etc. are also done simultaneously.

Depending upon the local requirements the periodical repair and cleaning programme for all the sewers in the system is prepared and followed. The frequency of cleaning depends on the nature of sewage flowing in the particular section. Flushing of sewers is also carried out periodically to clear laterals and sewers laid within sufficient slope for maintaining a velocity so as to remove the settled material.

3.7. JOINTING OF SEWERS

3.7.1. STONEWARE PIPES:

All the pipe joints shall be caulked with tarred gasket in one length for each joint and sufficiently long to entirely surround the spigot end of the pipe. This gasket shall be caulked lightly home but not so as to occupy more than a quarter of the socket depth.
The gasket shall then be filled with a mixture of one part of cement and one part of clean fine sand mixed with just sufficient quantity of water to have a consistency of semi-dry

condition and a fillet shall be formed round the joint with a trowel forming an angle of 45° with the barrel of the pipe (IS: 4217) Rubber gasket may also be used for jointing

.

3.7.2. CONCRETE PIPES:

The collars shall be placed symmetrically over the end of two pipes and the annual space between the inside of the collar and the outside of the pipe shall be filled with hemp yarn soaked in tar or cement slurry tamped with just-sufficient quantity of water to have a consistency of semi-dry condition, well packed and thoroughly rammed with caulking tools and then filled with cement mortar 1:2.

The joints shall be finished off with a fillet sloping at 45° to the surface of the pipe. The finished joints shall be protected and cured for at least 24 hours. Any plastic solution or cement mortar that may have squeezed in the pipe shall be removed to leave the inside of the pipe perfectly clean.

3.7.3. C.I. PIPES:

The C.I. pipes shall be examined for line and level and the space left in the socket shall be filled in by pouring molten pig lead. This shall be done by using proper leading ring. One or two air vents shall be provided around the lower end of the joint. The lead used shall be soft and of best quality conforming to IS: 782. The quantity and depth of lead to be used per joint as well as general procedure for joining shall be as per IS: 3114.

In special cases rubber or plastic rings may be used.

3.8. LOADS ON CONDUITS DUE TO BACK FILLING

Backfilling of sewer sanitary trench is required after installation of sewer pipes. Method of compaction and degree of compaction, equipments and sequence of sewer trench backfilling is discussed. Backfilling process requires substantial cautions and should be carried out properly. Sewer sanitary pipe disposition and deterioration need to be prevented while backfilling is carried out. This may be obtained by carefully selecting methods and machines for the task. The determination of backfilling technique is dependent on trench width, properties of excavated materials, degree of compaction and excavation approach. Generally, backfilling begins after concrete structures like arches and cradles have achieved adequate strength and withstand imposed backfill material loads without suffering damages. Backfilling of sewer sanitary trench is composed three main layers including embedment, final backfill and the third layer is finish grade material. It should be noted that each layer requires certain considerations that need to be considered. These zones of sewer sanitary trench backfill is discussed in the following sections:

3.8.1. EMBEDMENT ZONE OF BACKFILLING

It is the first layer and consist of haunching and initial backfill. Backfilling process starts from the selection and placement of embedment materials. The lower backfill layer is extended from the foundation up to 30cm above the pipe. This zone should be placed by hand or suitable machines and properly compacted to avoid dislocation and deterioration of installed pipes. It is recommended to use granular material since the application of considerable compaction efforts to gain specified density is not required. The placement of haunching that extends up to the spring line should be conducted with utmost caution while flexible pipes are used. In the case of high water table, it is required to decrease voids as minimum as possible to prevent the movement of soils.

3.8.2. INTERMEDIATE BACKFILL ZONE.

The selection of intermediate backfill material is commonly influenced by the required compaction degree. However, the use of excavated material is recommended especially in the regions prone to frost heave. The degree of compaction is based on the location of the project for instance 95% modified proctor compaction should be achieved in traffic area, 90% compaction needed in urban areas and small compaction degree will be required in rural area.

3.8.3. UPPER BACKFILL MATERIAL ZONE

The depth and compaction degree of upper zone is controlled by the type of the required finish grade, for instance, the area might be used for agriculture purposes or paved. In the latter case, the elevation of the upper zone need to be established properly to support different pavement layers. In the former case, top soil layer with depth of 100mm shall be provided. Sanitary sewer pipe might be subject to floatation before and during backfilling due to water accumulation in the trench. So, necessary measures need to be considered to prevent such detrimental situation.

3.8.4. DEGREE OF COMPACTION FOR SEWER TRENCH BACKFILLING

The required degree of compaction for sanitary sewer trench backfill is associated with the location of the project. For instance, high compaction degree shall be provided if the area is designated to be paved, but if the region is not heavily populated and do not subjected to heavy traffics less compaction would be satisfactory. Natural settlement of backfill material may be adequate in certain conditions like along outfall sewers in open country. The degree of compaction is computed in accordance with specification provided by American Association of State Highway and Transportation Officials. Modified proctor test is used to evaluate optimum moisture content in the laboratory, and various tests are available for the determination of compaction value in the field.

3.8.5. WIDTH OF TRENCH

When laying pipes, to attain its full potential as a load bearing structure, trench width, proper bedding and backfilling are equally as important as the actual pipe strength. In fact, almost 50% of the completed structure is attributed to proper design and good workmanship. Any increase in trench width above that specified will increase the load on the pipe and a narrower trench may impede the proper placing and consolidation of bedding. The trench should be dug so that the line, gradient and dimensions are as specifications or as agreed with site engineer with adequate working space. The bedding is intended to level out any irregularities in the formation and ensure uniform support along the barrel of pipe

Recommended Maximum Trench Widths measured at crown of pipe = Bd	
Pipe Diam.	**Trench Width**
150	.600
225	.700
300	.750
375	1.050
450	1.150
525	1.200
600	1.350
675	1.450
750	1.500
900	1.900
1050	2.050
1200	2.300
1350	2.450
1500	2.600
1800	2.950
2100	3.200
2400	3.500
2700	3.800

3.9. SHORING

The following are the functions of the timbering or shoring:

(i) To prevent the collapse of the sides of the trenches.

(ii) To reduce the width of the trench at the top to the minimum possible.

(iii) To prevent the seepage of ground water into the trench.
Various methods of shoring and bracing of trenches have been shown in following figures.
(iii) To prevent the seepage of ground water into the trench.

Following thumb-rules will help in deciding the size and spacing of the timber sheeting and bracing for supporting trench walls:

(a) When the trench is 1.2 to 2.0 m deep timber piling (polling boards) about 5 cm thick are provided. If the depth is more than thickness of polling boards may be kept 7.5 cm

(b) For the trenches more than 2.5 m in width and more than 1.5 m deep, in hard soil, it may be bracked with walling of 5 x 15 cm size.

(c) Both the trench walls should be supported properly by means of walling and struts. When the width of the trench varies from 30 to 240 cm the strut size may vary from 10 x 75 cm to 15 x 15 cm. The struts should be provided at about 1.25 m. vertical spacing on the walling.

Pulling out of shoring materials on completion of work should be carried out in stages and space occupied by planks/sheet shall be properly backfilled.

When sewer lines are to be laid below the ground water table, the ground water enters the trenches during excavation and causes much difficulties. Therefore, the dewatering of trenches is compulsory under such circumstances.

3.9.1. WELL POINT DEWATERING

For shallow depth of excavation, especially for laying pipelines this method helps remove groundwater from soil in a specific area so that pipelines, foundations, subsurface structure or soil remediation can be carried out.

It consists of small diameter wells that are connected to a header pipe and a wellpoint pump. The pump draws up water through notches in the well points by creating a vacuum in the header pipe. These pumps are designed for high air handling capacity to handle gasses, air, and water. Air control is important as excess air can cause cavitation, reducing the efficiency of the pump.

3.9.2. HORIZONTAL DRAINS

For long excavations for pipelines, a flexible, perforated pipe is installed horizontally using a trenching machine. The un-perforated end of the pipe is brought to the ground surface and attached to a wellpoint suction pump.

3.9.3. HORIZONTAL DIRECTIONAL DRILLED WELLS

This method is used where permanent dewatering solutions are required, like those needed beneath existing structures. It is also used for remedying contaminated groundwater, and tunnel construction. The areas associated with these structures are usually inaccessible and HDD wells provide a great dewatering solution.

3.9.4. DEEP WELLS

These wells are placed just outside the area of a proposed excavation site. Deep wells consist of a series of bored wells fitted with submersible pumps at the bottom. Each well is capable of creating a cone of depression around itself while drawing water to the surface.

Depending on the depth of the wells, several such wells when pumping together can effectively lower the groundwater level over a large area.

3.9.5. VACUUM WELLS

Similar to deep wells, these wells also use a vacuum pump at the surface in addition to the submersible pumps at the bottom. This makes it doubly effective by reducing pore water pressure in fine grained soils that do not drain well.

3.9.6. EDUCTORS

In soils such as silt, clay, and silty sands with low permeability, the eductor system works to control the pore water pressure. Where wellpoints and deep wells may not be effective in dewatering, eductors can be used to stabilize the slopes, and the base of the excavation.

High pressure water is circulated from a tank at the surface down to the eductor in the well fitted with a small diameter nozzle and venturi. A vacuum is created up to the level of the eductor which then draws the groundwater into the well from where it is removed using a riser pipe.

3.10. VENTILLATION ARRANGEMENT

All tunnels more than 15m in length shall be provided with Ventillation arrangement

3.11. DRAINAGE AND SEWER PIPE SLOPE

Proper slope of gravity drainage and sewer pipes is important so that liquids flow smoothly, which helps transport solids away without clogging. A pipe that is too flat will prevent waste from flowing away. It is also commonly thought that pipes that are too steep will allow liquids to flow so quickly that solids will not be carried away.

Drainage pipes are usually run at the minimum allowable slope so that ceilings can be kept as high as possible.

3.12. LAYING OF PIPE SEWERS

In laying sewers, the centre of each manhole shall be marked by a peg. Two wooden posts

100 mm x 100 mm and 1,800 mm high shall be fixed on either side at nearly equal distance from the peg or sufficiently clear of all intended excavation. The sight rail when fixed on these posts shall cross the centre of manhole. The sight rails made from 250 mm wide x 40 mm thick wooden planks and screwed with the top edge against the level marks

and shall be fixed at distances more than 30 m apart along the sewer alignment. The centre line of the sewer shall be marked on the sight rail. These vertical posts and the sight rails shall be perfectly square and planed smooth on all sides and edges. The sight rails shall be painted half-white and half-black alternately on both the sides and the tee heads and cross pieces of the boning rods shall be painted black. When the sewers converging to a manhole come in at various levels, there shall be a rail fixed for every different level.

The boning rods with cross section 75 mm x 50 mm of various lengths shall be prepared from wood. Each length shall be a certain number of metres and shall have a fixed tee head and fixed intermediate cross pieces, each about 300 mm long. The top edge of the cross pieces shall be fixed at a distance below the top edge equal to, the outside diameter of the pipe, the thickness of the concrete bedding or the bottom of excavation, as the case may be. The boning staff shall be marked on both sides to indicate its full length.

The posts and the sight rails shall not be removed in any case until the trench is excavated, the pipes are laid, jointed and the filling is started. When large sewer lines are to be laid or where sloped trench walls result in top-of-trench widths too great for practical use of sight rails or where soils are unstable, stakes set in the trench bottom itself on the sewer line, as rough grade for the sewer is completed, would serve the purpose.

3.12.1. STONEWARE PIPES: The stoneware pipes shall be laid with sockets facing up the gradient, on desired bedding. Special bedding, hunching or encasing may be provided where conditions so demand. All the pipes shall be laid perfectly true, both to line and gradient, IS 4127. At the close of each day’s work or at such other times when pipe is not being laid, the end of the pipe should be protected by a close fitting stopper.

3.12.2. RCC PIPES : The RCC pipes shall be laid in position over proper bedding, the type of which may be determined in advance, the abutting faces of the pipes being coated by means of a brush with bitumen in liquid condition. The wedge shaped groove in the end of the pipe shall be filled with sufficient quantity of either special bituminous compound or sufficient quantity of cement mortar of 1:3. The collar shall then be slipped over the end of the pipe and the next pipe butted well against the “O” ring by appliances to compress roughly the “O” ring or cement mortar into the grooves. Care being taken to see that concentricity of the pipes and the levels are not disturbed during the operation. Spigot and socket RCC pipes shall be laid in a manner similar to stoneware spigot and socket pipes. The structural requirements as discussed in IS 783 may be followed.

3.12.3.CAST-IN-SITU CONCRETE SECTIONS : For sewer sizes beyond 2 m internal diameter cast-in-situ concrete sections shall generally be used, the choice depending upon the relative costs worked out for the specific project. The concrete shall be cast in suitable number of lifts usually two or three. The lifts are generally designated as the invert, the side wall and the arch. Construction of Brick Sewers Sewers larger than 2 m are generally constructed in brick work. The brickwork shall be in cement mortar of 1:3 and plastered smooth with cement plaster of 1:2, 20 mm thick both from inside and outside. A change in the alignment of brick sewer shall be on a suitable curve conforming to the surface alignment of the road. The construction shall conform to IS 2212 in general.

3.12.4. CAST IRON PIPES : The pipes shall be laid in position with the socket ends of all pipes facing up gradient. When using lead joints, any deviations either in plan or in elevation of less than 11 1/4 degree shall be effected by laying the straight pipes round the flat curve of such radius that the minimum thickness of lead in a lead joint at the face of the socket shall not be reduced below 6 mm. The spigot shall be carefully pushed into the socket with one or more laps of spun yarn wound round it. Each joint shall be tested before running the lead, by passing completely round it, a wooden gauge notched out to the correct depth of lead and the notch being held close up against the face of socket. When using the “O” ring joints, each “O” ring shall be inserted fully and verified by a toll with prior marking of the socket depth, which, when inserted after the “O” ring joint will reveal that the “O” ring has been fully inserted in position. Special precautions by manufacturers, if any, shall also be followed. Flange joints shall be used with appropriate specials and tail-pieces when inserting a fitting like a meter or a valve in the pipeline. IS 3114 should be followed in setting out the sewers.

3.12.5. DUCTILE IRON PIPES : The same procedures and precautions for laying as in the case of cast iron pipes shall apply here also.

3.12.6. SOLID WALL UPVC PIPES : The single most important precaution is to ensure that the excavated trench is not water logged. Where situations imply water logging, it is mandatory to employ a well point dewatering system running 24 hours, 7 days a week to hold the subsoil water at least 50 cm below the bedding elevation.

Thereafter, the grade of the trench having been checked, lower the pipe with socket ends facing the up gradient. When a pipe needs to be cut to suit a given distance, the pipe shall be cut perpendicular to its axis, using a firm hand held saw. Then bevel the cut end by a bevelling tool or power tool to the same angle as in the original uncut pipe and mark the insertion line freshly using an indelible black paint to retain the guide limit for insertion. Carefully remove any loose soil from the socket and do not remove the "O" ring from its housing. Check by hand whether the "O" ring is seated uniformly. Thereafter, place the pipe spigot end near the socket.

3.12.7. SOLID WALL HDPE PIPES

Unlike in the case of CI, DI, UPVC pipe sewers, the HDPE sewers are normally butt welded and pre-assembled on ground and only then lowered inside the trench spanning manhole to manhole.

The butt-welding shall follow the manufacturer's recommendations. Where flanged joints are needed for attaching or inserting fittings and specials like valves, the free end of the HDPE pipe shall be butt-welded with a standard flange and thereafter the flanged jointing can be made. However, in the case of such pipes, the uplift during high groundwater conditions above the pipe level is a problem specifically in high ground water and coastal areas. The concrete surrounds or venteak piles shall be used to hold these in place in such conditions, where ground water can rise above the sewer.

3.12.8. STRUCTURED WALL PIPES

The IS 16098 (Part-1), IS 16098 (Part-2) and EN 13476 also cover the performance requirements for the respective materials. These pipes are manufactured with externally corrugated wall or with T-beam type of wall with hollows between the webs of the T beams. These are laid in almost the same way as the UPVC pipes. These outer-ribbed wall pipes are jointed with “O” rings after due cleaning of dust, etc., using push-tight method and these rings help in preventing the escape of the

contained fluid.

3.13. JOINTING OF SEWERS:

3.13.1. STONEWARE PIPES:

All the pipe joints shall be caulked with tarred gasket in one length for each joint and sufficiently long to entirely surround the spigot end of the pipe. This gasket shall be caulked lightly home but not so as to occupy more than a quarter of the socket depth.

The gasket shall then be filled with a mixture of one part of cement and one part of clean fine sand mixed with just sufficient quantity of water to have a consistency of semi-dry condition and a fillet shall be formed round the joint with a trowel forming an angle of 45° with the barrel of the pipe (IS: 4217) Rubber gasket may also be used for jointing.

3.13.2. CONCRETE PIPES:

The collars shall be placed symmetrically over the end of two pipes and the annual space between the inside of the collar and the outside of the pipe shall be filled with hempyarn soaked in tar or cement slurry tamped with just-sufficient quantity of water to have a consistency of semi-dry condition, well packed and thoroughly rammed with caulking tools and then filled with cement mortar 1:2.

The joints shall be finished off with a fillet sloping at 45° to the surface of the pipe. The finished joints shall be protected and cured for at least 24 hours. Any plastic solution or cement mortar that may have squeezed in the pipe shall be removed to leave the inside of the pipe perfectly clean.

3.13.3. C.I. PIPES:

The C.I. pipes shall be examined for line and level and the space left in the socket shall be filled in by pouring molten pig lead. This shall be done by using proper leading ring. One or two air vents shall be provided around the lower end of the joint. The lead used shall be soft and of best quality conforming to IS: 782. The quantity and depth of lead to be used per joint as well as general procedure for joining shall be as per IS: 3114.

In special cases rubber or plastic rings may be used.

3.14. HYDRAULIC TESTING OF PIPES SEWERS:

Following two tests are done for testing the pipe sewers:

3.14.1. WATER TEST:

Each section of the sewer is tested for water- tightness preferably between manholes. To prevent change in alignment and disturbance after the pipes have been laid, it is desirable to backfill the pipes up to the top, keeping at least 90 cm length of the pipe open at the joints. But in case of shorter pipe lengths of stoneware and R.C.C. pipes, it is not possible. With concrete encasement or concrete cradle, partial covering of the pipe is not necessary. In the case of the concrete and stone-ware pipes with cement mortar joints, the testing shall be done after making the joints. It is necessary that the pipelines are filled with water for about a week before commencing the application of pressure to allow for the absorption by the wall of the pipe.

The testing of the sewers is done by plugging the upper end with a provision for an air outlet pipe with stopcock. The water is filled through a funnel connected at the lower end provided with a plug. After expelling the air through the air outlet, the stopcock is closed and water level in the funnel is raised to 2 to above the invert at the upper end. Water level is noted after 30 minutes in the funnel and the quantity of water required to restore the original water level in the funnel is determined.

The pipe line under pressure is then inspected while the funnel is still in position. There should not be any leaks in the pipe or the joints except small sweating on the pipe surface which is allowed. Leakage in 30 minutes determined by measuring the replenished water in the funnel should not exceed 15 ml in the smaller dia. and 60 ml in the larger dia. per cm dia. of pipe for 100 m length. Any sewer or part that does not meet the test shall be emptied and repaired or re-laid as per requirements and tested again.

In case of concrete, R.C.C. and A. C. pipes of more than 600 mm dia the quantity of water in flow can be increased by 10% for each additional 100 mm of pipe dia. For brick sewers, regardless of their dia. the permissible leakage of water shall not exceed 10 m3/24 hrs. per km. pipe length.

3.14.2. AIR TESTING:

This testing is done in large dia. pipes when the required quantity of water is not available. It is done by subjecting the stretch of pipe to an air pressure of 100 mm of water by means of a hand pump. If the pressure is maintained at 75 mm, the joints shall be assumed to be watertight.

In case the drop is more than 25 mm the leaking joints shall be traced and suitably treated to ensure water-tightness. The exact point of leakage can be detected by applying soap solution to all the joints in the line and looking for the air bubbles.

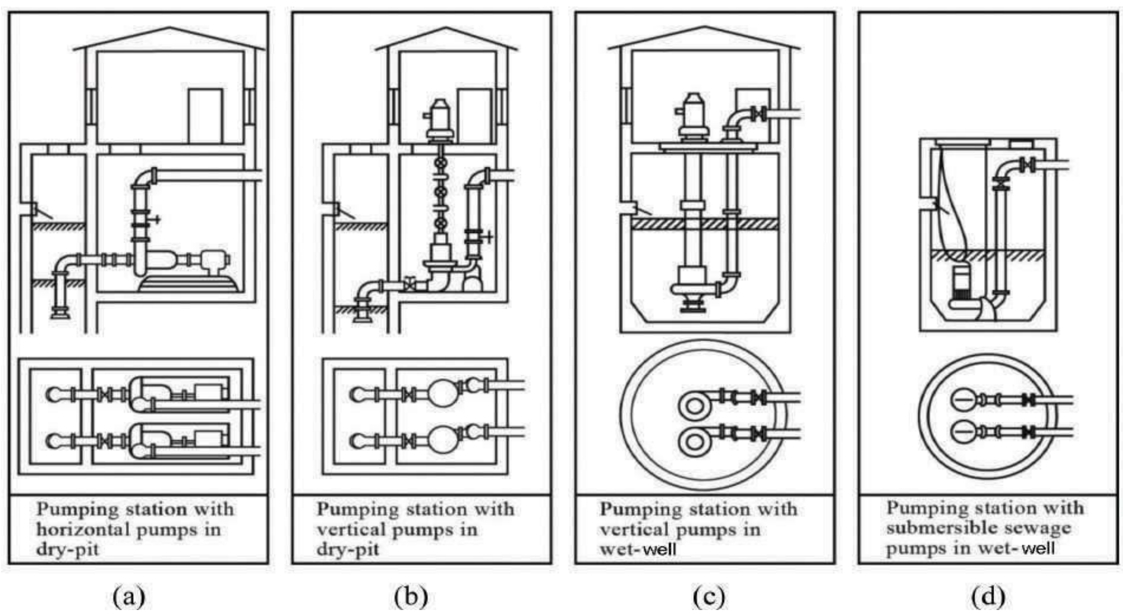
3.15. PUMPING STATIONS

Pumping stations are either as in-line for lifting the sewage from a deeper sewer to a shallow sewer orfor pumping to the STP or the out fall. They are required where low lying development areas cannotbe drained by gravity to existing sewerage infrastructure, and/or where development areas are too far away from available sewerage infrastructure to be linked by gravity. The O&M of pumping systems presented here applies to all such types of pumping stations.

3.15.1. TYPES AND STRUCTURE OF PUMPING STATIONS

The type of pumping stations can be (a) Horizontal pumps in dry pit, (b) Vertical pumps in dry pit, (c) Vertical pumps in suction well and (d) Submersible pumps in suction sump.

All these types include a sewage-receiving sump, which is called suction sump or wet well. These types of pump arrangements are shown in Figure 3.1.



Source: CPHEEO, 1993 Figure 3.1 Typical drywell and wetwell installations

3.15.2. DRY PIT

The size of the dry pit should be adequate for the number of pumps planned and should be suchas to handle the sewage load at the desired pumping capacity. Allowance should also be made for future requirements of additional or larger pumps. In the configuration, (a) separate dry pit and wet well are required: one to hold the sewage, and one to house the pumps and appurtenances. This option is required for installations where the pumps will otherwise need separate priming and where-as otherwise long suction pipes are needed.

It is typically used to pump large volumes of raw sewage, where uninterrupted flow is criticaland sewage solids could clog suction piping. It is also used to pump solids in pipe galleries between digesters or other solids-handling equipment. While construction costs may be higher and a heating, ventilation and cooling system is necessary when installed belowthe floor level, this configuration is best for O&M activities because operators can see and touch the equipment.

3.15.3. SUCTION SUMP OR WET WELL

Sewage sump is a compartment or tank in which sewage is collected. The suction pipe of apump may be connected to the wet well or a submersible pump may be located in the wet well. Sewage sump design depends on the type of pumping station configuration (submersible ordry well) and the type of pump controls (constant or variable speed). Wet wells are typically designed to prevent rapid pump cycling but small enough to prevent a long detention time and associated odour release.

Sewage sumps should always hold some level of sewage to minimise odour release. Bar screensor grinders are often installed in or upstream of the wet well to minimise pump clogging problems. Instead of manually operated screens at the bottom, which requires the staff to get down into the screen sump, it is better to install mechanical bar screens, which can automatically remove the screenings and lift the same safely above the ground level. There can also be two such screens oneafter the other for coarse screenings and fine screenings. This will require rectangular channels to maintain longitudinal non-turbulent linear flow.

3.15.4. LIFT STATIONS

In general, lift stations are invariably used in gravity sewer network where depth of cut of sewers poses a problem in high water prone areas. The procedure is to sink a wet well on the road shoulder or an acquired plot after the shoulder and divert the deeper sewer there. The submersible pump will lift the sewage and discharge it to the next on line shallow sewer. This is a very useful practice in such locations.

Equipment located in the wet well should be minimized, including suction and discharge valves, check valves, or other equipment that require routine, periodic maintenance. This equipment can belocated in separate and suitable dry pits located adjacent to the wet well to facilitate accessibility andmaintenance for the operator.

3.15.5. OPERATION AND MAINTENANCE

Pumping machinery is subjected to wear & tear, erosion and corrosion due to its nature offunctioning, and therefore it is vulnerable to failures. Generally, failures or interruptions are mostly attributed to pumping machinery rather than any other component. Therefore, correct operationand timely maintenance and upkeep of pumping stations and pumping machinery are of vital importance. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventoryof fast moving spare parts. Obviously due attention needs to be paid to all such aspects for efficientand reliable functioning of pumping machinery.

3.15.6. OPERATION OF THE PUMPS

The following points should be observed while operating the pumps.

- Dry running of the pumps should be avoided.
- Centrifugal pumps if installed with negative suction should be primed before starting.
- Pumps should be operated only within the recommended range of the head-dischargecharacteristics of the pump.

• If pump is operated at a point away from duty point, the pump efficiency normally reduces.

- Operation near the shut-off point should be avoided, as it causes substantial recirculationwithin the pump, resulting in overheating of sewage in the casing and consequently, overheating of the pump.

– As far as possible positive suction is to be provided to avoid priming during design itself.

– Voltage during operation of the pump-motor set should be within ±10 % of the rated voltage.Similarly, current should be below the rated current shown on the name plate of the motor.

– When parallel pumps are to be operated, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in the incoming feeder and should be adequate to allow the pump head to stabilise.

– When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep open the air vent of the pump next in sequence, before starting that pump.

– The stuffing box should allow a drip of leakage to ensure that no air passes into the pump and thatthe packing gets adequate wetness for cooling and lubrication. When the stuffing box is sealed with grease, adequate refill of the grease should be maintained.

– The running of duty pumps and standby pumps should be scheduled so that no pump remains idle for a long period and all pumps are in ready-to-run condition. Similarly, the running schedules should be ensured so that all pumps do not wear equally needing simultaneous overhaul.

– If any undue vibration or noise is noticed, the pump should be stopped immediately and the cause for vibration or noise should be checked and rectified.

– Generally, the number of starts per hour shall not exceed four. Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Although overloading lasts only for a few seconds, it reduces the life of the equipment.

– Troubles in a sewage pumping station can be mostly traced to the design stage itself. This isall the more true when too much grit is likely to come into the sewage pumping stations from sewage at monsoon time, which is difficult to handle. Hence, sewers should not collect any storm water.

3.15.7. UNDESIRABLE OPERATIONS

The following undesirable operations should be avoided:

3.15.7.1. OPERATION AT HIGHER HEAD

A pump should never be operated at a head higher than the maximum recommended head otherwise such operation may result in excessive recirculation in the pump, and overheating of the sewage and the pump. Another problem that arises if a pump is operated at a head higher than the recommended maximum head is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft, which may cause failure of the pump shaft. As a useful guide,appropriate marking should be made on the pressure gauge. Efficiency at a higher head is normallylow and such an operation is also inefficient.

3.15.7.2. OPERATION AT LOWER HEAD

If a pump is operated at a lower head than the recommended minimum head, the radial reactionon the pump shaft increases causing excessive unbalanced forces on the shaft, which may cause premature wear of bearings and possibly shaft failure if persisted. As a useful guide appropriate marking should be made on both pressure gauge and ammeter.

Efficiency at a lower head is normally low, hence such an operation is inefficient. In such cases, it is advisable to throttle the delivery side valve to create more head to work within safe head. This will also reduce the power. If this is a design flaw additional head has to be created at tail end by elevating the delivery. However,these are not energy efficient solutions; change of impeller to suit the actual head is the solution.

3.15.7.3. OPERATION ON HIGHER SUCTION LIFT

If a pump is operated on suction lift higher than the permissible value, pressures at the eye of impeller and the suction side fall below vapour pressure. This results in flashing of sewage into vapour. Thesevapour bubbles collapse during passage, resulting in cavitation in the pump, causing pitting on the suction side of impeller and casing, and excessive vibrations. In addition to mechanical damage dueto pitting, pump discharge also reduces drastically. Typical damage to impeller and sometimes to thecasing is shown in Figure 3.2.

Source: http://greathub.hubpages.com/hub/piping-and-pipes# Figure 3.2 Typical Cavitation Damage of an Impeller

3.15.7.4. OPERATION OF THE PUMP WITH LOW SUBMERGENCE

Minimum submergence above the bell-mouth or foot-valve is necessary to prevent entry of air into the suction of the pump, which gives rise to the vortex phenomenon, causing excessive vibration, overloading of bearings, reduction in discharge and in the efficiency. As a useful guide, thelowest permissible sewage level should be marked on the water level indicator. Usually the pump manufacturer indicates the minimum height of submergence. In the case of submersible pumps, theminimum depth is needed to ensure cooling of the motor while running.

3.15.7.5. OPERATION WITH OCCURRENCE OF VORTICES

If vibration continues even after taking all precautions, vortex may be the cause. Vortex should be stopped by using anti vortex fittings as described in chapter 4 of Part A of the manual:

A well-planned maintenance programme for pumping systems can reduce or prevent unnecessary equipment wear and downtime. (The following maintenance information applies to both sewage andsolids pumping systems.)

3.15.8. The following is a maintenance checklist for a basic pumping-station:

1. Check the wet well level continuously (whenever necessary).
2. Record each pump's "run time" hours (as indicated on the elapsed-time meters) at least once ina day and confirm that the pumps' running hours are equal.
3. Ensure that the control-panel switches are in their proper positions.
4. Ensure that the valves are in their proper positions.
5. Check for unusual pump noises.
6. At least once a week, manually pump down the wet well to check for and to remove debris that
7. may clog the pumps.

8. Inspect the float balls and cables and remove all debris to ensure that they operate properly.
9. Twisted cables are to be released that may affect automatic operations.
10. If a pump is removed from service, adjust the lead pump selector switch to the number that corresponds to the pumps remaining in operation. (This allows the lead pump levels to govern theoperating pump's starts and stops.).

3.15.9. PIPING AND APPURTENANCE MAINTENANCE

Properly maintaining pumping-station pipelines and other appurtenances can minimize pump loads.

Excessive head losses on either the suction or the discharge side of a pump can increase energy use and the wear rate and consequently, the O&M costs. Excessive head losses also may lead to process or treatment problems because solids move slower, so the proper solids balance is not maintained. Operators can monitor head losses by routinely checking the pressure gauges on both sides of the pumps.

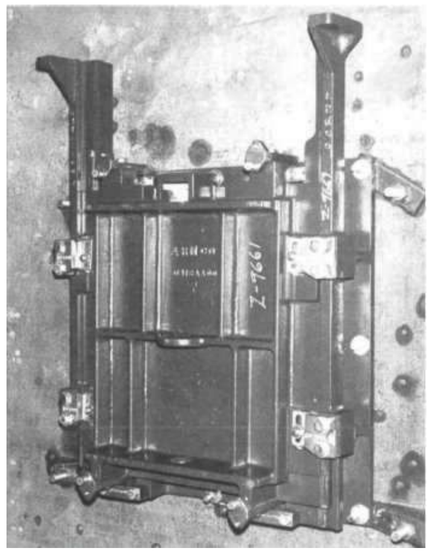
When operators notice excessive head losses (indicated by a pressure drop on the suction sideof the pump or an increase in pressure on the discharge side), they should determine whether the losses are a result of partial clogging, a restriction somewhere in the line, or materials built up onthe pipe wall. To find clogs, operators should start by checking the pressure at various points in the suction and discharge piping, and look for spots with abrupt head loss (such as valves or other constrictions). If something is caught in a valve or other appurtenance, the operator should stop thepump and physically open out the valve head and remove the blockage. In smaller pumps, it is easierto remove the entire valve, disassemble and remove the blockage, reassemble and refit. During suchtime, other pumps shall be run. Scum build-up problems typically are addressed via source control (for instance, by installing grease traps in the collection system at locations suspected or known to generate grease, such as restaurants, etc.).

3.15.10. GATES, VALVES AND ACTUATORS

3.15.10.1. SLUICE GATE

A sluice gate (Figure 3.3) is traditionally a wooden or metal plate, which slides in grooves in the sidesof the guide channel.

Sluice gates are commonly used to control sewage levels in STPs.



Attention should be paid to the following points for proper operation:

3.15.10.1.1. TEST FOR PROPER OPERATION

Operate inactive sluice gates by smearing grease on stem threads.

3.15.10.1.2. CLEAN AND PAINT

Clean sluice gate with wire brush and paint with proper corrosion-resistant paint.

3.15.10.1.3. ADJUST FOR PROPER CLEARANCE.

For gates seated against pressure, check and adjust top, bottom, and side wedges until each wedge applies nearly uniform pressure against gate in the closed position. This shall be done by the manufacturer and not the operator.

3.15.10.1.4. Check for the following:

- Ensure unobstructed operation of gate and headstock.
- Ensure that the spindle is not touching the stem guide.
- Remove foreign matter like paint, concrete, etc. in the fully open position of gate.

3.15.10.1.5. DO'S FOR SLUICE GATES

- Operate the gate at least once in every three months.
- Check the nuts of all construction and foundation bolts once in a year. Tighten the bolts, if loose.
- Examine the entire painted surface for any signs of damage to the protective paint.

3.15.10.1.6. DON'TS FOR SLUICE GATES

- Do not remove lock plates until the gate has been properly installed.
- Do not keep the gate out of operation for more than three months.
- Do not forget to set the stop nut in the correct position.
- Do not disturb the adjustment of wedge block bolts/studs.
- Do not over torque the crank handle/hand wheel.

3.15.10.2. VALVE

On the delivery side of centrifugal pumps, a non-return valve is necessary to prevent back-pressurefrom the delivery head on the pump, when the pump is shut off. To avoid water-hammer, which is likely to be caused by the closure of the valve, the valve may be provided with an anti-slam device, which may be either a lever and dead-weight type, a spring-loading type or the dash pot type.

Pumps may be run in parallel with different permutation of the standbys. Isolation valves would be needed to isolate those pumps, which are to be idle. Generally, the isolating valves are gate valves,which should preferably be of the rising stem type, since this type offers the advantage of visual indication of the valve-position.

For exterior underground locations, gate valves are generally used.

3.15.10.2.1. Gate Valve

A gate valve is a valve that opens by lifting a round or rectangular gate/wedge out of the path of thefluid as shown in Figure 3.4 overleaf. The distinct feature of a gate valve is that the sealing surfacesbetween the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel.Typical gate valves should never be used for regulating flow, unless they are specifically designed for that purpose. Gate valves require maintenance as indicated

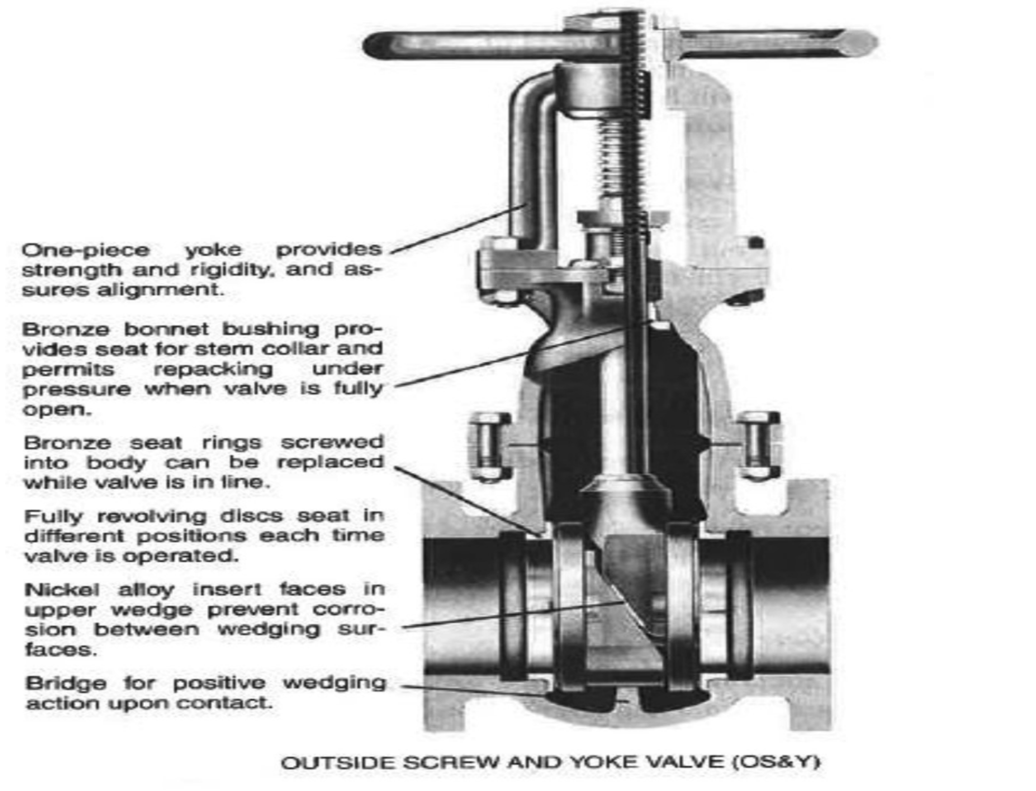


Figure 3.4 Gate valve

3.15.10.2.1.1. Replace packing : Modern gate valves can be repacked without removing them from service. Before repacking, open the valve wide. This prevents excessive leakage when the packing or the entire stuffing box is removed. It draws the stem collar tightly against the bonnet bushing on a rising stem valve.

3.15.10.2.1.2. Operate valve : Operate inactive gate valves to prevent sticking.

3.15.10.2.1.3. Lubricate gearing: Lubricate gate valves as recommended by the manufacturer. Lubricate thoroughly any gearing in large gate valves. Wash open gears with solvent and lubricate with grease.

3.15.10.2.1.4. Lubricate rising stem threads: Clean threads on rising stem gate valves and lubricate with grease.

3.15.10.2.1.5. Lubricate buried valves: If a buried valve is hard for working, lubricate it by pouring oil down through a pipe that is bent at the top end oiling the packing follower below the valve nut.

3.15.10.2.2. Non-Return Valve (Check Valve)

Normally, a check valve is installed in the discharge of each pump to provide a positive shutoff fromforce main pressure when the pump is shut off and to prevent the hydraulic force from drainingback into the wet well. The most common type of check valve is the swing check valve, which is shown in Figure 3.5.

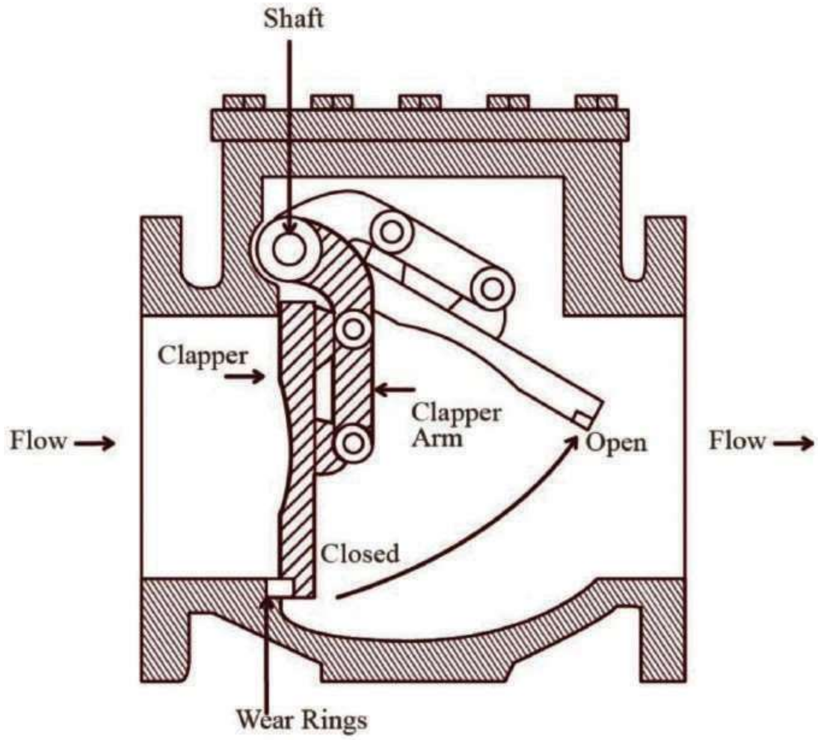


Figure 3.5 Check valve

This valve consists of a valve body with a clapper arm attached to a hinge that opens when the pumpstarts operating and closes to seal when the pump is shut off.

Check valves must close before the water column in the pipe reverses flow; otherwise, severewater hammer can occur when the clapper arm slams against the valve body seat. If this occurs, anadjustment of the outside weight or spring is usually required. A traditional clapper type of check valve has a lever on the extended shaft, which allows adjustment of the weight on the arm or springto vary the closing time. Wear occurs within the valve primarily on the clapper hinge-and-shaft assemblies and should be checked annually for looseness.

The preventive maintenance is to be done only by the manufacturer.

3.15.10.2.2.1. Inspect Clapper Facing : Open valves to observe condition of facing on swing check valves equipped with neopreneseats on clapper. If metal seat ring is scarred, dress it with a fine file and lap with fine emery paper wrappedaround a flat tool.

3.15.10.2.2.2. Check Shaft Wear : Check shaft wear on balanced disc check valve since disc must be accurately positioned inthe seat to prevent leakage.

3.15.10.2.3. Non-Return Valve (Ball Type)

Non-return valve depends on a light weight and suitable coated ball moving inside the flowing pipe to occupy an elevated angular position while the fluid is in pumping and dropping back to close the reverse flow through the pipe. Because it is a sphere sitting over a circular opening, it is expected to seat properly and seal the reverse flow. The material of the ball, the coating and its sturdiness against dents caused by the slide are important aspects. The ball is replaced by opening the top flange after switching off the pump. This can be installed in any position, vertical or horizontal.A non-return valve is shown in Figure 3.6.

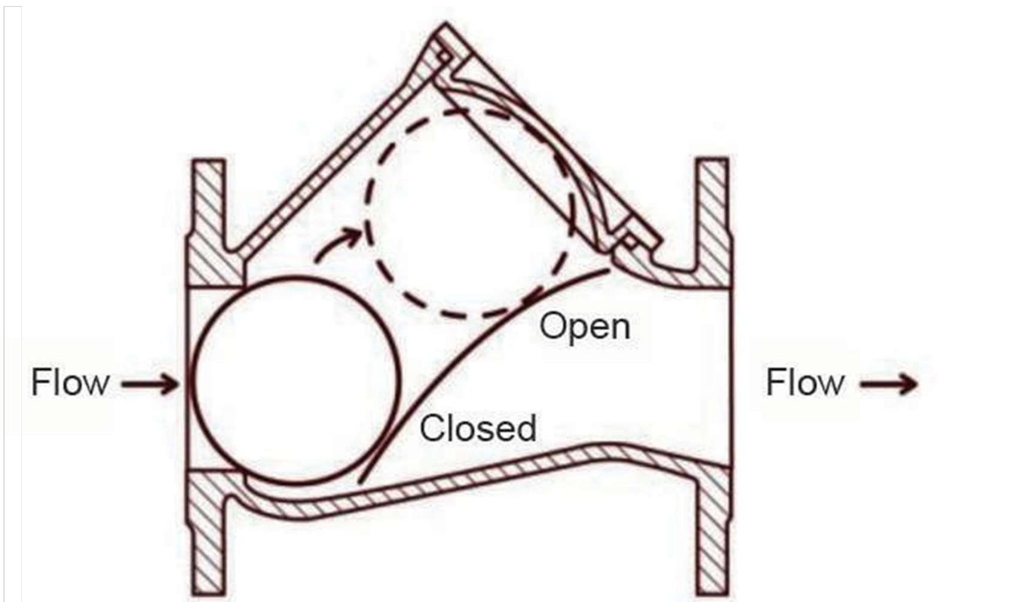


Figure 3.6 Typical ball type check valve

When flow occurs, the ball is lifted into the angular piping and is held there because its weight is lighter than the sewage and the velocity of flow. When the flow stops, it slides back and seals.

3.15.10.2.4. Butterfly Valve

Butterfly valves are another type of valve that have been successfully used as suction and dischargeisolation valves in pumping stations. They are frequently used in sewage plants where waste streamswith a high solids content are encountered, such as in sludge pumping systems. A butterfly valve consists of the valve body and a rotating disc plug that operates through 90 degrees.

This is usually a disc rotated by 90 degrees by external handle. In the open position, the disc is in line with the flow. In the closed position, the disc is at 90 degrees to the flow and it stops the flow. Usually, the axis is vertical although horizontal axis arrangement may also be used in smaller sizes.

The closing and opening can be manual or mechanized. The butterfly valves occupy less space and are generally preferred for pipe sizes larger than 150 mm.

Many agencies specify butterfly valves as opposed to gate valves because they are less susceptible to plugging.

Butterfly valves require the following preventive maintenance to be done by the manufacturer:

3.15.10.2.4.1. Adjust gland

The adjustable gland holds the plug against its seat in the body and acts through compressible packing, which functions as a thrust cushion.

Keep gland tight enough at all times to hold plug in contact with its seat. If this is not done, the lubricant system cannot function properly, and solid particles may enter between the body and plug and cause damage.

3.15.10.2.4.2. Lubrication

Apply lubricant by removing lubricant screw and inserting stick of butterfly valve lubricant for stated temperature conditions.

Be sure to lubricate valves that are not used often to ensure that they are always in operating condition. Leave lubricant chamber nearly full so that extra supply is available by turningthe screw down. Use lubricant regularly to increase the valve efficiency and service, promote easy operation, reduce wear and corrosion, and seal valve against internal leakage.

3.15.11. ACTUATORS

These are replacements for physical operation by the operators. Actuators are used for automation of valves. An actuator rotates the valve spindle or lifts and drops the same.

3.15.11.1. ELECTRIC GEARED MOTOR ACTUATOR

The actuator consists of a rotor stator unit driving an output shaft through a single stage-worm reduction gear, which incorporates an automatic mechanical device for changing manual drive to power drive. The actuator includes a travel-limit switch unit and a torque switch unit,and is of totally enclosed construction. When power fails, electric motor driven gear actuatorsretain their positions. When power supply returns, pay attention how the valves move. The electric motor driven gear actuator is shown in Figure 3.7 overleaf.

3.15.11.2. SOLENOIDS

Solenoids are the most common actuator components. It consists of a moving ferrous core (a piston) that moves inside wire coil. Normally the piston is held outside the coil by a spring.When a voltage is applied to the coil and current flows, the coil builds up a magnetic field that attracts the piston and pulls it into the centre of the coil. The piston can be used to supply alinear force. Diaphragm valve have small holes on it. The holes should be free from cloggingby debris otherwise the diaphragm may not open.

Figure 3.7 Electric motor driven gear actuator

3.15.11.3. PNEUMATICS

Pneumatic systems have much in common with hydraulic systems with a few key differences. The reservoir is eliminated as there is no need to collect and store the air between uses in the pneumaticsystem. Also because air is a gas, it is compressible and regulators are not needed to recirculate theflow; however, since the gas is compressible, the systems are not as stiff or strong.

In general, the pneumatics are liable to cause accidents such as when the air hose suddenlypulls out of the hose clamp and jets high pressure air on persons nearby. This should be avoided. The electric geared motor type is to be preferred. The pneumatic valve is shown in Figure 3.8.

Figure 3.8 Pneumatic valve

3.15.11.4. HYDRAULIC SYSTEM

Actuator (hydraulic motor and hydraulic cylinder) is operated by hydraulic fluids (hydraulic oil), which is pressurised by hydraulic pump driven by an electric motor. Generally, a smooth movementand variable speed can be achieved. Moreover, the installed relief valve can prevent the system from breakdown. It should be noted that hydraulic oil leaks as pressure increases. Check foroil leakage regularly. Hydraulic system should be kept clean because it is vulnerable to dustor rust. Take precautions to avoid fires because the hydraulic oil is combustible.

In all cases, preventive maintenance by manufacturer shall be done periodically and a wall chart exhibited on site.

3.15.12. SCREEN

Screenings in sewage from the incoming sewer below the ground level need to be separated and lifted above ground level, and removed either by mechanical or manual method.

3.15.12.1. TYPES OF SCREENS

3.15.12.1.1. Coarse Screens

Coarse screens are usually bar screens consisting of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. The openings are usually 25 mm. Hand-cleaned screens are usually inclined at 45 degrees to the horizontal.

3.15.12.1.2. Medium Bar Screens

Medium bar screens have clear openings of about 12 mm.

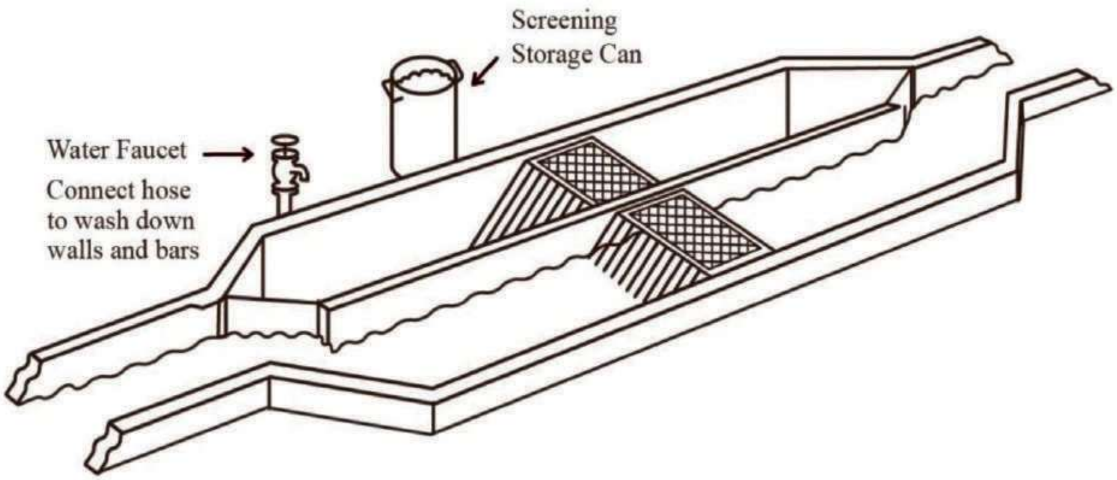
3.15.12.1.3. Fine Screens

Fine screens are mechanically-cleaned devices. Fine screens may be of the drum or disc type, mechanically cleaned and continuously operated. They are also used for protecting the beaches where untreated sewage may have to be discharged into the sea for disposal by dilution.

3.15.12.2. SCREENINGS REMOVAL METHOD

3.15.12.2.1. Manual bar screen

Hand cleaned screens should be cleaned as often as required to prevent backing up of sewage.A manually-cleaned bar screen is shown in Figure 3.9.



Source: EPA, 2008

Figure 3.9 Manual bar screen

The following are important for O&M of manual bar screen:

A. Preventive maintenance for checking and repairing the following once a week

Check whether the standing platform is at least 2 m wide with the first 1 m as slotted. An example of a risky platform is presented in Figure 3.10.

Figure 3.10 An example of risky platform

There is no space for the operator to stand after he has lifted and dumped screenings on the platform. Because of the lack of space, he may move backwards and fall into the sewage channel. Also, screens should be inclined to the horizontal by an angle of 60 degrees or more, otherwise, theoperator has to bend forward. The rear side of the platform should have handrails. If handrails are notprovided, enter this point in the site book.

1. Check the condition of ladders and paint them periodically.
2. Verify that there are no broken metal parts that protrude outside.
3. Once a month check the rigidity of handrails.
4. Verify the platform for its sturdiness by gently setting the foot on it.

Verify that the lighting is not in front or behind the operator. It should be above the operator, at least2.5m high and mounted on the sidewall or separate lamp posts. These lights should not have local on-off switches and must be fully lit in the nights. Verify that the operator platform and slotted platformhave 3m head room and provided with roof so that the operator is not drenched and he can lift the cleaning rake freely.

B. Regular maintenance on a daily basis and repairs

1. Verify that the screen rods have not broken loose.
2. Verify that the cleaning rake is well washed in running water after each use.
3. Verify that gum boots are kept inside a locker covered with mesh.
4. Verify that disposable gloves are available for all 3 shifts and a stock of one month is available.
5. Verify that helmet is available.
6. Operation
7. Before daily operation, verify all the above. If these points are not met, do not enter the screen area. Enter all missing items in the site register.
8. If all items are in order, do the cleaning once in four hours in each shift.
9. Ensure that operators do not stand one behind the other. This may cause an accident because while pulling the rake backwards, the operator in the front may hit and push the operator in the rear into the sewage channel.
10. Once the screens are cleaned and screenings are deposited on the slotted platform allow them to drip dry till the next cleaning after 4 hours.
11. Push the screenings with the rake to the side of the platform to drop them into the tipper positioned there.
12. Move the tipper to the vermin compost site, dump the contents in the pit and cover with earth as prescribed in Sec.3.4.4 “Disposal of Screenings.”

3.15.12.2.2. Mechanical Screen (Intermittent and Continuous)

Mechanically cleaned racks are generally erected almost vertically. Additional provision should be made for manual raking in case the mechanical rakes are temporarily out of order. Plants using mechanically cleaned screens have controls for:

a. Manual start and stop
b. Automatic start and stop by clock control
c. High level switch
d. High level alarm
e. Starting switch or overload switch actuated by loss of head and
f. Overload alarm.

There are various types of mechanisms in use, the more common being traveling rakes that bring the screenings up out of the channel and drop them into hoppers or other debris containers.A typical mechanically cleaned bar screen is shown in Figure 3.11 overleaf. The rotary drum screen otherwise known as arc screen by United Nations Industrial Development Organization (UNIDO)is shown in Figure 3.12 overleaf.

In the drawing, the screening rods are in the form of arc. The cleaning takes place when the meshing teeth at both ends of a diametrical rotating arm plough through the screen openings and push the screenings upwards. Upon exiting the upper end of the screen, which is well above the operating sewage level, a built in spring loaded arrangement in the diametrical rods jacks out the meshing teeth gently, which pushes the screenings gently into a collection trough.

The screenings can be manually removed or a conveyor belt can collect the screenings and drop them into a container on the ground through a drop chute.

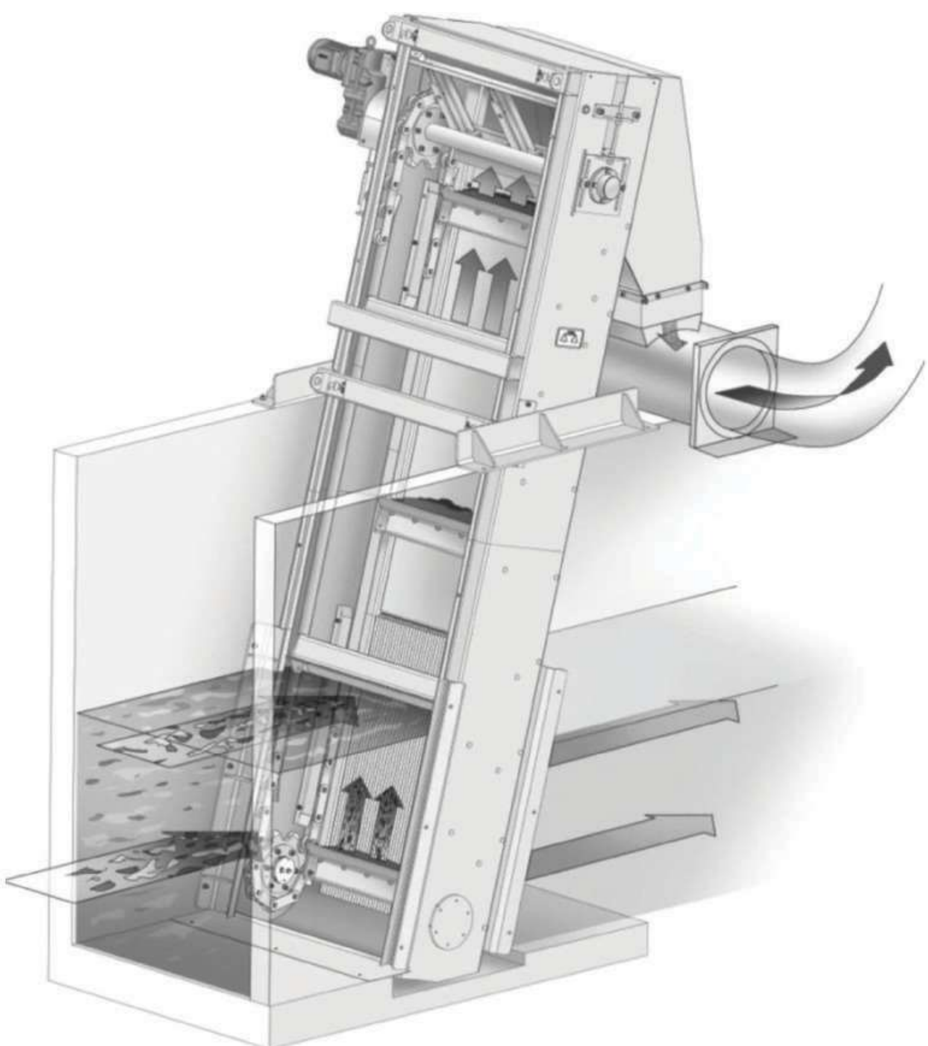


Figure 3.11 Mechanically-cleaned bar screen

A. Preventive Maintenance

- Verify the equipment manufacturer's manual for preventive maintenance instructions and carry out the same (if permitted to be done by the operator).
- Switch off electrical power before doing any work on the mechanical screen.

B. Regular maintenance on a daily basis and repairs

Before start of the day's work, check for any friction between metal parts. If friction exists and the sound is disturbing, disconnect the electric supply and divert all sewage to manual screens. Enter this action in the site register. Do not perform repairs by unauthorized personnel because it is dangerous.

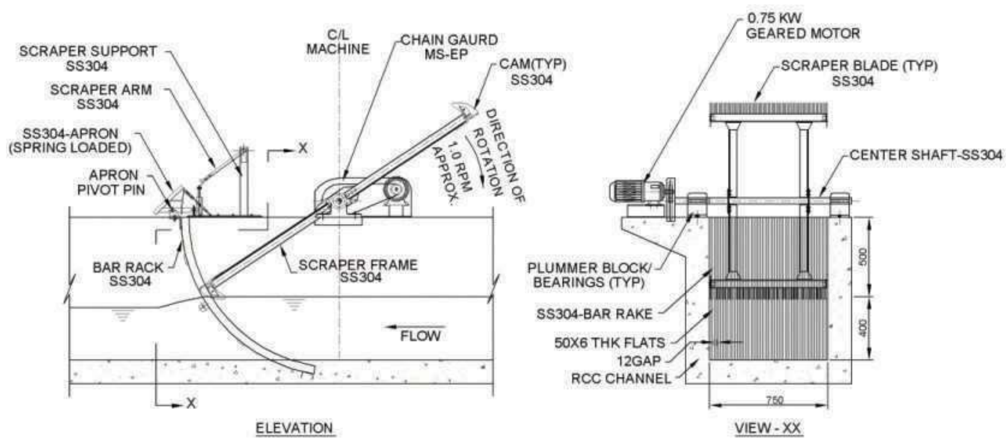


Figure 3.12 UNIDO type arc screen

- Check the alignment of the tipper plates. If the screenings are slipping back and are notgoing up, allow the machine to work and do not stop it. Enter the abnormality in the site register and request for visit by the manufacturer's engineer. Do not perform repairs by unauthorized personnel because it is dangerous.

C. Operation

- Before start of the day's work, do not approach the mechanical screen unless you are wearing, electrical gloves, safety helmet and safety boots.

- Before start of the day's work, switch off the mechanical screen and restart it. Watch forany friction or sparks. If you notice sparks, disconnect the electric supply and divert all sewage to manual screens. Enter the abnormality in the site register. Sometimes, these sparks can be dangerous and may cause electrocution.
- Follow the procedure for disposing screenings as described earlier.

Accessories (Conveyors)

Belt conveyors are used in conveying the screenings to the trolley parked by the side of the screen chamber. Generally, these are meant only for mechanical screens. For manually operated screens, the water content has to first drip out fully before the screenings can be put on the conveyor. In the case of mechanical screens, the angle is close to vertical, the height is more and dewatering is automatic, but this is not the case with manual screens. If it is to be used, then the conveyor belt hasto be behind the operator. The operator first picks up the screenings, drops it on the slotted platformand allows four hours for the screenings to drip fully. Thereafter, he can lift it by the same fork and turn it around 180 degrees and place it on the conveyor belt behind him. On the other hand, in smallerplants he can directly push the screenings to the slotted platform and into the trolley on the ground after the sidewall. All the guidelines for preventive maintenance, regular day-to-day maintenance andoperation, and site register entries by the operator are the same as before.

D. Disposal of Screenings

Screenings generally consist of non-bio degradable stuff like plastic sachets, milk packets, shampoo packets, etc., with very little organic content. Hence, it is best disposed of as a secure landfill, whichshould be prevented from direct rainfall and flow of overland rainwater. The procedure specified by the pollution control authority should be adhered to without fail.

3.15.13. GRIT REMOVAL

The different types of grit removal equipment are given in chapter 5 of Part-A of the manual. These are velocity controlled channels, detritors, aerated grit chambers, vortex type, etc.

3.15.13.1. Preventive Maintenance

Almost all these equipment are patented. Each manufacturer has proprietary schedules for preventive maintenance. These schedules should be followed. Preventive maintenance should be done only by themanufacturer or the erection contractor who has installed the equipment, and not by the operators.

3.15.13.2. Regular Day to Day Maintenance

The operator should hose the mechanical parts using the high-pressure hose, and pump the final treated sewage so that slime does not accumulate. Where flap gates or turnstiles are provided, the operator should necessarily "exercise" these once a day.

The operator should not enter the chambers unless the sewage entry is blocked, the chamberhas been dry for at least two hours and the operator is wearing an oxygen mask. In the case of velocity-controlled channels, the trip switch controlled traveling bridge with suspended suctionhoses for each channel connected to a vacuum pump set are standard items. If this system failsand grit accumulates in the channel, each channel should be taken out of sewage flow. Thescour valve should be opened below the chamber and the sewage after filtering through thein-built filter port should be allowed to drain to the site drain. Thereafter, the chamber should be allowed to air dry for at least two hours, high pressure water jetting, draining and air drying cycle carried out at least three times.

Subsequently, labourers can be deployed to scrap the grit, provided the labourers wear goggles, gloves, safety shoes and oxygen masks.

In general the vacuum pump is the main source of failure and these types of channels are to be usedonly in large STPs where other such equipments are also functioning and qualified operators are available in all the shifts.

The vortex type grit separators described in chapter 5 of part A manual are simpler devices to lift andclean the grit and discharge at a convenient elevation above the ground level.

3.15.13.3. Disposal of Grit

The grit is usually pre-rinsed in the grit removal chamber itself before it is evacuated from it.Figure 3.13 shows a typical grit chamber.

Figure 3.13 Typical grit chamber

Clean grit is characterized by the lack of odour. Washed grit may resemble particles of sand and gravel, interspersed with inert materials from households. Grit washing mechanism has to be included whenever the detention time is more and flow through velocity is less. Unless washed, it maycontain considerable amount of organic matter. This becomes an attraction to rodents and insects and is also unsightly and odorous. The grit should be contained in a secure landfill as directed by the local pollution control authority or disposed along with the municipal solid wastes, if permitted.

3.15.14. PUMP EQUIPMENT

The types of pumps are dealt with in chapter 4 of Part-A of the manual. These are horizontal centrifugal, vertical shaft centrifugal, dry submersible and wet submersible pumps.

3.15.14.1. PREVENTIVE MAINTENANCE

This shall be done only by the manufacturer / his authorized service agency / properly trained staff. The operator shall not carry out preventive maintenance.

3.15.14.2. REGULAR DAY-TO-DAY MAINTENANCE

This should include the tasks as given in Table 3.1.

Table 3.1 Tasks to be addressed in day-to-day regular maintenance

Description	Comments	Maintenance Interval			
		D	W	M	Y
Earthing	Check whether earthing is proper	yes			
Visual Appraisal	Check that safety aids and first aid are in place		yes		
Gland packing	Check for leaks & condition of mechanical seals			yes	
Alignment	Check alignment using computerized monitor				yes
Oil & Grease	Check for lubrication as per manufacturer			yes	
Motors	Check vibration and temperature		yes		
Mountings	Check for vibrations from foundation bolts			yes	
Bearings	Check for unusual sounds			yes	
Pump sequence	Start & stop the pumps as per duty condition	yes			
Foundation	Check for spalling or cracking			yes	

Note: D: Daily, W: Weekly, M: Monthly, Y: Yearly

Proper operation of submersible pump systems requires that minimum submergence shouldalways be maintained. This is for two primary reasons:

- Prevention of motor overheating
- Prevention of "vortex" and associated problems

The following should be inspected:

- Inspect seal for wear or leakage and repair, if required.
- Visually inspect the oil in the motor housing.
- Remove pipe plug from housing.

- Make sure oil is clean and clear, light amber in colour and free from suspended particles.
- Milky white oil indicates the presence of water.

If the system fails to operate properly, carefully read the instructions supplied during the time ofpurchase and perform maintenance recommendations.

Operation and Maintenance

Before starting the pump, check the following:

- Check insulation resistance by megger at free end of cable and verify with pump manual.
- Check continuity between ends of motor in the same phase and in all phases.
- Check resistance across moisture sensing wires and verify with pump manual.
- Physically rotate the coupling joint and verify smooth movement.
- Check for leaky oil plug and fix it before starting.
- Check for the bulbs indicating the on–off status of the pump and replace fused bulbs.
- Look for warning lamps for alerting the pumped liquid entering the oil chamber.
- Close the discharge valve before starting the pump. This is also taken care by check valve.
- Open the discharge valve gradually and not all of a sudden.
- While the pump is running at full flow, check the power consumed to be within the duty point.
- If the power consumed is very high, stop the pump and inform the manufacturer.

- Switch off the pump only after the discharge valve is closed.

3.16. ACCESSORIES

3.16.1. OIL AND GREASE

- Pumps, motors and drives should be oiled and greased strictly in accordance with the recommendations of the manufacturer. Cheap lubricants may often become the most expensive in the end.

- Oil should not be put in the housing while the pump shaft is rotating because a considerable amount of oil will be picked up and retained due to the rotary action of the ball bearings. When the unit comes to rest, an overflow of oil will occur around the shaft or oil will flow out of the oil cup.

3.16.2. BEARING

- Pump bearings should usually last for many years if serviced properly and used correctly.

- There are several types of bearings used in pumps such as ball bearings, roller bearings and sleeve bearings. Each bearing has a special purpose, such as thrust load, radial load and speed. The type of bearing used in each pump depends on the manufacturer's design and application.

- Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, to eliminate the problem.

3.16.3. PACKING GLAND

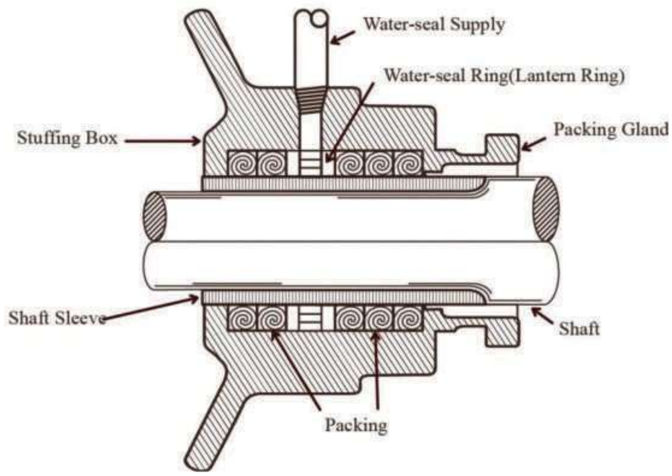
- Check packing gland, which is usually neglected and is a troublesome part as shown in Figure 3.14 overleaf.

- If the stuffing box leaks excessively when gland is pulled up with mild pressure, remove the packing and examine the shaft sleeve carefully.

- Replace grooved or scored shaft sleeve because packing cannot be held in stuffing box with roughened shaft or shaft sleeve.

• Replace the packing a strip at a time, tamping each strip thoroughly and staggering the joints.

Position the lantern ring (water sealing) properly.



Source: EPA, 2008 Figure 3.14 Packing gland

- If grease sealing is used, completely fill the lantern ring with grease before placing remaining rings of packing in place.

- The proper size of packing should be available in the plant's equipment files.

3.16.4. MECHANICAL SEAL

Many pumps use mechanical seals instead of packing as shown in Figure 3.15.

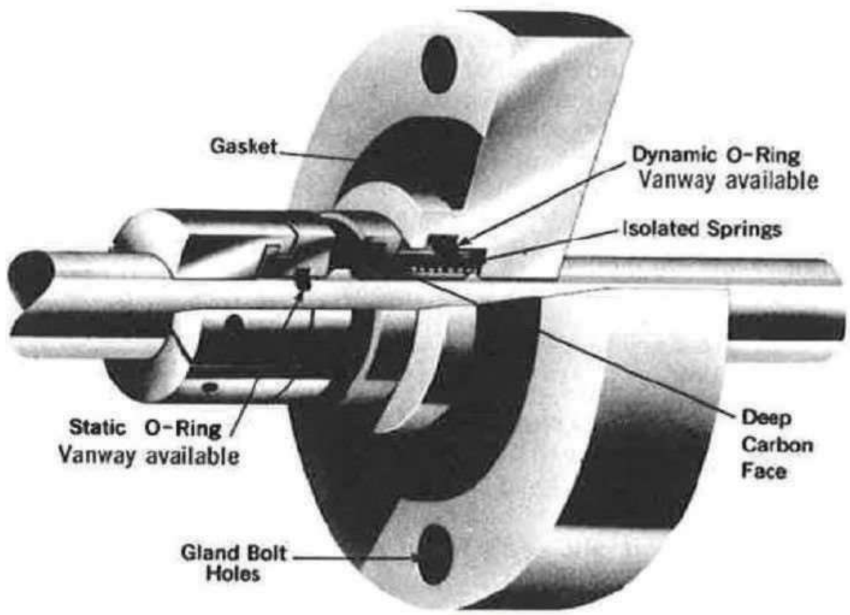


Figure 3.15 Mechanical seal

Mechanical seals serve the same purpose as packing; that is, they prevent leakage between the pump casing and shaft. The seals have two faces that close tightly and prevent the sewage from passing through them.

The different materials are selected for their best application. Some of the factors for selection of material are:

- ✓ Liquid and solids being pumped
- ✓ Shaft speed
- ✓ Temperature
- ✓ Corrosion resistance
- ✓ Abrasives

- ✓ Initially, mechanical seals are more expensive than packing when installed in a pump. This cost is recovered through maintenance savings over a period of time.
- ✓ Some of the advantages of mechanical seals are as follows:
- ✓ They last from three to four years without any maintenance, resulting in labour savings.
- ✓ Usually, there is no damage to the shaft sleeve at the time of their replacement.
- ✓ Continual adjusting, cleaning, or repacking is not required.

The construction of a mechanical seal is shown below.

- ➢ Whatever be the method used, the mechanical seal must be inspected frequently.
- ➢ Grease cups must be kept full at all times and inspected to make sure they are operating properly. When a pump is fitted with a mechanical seal, it must never run dry or the seal faces will be heated up and ruined.
- ➢ Mechanical seals should not leak from the gland. If a leak develops, the seal may require resurfacing or it may have to be replaced.
- ➢ Repair or replacement of mechanical seal requires the pump to be removed and dismantled.
- ➢ Seals are quite delicate and special care must be taken when installing them. Mechanical seals differ widely in their construction and installation, and the manufacturer's instructions must be followed.

3.17. FLOW MEASURING DEVICES

Flow, similar to water level (Refer to Sec.6.5.2 "Level Measuring Equipment"), is one of the most important parameters to be measured. The various types of flow-measuring devices have three basic criteria that determine their performance namely: area, velocity, and device characteristics. The two basic types of flow measurements are open-channel and closed-pipe. For good measuring device performance, both types require approach conditions free of obstructions and abrupt changes in size and direction. Obstructions and abrupt changes produce velocity-profile distortions that lead to inaccuracies.

3.17.1. WEIR FLOW-METER

A weir measures the liquid flowing in open channels or partially filled pipes under atmospheric pressure as shown in Figure 3.16.

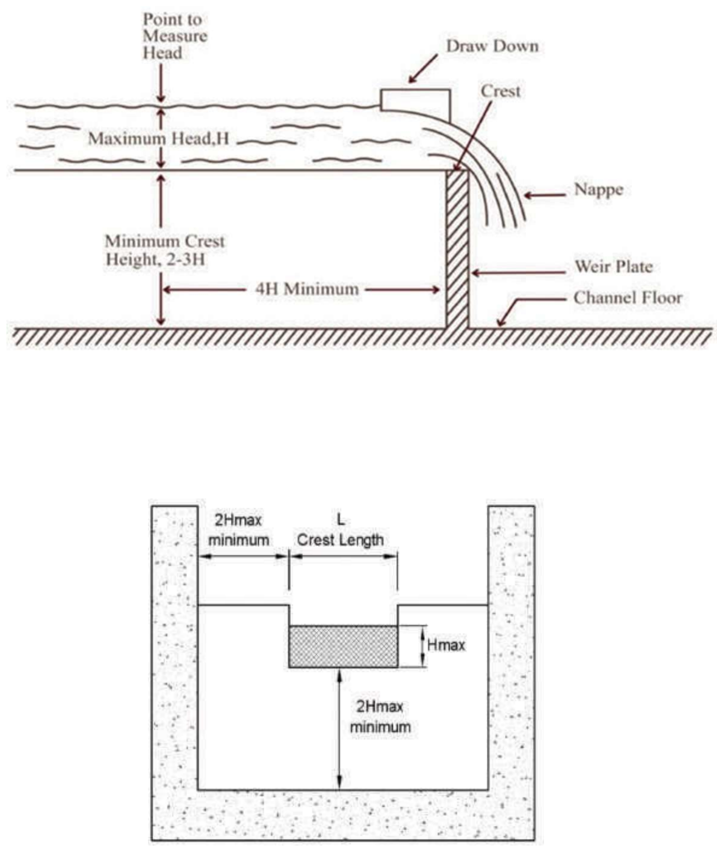


Figure 3.16 Typical weir section and elevation

This device causes the flow to take on certain characteristics (such as shape and size) depending on the device used.

Changes in flow-rate produce a measurable change in the liquid level near or at the device.

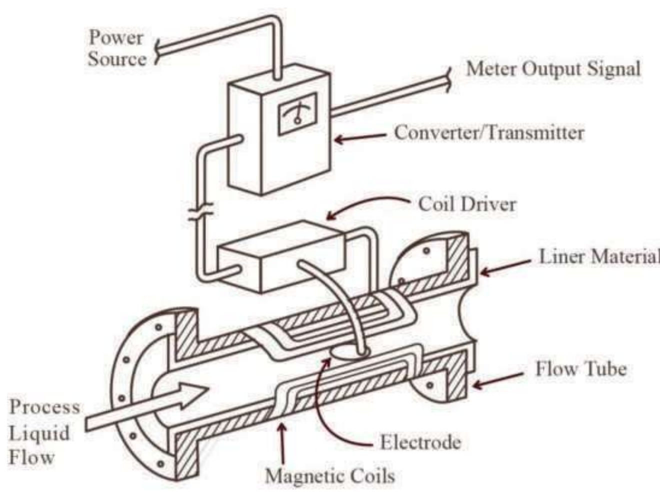
This level is related to flow-rate by an appropriate mathematical formula. The specific device determines the location and accuracy of level measurements and is extremely important for accurate performance.

Measurement errors occur if the actual crest height differs from the designed height due to accumulated matter on the channel floor. The sediments must be removed.

Floating matter or surface wave may cause incorrect level measurements and lead to errors in flow measurements. Therefore, floating matter should be removed immediately.

3.17.2. ELECTROMAGNETIC FLOW-METER

Magnetic flow meters are used extensively in applications ranging from filtered sewage to thickened or digested solids. They function by electromagnetic induction, in which the induced voltage generated by a conductor moving through a magnetic field is linearly proportional to the conductor's velocity. As the sewage (the conductor) moves through the meter (generating the magnetic field), the voltage produced is measured and converted to a velocity and, thus, a flow-rate. Magnetic meters require a full pipe flow for proper operation. Proper grounding is important for certain brands. In applications where greasing of electrodes is likely, additional equipment for degreasing the electrode may be required. Magnetic flow meters provide no obstructions and are manufactured with abrasion-and corrosion-resistant liners, which is why they are frequently used in solids metering. Repairs should be done only by the manufacturer's representatives. Electromagnetic flow meters rarely break down because they have no moving parts. Dirt on sensors should be cleaned because that may cause error in measurements. The working principle is shown in Figure 3.17.

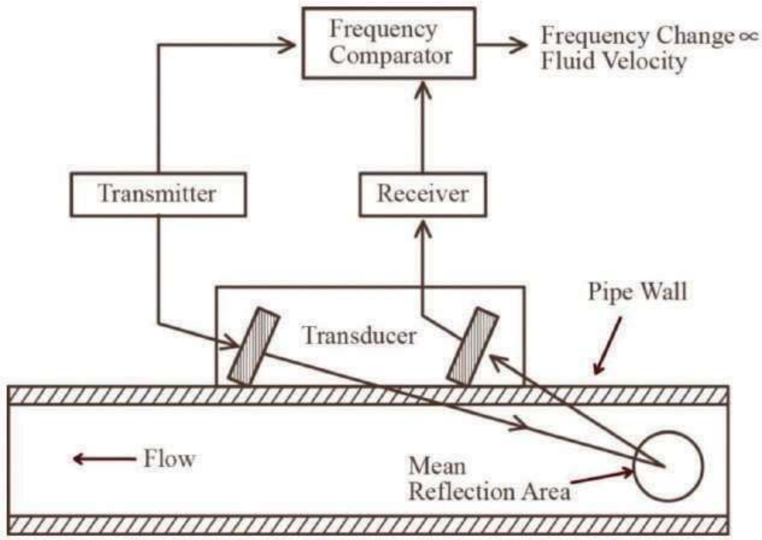


Source: WEF,2008 Figure 3.17 Magnetic flow meter

3.17.3. ULTRASONIC FLOW-METER

Ultrasonic flow meters are based on the measurement of ultrasonic wave transit time or frequency shift caused by the flowing fluid. An instrument that measures wave-transit time is called a time-of-flight or counter-propagation ultrasonic flow meter.

Ultrasonic waves of known frequency and duration are beamed across the pipe at known angles. The waves are sensed either directly by an opposing receiver or indirectly as reflected waves. The changes in wave transit time or frequency caused by the flowing liquid are linearly proportional to the liquid velocity. This velocity is converted from flow and output to a display by conversion electronics. The presence or absence of air bubbles and density of solids in the fluid being metered affect the meters. Operators should follow the manufacturer's specifications and carefully match the meters to the application. The working principle is shown in Figure 3.18.



Source: WEF,2008 Figure 3.18 Reflecting ultrasonic flow meter

3.17.4. FLUORESCENT TRACERS

Florescent tracer method requires the use of a tracer like Rhodamine B Dye, which is injected using a peristaltic pump from a small volume of a known concentration of dye solution. The dye is injected into the gravity or pumping main. After traveling and getting mixed, the dye concentration is measured at a distance away. The mass of the dye is the same in the beginning and after traveling. The instrument used is called Fluorometer. The dye will automatically degrade and it does not affect the water body.

3.18. PREVENTIVE MAINTENANCE

Equipment has become more complex with the application of advanced technologies and automation systems in recent years. Thus, high technical knowledge is required and technicians, technical tools and special instruments are necessary for implementing preventive maintenance of the equipment. Unlike O&M contractors, manufacturers can provide such skilled staff and special tools. The manufactures can provide safe and secure maintenance based on their long experience and abundant information on their products. Preventive maintenance after expiry of warranty period should be availed from the manufacturers continuously.

A good maintenance programme is essential for a pumping station to operate continuously at peak design efficiency. A successful maintenance programme will cover everything from mechanical equipment, such as pumps, valves, scrapers and other moving equipment, to the care of the plant grounds, buildings and structures. For preventive maintenance, it is advisable to follow a schedule for the maintenance of the equipment.

The schedule covers recommendations for checks and remedial actions to be observed at different intervals such as daily, monthly, quarterly, bi-annually and annually.

Operators should receive training to obtain more knowledge of characteristics and structure of machinery and to improve their maintenance skill.

3.18.1. MECHANICAL MAINTENANCE

Mechanical maintenance is of prime importance, as the equipment must be kept in good operating condition for the plant to maintain peak performance. Manufacturers provide information on the mechanical maintenance of their equipment. Operators should thoroughly read manuals on the plant equipment, understand the procedures, and contact the manufacturer or the local representative if there are any questions. The instructions should be followed very carefully when performing maintenance on equipment. Operators also must recognise tasks that maybe beyond their capabilities or repair facilities, and should request assistance when needed.

3.18.2. MAINTENANCE OF CIVIL STRUCTURES

Building maintenance is another programme that should be maintained on a regular schedule. Buildings in a treatment plant are usually built of sturdy materials to last for many years. Buildings must be kept in good condition by repairs. For selecting paint for a treatment plant, it is always a good idea to have a painting expert help the operator select the types of paint needed to protect the buildings from deterioration. The expert also will have some good ideas as to colour schemes to help blend the plant in with the surrounding area. Consideration should also be given to the quality of paint. A good quality, more expensive material will usually give better service over a longer period of time than the economy-type products.

Building maintenance programmes depend on the age, type and use of a building. New buildings require a thorough check to ensure that essential items are available and are working properly. Older buildings require careful observation and prompt attention to detect leaks, breakdowns and replacements beforehand. Attention must be given to the maintenance requirements of many items in all plant buildings, such as electrical systems, plumbing, heating, cooling, ventilating, floors, windows, roofs, and drainage around the buildings. Regularly scheduled examinations and necessary maintenance of these items can prevent many costly and time-consuming problems in the future.

In each plant building, periodically check all stairways, ladders, catwalks and platforms for adequate lighting, head clearance, and sturdy and convenient guardrails. Protective devices should be around all moving equipment.

Whenever any repairs, alterations or additions are made, avoid building accident traps such as pipes laid on top of floors or hung from the ceiling at head height, which could create serious safety hazards.

Keep all buildings clean and orderly. Supervisory work should be done on a regular schedule.

All tools and plant equipment should be kept clean and in their proper place. Floors, walls and windows should be cleaned at regular intervals to maintain a neat appearance.

3.18.3. VALVE MAINTENANCE

Valves should be lubricated regularly (according to the manufacturer's instructions), and valve stems should be rotated regularly to ensure ease of operation. These activities should be part of a regular pump-maintenance programme.

3.18.4. ELECTRIC ACTUATOR MAINTENANCE

- Declutch and operate the manual hand wheel.
- Check oil level and top up, if required.
- Re-grease the grease lubricated bearing and gear trains, as applicable.
- Check the insulation resistance of the motor.
- Check for undue noise and vibration and take necessary rectification measures.
- Tighten limit switch cam ends. Check for setting and re-adjust, if necessary.
- Examine all components and wiring thoroughly and rectify as necessary.
- Change oil or grease in the gearbox and thrust bearing.
- Check the condition of the gears and replace them if teeth are worn out.

3.18.5. FLOW METER MAINTENANCE

Each individual sensing meter will have its own maintenance requirements.

The single most important item to be considered in sensor maintenance is good housekeeping. Always keep sensors and all instrumentation very clean. Good housekeeping and the act of providing preventive maintenance for each of the various sensors, includes ensuring that foreign bodies do not interfere with the measuring device. Check for and remove deposits that will build up from normal use. Repair the sensor or measuring device whenever it is damaged.

External connections between the sensing and conversion and readout devices should be checked to ensure such connections are clean and connections are firm. Be sure no foreign obstruction will interfere or promote wear. On mechanical connections, grease as directed; on hydraulic or pneumatic connections, disconnect and ensure free flow in the internal passage.

3.18.6. MAINTENANCE OF PUMPS

The maintenance schedule should list out items to be attended to at different periods, such as daily, semi-annually, annually and as needed.

3.18.6.1. DAILY OBSERVATIONS

- Leakage through packing
- Bearing temperature
- Undue noise or vibration
- Pressure, voltage and current readings

3.18.6.2. SEMI-ANNUAL INSPECTION

- Free movement of the gland of the stuffing box
- Cleaning and oiling of the gland bolts
- Inspection of packing and repacking, if necessary
- Alignment of the pump and the drive
- Cleaning of oil-lubricated bearings and replenishing fresh oil.

- If bearings are grease-lubricated, the condition of the grease should be checked and replaced with correct quantity, if necessary.
- An anti-friction bearing should have its housing packed with grease so that the void spaces in the bearings and the housing are 1/2 to 2/3 filled with grease. A fully packed housing will cause the bearing to overheat and will result in reduced life of the bearing.

3.18.6.3. ANNUAL INSPECTION

- Cleaning and examination of all bearings for flaws developed, if any
- Examination of shaft-sleeves for wear or scour.
- Checking clearances

Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearances indicate a drop in the efficiency of the pump. If the wear is only on one side, it means misalignment. Not only should the misalignment be corrected, but also the causes of the misalignment should be investigated and the clearances reset to the values recommended by the manufacturers. If the clearance on wear is seen to be 0.2 or 0.25mm more than the original clearance, the wearing ring should be renewed or replaced to obtain the original clearance.

These are to be done by the equipment representative.

- Impeller-hubs and vane-tips should be examined for any pitting or erosion.
- End-play of the bearings should be checked.
- All instruments and flow-meters should be re-calibrated.
- Pump should be tested to ensure proper performance is being obtained.
- In the case of vertical turbine pumps, the inspection can be bi-annual. Annual inspection is not advisable because it involves disturbing the alignment and clearances.

3.18.6.4. ANNUAL MAINTENANCE AND REPAIRS

- Consumables and lubricants
- Adequate stock of items as packing glands, belts, lubricating oils, greases should be maintained.
- Replacement of spares
- To avoid downtime, a stock of fast-moving spares should be maintained. A set of recommended spares for two years of trouble-free operation should be ordered along with the pump.

3.18.6.5. REPAIR WORKSHOP

The repair workshop should be equipped with tools such as bearing-pullers, clamps, pipe-wrenches, and other general-purpose machinery such as welding set grinder, blower, drilling machine, etc.

3.19. RECORD KEEPING

The purpose of recording data is to track operational information that will identify and avoid duplicating optimum operating conditions.

A record of equipment performance and repairs allow O&M personnel to properly evaluate equipment's effectiveness and determine if the equipment meets the objectives to justify its purchase and installation.

As a minimum, the following basic information should be maintained for each equipment in the pumping station:

- Plant equipment identification number
- Manufacturer

- Model number and serial number
- Type
- Dates of installation and removal from service
- Reasons for removal
- Location when installed
- Calibration data and procedures
- Hours required to perform maintenance
- Cost of replacement parts
- O&M manuals, references and their locations
- Apparatus failure history

Inspection reports should be prepared for each sewage pumping station according to the equipment installed.

An example of an annual inspection report for pumping station is shown in Table 3.2 overleaf.

Recommended maintenance/inspection tasks for equipment in pumping stations are summarised by frequencies and are listed in Table 3.3. Because the required maintenance / inspection and their frequencies may differ depending on the equipment installed, maintenance plans should be prepared according to manufacturer's instruction manuals of related equipment.

3.20. DUTIES OF SITE ENGINEER IN CHARGE AND HIGHER UPS

The site engineer should first check the entries of the operator in the previous three shifts and take corrective action, or alert the supervisor by e-mail and make an entry in the site register. If the site engineer cannot correct the problem within two weeks, he should directly send an e-mail message tothe plant incharge. If no action is taken even after two weeks, the complete responsibility will rest withthe plant incharge from then onwards, including the responsibility for any accidents/fatalities causedby not taking the requisite action.

3.20.1. IF THE PUMPING STATION IS UNDER O&M BY THE CONTRACTOR

The references to operator, site engineer and plant incharge inevitably apply to the staff of the contractor also. The engineer in charge of supervising the contractor's work should review the site register once a fortnight and institute such remedies as available under the contract.

Table 3.2 Annual inspection report for pumping station

Pumping station annual inspection report					
Date					
Mechanical	General condition of equipment				
	Sewage pump			Sump pump	Remarks
	No.1	No.2	No.3		
1. Pump					
Bearings					
2. Gates					
Gate operator (manual)					
Gate operator (motor)					
Stems					
3. Crane and hoist					
4. Siphon breaker					
5. Trash racks					
Drive chain					
Bearings					
Gear reducers					
Electrical	Date				
1. Motors					
2. Motor bearing					
3. Switchgear controls					
4. Control panels					
General					
1. Water levels	Elevation		Remarks		
Forebay					
Sumps					
Building and grounds	Date				
		Remarks			
1. Sump					
2. Forebay					
3. Discharge chamber					
4. Gatewell to river outlet					
5. Structure					
6. Fire extinguishers					
7. Tools and cabinets					
8. Painting					
9. Caulking					
10. Grating, rails and ladders					
11. Water system and plumbing					
12. Louvers and ventilators					
13. Windows					
14. Doors					
Remarks					

.

Table 3.3 Recommended maintenance for pumping equipment

	start up	monthly	3 month	6 month	1 year	5 year	Oper hrs
Trash rake		GI,O,CL			CL		
Motors				AL	PG	CL	
Heaters	GI						
Gear reducers		GI		CH			
Drive chain	PG						PG
Pillow blocks				PG			
Torque limit coupling					PG		
Shear pin & sprocket		GI					
Trip cam		GI					
Control panel					GI,CL		
Sub-station drainage					GI		
Building structure			GI				
Trash-rack				GI			
Toilet facility				GI			
Domestic water				GI			
Holding tank			GI		PO		
Siphon breakers			GI				
Unit heaters					GI		
Fire extinguishers		GI		GI			
Switch gear	GI						
Bus & connections					GI,CL		
Instruments & lamps	GI				GI,CL		
Heaters					GI		
Lighting panel	GI				GI		
Control panel	GI				GI		
Grounding					GRT		
Float control	GI				GI		
Main pump motors							
Entrance channel						GI,RS	
Sump					GI,RS		
Gates				GI,O,CL			
Stem	GI			CL,SG			
Thrust nut	GI			CL,SG			
Manual operators					PG		
Motor operators					GI,CL		

Legend

O	Operate	GRT	Ground resistance test	MR	Megger and record
CH	Change	TO	Test oil	PG	Pressure grease
CL	Clean	GI	General inspection	SG	Surface grease
AL	Add lubricant	PO	Pump out	TS	Test
RS	Remove silt	RC	Remove condensate		

PART C WASTE WATER MANAGEMENT

CHAPTER 4 REUSE AND RECYCLE OF WATER

4.1. INTRODUCTION

India is home to about 17% of the world population but only 4% of the world water resources. The Indian economy and society face daunting challenges in the water sector. The demands of a rapidly industrialising economy and urbanising society come at a time when the potential for augmenting supply is limited, water tables are falling and water quality issues have increasingly come to the fore. Both our rivers and our groundwater are polluted by untreated effluents and sewage continuing to be dumped into them. Besides, climate change poses fresh challenges with its impacts on the hydrologic cycle.

Efforts are required for effective and efficient water management to satisfy the various sector needs in the years to come. Wastewater recycling and reuse provides an opportunity to ease some of this stress. The major advantage is that an alternative and permanent resource is ensured allowing water shortages to be reduced, natural resources to be better conserved and water shortages caused by climate change to be alleviated.

4.2. WASTE WATER RECYCLING AND REUSE

Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin (ground water recharge). Water recycling offers resource and financial savings. Wastewater treatment can be tailored to meet the water quality requirements of a planned reuse. The use of grey water at decentralized sites for landscape irrigation and toilet flushing reduces the amount of potable water required for these applications.

Water reuse accomplishes three fundamental functions:

- Treated waste water is used as a water resource for beneficial purposes,
- Treated effluent is kept out of streams, lakes, etc, reducing the pollution of surface and ground water, and
- Protects public health.

Recycled water has many applications and can be used to fulfill most types of water needs, subject to the level of treatment provided to the waste water. Some common uses of recycled water are in:

- Agriculture
- Landscape
- Public parks
- Golf course irrigation
- Cooling water for power plants and oil refineries
- Processing water for mills, plants
- Toilet flushing
- Dust control
- Construction activities
- Concrete mixing
- Artificial lakes

Cities need to implement reuse and recycling options when designing their waste water treatment plants. Industrial use is a promising reuse sector but the large geographical size of Indian cities can be a challenge for safe conveyance of water for reuse or recycled water. Before progressing to reuse, cities also need to ensure proper treatment of sewage generated.

4.3. GUIDING PRINCIPLES

Though the possibilities of using treated sewage for various uses in other parts of the world are inspirational, still a blanket adoption in India needs to be tempered with local factors of affordability, sustainability and above all public acceptance. Moreover, each situation needs to be evaluated on its own and beyond the secondary treatment, all technologies are necessity driven. In India, treated sewage has historically been used for a variety of applications such as Farm Forestry, Horticulture, Fish culture and Indirect and incidental uses. The municipal waste water and industrial effluent are occasionally also being treated up to tertiary level and used for various purposes other than drinking by various industries and cities as part of dispersed initiatives. As such, there is a need to have a set of guidelines for the mentioned reuse prospects.

4.3.1 AGRICULTURE

Seventy percent of the water consumed around the world is used for agriculture. In some arid and semi-arid countries, the majority of irrigation water is recycled water. Over and above the usual factor of chronic water shortage, the need for an alternative water resource has accelerated over the last few years due to increasingly severe and repetitive droughts.

4.3.1.1 Key Principles

Following key principles should be paid attention before deciding use of treated sewage for agriculture:

4.3,1.1.1 Being an agrarian economy, this is a very compelling use for India, but should never be used for edible crops or plants that produce millets etc.

4.3.1.1.2. The use of untreated sewage for whatever form of agriculture leads to a situation where the treated sewage entering another basin from its parental basin creates issues of water rights and as far as possible, inter basin transfer of such reuse are not to be encouraged.

4.3.1.1.3 Agricultural use being more pertinent in rural settings, local sewage is best treated with stabilization ponds followed by maturation ponds.

4.3.1.1.4 Rotational crop pattern shall be investigated for an all the year round utilization and designed such that the runoff of treated sewage in summer is minimized.

4.1.1.1.5 As far as possible, manual direct handling shall be avoided and field channels are better suited as compared to sophisticated drip irrigation etc.

4.1.1.1.6 The discharge standard for disposal on land is prescribed by the MoEF.

4.1.1.1.7 Specific limitations on individual parameters when the treated sewage is to be considered for irrigation are addressed herein.

The quality of water for irrigation is determined by the effects of its constituents both on the crop and the soil. The deleterious effects of the constituents of the irrigation water on plant growth can result from

(i) Direct osmotic effects of salts in preventing water uptake by plants,

(ii) Direct chemical effects upon the metabolic reactions in the plant and

(iii) Any indirect effect through changes in soil structure permeability and aeration.

The suitability of the irrigation water is judged on the basis of soil properties, quality of irrigation water and salt tolerance behavior of the crop grown in a particular climate. The water quality ratings along with the specific soil conditions recommended are shown in Table 6.1 (overleaf).

These limits apply to the situations where the ground water table is always at 1.5m below the ground level. The values have to be reduced by half, if the water table comes up to the root zone.

If the soils have impeded internal drainage either on account of presence of hard stratum, unusually high amounts of clay or other morphologic reasons, the limit of water quality should again be deliberately reduced to half. In cases where canal irrigation exists during the lean period, treated sewage of higher electrical conductivity could be used.

TABLE 4.1 WATER QUALITY RATINGS

TABLE 4.1 WATER QUALITY RATINGS

Nature of soil	Crop to be grown	Permissible limit of Electrical Conductivity of water for safe irrigation (micro-mhos/cm)
Deep black soils and alluvial soils having a clay content more than 30%	Semi-Tolerant	1,500
Fairly to moderately well drained soils	Tolerant	2,000
Heavy textured soils having a clay content of 20-30%	Semi-Tolerant	2,000
Soils well drained internally and having good surface drainage system	Tolerant	4,000
Medium textured soils having a clay content of 10-20%	Semi-Tolerant	4,000
Soils very well drained internally and having good surface drainage system	Tolerant	6,000
Light textured soils having a clay content of less than 10%	Semi-Tolerant	6,000
Soils having excellent internal and surface drainage	Tolerant	8,000

Source: CPHEEO, 1993

TABLE 4.1 WATER QUALITY RATINGS

4.3.1.2 Osmotic Effects

When water is used for cultivation on land, some of it may run off as surface flow, or be lost by direct surface evaporation, while the remainder can infiltrate into the soil. Of the infiltrated water, a part of it can be for consumptive use, and part is held by the soil for subsequent evaporation and the remaining surplus percolates or moves internally through the soil. The water retained in the soil is known as the 'soil solution' and tends to become more concentrated with dissolved constituents as plants take relatively purer water. An excessive concentration of salts in the soil solution prevents water uptake by plants. Table 6.1 mentions the permissible levels of electrical conductivity (EC) and hence, total salts in water for safe irrigation in the different types of soils. It may be pointed out that good drainage of the soils may be a more important factor for crop growth than the EC of the irrigation water, as leaching of soils results in maintaining a low level of salt in soil solution in the root zone.

4.3.1.3 Toxic Effects

Individual ions in irrigation water may have toxic effects on plant growth. Table 6.2 lists some of the known toxic elements and their permissible concentration in irrigation waters when continuously applied on all soils and also when used on fine texture soils for short terms.

Table 4.2. Maximum permissible concentration of toxic elements in irrigation waters

Element		Maximum permissible concentration (mg/l)	
		On all soils in continuous use or acidic soils	For short term use of textured alkaline soils
Aluminium	Al	1.0	20.0
Arsenic	As	0.1	2.0
Beryllium	Be	0.1	0.5
Boron	B	0.5	1.0
Cadmium	Cd	0.01	0.05
Chromium	Cr	0.10	1.0
Cobalt	Co	0.05	5.0
Copper	Cu	0.2	5.0
Iron	Fe	5.0	20.0
Lead	Pb	5.0	10.0
Lithium	Li	2.5	2.5
Manganese	Mn	0.20	10.0
Molybdenum	Mo	0.01	0.01
Nickel	Ni	0.20	2.0
Selenium	Se	0.005	0.01
Vanadium	V	0.10	1.0
Zinc	Zn	2.0	10.0

Source: Environment Studies Board, 1973, CPHEEO, 1993

Many of these are also essential for plant growth. The suggested values for major inorganic constituents in water applied to land are presented in Table 4.3.

Table 4.4 Presents the suggested limits for salinity in irrigation waters.

Table 4.3 Suggested values for major inorganic constituents in water applied to the land
Source: IS: 10500

Problem and Related Constituent	Impact on the land		
	No problem	increasing Problem	Severe
Salinity			
Conductivity of Irrigation water (millimhos/cm)	< 0.75	0.75 – 3.00	> 3.00
Permeability			
Conductivity of Irrigation water (millimhos/cm)	< 0.50	< 0.50	< 0.20
Sodium absorption ratio (SAR)	< 18.0	18.0 - 26.0	26.0
Specific Ion Toxicity (from root absorption)			
Residual Sodium Carbonate (RSC), (meq/l)	< 1.25	1.25 – 2.5	> 2.5
Sodium (Na, %)	(A)	(A)	(A)
Chloride, meq/l	(B)	(B)	(B)
Chloride, mg/l	< 142.00	142.00 -355.00	> 355.00
Boron, mg/l	< 1	1– 4	> 4
Specific Ion Toxicity (from foliar absorption, sprinklers)			
Sodium (Na, %)	(C) < 40	(C) 40 - 60	(C) > 60
Chloride. meq/l	< 250	250 – 1,000	> 1,000
Miscellaneous			
NO_3(mg/l) for sensitive crops	(D)	(D)	(D)
pH	6.5 – 8.5		

Note:

A. No guidelines laid down, but increasing concentration affects soil structure and permeability

B. No guidelines laid down, but may have direct toxic effect with sodium

C. No guidelines laid down, but these are recommended values

D. No guidelines – it is an essential plant nutrient, but excess may delay the maturity of seed growth in some plants.

Table 4.4. Suggested limits for salinity in irrigation waters

Crop Response	TDS mg/L	EC, mhos/cm
No detrimental effects will usually be noticed	500	0.75
Can have detrimental effect on sensitive crops	500 – 1,000	0.75 - 1.50
May have adverse effects on many crops	1,000 – 2,000	1.50 - 3.00
Can be used for salt tolerant plants on permeable soils with careful management practices	2,000 – 5,000	3.00 - 7.50

Source: CPHEEO, 1993

4.3.1.4 Sodium Hazard

In most normal soils, calcium and magnesium are the principal cations held by the soil in replaceable or exchangeable form. Sodium tends to replace calcium and magnesium when continuously applied through irrigation water. An increase of exchangeable sodium in the soil causes deflocculating of soil particles and promotes compaction, thereby impairing soil porosity and the water and air relations of plants.

The sodium hazard of irrigation water is commonly expressed either in terms of percent soluble sodium (PSS) or sodium adsorption ratio (SAR). Generally the sodium hazard of soil increases with the increase of PSS or SAR of irrigation water and exchangeable sodium percentage of the soil. The maximum permissible value of PSS in irrigation water is 60. Where waters with higher PSS values are used, gypsum should be added to the soil occasionally for soil amendment. SAR values greater than 18 may adversely affect the permeability of soils.

4.3.1.5 Residual Sodium Carbonate

Hazardous effect of sodium is also increased, if the water contains bicarbonate and carbonate ions in excess of the calcium and magnesium. In such cases there is a tendency for calcium and magnesium to precipitate as carbonates from the soil solution and thereby increase in the relative proportion of exchangeable sodium. Values of residual sodium carbonate (RSC) less than 1.25mg/l are considered safe and above 2.5mg/l as unsuitable.

4.3.1.6 Organic Solids

While stable organic matter improves porosity of soil, thereby facilitating aeration, an excessive application of unstable organic matter would lead to oxygen depletion in the soil. Depositing of sediments especially when they consist primarily of clays or colloidal material may cause crust formations, which impede emergence of seedlings. In addition, these crusts reduce infiltration with the consequent reduction of irrigation efficiency and less leaching of saline soils.

4.3.1.7 Other Considerations

Soils are usually well buffered systems. The pH is not significantly affected by application of irrigation water. However, extreme values below 5.5 and above 9.0 will cause soil deterioration. Development of low pH values in soils promotes dissolution of elements such as iron, aluminium or manganese in concentrations large enough to be toxic to plant growth. Similarly, water having high pH values may contain high concentration of sodium, carbonates and bicarbonates, the effect of which has been discussed earlier.

Chlorides and sulphates are toxic to most crops in high concentrations. Ordinarily, the detrimental effects of salinity on crop growth become perceptible first. Excessively high or low temperature in irrigation water may affect crop growth and yields. A desirable range of water temperature is from 12 to 30°C.

4.3.2 GUIDING PRINCIPLES - FARM FORESTRY

Much of the provisions in Section 6.3.1 shall apply here also except that the SAR and RSC criteria may not be of serious importance. Besides, the non-water needs in rainy periods are to be borne in mind for diverting the treated sewage away from the farm forestry. It will be a better proposition to carry out all treatments at the STP itself and not split between STP and farm.

4.3.3 GUIDING PRINCIPLES - HORTICULTURE

Same as in Section 6.3.2 above, except that the TDS limit shall not exceed the TDS limit of the groundwater at any time and even if the RSC limitation is met, the alkalinity to be moved from bicarbonates to chlorides or sulphates to prevent scaling of the tender leaves and petals in high summer and also choking the soil pores by evaporation of the temporary hardness.

4.3.4 GUIDING PRINCIPLES - TOILET FLUSHING

Reusing bathroom and sink water for flushing and cleaning toilets results in significant impact on fresh water conservation

Considering that the Indian water closets when flushed can sprout and splash the flush water above the rim and onto the foot rest areas, it is necessary that such reuse shall be only after activated carbon and ultra filtration membranes. It shall not be made mandatory in layouts and confined condominiums and multiplexes and encouragement and persuasion shall be adopted, than a collision course or mandating it which is not justifiable by any means for if nothing else, sentimental reasons which rule high in Indian way of life. Similarly, small layouts being mandated to provide STP is to be viewed as decentralized sewerage and the sustainability of these by the proposed number of plot owners shall be assessed before sanctioning them, as otherwise, the policy of septic tanks on-site followed by twin drain shall be encouraged as a practical possibility. In any case, small layouts shall not be forced to erect reuse practices as absence of proper O&M can only create a mini epidemic of sorts.

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4.3.5 GUIDING PRINCIPLES - INDUSTRIAL AND COMMERCIAL

One of the greatest potentials for water reuse is to add to or to replace the use of drinking water and/or natural resources in industry. Industry is the second biggest water consumer after agriculture and accounts for around 25% of world's demand.

In general, the reduction of water demand in industry, up to and including the end of industrial water cycle, includes three water-saving strategies and the minimisation of wastewater discharge:

(1) Cascading reuse, involving direct reuse with little or no treatment;

(2) Recycling of water following suitable treatment;

(3) Wastewater reduction at source by reducing the water requirements of industrial processes.

Industrial wastewater reuse and internal recycling are well-established practices. Their development potential should increase in the future with the growth in water deficits and the supply costs of fresh water as well as increasingly stringent regulatory requirements regarding discharges.

Water reuse has been traditionally practised for years in the oil and gas, textile, car, paper and pulp and energy production industries and more recently in the electronic and food industries.

Although existing types of industrial water reuse are wide, the main uses are:

- Open or closed-circuit cooling systems,
- Cleaning water,
- Boiler feed water,
- Process water,
- Various other uses such as fire-fighting, cleaning, etc.

The requirements and areas of application of industrial water recycling depend upon the industry, specific industrial processes as well as their efficiency targets. For this reason, it is impossible to standardise quality requirements for recycled water as it is used for different purposes.

4.3.6 GUIDING PRINCIPLES - GROUNDWATER RECHARGE

At this point of time, the spread in the infiltration basins is fraught with many challenges as dust control, algae problems and essentially silica ingress into groundwater, in addition to the danger of the TDS and nitrate of applied sewage being higher than the TDS and nitrate of the groundwater. Further, financial ability of local bodies may not support this expenditure, which does not generate revenue except on a notional scale. On the contrary, if it is deep well injection on the lines of the first version of the Orange County plant, where injection wells were driven to about 100 m below ground to prevent seawater intrusion in water short coastal area, can be encouraged with appropriate safeguards.

4.3.7 GUIDING PRINCIPLES - INDIRECT REUSE AS POTABLE RAW WATER SOURCE

The indirect use of treated sewage has been going on in many ways and is detailed below. The reason that indirect water reuse is not to be considered to pose a health risk is that the treated wastewater benefits from natural treatment from storage in surface water and aquifers and is diluted with 'ordinary' river/ground water before abstraction to ensure good drinking water quality (part of a multi barrier approach in the water safety plan).The storage time provides a valuable buffer to measure and control quality.

4.3.7.1 Treated Sewage Into Perennial Rivers

When sewage is treated and discharged into perennial flowing rivers and the blended river water is drawn downstream of the point of such blending as raw water for treatment in public water supply schemes. This is indirect potable use after blending. This is historical and ongoing all around. However, of late, the organic load due to the discharged treated, partially treated and non point sewage becomes in excess of the self purifying capacity of the river. Thus, the river water is not actually fresh water. The water quality of Yamuna river for Agra water supply scheme requires to be first treated in MBBR to purify the river water to a level as raw water for the downstream WTP. When it passes through flowing surface water it has the potential disadvantages of contamination by human and animal activities adding organic matter and waterborne pathogens unless the river stretch is protected from such activities. The guiding principle in such cases for the ULBs will be to at least intercept the sewage outfalls and provide adequate STPs and follow the recommended quality criteria for the treated sewage.

4.3.7.2 Treated Sewage Into Non-Perennial/ Dry River Courses

There are locations where the rivers are not perennial or almost dry throughout the year except some monsoon runoff. In this case the discharged treated sewage sinks into the aquifer zone and is extracted by infiltration wells or galleries. The advantage of direct dilution from surface water is lost, but the additional purification in the soil and dilution from the aquifer water are happening. An example is the case of the Palar river course in Tamilnadu. The surface water flow in this occurs only for about a week if the monsoon is normal and if the water spills beyond the upstream impoundments. The aquifer however supports the public water supply of over 30 habitations along its dry tract of nearly 80 km before the sea. The partly treated sewage of the en route habitations do reach this river course at intervals. So far, no epidemics have been met with. This may be due to the above said additional purification in the soil and dilution by aquifer water. However, if these are exceeded by the contamination load, there can be immediate health problems. The guiding principle in such cases for the ULBs will be

(a) to keep a check on the raw water quality from the infiltration wells to detect sudden increase in contaminants and

(b) at least intercept the sewage outfalls and provide adequate STPs.

4.3.7.3 Treated Sewage Into Surface Water Reservoirs

This may occur when the surface water reservoirs receive the inflow from rivers and become impoundments from which the raw water is taken for public water supplies. Here also, the same position as in 6.3.7.1. would apply.

When it passes through reservoirs, it has the potential issues of evaporation losses and algae. The algae create taste and odour concerns and metabolic products of dead and decaying organisms as precursors which on chlorination are suspected to cause Trihalomethanes.

Upon chlorination, the residuals of insecticides and fertilizers are referred to as Endocrine Disruptor chemicals (EDCs) and this requires the use of Granular Activated Carbon filtration and sanitary protection of the catchments.

4.3.7.4 Treated Sewage Into Conjunctive Uses In Surface Water And Aquifer

Conjunctive use of surface water and aquifer water is also being practiced as a method of indirect potable reuse.

4.3.7.5 Treated Sewage Into Soil Zone And Reuse As Industrial /Agricultural Raw Water

This is referred to as Soil Aquifer Treatment (SAT). This indirectly conserves freshwater, which would have been otherwise used up in industry and agriculture. The

Chennai UNDP studies established the technical and financial feasibility of treated city sewage to be applied on spreading basin and the SAT water extracted from bore wells around the periphery for needs of petro-chemical industries some 20 km away. However, even after 2 decades, the proposal is yet to take shape. This is due to public fear of such recharge getting into contact with nearby freshwater aquifers used by the population and irreversibly contaminating them.

At the same time, similar schemes are successfully operated in many parts of the world for meeting the agricultural water needs notably in Israel and USA, where the proximity to habitations issues are not arising and engineered artificial sandy tracts are constructed amidst sand dunes. The issue here is to that extent, the freshwater is conserved and hence, this is also an indirect reuse. The guiding principle for ULBs in this case will be to ensure that such SAT is prima facie only after the sewage is treated to the limits as mentioned in Table 6.5.

In any case, an assessment of potential impacts on underlying groundwater aquifers shall be determined comprehensively by extensive public consultation processes.

Table 4.5 Recommended guidelines for treated sewage if discharged in to surface water to be used as source of drinking water

Parameter	MOEF Standards (A)	Recommended Values
BOD, mg/L	30	Less than 10
SS, mg/L	100	Less than 10
TN, mg/L	100	Less than 10
Dissolved P, mg/L	5	Less than 2
Faecal Coliforms, MPN/100 mL	Not specified	Less than 230

Source: General Standards, Environmental Protection Rule, 1986

4.3.7.6 Treated Sewage Deep Well Injection as Sea Water Intrusion Barrier

The seawater intrusion into inland coastal aquifers is a classic problem in many coastal locations. This occurs mainly due to the extraction of the fresh water from the fresh water lens beyond the safe yield limits. Once the seawater has intruded, this is not easy to be reversed. The Orange County Water District example in California, USA is perhaps the first in the world during the 1970s to demonstrate the use of tertiary treated, RO processed sewage to be blended with ground water and injected into a series of such barrier wells.

It is reported that there are over 600 such wells in USA on the east and west coasts. Though this may be technically possible, the issue is the costs involved in the extra treatment of Reverse Osmosis (RO) and disposal of RO rejects in to the sea after meeting the discharge limit mentioned in Table 6.5. In addition, the issues of consistent reliability of treated quality and safeguards of system redundancies also arise.The other issue is the cost comparison between the water conserved by such sea water intrusion barrier and that produced by sea water desalination with the added cost of distributing it all over the habitation by piping. In the case of the conserved water by seawater barrier injection, it is available for the user to extract it at his convenience right in the aquifer where he lives. Thus, the guiding principles in the case of seawater barrier injection option are primarily, public acceptance and the financial sustainability besides risk mitigation to get over system redundancies.

4.3.8 GUIDING PRINCIPLES - OTHER USES

These are already happening anyway and can be continued with appropriate safeguards, the essentials being the adequate chlorination to maintain residual chlorine of 0.5mg/l at the point of use and the colour to be aesthetically acceptable especially while applying in public places.

4.3.9. STANDARD OF TREATED SEWAGE AND ITS USES

In addition to the guiding principles mentioned earlier the recommended treated sewage quality as in Table 6.6 is proposed to be achieved for the stated uses. Hence, in order to achieve the desired water quality, excess chlorination, granular activated carbon adsorption / ozonation and /or various kind of filtration including membrane are recommended. For recreational impoundments for non-human contact, residual chlorine is not required so as to protect aquatic species of flora and fauna.

Table 4.6 recommended norms of treated sewage quality for specified activities at point of use

	Parameter	Toilet flushing	Fire protection	Vehicle Exterior washing	Non-contact impoundments	Landscaping, Horticulture & Agriculture			
						Horticulture, Golf course	crops		
							Non edible crops	Crops which are eaten	
								raw	cooked
1	Turbidity (NTU)	<2	<2	<2	<2	< 2	AA	< 2	AA
2	SS	nil	nil	nil	nil	nil	30	nil	30
3	TDS	2100							
4	pH	6.5 to 8.3							
5	Temperature °C	Ambient							
6	Oil & Grease	10	nil	nil	nil	10	10	nil	Nil
7	Minimum Residual Chlorine	1	1	1	0.5	1	nil	nil	nil
8	Total Kjeldahl Nitrogen as N	10	10	10	10	10	10	10	10
9	BOD	10	10	10	10	10	20	10	20
10	COD	AA	AA	AA	AA	AA	30	AA	30
11	Dissolved Phosphorous as P	1	1	1	1	2	5	2	5
12	Nitrate Nitrogen as N	10	10	10	5	10	10	10	10
13	Faecal Coliform in 100 ml	Nil	Nil	Nil	Nil	Nil	230	Nil	230
14	Helminthic Eggs / litre	AA	AA	AA	AA	AA	<1	<1	<1
15	Colour	Colourless	Colourless	Colourless	Colourless	Colourless	AA	Colourless	Colourless
16	Odour	Aseptic which means not septic and no foul odour							

All units in mg/l unless specified; AA- as arising when other parameters are satisfied;

A tolerance of plus 5% is allowable when yearly average values are considered.

However, for use in Wetlands, Wildlife habitat and Stream augmentation the recommended water quality in Table 6.7 for inland surface water discharge suffices the purpose. For uses in the construction industry like (a) Soil compaction, (b) Dust control, (c) Washing aggregate the recommended water quality in Table 6.7 for inland surface water discharge guidelines are sufficient. While for preparing concrete mix, the acidity < 50 mg/L as $CaCO_3$, SO_4 < 400 mg/L, TDS < 3,000 mg/L, Chloride < 500 mg/Lrespectively as in IS: 456 are to be considered.

Table 4.7 Use based classification of surface waters in India(All values are in mg/l unless otherwise specified therein)

Class	Designated best use	Criteria	Limits
A	Drinking water source without conventional treatment but after disinfection	pH	6.5 to 8.5
		Dissolved Oxygen (D O)	6 or more
		BOD	2 or less
		Total Coliform MPN / 100 ml	50 or less
B	Outdoor bathing (organized)	pH	6.5 to 8.5
		Dissolved Oxygen (D O)	5 or more
		BOD	3 or less
		Total Coliform MPN / 1000 ml	50 or less
C	Drinking water source with conventional treatment followed by disinfection	pH	6.5 to 8.5
		Dissolved Oxygen (D O)	4 or more
		BOD	3 or less
		Total Coliform, MPN / 1000 ml	5000 or less
D	Propagation of wild life and fisheries	pH	6.5 to 8.5
		Dissolved Oxygen (D O)	4 or more
		Free Ammonia	1.2 mg/l or less
E	Irrigation, industrial cooling, and controlled waste disposal	pH	6.0 to 8.5
		Electrical Conductivity, micro mhos/cm	< 2250
		Sodium Absorption Ratio (SAR)	< 26
		Boron	< 2 mg/l

Source: The Environment (Protection) Rules, 1986 in http://cpcb.nic.in/GeneralStandards.pdf

4.3.7 PUBLIC EDUCATION

Education is the key to overcoming public fears about a reuse system, particularly fears that relate to public health and water quality. Abroad, in-depth public relations programme and a demonstration project are especially helpful when the reuse project is the first of its kind in the state.

4.3.8 PIPING AND CROSS-CONNECTION CONTROL

A residual chlorine > 0.5 mg/l in the distribution system is recommended to reduce odours, slime and bacterial growth (US EPA2004). It is crucial to be able to differentiate between piping, valves and outlets that are used to distribute treated effluent or reclaimed water and those that are used to distribute potable water. One method used for this purpose is colour-coding the components used to distribute reclaimed water not intended for drinking water. Another method is to post areas such as parks and yards with warning signs stating that the piped water there is not for human consumption. The signages should be in all the major languages of the region.

Table 4.8 Contribution of human wastes in grams per capita per day

Parameters					Range
1	Biochemical oxygen demand, BOD				45-54
2	Chemical oxygen demand, COD				1.6-1.9 times BOD
3	Total organic carbon, TOC				0.6-1.0 times BOD
4	Total solids, TS				170-220
5	Suspended solids, SS				70-145
6	Grit (inorganic,0.2 mm and above)				5-15
7	Grease				10-30
8	Alkalinity as calcium carbonate ($CaCO_3$)				20-30
9	Chlorides				4-8
10	Total nitrogen N				6-12
11	Organic nitrogen				~0.4 total N
12	Free ammonia				~0.6 total N
13	Nitrate				~0.0-0.5 total N
14	Total phosphorus				~0.6-4.5
15	Organic phosphorus				~0.3 total P
16	Inorganic(ortho- and poly-phosphates)				~0.7 total P
17	Potassium(as potassium oxide K_2O)				2.0-6.0
Microorganisms in 100 ml of sewage					
18	Total bacteria	10^9-10^{10}	22	Protozoan cysts	Up to 10^3
19	Coliforms	10^9-10^{10}	23	Helminthic eggs	Up to 10^3
20	Faecal streptococci	10^5-10^6	24	Virus (plaque forming units)	10^2-10^4
21	Salmonella Typhosa	10^1-10^4			

Source: Arceivala, 2000

PART C WASTE WATER MANAGEMENT

CHAPTER 5 ELECTROMECHANICAL ITEMS

5.1. GENERAL

Quality Control is a series of activities systematically carried out to fulfill requirements of quality for the procurement of materials and works. Quality control is used to verify that the product delivered are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, close review of the product and the testing process. Quality Control is an essential part of any production. Quality control is required in infrastructure development also, such as in water supply sector.

This section is prepared to provide a base document to effect quality control in the electro-mechanical works / such component in various works carried out by Kerala Water Authority. This is intended to enable the engineers and supervisory staff to check the different activities of electro-mechanical works with reference to the quality aspects and ensure that standards envisaged are achieved.

5.2. GOALS OF QUALITY CONTROL IN ELECTRO-MECHANICAL WORKS.

5.2.1. Quality control aims to ensure quality of the installed products as per the standards.

5.2.2. The activities or techniques used to achieve and maintain the product quality, process and service comes under quality control.

5.2.3. Quality control is exercised by finding and eliminating causes of quality problems through tools and equipment so that user requirements are satisfied.

5.3. QUALITY CONTROL SYSTEM FOR ELECTRO-MECHANICAL WORKS.

KWA shall follow a three-tier quality control system for ensuring quality of electro-mechanical works executed. This includes technical audit after completion of construction. The system envisaged is as below:

5.3.1. FIRST TIER QUALITY TESTING.

In first-tier Quality Control testing, the Contractor has to carry out the required tests at his own cost during the course of a work. First tier quality control tests are mandatory for all projects including maintenance and repair works. If any test cannot be carried out with the facilities available with the Contractor, it shall be got done in an approved laboratory by the Contractor at his own cost.

If the QC test is done in the field laboratory established at site, the test results shall be signed by the Overseer/Assistant Engineer, whoever is supervising the work. It shall also be signed by the Contractor. Copy of test results shall be forwarded by the Assistant Engineer to the Assistant Executive Engineer/Executive Engineer concerned for review.

5.3.2. SECOND TIER QUALITY TESTING.

Second-tier Quality Control checks / tests are to be done by the Electrical and Mechanical quality control units of KWA on a random basis. However, it is desirable that the Quality Control unit does quality control tests for all major and important items of electro-mechanical installation. The frequency of tests shall be as given in this Manual or as specified in the Contract. The electrical and mechanical quality control unit is authorized to inspect all projects of electro-mechanical works undertaken by KWA, including maintenance and repair works, irrespective of the estimated cost and conduct quality tests.

5.3.3. THIRD TIER QUALITY TESTING.

In the third tier of quality testing, technical audit shall be done by an external agency/expert empanelled for the purpose after the electro-mechanical work is completed. All tests carried out in the first tier and second-tier quality control testing shall be reviewed during technical audit. Technical Audit shall be completed within six months from the date of installation of electro-mechanical component.

5.3.4. MANDATORY TWO-TIER QUALITY CONTROL.

5.3.4.1. Two-tier design and document quality control is mandatory for all pumps / replacement of pumps for which the power capacity calculated based on design duty conditions and specified pump efficiency exceeds 50HP.

5.3.4.2. Two-tier quality control including design and document control is mandatory for all pumps / replacement of pumps for which the power capacity calculated based on design duty conditions and specified pump efficiency exceeds 100HP.

5.3.4.3. Two-tier quality control including design and document control is mandatory for all the electro-mechanical components of the water treatment plants for which the capacity exceeds 50mld.

5.3.4.4. Two-tier quality control including design and document control is mandatory for all the electrical sub-stations / sub-systems of electrical substations.

5.3.4.5. Two-tier quality control including design and document control is mandatory for all replacement of transformers.

5.3.5. THIRD PARTY TESTING.

Third party testing is carried out by an independent agency other than KWA or the Contractor. This is required when the Contractor raise a dispute due to difference in the test results of first tier and second-tier testing or certain specific tests cannot be carried out with the facilities available in the Contractor's or Department laboratories or existence of manipulated results are suspected.

The Executive Engineer (Electrical / Mechanical – Quality Control) shall decide whether a third part testing is required to settle the dispute. If so, he shall issue a written direction to carry out a test by another approved agency. The test shall be arranged to be done in the presence of the Assistant Executive Engineer/Assistant Engineer and the Contractor. The result obtained in this test shall be final and binding on both the Contractor and the Department. The expenses for third party testing shall be met by the Contractor. Third-party testing is expected to provide a nonbiased view and thus a better confidence in the test results.

With respect to the methodology of independent testing, the following aspects are important in order to achieve the right quality:

5.3.5.1. The agency must be able to choose and apply the test method that provides a technically correct answer to the problem.

5.3.5.2. The testing must be performed efficiently, also in such a way that delivery times can be met and costs and charges minimized.

5.3.5.3. The agency must be able to provide reliable results with accuracy appropriate to the needs.

5.3.5.4 The testing agency must have the necessary expertise available to be able to assist in the evaluation of the test results and to provide other relevant technical services of an advisory nature.

v) The reports and presentations of the results must be clear and complete.

5.4. ORGANIZATIONAL SET-UP FOR IMPLEMENTATION OF QUALITY CONTROL OF ELECTRO-MECHANICAL SYSTEMS.

5.4.1. MECHANICAL.

Mechanical Quality Control Lab shall be set up for the ensuring quality of the mechanical installations in KWA. The labs shall have amenities like building, testing equipment, vehicles, computers, and software etc. The activities of the lab shall be monitored by the Executive Engineer (Mechanical – Quality Control). Two Assistant Executive Engineers (Mechanical – Quality Control) and four Assistant Engineers (Mechanical – Quality Control) shall be appointed for assisting the Executive Engineer (Mechanical). All the Engineers should have relevant qualification in the Mechanical branch of Engineering.

The Executive Engineer (Mechanical – Quality Control) shall conduct quarterly review the Quality Control activities and submit a report, including recommendations for the betterment of quality control activities, to the Technical Member.

5.4.2. ELECTRICAL.

Electrical Quality Control Lab shall be set up for the ensuring quality of the electrical installations in KWA. The labs shall have amenities like building, testing equipment, vehicles, computers, and software etc. The activities of the lab shall be monitored by the Executive Engineer (Electrical – Quality Control). Two Assistant Executive Engineers (Electrical – Quality Control) and four Assistant Engineers (Electrical – Quality Control) shall be appointed for assisting the Executive Engineer (Electrical). All the Engineers should have relevant qualification in the Electrical branch of Engineering.

The Executive Engineer (Electrical – Quality Control) shall conduct quarterly review the Quality Control activities and submit a report, including recommendations for the betterment of quality control activities, to the Technical Member.

5.5. INTIMATION TO THE MECHANICAL / ELECTRICAL QUALITY CONTROL UNIT

Agreement Authority shall forward copy of contract documents to the concerned Executive Engineer, quality control unit within 10 days of executing agreement. The Assistant Executive Engineer in charge of the work shall ensure that the date of commencement of each item of work is intimated in a timely manner to the concerned Executive Engineer of the quality control unit for arranging second-tier quality control testing.

5.6. TECHNICAL COMMITTEE

5.6.1. The Technical Committee, chaired by the Technical Member, and all the Chief Engineers of KWA as members, shall give timely instructions for effective implementation of the quality control system in KWA. The Technical Committee shall also consider the reports / recommendations submitted by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same and recommend suitable action to the Managing Director / Authority for the effective implementation of quality control / betterment of quality control activities of electro-mechanical works in KWA.

5.6.2. The Technical Committee shall also consider the electro-mechanical quality control formats / checklist newly prepared / modified and submitted by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

5.6.3. The Technical Committee shall consider the recommendations submitted by the Executive Engineer (Electrical / Mechanical – Quality Control) regarding blacklisting of manufacturers of poorly performing material / equipment component and recommend the Managing Director / Authority for suitable action.

5.6.4. The Technical Committee shall consider the lists of electromechanical materials / equipment components for which manufacture certificate / KWA team or third-party inspection is required, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

5.6.5. The Technical Committee shall consider the methodology to be adopted for the random selection / frequency of quality assurance activities for the procurement of materials / works for which the two-tier quality control is not mandatory as per clause no. 3.4, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

5.6.6. The Technical Committee shall consider the list of agency / experts / laboratories to be empaneled for third tier quality testing, newly prepared / recommended for revision, by the Executive Engineer (Electrical / Mechanical – Quality Control), scrutinize the same, and recommend for concurrence / approval / suitable action by the Managing Director / Authority.

5.7. TECHNICAL SPECIFICATIONS AND SPECIAL CONDITIONS OF CONTRACT DOCUMENT

5.7.1. DUTY CONDITIONS / TECHNICAL SPECIFICATIONS.

The quality of the electro-mechanical works in KWA shall be ensured based on the technical specification as per contract requirements and as per the latest edition of the relevant Indian / International Standards. The duty conditions / technical specification shall be finalized as per the design requirement for each individual work and a detailed account of the same shall be incorporated into the contract document, including drawings.

5.7.2. TECHNICAL SPECIFICATIONS / SPECIAL CONDITIONS.

The Technical Specification / Special Conditions of Contract Document shall be prepared in accordance with the Indian Electricity Act / Indian Electricity Rules / Central Electricity Authority Regulations / Guidelines of Department of the Electrical Inspectorate, Government of Kerala and other applicable Acts, Rules, Regulations and Guidelines.

5.8. INSPECTIONS AND TESTS

Materials and components to be incorporated into electro-mechanical works shall be inspected as soon as they are delivered, to ensure that they meet the specifications and design requirements, are in agreement with shipping documentation, and are accompanied by manufacturers certifications or third-party inspection certificates, as applicable. Accepted materials and equipment shall be properly stored until needed. If manufacturers installation instructions conflict with design or contract requirements, installation shall proceed only after the conflict has been resolved.

A series of inspections and tests during installation and at the completion of electro-mechanical works shall be performed as follows:

- **Preparatory Inspections:** Prior to installation, the Civil and Structural works where electro-mechanical equipment is to be installed shall be inspected to ensure conformance with designs and equipment installation requirements.

- **Installation Inspections and Tests:** A system of inspections and tests, as specified in the contract or recommended by the equipment manufacturer, shall be employed throughout movement to position and installation of equipment and systems. Inspections shall be performed at critical points during installation. Surveillance shall be provided throughout the progress of the work to ensure that installation is performed in accordance with the requirements and specifications, approved drawings, acceptable workmanship standards and configuration control requirements. All field modifications and retrofit work shall be performed under strict surveillance.
- **Installation Verification Inspections:** Prior to all mechanical and electrical testing, verification inspections shall be performed to ensure that equipment has been satisfactorily installed.
- **System Tests:** These tests shall be conducted as appropriate to demonstrate that the installed systems are free from damage due to shipment and installation, and that equipment performs in accordance with specifications.
- **Integrated Tests:** After completion of system tests, integrated tests shall be performed to demonstrate that the system performs satisfactorily when connected to its interfacing systems or sub-systems. These tests will be followed by commissioning tests.
- **Commissioning Tests:** These consists of a series of tests performed under service operating procedures to demonstrate compatibility of the physical plant with operating procedures.
- **Final Inspections:** Final Inspections shall be performed to ensure that the completed work is in accordance with the requirements and specifications, and that all previously identified discrepancies have been resolved satisfactorily.

5.9. CONTROL OF ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENTS

This article provides and overview of control requirements for electro-mechanical materials and equipment components, including manufacturer's certification and KWA team / third-party inspection.

5.9.1. QUALITY ASSURANCE ELECTRO-MECHANICAL MATERIAL / EQUIPMENT COMPONENT

The Quality assurance process is needed to ensure process quality during manufacturing and inspection stage in order to satisfy the standards of quality laid down and to meet the purpose for which it is being procured.

5.9.1.1. The Engineer in charge shall ensure that the materials / equipment which are intended to be procured have been manufactured as per the relevant BIS/International standards & technical specifications and as per the contract requirement. To achieve the same, the bid document should specify the standards, details of inspection and tests to be carried and stages and manner for carrying out the same.

5.9.1.2. Inspection has to be resorted to wherever necessary to ensure that the quality, functions etc. of the materials and equipment to be procured comply with specifications as per the contract requirement. The Inspecting Engineer shall be conversant with the materials / equipment, its specifications & Standards.

5.9.1.3. The Engineer authorized to receive materials and equipment should satisfy himself that the materials / equipment is in conformity with the specifications as per the contract requirement. Any materials / equipment which do not conform to specification or not as per approved samples or which is damaged or defective in any respect should summarily be rejected.

5.9.2. INSPECTION

Inspection has to be resorted to wherever necessary to ensure that the quality, functions etc. of the materials / equipment to be procured comply with specifications as per the contract requirement. Any discrepancy, defects, deviations etc. noticed during testing shall be duly notified to the Manufacturer in writing in order to attend the same as per the conditions in the contract document.

Depending on the nature of materials / equipment being procured, usually, the following types of inspection may be adopted.

5.9.2.1. Stage Inspection:

This type of inspection has to be conducted for materials / equipment having long manufacturing process and for which quality of each component has to be ensured during manufacturing process such as Power Transformers, Circuit Breakers etc. These inspections may be carried out as many times as required for the materials / equipment.

5.9.2.2. Prototype Inspection:

In a contract containing bulk quantity for particular materials / equipment of major equipment / items, a prototype inspection shall be conducted as per approved drawings and guaranteed technical specifications before issuing sanction for bulk manufacturing. This procedure is preferred for all new designs proposed by manufacturers.

5.9.2.3. Pre-Dispatch Inspection:

When the materials / equipment to be procured are ready for Factory inspection the purchaser will witness the various factory acceptance tests as per approved Factory Acceptance Test procedures. Only after successful completion of the factory acceptance test, the clearance for dispatch of materials / equipment shall be issued.

5.9.2.4. Inspection of materials and equipment components on receipt at consignee's / user's premises:

Such inspection is done on receipt of materials / equipment at site before accepting the same against the quantity and quality ordered as per the specification and standards. Also, samples will be taken and sent for Site Acceptance Tests, if required, as per the Site

Acceptance Test procedures. Only materials / equipment accepted as above shall be utilized for works.

5.9.2.5. Post installation Inspection:

The inspection of the materials / equipment installed at site shall be carried out by competent authority for checking its readiness for commissioning and discrepancies noticed shall be recorded and brought to the notice of contractor / manufacturer.

5.9.2.6. Testing & Commissioning of the materials and equipment components:

The functional performance and output of the materials / equipment shall be ascertained during the testing and commissioning of the same as per the Guaranteed Technical Particulars specified as per contract requirements.

5.9.2.7. Inspection Test procedures and Formats:

All Test procedures as per relevant standards shall be submitted by the contractor / manufacturer to the Engineer in charge in advance along with the inspection call letter for approval.

Complete lot of the materials / equipment or designated batches of materials / equipment as per contract shall be offered for inspection, as per the delivery schedule in the contract. All cost of testing equipment, tools, manpower, goods etc. used during any of the above inspection/testing shall be the responsibility of the contractor as a part of the contract.

5.9.2.8. Outside Testing Laboratories:

If necessary to conduct type test, acceptance test or special test at outside laboratories, when facilities for these tests are not available in-house with the contractor or KWA, he may obtain prior approval of the testing lab from the Engineer in charge along with required Test procedures and formats. Cost of such tests also would be borne by the contractor.

5.9.3. INSPECTION AND DISPATCH

The Inspecting Engineer after inspection of the materials / equipment should submit a sealed Inspection Report along with inspection summary with specific recommendation for acceptance / rejection immediately after satisfactory completion of inspection and witnessing tests. Representatives of both contractor / Manufacturer and the Authorized Engineer shall sign the test/inspection reports in proof of the testing/inspection carried out. The inspected materials / equipment, if required as per the contract requirement, shall be stamped, labelled, marked, or sealed, in such a way as to make subsequent identification of accepted lots. Rejection notes shall be issued by the Engineer in charge immediately for the materials / equipment not meeting the contract requirements.

5.9.4. ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENTS TO BE CERTIFIED BY MANUFACTURER.

Acceptance of certain manufactured materials and equipment components, as stipulated in the contract, shall be based on test certificates from the manufacturer conforming to relevant Indian / International Standards. Materials and equipment components conforming to Indian standards shall invariably bear ISI mark. The Engineer in charge of the work shall review the manufacturer's certificates for conformance to contract requirements before these items are delivered to the site. Upon their delivery and before their installation or otherwise incorporation in the works, the Engineer in charge of the works shall inspect the condition of these items. It may be decided to test the delivered items by another agency or laboratory. The cost of such tests shall be borne by the contractor.

Following is a sample list of materials and equipment component subject to be certified by the manufacturer. The sample list is only for guidance purpose.

- Flow-measuring devices – General.
- Batteries.
- Firefighting equipment.
- All other electro-mechanical items as required by the contract.

5.9.5. ELECTRO-MECHANICAL MATERIALS AND EQUIPMENT COMPONENT TO BE INSPECTED BY THE KWA TEAM / THIRD PARTY.

Materials and equipment to be inspected by KWA team / third party may vary from work to wok and package to package, as required by the contract. KWA team / third party inspection should normally take place at factory during or upon completion of manufacture. Before site delivery, the Engineer in charge shall review the KWA team / third-party inspection certificates for conformance to the contract requirements. Upon delivery and before installation or incorporation in the works, the Engineer in charge shall inspect the physical condition of these items, and if necessary, test them on site. Inspection criteria should be stipulated in the contract document.

Following is a sample list of materials and equipment to be inspected by KWA team / third party, normally done at the manufacturing facility, during or upon completion of manufacture. The sample list is only for guidance purpose.

- Flow-measuring devices – Special.
- Cranes and lifting tackles.
- Electrical Cables – Special.
- Butterfly Valves.
- Sluice Valves.
- Reflux Valves.
- Air Valves.
- Control Valves.
- Vertical Turbine Pumps / Centrifugal Pumps / Other Pumps.
- Motors.
- Electrical Starters.
- Power Transformers.
- Switch Boards (HV/MV/LV)
- Battery Chargers.
- Motor Control Center.
- Indication-cum-enunciation panel.

- Capacitors.
- Sluice Gates.
- All other electro-mechanical items as required by the contract.

5.10. DESIGN QUALITY CONTROL

The duty conditions and technical specification of the material / equipment component shall be arrived at after collecting all the relevant data and proper analysis and shall be in agreement with related specifications of other components of the system. The same shall be finalized only after detailed design based on results of the analysis of the all the relevant data. Detailed drawings and technical specifications shall be prepared to describe the proper assembly / installation of the material / equipment component.

5.11. MATERIAL / EQUIPMENT COMPONENT / SYSTEMS IN WHICH SCOPES OF BOTH THE ELECTRICAL AND MECHANICAL QUALITY CONTROL UNITS ARE INVOLVED.

Material / equipment component / systems for which scope of both the electrical and mechanical quality control units are involved, a committee of Executive Engineer (Electrical – Quality Control) and Executive Engineer (Mechanical – Quality Control) shall be responsible for the quality control activities.

5.12. PERFORMANCE QUALITY.

The performance of the electro-mechanical materials shall be monitored by the Engineer in charge for the warranty period or for two years after installation / commissioning, whichever is maximum. The Executive Engineer (Electrical / Mechanical – Quality Control) shall keep a track of such reports / checklists and recommend the manufacturers whose material / equipment component has frequent unsatisfactory performance, for blacklisting. Such recommendations of blacklisting of manufacturers with poorly performing material / equipment component shall be submitted to the Technical Member.

5.13. QUALITY CONTROL METHODS.

5.13.1. THE QUALITY OF ELECTRO-MECHANICAL WORKS SHALL BE ENSURED THROUGH, BUT NOT LIMITED TO, THE FOLLOWING METHODS.

- Obtaining manufacturer certificates.
- KWA team / Third party inspection.
- Random inspection by Electrical / Mechanical quality control units.
- Maintaining quality assurance check lists for procurement of electro-mechanical materials / equipment.
- Maintaining quality assurance check lists for installation / maintenance of electro-mechanical material / equipment works.

5.13.2. The formats / check lists for procurement / installation / maintenance of various electro-mechanical materials / equipment shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The formats / check lists shall be updated, revised, and documented whenever found necessary. The formats / check lists thus prepared shall be submitted to the Technical Member for concurrence / approval.

5.13.3. Lists of electromechanical materials / equipment components for which manufacture certificate / KWA team or third-party inspection is required, shall be prepared, and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The lists shall be updated, revised, and documented whenever found necessary. The lists thus prepared shall be submitted to the Technical Member for concurrence / approval.

5.13.4.. The methodology to be adopted for the random selection / frequency of quality assurance activities for the procurement of materials / works for which the two-tier quality control is not mandatory as per clause no.3.4, shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The methodology / frequency of activities shall be updated, revised, and documented whenever found necessary. The methodology / frequency of activities thus prepared shall be submitted to the Technical Member for concurrence / approval.

5.13.5. The list of agency / experts / laboratories to be empaneled for third tier quality testing shall be prepared and documented by the Executive Engineer (Electrical / Mechanical – Quality Control). The list shall be updated, revised, and documented whenever found necessary. The lists such prepared shall be submitted to the Technical Member for concurrence / approval.

5.13.6. The Executive Engineer (Electrical / Mechanical – Quality Control) shall ensure that all the necessary formats / check lists / data entry modules / report generation facility related to quality control are incorporated into the software.

5.14. SAMPLE CHECK LISTS FOR ELECTROMECHANICAL WORKS.

Sample checklist for electrical and mechanical works are given below. The sample checklists are only for guidance purpose.

5.14.1. SAMPLE CHECK LIST FOR ELECTRO-MECHANICAL WORKS WHICH INVOLVES PROCUREMENT OF MATERIALS / EQUIPMENT COMPONENT WHICH REQUIRES MANUFACTURER CERTIFICATE.

Sl. No.	Particulars.	Conformity.	Remarks.
1.	The material / equipment component was packed and forwarded properly.	Yes / No / Not Applicable.	
2.	The material / equipment component was received at site in good condition.	Yes / No / Not Applicable.	
3.	The manufacturer has provided certification regarding the quality / conformity of the material / equipment with the	Yes / No / Not Applicable.	

	relevant standards / conformity of factory acceptance tests.		
4.	The certificate provided by the manufacturer is in the prescribed format and acceptable.	Yes / No / Not Applicable.	
5.	The material / equipment satisfies all the parameters of the site acceptance tests.	Yes / No / Not Applicable.	
6.	The results of preparatory inspections carried out at place of installation were satisfactory.	Yes / No / Not Applicable.	
7.	The results of installation inspections and tests carried out during the installation were satisfactory.	Yes / No / Not Applicable.	
8.	The results of installation verification inspections carried out after the installation were satisfactory.	Yes / No / Not Applicable.	
9.	The results of system tests carried out were satisfactory.	Yes / No / Not Applicable.	
10.	The results of integrated tests carried out were satisfactory.	Yes / No / Not Applicable.	
11.	The results of commissioning tests carried out were satisfactory.	Yes / No / Not Applicable.	
12.	The results of final inspections carried out were satisfactory.	Yes / No / Not Applicable.	
13.	The work was carried out in accordance with the relevant	Yes / No / Not Applicable.	

	Acts / Rules / Regulations / Guidelines.		
14.	The material / equipment was successfully / satisfactorily commissioned.	Yes / No / Not Applicable.	

5.14.2. SAMPLE CHECK LIST FOR ELECTRO-MECHANICAL WORKS WHICH INVOLVES PROCUREMENT OF MATERIALS / EQUIPMENT COMPONENT WHICH REQUIRES KWA TEAM / THIRD PARTY INSPECTION.

Sl. No.	Particulars.	Conformity.	Remarks.
1.	The material / equipment satisfies all the parameters of Factory Acceptance Test during the tests at the manufacturer facility.	Yes / No / Not Applicable.	
2.	The material / equipment was packed and forwarded properly.	Yes / No / Not Applicable.	
3.	The material / equipment was received at site in good condition.	Yes / No / Not Applicable.	
4.	The technical specification / performance curves of the material / equipment provided by the manufacturer agrees with the duty conditions specified in the contract.	Yes / No / Not Applicable.	

5.	The material / equipment satisfies all the parameters of the site acceptance tests.	Yes / No / Not Applicable.	
6.	The results of preparatory inspections carried out were satisfactory.	Yes / No / Not Applicable.	
7.	The results of installation inspections and tests carried out during the installation were satisfactory.	Yes / No / Not Applicable.	
8.	The results of installation verification inspections carried out after the installation were satisfactory.	Yes / No / Not Applicable.	
9.	The results of system tests carried out were satisfactory?	Yes / No / Not Applicable.	
10.	The results of integrated tests carried out were satisfactory.	Yes / No / Not Applicable.	
11.	The results of commissioning tests carried out were satisfactory.	Yes / No / Not Applicable.	
12.	The results of final inspections carried out were satisfactory.	Yes / No / Not Applicable.	
13.	The work was carried out in accordance with the relevant Acts / Rules / Regulations / Guidelines.	Yes / No / Not Applicable.	
14.	The material / equipment was successfully / satisfactorily commissioned.	Yes / No / Not Applicable.	

5.14.3. SAMPLE CHECK LIST FOR DESIGN QUALITY CONTROL.

Sl. No.	Particulars.	Conformity.	Remarks.
1.	Sufficient data for the design / determination of technical specifications / duty conditions was collected.	Yes / No / Not Applicable.	
2.	Proper analysis of the collected data was carried out.	Yes / No / Not Applicable.	
3.	Design / drawings were prepared in accordance with the relevant Indian / International standards / accepted norms / guidelines / manuals.	Yes / No / Not Applicable.	
4.	Duty conditions / technical specifications were finalized after carrying out the analysis of the collected data and / or after the design.	Yes / No / Not Applicable.	

14.4. Sample checklist for performance quality.

Sl. No.	Particulars.	Conformity.	Remarks.
1.	The material / equipment component performed satisfactorily during the warranty period / first two years after installation / commissioning.	Yes / No.	

2.	If No, whether the manufacturer may be considered for blacklisting?	Yes / No / Not Applicable.	

5.14.5. SAMPLE CHECKLIST FOR DOCUMENT CONTROL.

Sl. No.	**Particulars.**	**Conformity.**	**Remarks.**
1.	The duty conditions / technical specifications were finalized as per the design quality control requirement for each individual work and a detailed account of the same were incorporated into the contract document, including drawings.	Yes / No / Not Applicable.	
2.	The Technical Specification / Special Conditions of contract document were prepared in accordance with the Indian Electricity Act / Indian Electricity Rules / Central Electricity Authority Regulations / Guidelines of Department of the Electrical Inspectorate, Government of Kerala and other applicable Acts, Rules, Regulations and Guidelines.	Yes / No / Not Applicable.	

5.15. SOFTWARE AND REPOSITORY OF QUALITY CONTROL RECORDS.

5.15.1. The Software 'Project Status Alert System of KWA' (PASK) shall act as a monitoring tool for quality control for electro-mechanical works in KWA. It shall also act as a repository of records of quality control such as formats, certificates, reports, checklists etc. The software shall be enabled for all quality control activities. New modules for the above purpose shall be incorporated into the software.

5.15.2. A module for recording the performance of electrical / mechanical component and for generating manufacturer-wise abstract with good performance / bad performance shall also be incorporated into the software.

5.15.3. Provision for three-tier quality control and related document upload / facility for data entry shall also be incorporated into the software.

5.15.4. The Executive Engineer (Mechanical / Electrical – Quality Control) shall be responsible for incorporating new / modified formats / checklists into the software.

5.15.5. The Engineer in charge of the works shall enter each electro-mechanical work in the PASK. The formats / check lists integrated into the software shall be updated upon each event in the format / check list. All the manufacturer certificates, test certificates, inspection reports etc. related to the quality control activity shall be uploaded in the software.

5.15.6. For quality control activities of collective responsibility of Electrical and Mechanical quality control units, dual approval facility shall be incorporated into the software.

5.15.7. Facility for necessary report generation on various quality control activities including reports on improper data entry shall be incorporated into the software.

PART C WASTE WATER MANAGEMENT

CHAPTER 6 SERVICE CONNECTIONS

6.1. GENERAL

Providing sewer connection from the silt trap at the boundary of the consumers' premises up to the existing branch or sub branch sewer using Indian Standard Stone Ware Pipes / PVC pipes and appurtenances; connecting with the man hole in the branch or sub branch line, testing the joints etc. complete including trenching and refilling in all kinds of soil up to the specified depth , lighting, watching, providing caution boards , controlling traffic ; and restoring the road surface by providing PCC using 20mm metal to the tar/concrete cut portion etc. complete as per the direction of the departmental officers.

Access of rain water flow from roof, courtyards, terraces, platform or any other open or closed yards or space of the premises into the sewer connection shall be prevented.

All waste water from every part of the building , such as kitchen, bathroom, washing place, urinals, stables, cone or shed etc shall be diverted through drains of specified type approved by the AEE, not smaller than 100mm diameter constructed or laid to grade and level approved and adopted by the Authority in its sewer installation works. Such drains shall invariably end in a silt pit before joining the sewer connection.

Entry of waste water to a drain shall only be through a trap of the type and size approved by the Authority. The trap shall be provided at the nearest point of entry of waste water to the drain.

The drain shall be ventilated using vent pipe of the type and quality approved by the Authority and of size not lesser than 50mm. Independent vent pipes shall be provided for all water closet and shall project to a height of one meter above the base of the roof and shall be protected with insect nets

All sinks working places, bathing places, urinals and similar places shall be made impervious by paving or by rendering surface treatments approved by the Authority.

6.2. QUALITY STANDARDS

6.2.1. Class 6 uPVC pipes conforming to IS 4985 and uPVC specials conforming to IS 13593 shall be used for sewer connections with uPVC pipes.

6.2.2. Glazed Stoneware pipes and fittings confirming to IS 651 shall be used for sewer connections with Stone Ware pipes.

6.2.3. All IS Standards as per latest revision to be adopted