O&M MANUAL FOR SEWERAGE SYSTEMS

ENERGY MANAGEMENT AND OPERATION & MAINTENANCE OF 16 SELECTED MCs SERVICES INFRASTRUCTURE ASSETS PROJECT

APRIL 15, 2023

PITCO (PRIVATE) LIMITED

Contents

1. **SEWERAGE SYSTEM** **4**
1.1. Introduction 4
1.2. Source of wastewater 4
1.3. Classification of Sewers 4
1.4. The sewage collection system 5
1.5. Pipe Materials 5
1.6. Self-cleansing Velocity 5
1.7. Manholes 5
1.7.1. Purpose of Manholes 5
1.7.2. Spacing of manholes 6
1.7.3. Manhole covers 6
1.8. Sewer Joints 8
1.9. Bedding Under RCC Pipe 9
1.9.1. Sand Bedding 9
1.9.2. Crushed Stone- Class B Bedding 9
1.9.3. Concrete Cradle- Class A Bedding 9
1.10. House Connections 9
1.10.1. Proposed SOP for installation of sewer house connection 10
1.10.2. Septic Tanks 10
1.11. Types of gratings 11
1.11.1. Road Drainage Gullies 11
1.11.2. Trench drain grates 12
1.11.3. Sewer grates (inlet frame) 12
1.11.4. Pipe Grates 13
1.11.5. Maintaining Drainage Gratings 13
1.11.6. Fixing the gratings 14
1.12. Types of maintenance of sewerage system 14
1.12.1. Necessity of Maintenance 14
1.12.2. Objectives of Maintenance 15
1.12.3. Preventive Maintenance 15
1.13. Major issues in sewerage system 15
1.13.1. Leaking joints: 16
1.13.2. Corrosion of Sewer Pipes (Crown Failure) 17
2. **SEWER SYSTEM INSPECTION AND EXAMINATION** **22**
2.1. Significance of Inspection and Examination 22
2.2. Essentials for inspection and examination 23
2.2.1. Preliminary inspection 24
2.2.2. Inspection and Examination Types 24
2.2.3. Manhole and sewer inspection and examination 26
2.2.4. Judgment of inspection and examination results 37
2.2.5. Record Keeping 38
3. **CLEANING OF SEWER** **43**
3.1. Protection of Sewer Systems 43
3.2. Safety Practices 43
3.2.1. Safety measures on sewer facilities 43
3.2.2. Safety measures before sewer cleaning 45
3.3. Sewer Cleaning 48

3.3.1. Sewer & manhole cleaning procedures suitable for MCs 48
3.3.2. Cleaning Equipment and Procedures 49
3.3.3. Manual cleaning 49
3.3.4. Mechanical cleaning 50
3.3.5. Maintaining record of cleaning 53
3.4. Protection Against Infiltration and Exfiltration 55
3.4.1. Measures Against Infiltration of Rainwater 55
3.4.2. Measures Against Exfiltration of Untreated Sewage 55
3.5. Manholes And Appurtenances 56
3.5.1. Checking the current situation 57
3.5.2. Damage or wear 57
3.5.3. Conditions Inside Manhole 57
3.6. House Service Connection 58
3.6.1. Examination of house connection 58
3.7. Accidents related to Sewer Facilities 59
3.7.1. Need for Traffic Control 59
4. O&M OF DISPOSAL PUMPING STATIONS/LIFT STATIONS 60
4.1. Introduction 60
4.2. Typical design of a disposal pump station 60
4.2.1. Influent Chamber & Channels 60
4.2.2. Pump Station Overflow 60
4.2.3. Influent Channels and Bar Screens 61
4.2.4. Wet Wells 61
4.2.5. Pumping station capacities 61
4.2.6. Wet Well Design 62
4.2.7. Suction and Discharge Piping 65
4.3. Understandings Centrifugal Pumps 66
4.3.1. Understanding Suction Lift of the pump 66
4.3.2. Understanding Pump Performance 68
4.4. Affinity Laws - Centrifugal Pumps 76
4.4.1. Wastewater Pumps used in current project of PMDFC 76
4.4.2. Supervision of operation 77
4.4.3. Increased wear due to dry running Damage to the pump set! 78
4.4.4. While the pump is in operation, observe and check the following points: 78
4.4.5. Visual inspection through the inspection hole 78
4.4.6. Risk of injuries, damage to the pump! 78
4.4.7. Undesirable Operations 78
4.5. Maintenance of Pumping Station 80
4.5.1. O&M of Bar Screen 80
4.5.2. Cleaning of wet well 82
4.5.3. Penstock / Sluice Gate 83
4.5.4. Sump/Intake well Maintenance 84
4.5.5. Pump House Maintenance 85
4.5.6. Tools And Testing Instruments 85
4.5.7. Pumps Maintenance: 86
4.5.8. Trouble shooting 98

1. SEWERAGE SYSTEM

1.1. Introduction

In engineering parlance, **operation** refers to daily operation of the components of a sewerage system such as collection system, pumping stations, pumping mains, and equipment, etc., in an effective manner by various technical personnel, and is a routine function. The term **maintenance** is defined as the art of keeping the structures, plants, machinery and equipment and other facilities in optimum working order. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs, corrective action and planned maintenance.

The infrastructures which need to be addressed are as follows:

- Sewage collection System including house service connections and manholes
- Pumping Stations
- Pumping Mains

Some of the key issues contributing to the poor Operation & Maintenance have been identified as follows:

i. Lack of finance, inadequate data on Operation & Maintenance
ii. Inadequate training of personnel
iii. Lesser attraction of maintenance jobs in career planning
iv. Lack of performance evaluation and regular monitoring
v. Inadequate emphasis on preventive maintenance
vi. Lack of operation manuals
vii. Lack of appreciation of the importance of facilities by the community
viii. Lack of real time field information etc.
ix. O&M contractors not having permanent staff.
x. Connection of road gullies to sanitary sewer system, which are major contributors of slit and floating matter such as plastic bags, wood pieces etc.
xi. Lack of storm sewer system.
xii. Wastage of potable water, due to supply of unmetered water supply at cheap water tariff and free water connections which add to the load of domestic sewage.

Therefore, there is a need for clear-cut sector policies and legal framework and a clear demarcation of responsibilities and mandates within the sewerage sub-sector.

1.2. Source of wastewater

Following are the principal sources of waste water

- Domestic
- Industrial
- Storm water

1.3. Classification of Sewers

- **Laterals** – Sewers that discharge into a secondary or other sewer and have no other tributary; (9-inch dia).

- **Secondary Sewers** – Also known as branch or sub-main sewers, into which two or more laterals discharge, carry the flows to the primary collector or interceptor; (9 to 15-inch diameter).
- **Primary sewers** – Also known as main or trunk sewers, into which laterals and secondary sewers discharge, carry flows to interceptor or pump station; (18-inch diameter and larger).
- **Interceptors** – Sewers that receive flows from a number of transverse or tributary sewers, and conduct such flows to a point for pumping, treatment, or disposal; (similar range of sizes as of primary sewers.

1.4. The sewage collection system

- Normally lateral sewers are installed in the less populated streets.
- These laterals of many streets terminate into secondary sewers (9-15inch size) on relatively wide roads.
- Primary sewers – Also known as main or trunk sewers, into which laterals and secondary sewers discharge, carry flows to interceptor or pump station; (18-inch diameter and larger).

1.5. Pipe Materials

- Reinforced concrete sewer pipes have been in use for sewerage system since long time due to ease in availability and in a wide range of size.

1.6. Self-cleansing Velocity

- The minimum self-cleansing velocity is kept 2.50 ft/sec in designing of the sewerage system. For this purpose, the slope of various sizes of pipes is kept as under:

Table 1-1 Slopes of sewer

Sewer size (inches)	Minimum slope
9	0.00440
12	0.00300
15	0.00300
18	0.00180
21	0.00140
24	0.00120
27	0.00100
30	0.00090
36	0.00080
42	0.00057
48	0.00048
54	0.00041
60	0.00035
66	0.00031
72	0.00028

1.7. Manholes

1.7.1. Purpose of Manholes

They are provided for:

- Cleaning
- inspection and
- house connection

And they are provided at:

- Change in Sewer direction
- Change in sewer diameter
- Change in slope

1.7.2. Spacing of manholes

Manholes are provided in a sewerage system as a mean of access for inspection and cleaning. These are essentially required at points where there is change in grade, size, direction and at all intersections. Sewers can be categorized as

(1) Non man entry sewers (9” to 42” i/d)

(ii) Man, entry sewers (48”i/ d and above)

Table 1-2 Manhole spacings

Sewer Size	Spacing
9”- 15” dia	50-100ft
18”-27” dia	100-150 ft
30”- 42” dia	150-200 ft
48-60” dia	300-400 ft
66-72” dia	400-500 ft
Conduit sewers	500 ft

1.7.3. Manhole covers

Two types of manhole covers are provided in this project

- RCC for main Roads
- Reinforced plastic composite for small streets because their loading capacity is about 10 ton only.

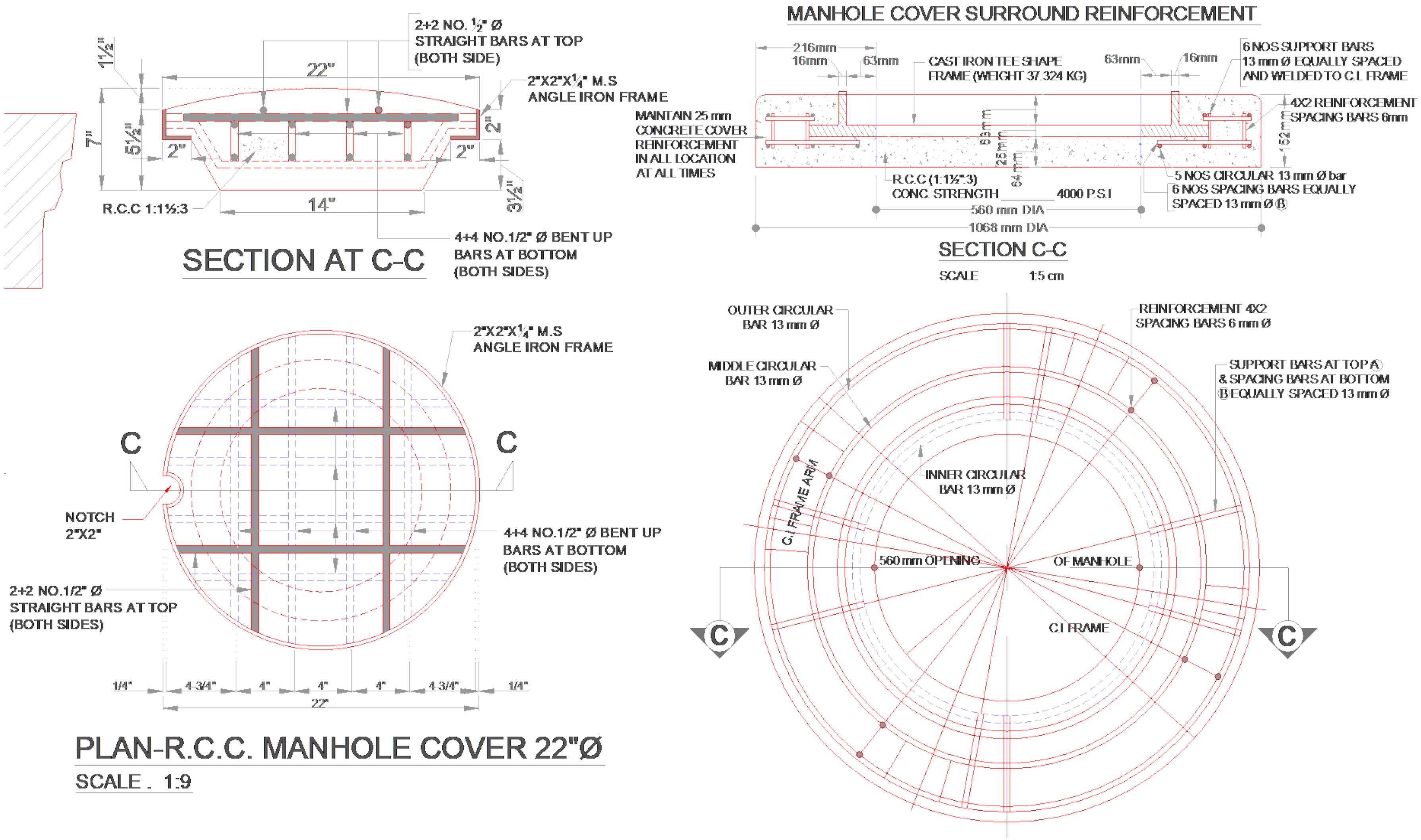


Figure 1-1 Manhole cover[1]

[1] Source: WASA Lahore design criteria

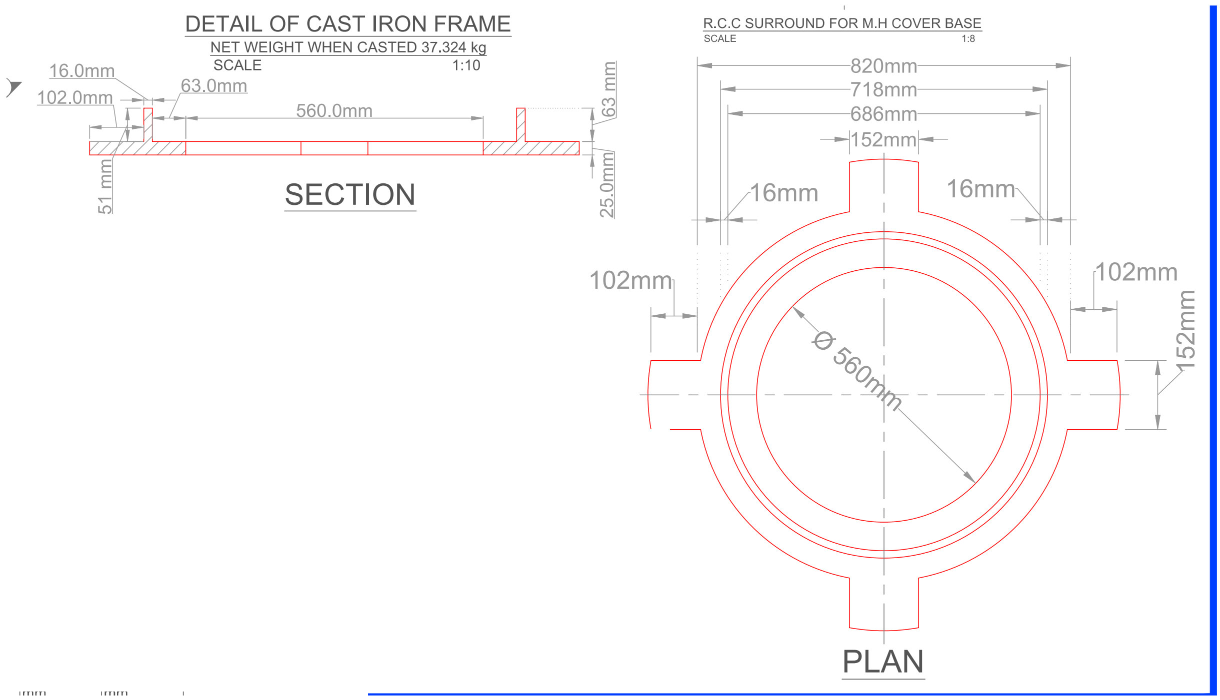


Figure 1-2 Manhole covers frame[2]

1.8. Sewer Joints

- For RCC pipe sewers rubber gasket joints are used, pipe ends being bell and spigot or tongue and groove design.

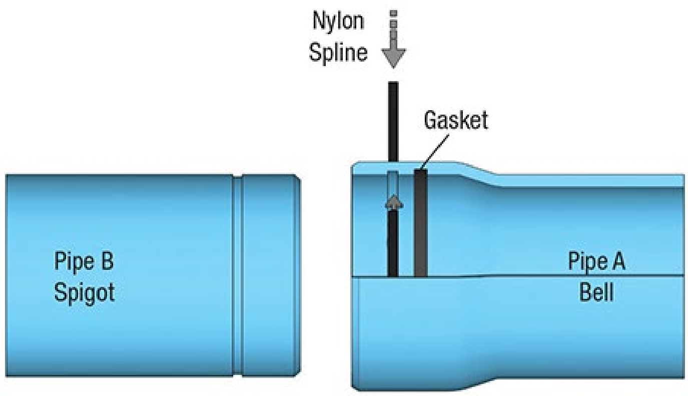


Figure 1-3 Bell and spigot joint

[2] Source: WASA Lahore design criteria

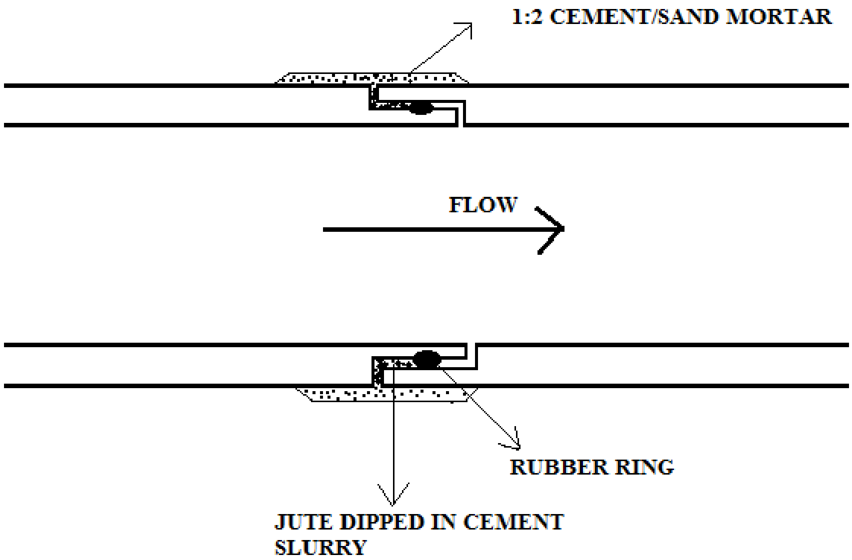


Figure 1-4 Tongue and groove design

- Leakage Tests should be carried out for newly constructed sewers, by water testing.

1.9. Bedding Under RCC Pipe

If sewer is simply laid by placing the pipe on flat trench bottom, the pipe will not be able to support the load significantly greater than the "Three Edge Bearing test". However, if bedding touches at least lower quadrant of sewer and backfill material is carefully tempted, the supporting strength of pipe significantly increases. Load factors represent this increase in strength.

Load Factor = Load Carrying Capacity/ 3-Edge bearing strength

1.9.1. Sand Bedding

In this project sand bedding is used under sewers having less size than 24 inch.

1.9.2. Crushed Stone- Class B Bedding

Dry rammed crushed stone bedding will be used for RCC pipe sewers of size 24" i/d and large in dry conditions. The thickness will be 3" below the pipe up to 27" i/d, 4" up to 60" i/d & 6" thickness for sewer size 66" i/d and above. A load factor of 1.9 may be used.

1.9.3. Concrete Cradle- Class A Bedding

Concrete cradle bedding will be used for RCC pipe sewers below the water table level. The concrete used should be of specified quality and strength. The concrete cradle should be properly shaped and designed specifically proportioned to amply protect and strengthen the sewer pipe. Generally, a load factor of 3.0 may be used for RCC sewers with concrete cradle bedding.

1.10. House Connections

Common practice is to run the house sewers to manholes in the main sewer line. In densely built-up areas, there are numerous connections discharging into each manhole, consideration has, therefore, been given to closer spacing of manholes in lateral and secondary sewers (50ft to 100 ft for 9" to 15" i/d sewers) normally having shallow depth. For deeper sewers where closely, spaced manholes are not economical shallow sidewalk junction boxes can be provided ultimately connected to a sewer manhole[3].

1.10.1. Proposed SOP for installation of sewer house connection

(1) Following documents may be provided with the connection form:
- Attested photocopy of CNIC
- Attested photocopy of sale deed/proof of ownership
- Copy of the assessment (Excise Dept.) specify the dept. instead of giving abbreviations.
- Site Plan to indicate location of property.

(2) The MC Maintenance staff issues the New Connection Form after the submission of an application (A written consent of the owner giving his attested copy of valid CNIC)

(3) This new connection form also includes the connection agreement between the consumer and MC. The Officer In charge after site verification and arrears report sends form to the concerned Revenue Section for issuance of demand notice/challan. The concerned section will return the new connection form along with the security challan. Next the Officer In charge after recovery of security will order the installation of a new sewer connection and will return the new connection form (after filling in the installation date) along with security paid challan for billing purposes. An estimated advance bill for 6 Moths is included in the challan which is later adjusted in the monthly bills.

(4) For House property of 12 Marla or more construction of septic tank of approved design is mandatory. The wastewater from his house/property will first enter into the septic tank and then from septic tank to Mc, s sewer/drain.

(5) No one without seeking written consent of the Engineer shall commence any work. The Engineer on behalf of the MC may discontinue the use of or demolish any obstruction, private connection pipe drains or sewer.

1.10.2. Septic Tanks

Septic Tanks shall be provided in the residential and commercial buildings. All the sullage water of the buildings shall be connected to the septic tank and then to the public sewer.

The minimum sizes of septic tanks for residential plots will be as follows:

Table 1-3 Minimum size of septic tank[4]

Plot size	Depth	Length	Width
Less than 1Kanal	4 ft-3inches (1.29m)	8 ft (2.44m)	4ft (1.22m)
1-Kanal to 2 Kanal	4 ft-3in (1.29m)	9 ft (2.74m)	4 ft- 6inches
Above 2-Kanal	4 ft-3inches (1.29m)	10 ft (3.05m)	5ft (1.52m)

- Size of septic tanks for commercial and public buildings shall be as per requirements of Public Health Department.
- The roof of every building and floor of balcony abutting a street or constructed over a street shall be drained by means of down take pipes.

[3] Source: WASA Lahore design criteria
[4] Amended_Building_Regulations_2019_with_amendment_approved_till_28_01_2020

1.11. Types of gratings

In Government sector (Punjab)the Gully gratings are used as per following design:
Providing and fixing M.S Grating comprising of Angle Iron frame size 1.50” x 1.50” x 3/16” and ½” square bars duly welded @ 4” c/c, including painting charges etc complete in all respect.
In AJK the design is as under:
Gully grating shall be provided on the road junctions by means of a 9-inch dia. RCC sewer pipe connecting the nearest manhole with the chamber of size l ft.– 6 inches x 1 ft. – 6 inches. The pipe is laid in such a manner that other services such as water supply and sewerage system are not disturbed or interfered.
Gullies fall into two main categories; road gullies and domestic gullies.

1.11.1. Road Drainage Gullies

Figure 1-5 Road grating

Road gullies, as the name would suggest, are designed to discharge surface water from roads and highways, where often large volumes of surface water can build-up. Road gullies are designed to be much more robust than domestic gullies, in order to withstand the heavier trafficked environments in which they are installed. These are most commonly made from concrete or HDPE.

1.11.1.1. Hydraulic efficiency

A storm grate’s first job is to move surface water into the sewer system. The size and shape of the grating is what determines their hydraulic efficiency. Varying situations change the rate of flow of a grate: a drainage grate at the bottom of a pool processes water differently than one on the side of the road. The open area of a grate, design of the holes, acceleration of water due to gravity, depth of water, and perimeter length of the grate all determine how much surface water a sewer grate can remove.

1.11.1.2. Debris removal or passthrough

Grates should strain out the sort of debris that can clog a sewer system like the fall of large leaves in the autumn. At the same time, small particles should generally pass through, so they do not clog the grate itself.

1.11.1.3. Strength and resilience

Most storm drain grates are made from cast iron, for both strength and resilience. Strength is necessary in any place the grates will be driven over by cars and trucks: there are even extra heavy-duty grates appropriate for airports and shipping docks. Resilience is the grate’s ability to withstand weathering over time with minimal maintenance. Cast iron is often chosen because it develops a patina that prevents destructive corrosion from setting in.

Figure 1-6 Various types of gully gratings in open market

1.11.2. Trench drain grates

Trench drain is long, narrow, linear drain that works as small collection capillaries in a sewer system. Trench can often be spotted in pedestrian spaces, stretching across sidewalks and driveways, through plazas, and edging green spaces.

Standard trench grates have a greater hydraulic capacity than heel-proof grates. They are a better choice for places where silt or clay might clog a small slot.

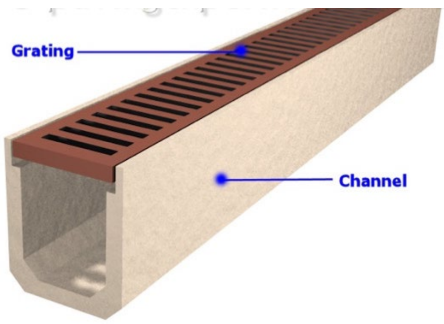


Figure 1-7 Trench grating

1.11.3. Sewer grates (inlet frame)

Sewer grates are the most recognized storm water management grates urban landscape, positioned in gutters between curb and roadway. They come in many different shapes and sizes. The different lattices available offer different hydraulic capacity and debris straining while removing water from the street.

1.11.4. Pipe Grates

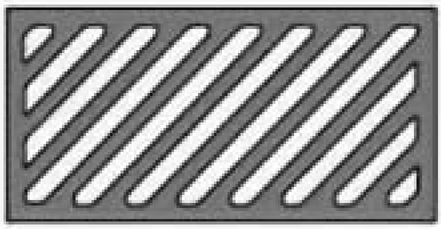


Figure 1-8 Pipe grating

a) Diagonal alignment (average water flow)

In tests of drain clearing capacity given different slopes and water volumes, diagonal drains are the middle of the pack. Vane and sinusoidal grates clear 0.1-0.5 cubic feet per second (cfs) more in most conditions; horizontal and vertical drains clear 0.1-0.15 cfs less.

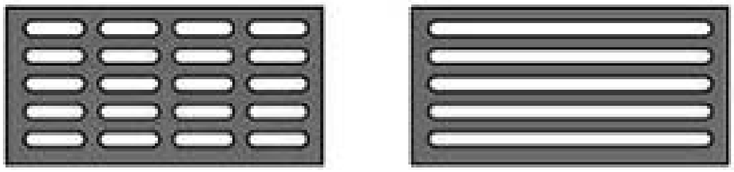


Figure 1-9 Diagonal grating

b) Horizontal alignment or cross-drain (lower water flow)

Horizontal alignment or cross-drain systems are slightly more efficient than standard vertical systems but may be more troublesome for bicycles.

c) Vertical alignment or standard (lower water flow)

For many cities with low flood risk, vertically aligned storm drain grates are the standard system. They are often easier for bicycles to ride over.[5]

1.11.5. Maintaining Drainage Gratings

(a) Visual inspection of the gratings:

- Check the gratings of drainage channels for mechanical damage and/or clogging by debris entry
- With bolted gratings, check that all screw and locking handle connections are properly secured
- Ductile iron gratings can show signs of corrosion. This has no effect on the functioning of the channel
- During the visual inspection of the channel base and trash boxes through the grating, a visual check must be made to see whether there is a large amount of debris in the channel base or in the mud bucket.
- The amount of debris in the channel base can be determined with the help of a folding ruler which is placed through the grating on the channel base.

[5] A guide to storm drain grates https://www.reliance-foundry.com

- Removing gratings with narrow openings (e.g. perforated grating) for a visual inspection of the channel base and trash boxes.
- An inspection camera can be used with monolithic drainage channels or slotted channels.

(b) Cleaning and maintenance of the gratings:

- Coarse debris and solids (e.g. cigarettes, paper, small stones) can be swept away with a broom.
- Clean the openings of the gratings thoroughly, e.g. with a high-pressure cleaner, to ensure the drainage function.
- Small stones can be removed with a screwdriver or other pointed object. Care must be taken not to damage the gratings.
- Cleaning of the channel bodies and trash boxes

1.11.6. Fixing the gratings

The grating can be either screwed or clamped or a combination of both types of fastening.
The following tools can be used to remove the gratings.

- Gratings fixed with a hexagon head screw:
  Wrench size 13 and 17
- Gratings which are fixed with a hexagon socket screw:
  Wrench size 5 and 6
- When reinserting grating, the maximum tightening torque should not be exceeded:
- Channels with plastic locking handle of nominal widths 100 mm and 150 mm should be tightened with four turns after the screw has been tightened.
- When screwing the grating with steel locking handles, a maximum tightening torque of 5 Nm must not be exceeded.

1.12. Types of maintenance of sewerage system

There are three types of maintenance of a sewerage system:

- Preventive
- Routine
- Emergency

Preventive or routine maintenance should be carried out to prevent any breakdown of the system and to avoid emergency operations to deal with clogged sewer lines or overflowing manholes or backing up of sewage into a house or structural failure of the system. Preventive maintenance is more economical and provides for reliability in operations of the sewer facilities. Emergency repairs, which would be very rare if proper maintenance is carried out, well also, have to be provided for. Proper inspection and preventive maintenance are necessary.

1.12.1. Necessity of Maintenance

Sewer maintenance functions are most often neglected and given attention only as emergency arises. Adequate budgets are seldom provided for supervision, manpower and equipment, unlike the case for maintenance of other utilities like electric cables, telephone cables, gas and water mains. Such attitude towards sewer maintenance is found even in large cities. Considering the health hazards that the public at large has to face, it is appropriate to provide sufficient funds to take care of men, material, equipment and machinery required for efficient maintenance.

All efforts should be made to see that there is no failure in the internal drainage system of premises; a serious health hazard results when sewage backs up through the plumbing fixtures or into the basements. The householder is confronted with the unpleasant task of cleaning the premises after the sewer line has been cleaned. Extensive property damage may also occur, particularly where expensive appliances are located in the basements.

Maintenance helps to protect the capital investment and ensures an effective and economical expenditure in operating and maintaining the sewerage facilities. It also helps to build up and maintain cordial relations with the public, whose understanding and support are essential for the success of the facility.

The sewerage system in Punjab Pakistan is partially combined system meaning storm water is also disposed of partially through sewerage system.

1.12.2. Objectives of Maintenance

Quality maintenance of sewerage system consists of the optimum use of labour, equipment, and materials to keep the system in good condition, so that it can accomplish efficiently its intended purpose of collection and transportation of sewage to the treatment plant.

1.12.3. Preventive Maintenance

Preventive maintenance is a set procedure whereby each component of the system goes through a systematic check and these components are brought into dependable use. An example can be checking the volume and consistency of oil in the gearbox after a specified number of hours of operation and correcting the situation either by topping up or replacing fully as needed. The preventive maintenance issues, checking parameters and timings are all given by every equipment vendor as a manual. Carrying out these tasks is to be done by the respective equipment vendor under a separate contract called preventive maintenance contract and should be delinked from the O&M contract. Most often this is not fully recognized and what could have been saved by preventive maintenance finally ends up "breakdown repairs." This situation needs its importance.

1.13. Major issues in sewerage system

- **Solid waste:** Solid waste dumping into sewers is the main problem in O&M of sewerage system efficiently.

Figure 1-10 Solid waste dumping in the sewer

The main causes of this problem are:

- **Solid waste:** MC does not have capacity to lift all solid waste of the City.
- **Social problem:** In spite of repeated campaigns people are not aware of consequences of throwing solid waste into sewers.
- **Overflowing Sewers:** Undersized sewers, sewers laid by other agencies without proper grade.
- Deterioration of the material due to age factor:
- **Attack of hydrogen sulphide: Crown failure**

- **Settlement of bedding:** Proper bedding required not used as explained in previous sections.
- **leaking joints**: A crack or a leaking joint will allow subsoil water and soil to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer.
- Very often soil with water is carried away below the bedding along the length of the sewer.
- The mushroom growth of private housing schemes in the Cities has created serious sanitation issues. These schemes dispose of sewage into open fields, water bodies or storm water channels without considering proper long-term solution of disposal of wastewater.
- Temporary lift stations have become permanent and consequently the storm water channels have become sewage carriers.
- **Receiving Bodies:** All the wastewater is being discharged into the rivers without any prior treatment causing severe environmental issues such as deteriorating water quality, decrease in number of fishes, damage to the underground water aquifer due to seepage of wastewater and public nuisance. The deteriorating state of Rivers is further aggravated due to low annual water flows itself, due to this factor the dilution available in the river has drastically reduced which eventually increases the concentration of pollutants in the river body.
- Excessive loading, either internally or externally, causes horizontal breaks.
- Breaks caused by internal pressure gives cracks in the sewer while external overload causes the top of the pipe to crush-

1.13.1. Leaking joints:

- Sewer deterioration begins with initial defects such as overloading of the sewer pipe, which can result in the sewer cracking. This classic failure features cracks at the crown, springing and invert. Unfortunately, it is very hard to see the crack in the pipe invert because it is normally under water. The cracks at the springing are also obscured because at this point, they are in compression.

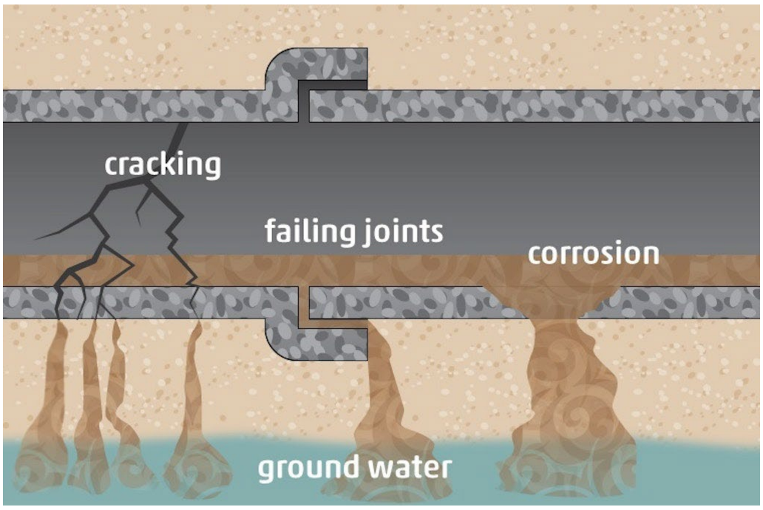


Figure 1-11 Leaking joints of sewer

Ultimately, the initial failure results in the soil around the pipe being eroded by the infiltration of ground water and exfiltration of the sewage. This process gradually washes away the fines in the soil, and over time soil

- A crack or a leaking joint will allow subsoil water and soil to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer. Very often soil with water is carried away below the bedding along the length of the sewer.

- Support is reduced. When this happens, the pipe starts to deform and eventually the sewer collapses.
- Leaking joints can also lead to sewer failure. In this case an elastomeric seal could either fail or the angular deflection could be greater than the joint can withstand. Alternatively, the mortar in a brick sewer can weaken
- Over time, resulting in the infiltration and exfiltration of groundwater. This leads to the erosion or loss of ground support and eventually the collapse of the sewer.
- In addition, displaced joints can also cause sewer failure, as can a hole or defect in the sewer. This type of failure is usually caused by the use of rods to clean the sewer or a third party carrying out an excavation close to the sewer.

1.13.2. Corrosion of Sewer Pipes (Crown Failure)

1.13.2.1. Corrosion induced by Microbial

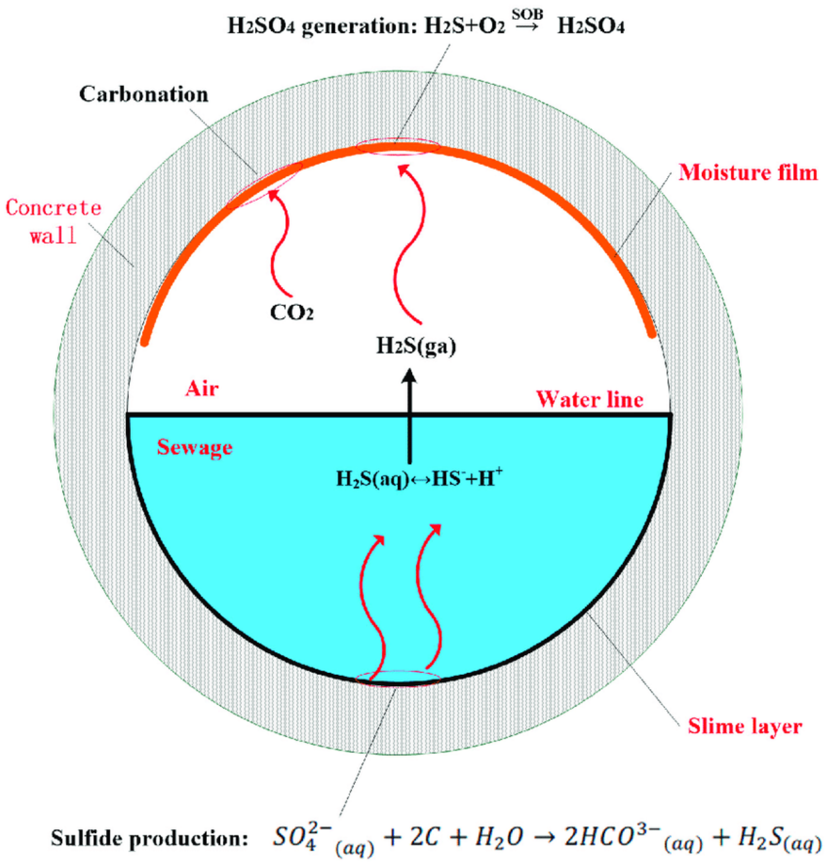


Figure 1-12 Corrosion induced by microbial

- In sewer systems, when hydrogen sulfide gas (H2S) emitted from sewage meets condensing moisture, the process can form sulfuric acid (H2SO4) that corrodes the concrete in sewer pipe rapidly. This is known as the microbially induced corrosion.
- Acid corrosion causes a gradual loss of concrete, which significantly reduces the service life of concrete structures in sewer pipes and may lead to crown failure and ultimately the sewer structure fails to withstand and collapses.

Acid corrosion causes a gradual loss of concrete

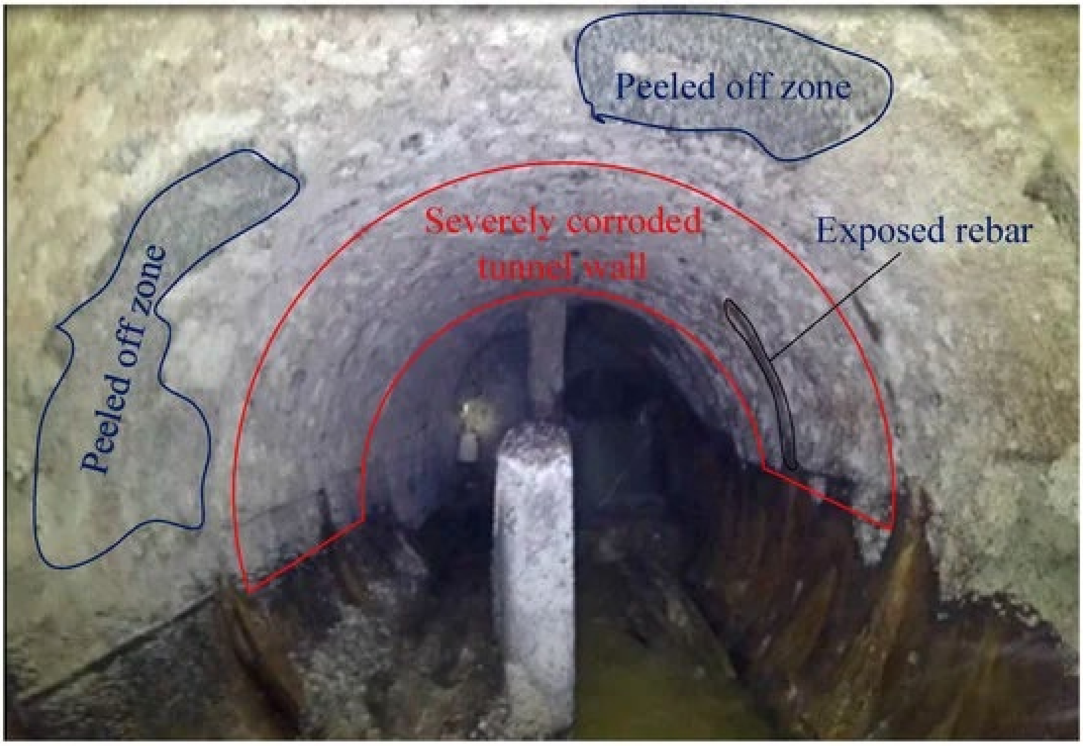


Figure 1-13 Sewer deterioration due to Corrosion

- As long as an aerobic zone is present in the slime layer, sulfide(H_2S) diffusing out of the anaerobic zone will be oxidized and will not enter the wastewater stream.
- If the oxygen concentration in the stream approaches zero (i.e., < 0.1 mg/l) insufficient oxygen will be present in the slime to oxidize all of the sulfide diffusing out of the anaerobic zone, and sulfide will enter the stream.
- If the stream is stationary or moving slowly, local anaerobic conditions may occur near the pipe wall and some sulphide may escape, even though the DO concentration in the bulk liquid may be several milligrams per litter.
- When sulphide produced in the slime layer diffuses into a wastewater stream containing Dissolved Oxygen, sulphide may be oxidized chemically or biochemically. In typical municipal wastewaters, biological oxidation to thiosulfate is the prevalent mechanism
- H2S and carbon dioxide (CO2) are transported through the biofilm into the wastewater stream where some is volatilised into the sewer headspace when the pH is below about 8.5. Corrosion of exposed concrete or metal surfaces occurs from the bacterial oxidation of H2S to sulfuric acid under aerobic conditions.
- Sulphuric acid (H2SO4) forms as the H2S leaves the wastewater, enters the air in the headspace between the wastewater and the top (crown) of the sewer pipe, and diffuses into the condensation present on the crown and walls of the gravity sewer.

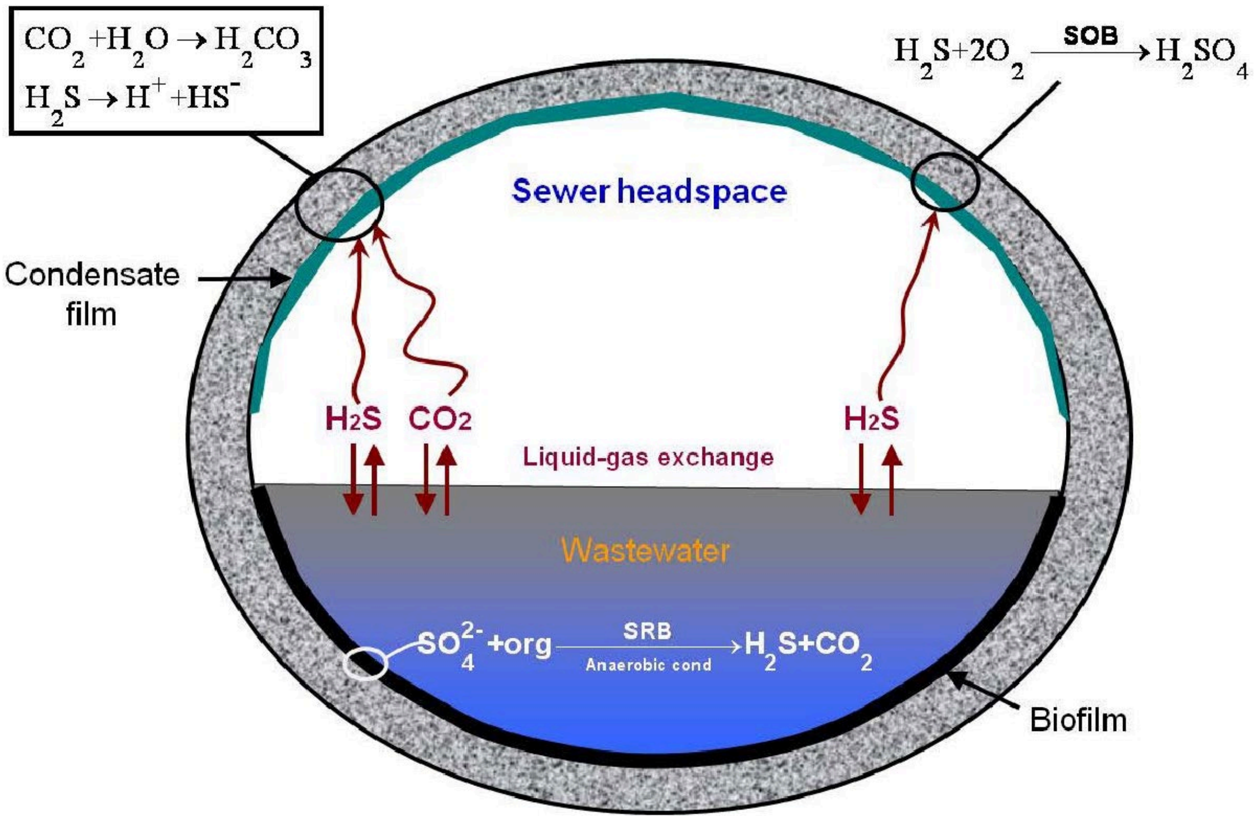


Figure 1-14 Sulphuric acid formation

1.13.2.2. The Sewer Sulfide Cycle

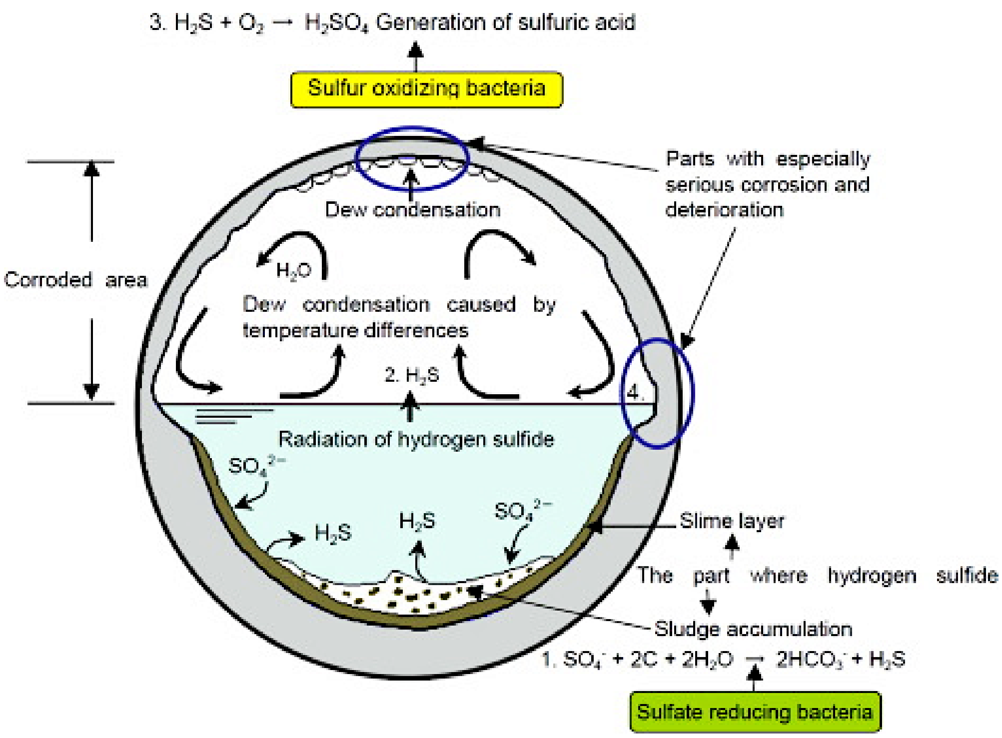


Figure 1-15 The sewer sulphide cycle

- Anaerobic bacteria are present in a thin slime layer on the submerged surface of the sewer pipe. Sulphate, which exists in wastewater, is converted to Hydrogen sulphide by anaerobic bacteria in the slime layer.
- The generated Hydrogen sulphide escapes to the exposed sewer atmosphere where it is transformed to sulphuric acid by aerobic bacteria in the presence of Oxygen.
- The acid reacts with the cementitious sewer pipe, which forms gypsum and causes corrosion.
- The sulfuric acid drips back down into the wastewater where it is neutralized back into sulfate, and the process begins all over again and termed as the —Sewer Sulfide Cycle,

1.13.2.3. High alkalinity of new pipe slows down the sulphuric acid formation

- Sulphuric acid formation is initially a slow rate process on new concrete due to the high alkalinity of the concrete itself (pH ranging from 11 to 13). *Thiobacillus (sulphide oxidizing bacteria)* are unable to survive under high pH conditions.
- Aging of the concrete results in a decrease of surface pH to between 7 and 8. At this pH, a different species of *bacteria* colonises the concrete surface, further reducing the pH of the condensate to less than 5.
- From this point corrosion proceeds faster if other environmental agents (H2S, humidity and temperature) are present.

1.13.2.4. H2S formation is dependent upon pH

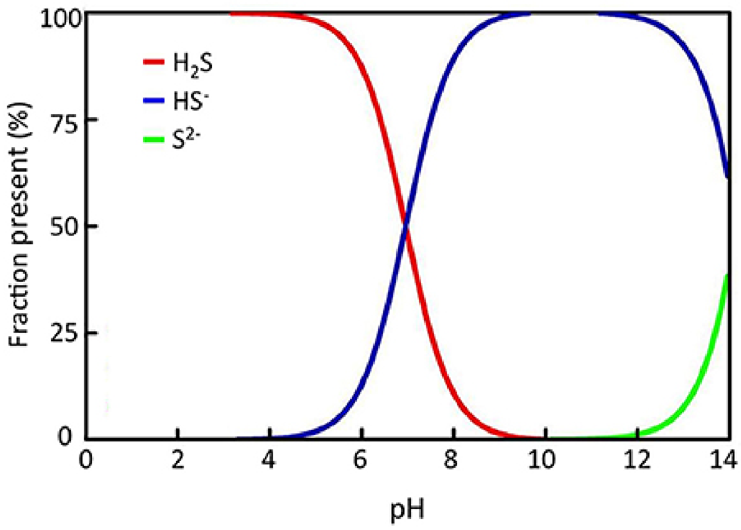


Figure 1-16 H2S formation relative to PH concentration

- The amounts of the three-sulphide species present (H2S, HS-, and S2-) are also pH dependent.
- The amount of H2S is very sensitive to pH.
- At a pH of 7, 50% is present as H2S.
- At pH < 5.5, almost all sulphide is H2S (> 97%)
- while at pH > 8.5, less than 3% is present as H2S.

1.13.2.5. Factors Affecting Sulphide(H2S) Generation in Sewers

Table 1-4 Factors Affecting Sulphide(H2S) Generation in Sewers

Factors	Effect
Dissolved oxygen (DO)	Low DO favours proliferation of anaerobic bacteria and subsequent sulphide generation
Biochemical oxygen demand (BOD) (organic strength)	High soluble BOD encourages microbial growth and DO depletion.
Temperature	High temperatures increase microbial growth rate and lowers DO solubility. It has been reported that the rate of sulphide production is increased 7 percent/°C up to 30°C. This is approximately equivalent to a doubling of the reaction rate for every 10°C increase in temperature.
pH	Low pH favours shift to dissolved H_2S gas.
Presence of sulphur compounds	Sulphur compounds are required for sulphide generation. The concentrations of these compounds can be very significant when they are the result of groundwater and sea-water infiltration and in some cases due to trade waste.
Hydraulic Drops	Can promote H_2S release, turbulence and may cause outgassing.
Surcharging	Reduces oxygen transfer and promotes sulphide generation, will not corrode while surcharged. Can also cause foul air release as the sewer headspace is restricted, causing pressurization and driving air out of the sewer.
Slope, velocity and change in direction	Affects degree of reaeration, solids deposition, H2S release, thickness of slime layer. Note that change in direction can cause similar effects, as velocity suddenly decreases and turbulence increases.
Accumulated grit and debris	Slows wastewater flow, traps organic solids.
Sewer pipe materials	Corrosion resistance of pipe materials varies widely. Porous materials, such as concrete, favor biofilm attachment, while comparatively less porous materials such as plastic support a smaller a biofilm and the biofilm is more easily scoured off.

1.13.2.6. Crown Failure Prevention

- The critical dissolved oxygen concentration in the wastewater below which sulphate reduction (formation of H2S) can occur is 0.1 to 1.0 mg/I. Above 1.O mg/I, sulphate reduction will be eliminated.
- Presence of DO in the stream will also encourage growth of the aerobic portion of the slime layer, increasing the distance through which organic matter and sulphate must diffuse to reach the anaerobic zone.
- Any Hydrogen sulphide produced in the active anaerobic zone is likely to be oxidized as it passes back through the aerobic zone if Oxygen is sufficient (above 1.O mg/I).
- Controlling the hydraulic retention time in long sewers to avoid anaerobic conditions.
- Adopting strategies to reduce turbulence, ensure that the sewer headspace is not too restricted (and does not surcharge) and to allow the free flow of sewer air will be required. The reason for this is

that restriction in headspace will increase the pressure which will force air out at uncontrolled locations.

- Managing the release of sewer gases requires effective containment so that gases are only released at designed locations, such as educts.
- Avoiding gravity sewers with low sewage velocities.
- Clean sewers of settled debris to reduce the area of slime layer and minimize dissolved sulfide generation.
- Industrial discharges with high concentrations of BOD increases the sulphide formation

1.13.2.7. Measurement and Monitoring of Corrosion

- Regular inspection of the sewer can pinpoint the sewer that needs to be attended to before there is a complete failure or collapse because it takes a very long time from the onset of the first initial defect to the collapse of the sewer. The type of break often gives a clue to the cause.
- Acid attack is confined to the interior, unsubmerged portion of the sewer pipe and is heaviest at the crown and just above the liquid level. Concentrations of sulfuric acid can reach 5 percent and a high percentage of this acid will react with the exposed surfaces and be neutralized by the alkalinity of the concrete. An acid attack situation can easily be demonstrated by testing the wall crust for pH.
- A sewer system map should be prepared for detailed assessment.
- The information should include age, size, 'and types of pipes; slopes of the lines; wastewater flows; and accurate manhole locations.
- Soft deteriorated concrete should be first chipped away to determine the depth of corrosion penetration.
- Core samples should be taken to determine wall thickness, alkalinity, and compressive strength at various locations along the sewer.[6]

2. SEWER SYSTEM INSPECTION AND EXAMINATION

2.1. Significance of Inspection and Examination

Sewage is supposed to be transported safely through sewer networks from individual discharge to sewage treatment facilities or final disposal. In order to ensure that both new and old collection systems continue to fulfil their intended functions, operation and maintenance strategies are developed using information gathered through inspection and examination. Inspection and testing are essential for:

- Identification of existing or potential issues in the collection system
- Evaluation of the gravity of the identified problems
- Locating the precise position of problem areas
- Provision of concise, transparent, and meaningful reports to supervisors regarding the identified issues

The detection of existing leaks so they can be repaired, and preventing potential leaks in the sewers are the two main goals of inspection and examination.

Many sewage failures are directly attributable to a mistake made by the designer and a flaw in the construction process. The structural failure of the sewer may be caused by ageing, degradation of the

[6] SA Water: Sewer Network Hydraulic Design Considerations

sewer's material from attack by hydrogen sulphide or other corrosive chemicals, foundation settlement, and leaking joints. It takes a very long time from when the first problem appears till the sewer collapses. The sewer will eventually collapse because of sluggish foundation settling caused by cavities surrounding it created by subsurface water and soil combination entering the pipe through a crack or leaky joint.

Along the length of the sewer, soil with water is frequently transported away beneath the bedding. The type of failures frequently provides a hint as to the cause. A clear vertical break in the pipe indicates a shear failure caused by a poor foundation or ground movement. Horizontal breaks are brought on by excessive internal or external loading., whereas external overload crushes the top of the pipe, internal pressure breaks result in cracks in the sewer. Prior to a total breakdown or collapse, routine sewer inspection can identify the sewer that has to be repaired. The maintenance engineer needs to implement sufficient inspection and examination programs to prevent the major sewer system damages mentioned above.

2.2. Essentials for inspection and examination

The operation and upkeep of the facilities depend on documents and data that can provide information on the condition of sewer facilities. However, examination and inspection of the whole data on sewer facilities that cover a large area can take a tremendous amount of time and money.

It is, therefore, advised to do a preliminary inspection first to more easily gather documents and data that can be used to prioritize which facilities should be reviewed and inspected, as well as which ones should be examined and inspected at the end of data collection. The procedure is to first gather the fundamental data through a preliminary inspection in order to examine and inspect the facilities in a specific length or area of the sewers, as described below.

The approach for each inspection step is thoroughly explained in the next section. The steps involved are:

- Initial Inspection
- Inspection and Examination
- Evaluation of Inspection Results
- Decisions regarding necessary measures for repair, replacement, and modifications

Table 2-1 Initial inspection for newly constructed sewers[7]

Category/Inspection stages	Manhole	Sewer	Inverted siphon	Any other sewerage infrastructure
First/Initial inspection	During the first 3 months of start of Defect Liability Period (DLP) to expose any inherent/hidden construction deflects			
Final inspection	During the last 3 months of the DLP.			
Additional inspections if the DLP is greater than 4 years	Every 2 years after first inspection.			

[7] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

Table 2-2 Initial inspection for manholes & sewers[8]

Category/Road & Traffic Conditions	Manhole	Sewer
Roads having heavy & mixed traffic	Once a year	Once every 2 years
Roads 2m to 5m wide having mixed traffic	Once every 2 years	Once every 2 years
Less than 2 m wide lanes/roads	Once every 3 years	Once every 3 years
Footpaths	Once every 2 years	Once every 3 years

Table 2-3 Initial inspection for other facilities[9]

Category	Invert siphon	Force main and their appurtenance
Other Facilities	Once a year	Once a year

If any sewage system components are found to be defective, distressed, or otherwise dysfunctional, corrective action should be taken right away.

2.2.1. Preliminary inspection

During the preliminary inspection of the sewerage system, subsidence, collapse, and overflows on the roads on which sewers are laid, should be confirmed. Deformation or damage to facilities, and deposits of sand and silt are to be confirmed during observation from the manhole. If damage or possibility of damage to the facility or if any of the abnormalities listed below are confirmed during the preliminary inspection, the facility manager should examine and inspect the relevant locations for the following:

- Corrosion, wear, damage or crack in the facility
- Water infiltration
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole
- Abnormal odors
- Clogging and overflowing

2.2.2. Inspection and Examination Types

Inspections and tests are required to determine how well the sewers are functioning. Inspection and examination can be divided into two categories described below.

2.2.2.1. Direct Method

This refers to someone physically assessing the state of a sewer before it is put into service. After a sewer has been put into operation, this should never be done. Even for brand-new sewers, the interior diameter must be greater than 2 meters. It is required to take all necessary safety measures when operating in tight places. It is strictly forbidden to use any tool, even a hammer, to hit the sidewall. Its sole function will be to

[8] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf
[9] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

provide a visual indication of how fully formed the pipe joints are. This practice is to be outlawed permanently once a sewer is put into operation.

2.2.2.2. Indirect Inspection and Examination

These can be classified by a variety of methods as in Table -2.4 below

2.2.2.3. What issues are to be inspected?

- Corrosion, wear, damage or crack in the facility
- Water infiltration
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole
- Abnormal odors
- Clogging and overflowing

Table 2-4 Methods of indirect inspection viable for Mcs[10]

Technology		Sewer type Gravity	Diameter	Internal condition	Wall	Leakage	Remarks
Camera	Digital cameras	●	150-1500	●	●	●	
	Zoom cameras	●	>150	●	●	●	
	Push-camera		≤300	●	●	●	
Acoustic	In-line leak detectors	●	≥100			●	
	Acoustic monitoring systems		≥450		●		
	Sonar/ ultrasonic	●	≥50	●	●		

Even though there are so many technologies available, the technology to be chosen will depend on the affordability of the user departments. A simpler and applicable technology compilation is as shown in Table 2.5.

Table 2-5 Sewer system inspection technologies most widely used[11]

No.	Technology	Application		
		Sewer Size	Sewer Material	Sewer Condition
1	Light and Mirror	Up to 300 mm	Any	Empty
2	Closed Circuit Camera	Any size	Any	Empty

[10] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf
[11] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

No.	Technology	Application		
		Sewer Size	Sewer Material	Sewer Condition
3	Sonar Systems	Any size	Any	Fully flowing

Among all known technologies, the light and mirror are the earliest. Two manholes are opened one after the other and are suitably vented for roughly an hour. Then, a long hand-held mirror fixed at a 45-degree angle to the handle is lowered into the bottom of the manhole, and a torch light is directed downward at the mirror such that the light beam is bent by 90 degrees to pass through the sewer pipe horizontally and be seen in the other manhole.

Dusk makes this simpler; it can be easily determined if the pipe's bore is blocked, clear, or laid straight.

The closed-circuit camera goes through the sewage and transmits the image of the inside to a TV in the van using a remote-controlled connected power supply from the van. It is analogous to the sonar system. High frequency sound waves are emitted by a robot as it travels through the sewage, hitting the pipe surfaces and reflecting back to the source. This can be programmed to check the structural integrity of the sewer pipe wall by knowing the material used to build it.

Tree roots piercing the seams and encroaching within the sewers is a traditional issue with stoneware sewers built through light forest or densely planted terrain. They congeal into a blockage and clog the sewer.

Similarly, sonar surveys, which may offer the frontal image of the wall on a 360-degree vertical spiral around the horizontal axis, can be used to determine the structural state of old sewers like brick arch sewers and concrete pipes. Information on the deflection and sidewall breaks of the sewer can also be provided by the system.

2.2.3. Manhole and sewer inspection and examination

The maintenance staff should determine the urgency and the nature of any irregularity that is discovered during a preliminary internal inspection or that is spotted from the outside before conducting a thorough inspection and analysis. One or more of the following methods are used to inspect the majority of sewer lines and manholes.:

2.2.3.1. A. Visual Examination

The visual inspection of a manhole entails visually examining the manhole cover and the surrounding area of the manholes inside components. The inspector must enter the manhole safely in order to inspect the interior of the manhole. The status of the following items is the focus of the visual manhole inspection:

- Internal surface of manhole
- Sewer, viewed from the manhole, both on the upstream and downstream sides
- Groundwater infiltration

Either a mirror or a bright light should be used for observation, or a TV camera designed for checking conduits should be used, to view the interior components of the sewer from the manhole.

Figure 2-1 Sewer inspection with light and mirror

Main features of manhole visual inspection:

- High inspection accuracy due to actual observation of the abnormality made by the inspector
- Cheaper than using a TV camera for inspection.
- Inspection findings eventually turn into highly relevant O&M data

The stepwise procedure for manhole visual inspection is described below:

- Preparation
- Inspection of manhole cover and its surrounding area
- Inspection of inside of manhole
- Clearance
- Work Completion

2.2.3.2. Inspection of manhole using pole-mounted TV camera

A camera and light are attached to the front of an extendable working rod to create a pole-mounted TV camera. This device is placed into the manhole from the ground, and the inspector there views a monitor and examines the pipe's internal components through the camera.

Advantages and disadvantages direct visual method versus pole-mounted by TV camera are shown in Table 2.6.

Table 2-6 Direct visual method vs pole-mounted tv-camera: advantages and disadvantages[12]

Advantages	Disadvantages
Observations can be made quickly and easily after the inspection. In addition, photographs/images of the inspection data may be recorded.	Scope of inspection is limited to the area surrounding the pipe's mouth.
The inspector's work is safe because it is done above ground, where there is no risk of an oxygen shortage or mishaps from falls.	Fine cracks or offset in the horizontal direction cannot be seen.

[12] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

Advantages	Disadvantages
	It is impossible to understand the state of the sewer pipe's side surfaces (sides cannot be viewed).

2.2.3.3. Closed-Conduit Television Inspection (CCTV)

The most popular, long-lasting, and cost-efficient approach to examine a sewer's internal condition is through television (TV) inspections. An example of a television inspection is the closed-circuit TV camera, which is propelled through the sewage by a remote-controlled wired power supply from a van. It travels through the sewer and transmits the image of the interior to a TV in the van. Sewer lines with a diameter between 150 and 1,200 mm are compatible with CCTV inspections. CCTV inspection is another option for pipes with a bigger diameter.

CCTV inspection can be employed for various purposes:

- Before accepting the new sewers, demand that a contractor or construction organization fix any flaws.
- Locate and confirm the precise locations of service connections and other pipe construction points and update any as-built maps as necessary.
- Determine the order of importance for "as needed" remedial maintenance on old pipes.
- For a preventative maintenance program encompassing a full collection system, ensure the most efficient and effective use of personnel and resources.
- Check the lateral and branch sewer connections made for health services. Observe such connections to see if infiltration, roots, debris buildup, and certain internal inflows are negatively impacting the capacity of sewers.

Figure 2-2 Sewer inspection with camera

CCTV system comprises the following components which are normally included in some sort of permanently mounted van or trailer:

- Television camera
- Camera light
- Power cable reel and video unit

- Television picture monitor
- System power control center or module
- Portablepower source
- Camera carrying skids
- Camera pulling winch
- Camera return winch
- Footage counter
- Sound power telephone communication system
- Float liner pipe stringing line
- VTR equipment with reel

The positioning of CCTV camera should be as close as possible to the center of the pipe. In larger sewers, the camera and lights are mounted on a raft that is floated from one manhole to the next. The camera and lights may be rotated both vertically and horizontally to provide a clear view of the features on the sewer walls. In smaller sewers, the wire and camera are hooked to a sled, to which a parachute or drogue is attached and floated from one manhole to the next. The detailed operation procedure for CCTV camera inspection is given below:

- Preparation Process
- Cleaning Process
- Sewer inspection with TV Camera
    - identification, evaluation and recording of results
    - Report Preparation
- Clearance
- Work completion

2.2.3.4. Inspecting Water Infiltration

The pipelines and treatment facilities will suffer if penetration of water more closely matches the projected water flow in the sewerage system.

Additionally, this causes the sewage treatment plant's treatment costs to rise (STP). Either the drainage system or the pipeline must be adequate to prevent water infiltration.

Determining the route of water penetration and combining cross connection, flow rate, and waterproofing examinations are therefore necessary. Flow-rate inspections are beneficial because they can gather information that can be used to improve and modify the pipe facilities.

2.2.3.5. Inspecting Cross Connections

The connection of storm water equipment to the sewers in a different sewage system must be inspected to ensure this is not the case. The scope of inspection is from the house drainage facility to the main sewage pipe.

Cross connections can be inspected using three common techniques, including the smoke test, the echo sound test, and dye test.

a) Smoke Test

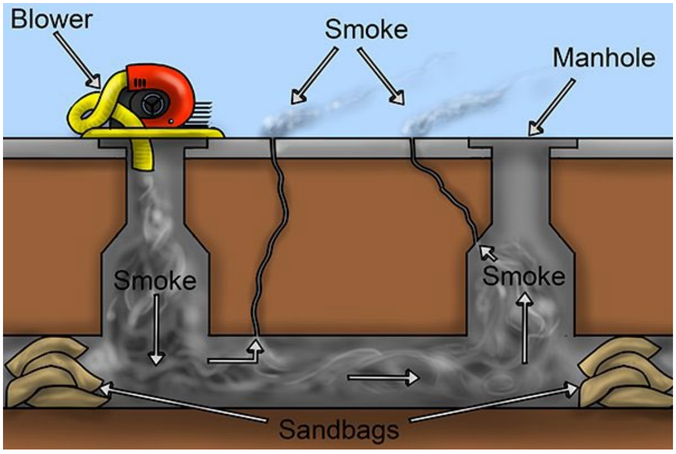


Figure 2-3 Smoke test

A straightforward procedure known as a smoke test involves pumping significant amounts of air and smoke into a sanitary sewer line, typically through a manhole. As it follows the path of least resistance, the smoke quickly reaches locations with surface water inflow.

If there is a route for the smoke to travel to the surface, it will be able to detect fractured mains and laterals, broken manholes, and even illegal connections. The main lines and laterals can be inspected using smoke testing. As smoke moves across the system, it spots issues in every connected line, including those that were previously unknown, believed to be independent, or assumed to be unconnected. Dry weather produces the best outcomes since it gives smoke a better chance to rise to the surface.

Blower, smoke generator/materials, and other essential equipment are utilized during smoke testing operations. Both traditional smoke candles and smoke fluids are currently available for smoke tests. Each piece of equipment is described below:

A blower device is typically a squirrel cage blower with a belt drive and a gasoline engine. Usual blower capacity is between 3,000 and 5,000 m3/hr. The blower's base has a rubber gasket underneath it, allowing it to set over and blow air into an open manhole.

smoke candles: To utilize **smoke candles**, simply place them on the blower's side that receives fresh air. After being lit, the smoke is released and is taken in by the fresh air before being blown into the manhole and throughout the entire system. Smoke candles come in a variety of sizes and can be combined or used alone to suit any need. This kind of smoke is produced by a chemical reaction, which results in smoke with a high concentration of air moisture. It is incredibly effective at finding leaks and is highly visible even at low quantities.

A smoke fluid system is another option for producing smoke. They can be used successfully, but it's necessary to comprehend how they operate. This system works by injecting a smoke fluid—typically a petroleum-based substance—into the hot exhaust stream of the engine, where it is heated in the muffler (or heating chamber), and then expelled into the air intake side of the blower. 12 smoke candles cost more than one gallon of smoke fluid on average. Smoke fluids, however, may not always produce smoke of the same caliber. It's crucial to realize that while utilizing smoke fluid, the cooling process starts as soon as the fluid is put into the heating chamber (or muffler). Eventually, the heating chamber will reach a temperature where it is not hot enough to totally transform all the fluid into smoke, resulting in thin/wet smoke. Depending on how quickly the fluid is moving, this could potentially happen. It can be particularly challenging to see farther away if the smoke has turned thin. Blocking off lines is often a smart idea for any form of smoke, but when utilizing smoke fluid, it practically becomes a requirement.

Manhole Smoke Blower　　Smoke Bombs　　Smoke Fluid

Figure 2-4 Materials for smoke test

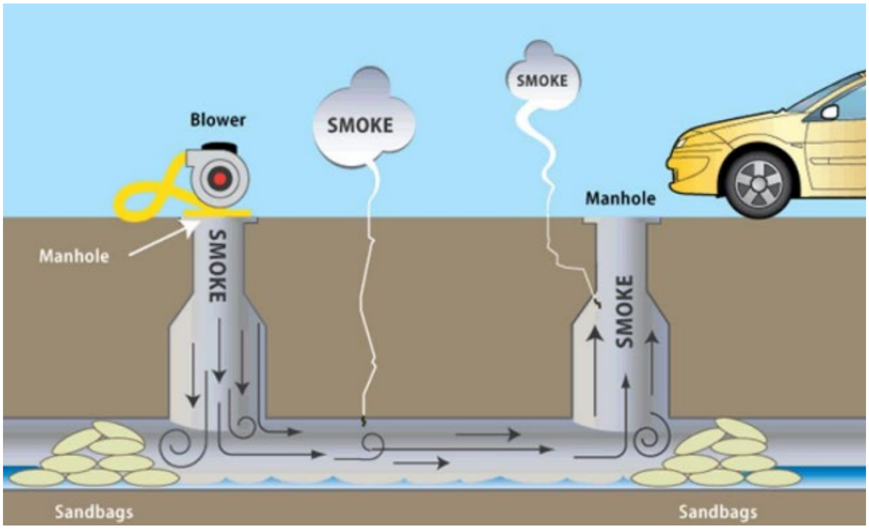


Figure 2-5 Illustrative sketches of smoke test

The summary **work procedure for smoke test** is described below.

Preparatory Work

- Have a meeting
- Inspect the site
- Take some security measures
- Measure gases by gas detector

Smoke Test

- Detect smoke rising points
- Locate mis-connected pipes
- Take photos
- Record the sewer line problem in the field notebook

Work Completion

- Ventilate by a blower
- Notify residents about the completion of work

➢ Clean up the site

Features of the smoke test

- The status of connection of drainpipes in each space can be checked in a short time.
- Inadequacies in the house drainage facility can be quickly detected. Smoke test procedure shown in Figure 2.6.

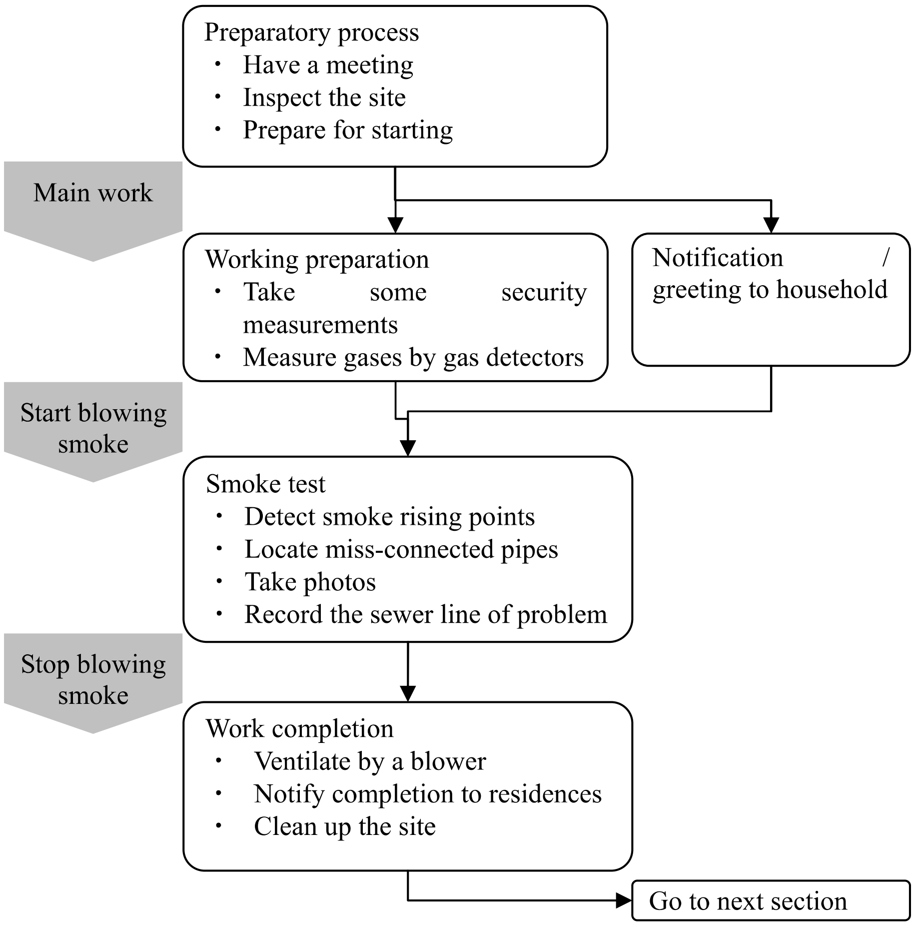


Figure 2-6 Work procedure of smoke test

b) Echo Sound Test

This method is used to confirm that the piping facilities are correctly connected. It is an effective method for identifying and knowing the plumbing systems and tracing the precise routes of sewers and lateral sewers. Ultrasonic waves are used (transmitter and receiver) to carry out the test. The work procedure for echo sound test is explained below.

Preparatory Work

➢ Have a meeting with maintenance staff

➢ Inspect the site

➢ Make construction schedule

➢ Collect relevant documents and materials

➢ Take some security measures

➢ Measure gases by gas detector

Echo Sound Test

- Investigate connection conditions
- Locate mis-connected points
- Take photos
- Record the sewer line problem in the field notebook

Making a Report

- Compile data collected during the test
- Summarize records in charts
- Make a photo album
- Update charts and record in the ledger

Features of the echo sound test are:

- Simple method to identify whether a pipe has been connected or not.
- Particularly effective to determine connection conditions of lateral sewers.
- Cannot identify clogging or trap.

c) Dye Test

A dye test is used to determine whether specific buildings or fixtures are legally connected to a wastewater collecting system, as well as whether any sewers have spilled or leaked.

Additionally, a dye test is performed to identify linkages between sanitary and storm sewers. This kind of testing can use a special dye.

Examples of common dye tests include structures that might not exhibit smoke at vents during a smoke test because of dips or traps in the service connection pipes, yards or storm drains that may be connected to a lateral sewer or the building sewer, and any suspected inflow or surface drainage into the collection pipe.

Estimating flow velocity and checking for infiltration and exfiltration are two more applications for dye testing. It is possible to find extraction areas that are not visible on TV inspection, like an open joint that is in line and on grade, by moving a bag of dye up a sewer and halting at brief intervals.

One operator must apply the dye to the suspected spot, and another must keep watch at the next downstream manhole from the suspected location in order for the dye testing to be successful. The water is turned on and the dye powder or tablet is thrown straight into the drain when a plumbing device, such as a closet bowl or basin, is being utilized. Pouring a bucket of water with dye powder is recommended in areas without an immediate water source, such as a roof gutter or storm drain in dry weather. Depending on how far the next manhole is away and the current flow, different amounts of water and color are required.

An estimation of the anticipated flow time to the downstream manhole may be made using an assumed flow velocity. Since the dyeing process frequently takes much longer than anticipated, give yourself plenty of time. When several dye tests need to be run on the same line or stretch of sewer system, the first dye test should begin at the facility that is the furthest downstream and gradually move upstream for the other dye tests. In contrast, if you dye the facilities upstream first, the flow is then required to wait several hours or until the following day to undertake additional testing.

2.2.3.6. Inspection of Flow Rate

The flow rate inspection should be performed in areas where there is a high risk of infiltration, such as areas with high groundwater levels, portions of river crossings, or areas close to rivers.

a) Flow Rate Measurement

Both continuous and instantaneous measurements of flow are possible. A typical continuous system for measurement comprises a flow sensor, primary flow device, flow recorder, transmitter, and totalizer. The primary flow gadget can be used to measure the flow right away.

The principal flow device is the heart of a typical continuous flow measuring system. This device is made to provide predictable hydraulic responses that depend on the amount of water or wastewater that passes through it. Weirs and flumes, which correlate water depth (head) with flow, venturi and orifice type meters, which correlate differential pressure with flow, and magnetic flow meters, which correlate induced electric voltage with flow, are examples of such devices. When installed and constructed in accordance with accepted standards, these common primary flow devices have shown to be precise.

The primary flow measurement device's specific hydraulic responses must be measured by a flow sensor in order to be transmitted to the recording system. Typical sensors include floats, differential pressure cells, capacitance probes, pressure transducers, ultrasonic transmitters, and electromagnetic cells, among others. The sensor signal is typically translated into units of flow that are directly recorded on a chart or transferred into a data system utilizing mechanical, electromechanical, or electronic methods. Systems that use recorders are frequently fitted with flow totalizers that show the total flow in real time.

Obtaining continuous flow data at a site where only instantaneous flow data are being obtained is a key factor for the investigator during wastewater research. Installation of a portable field sensor and recorder is required if an open channel primary flow device is used to make instantaneous measurements. Systems for measuring wastewater flow are often quite precise. It is deemed undesirable to employ a continuous flow monitoring equipment to measure wastewater flow if it cannot do so within 10% of the actual flow.

b) Pumping Test

This technique is used to gauge the rate at which water has infiltrated the pipeline. Within a short period of time, it is possible to determine the flow rate of infiltrated water into the area or system. However, because the flow velocity of infiltrated water changes with groundwater levels, it is important to confirm the weather and precipitation conditions at the time of measurement.

A cut-off plug should be put in during the inspection of each space to drain off household wastewater from the test. This should ideally be done at night, when the amount of sewage produced by households is minimal.

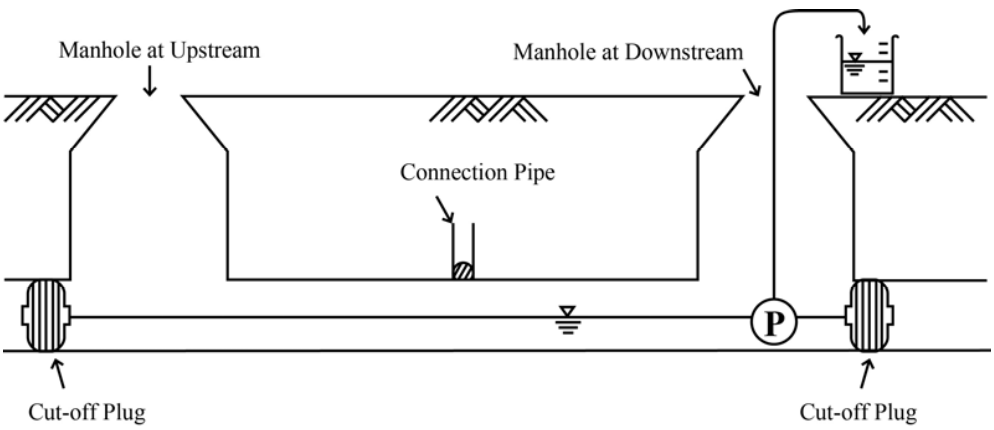


Figure 2-7 Work procedure for measurement of pumped water

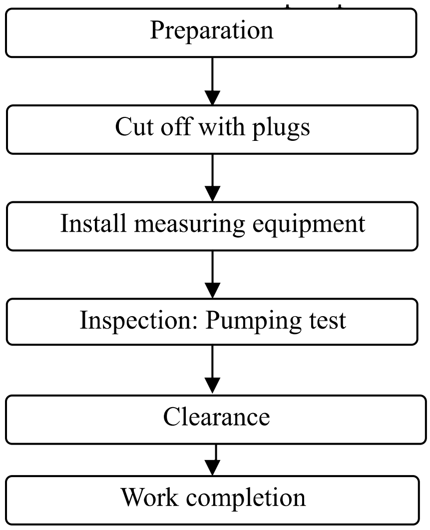


Figure 2-8 Work procedure of pumping test

2.2.3.7. Inspection of Corrosion and Deterioration

TV cameras should be used to assess the level of deterioration or corrosion within the sewer. Concrete pipe, ceramic pipe, hard unplasticized polyvinyl chloride (uPVC), brick, high density polyethylene (HDPE) pipe, ductile pipe, and glass fiber reinforced plastic (GRP) pipe are some of the materials used in the piping facility. As a result, the conditions for corrosion and deterioration vary.

Some of the methods for inspecting corrosion and deterioration conditions of a sewer include:

- Inspection by TV camera of the wall surface condition
- Crack inspection
- Neutralization test

The reasons for deterioration/failure of structural concrete parts of the piping facilities are the following:

- Cracks development in concrete due to concentrated loads)
- Deterioration of structure due to aging
- Corrosion of concrete structures due to sulphuric acid from the generation of hydrogen sulphide

In a facility where sewage is retained for an extended period of time, the sewage is likely to get anaerobic and produce dissolved sulphur, which causes concrete corrosion because it forms sulphuric acid. locations where sewage is prone to cause concrete deterioration:

- Piping systems at the pressure pipe's discharge location (including manhole pump)
- Ends of the sump discharge points upstream and downstream
- Ends of upstream and downstream of areas where sulphide-containing discharges take place
- Areas downstream of an inverted syphon

2.2.3.8. Other Examinations

The following special tests are used to thoroughly examine a facility's conditions. Various types of data that can be analyzed for investigating gas exploration are provided.

- Examining the invert elevation of sewers: Understanding pipeline conditions and comparing records from sewerage facilities.

- Examining the sediment: Look for sediment materials like sand and silt that may have entered a damaged sewer or through a junction that is loose from the outside. Around the sewer, this sand and silt may build up and create cavities.
- Confirming gases produced in the pipe facilities by a dangerous gas detection check. Gases that are present in a piping facility and the quality of the water are closely related. The gas analysis equipment in a piping facility is shown in Table -- below.

Table 2-7 Gas analysis[13]

Name of Gas	Symbol	Unit
Carbon monoxide	CO	%
Carbon dioxide	CO_2	%
Hydrogen sulphide	H_2S	ppm
Ammonia	NH_3	Ppm
Oxygen	O_2	%
Methane	CH_4	Ppm
Nitrogen Oxide	NO_x	Ppm

A few essential gases are crucial monitoring variables to prevent gas-related mishaps for the sewer/drainage maintenance team's employees. This includes carbon monoxide, oxygen deprivation, and hydrogen sulphide.

2.2.3.9. Precautions

Some of the safety precautions to be followed are listed below:

- When working in manholes, safety precautions should be taken to maintain pedestrian safety, prevent oxygen deficit, and take protection against hydrogen sulphide, among other things. Manual sewer/septic tank cleaning should be avoided to protect workers' health because it increases the likelihood that they will come into touch with sewage and sludge.
- As a result, cleaning tools and machines are required. Additionally, safety precautions should be performed when clearing out manholes.
- Drinking water supplies can become contaminated with sewage when water supply pipes pass through sewer manholes, typically in narrow streets. This is especially true when water supply pipe joints are enclosed in sewer manholes, and it also happens anytime water supply pipe joints burst.
- Therefore, it is never advisable to encase water supply pipelines in a sewer manhole. If such a situation is noticed, the affected community should be provided with clean drinking water by other temporary means, such as water tankers or by laying separate pipe over the ground or road surface, and any portion of water supply lines that are located in sewer manholes should be moved out of the manholes immediately.

Decentralized sewer systems require extra care, especially when small-bore or shallow sewer systems are used.

[13] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

2.2.4. Judgment of inspection and examination results

When an irregularity is discovered by studies and analyses, it is vital to determine if immediate repairs or modifications are required or whether regular operation and maintenance would be adequate for proper maintenance of piping facilities. The facility manager should decide after taking into account the pipe's material, age, where it was buried, wastewater quality, groundwater state, local environment, and other factors.

The following factors can be used as evaluation/judgement criteria:

- Criteria for emergency responses
- Judgement based on an inspection or examination's findings
- Testing Criteria

2.2.4.1. Criteria for Emergency Response

Inspections or reports from the outside world typically reveal anomalies relating to piping facilities. When an accident has already occurred, quick action should be taken. Further, action should be taken immediately if the following events are confirmed.

- Road surface: There is irregularity that may result in a change in level that causes subsidence or impediment to operation.
- Manhole: There is a level differential that may cause operation to be obstructed.
- Inverted siphon: Water is too high on the upstream side.

2.2.4.2. Judgement based on Inspection and Examinations' findings

Based on the findings of the visual inspection, testing should be done for both the entire span and each individual pipe. Tables 1.8 and 1.9 provide information on the testing criteria.

The three criteria for testing the overall span are as follows (A, B and C):

- Functional degradation
- Deterioration and
- Abnormalities

Table 2-8 Overall sewer span testing criteria[14]

Item		Rating		
		(A)	(B)	(C)
Corroded pipe		Reinforcing bars exposed	Aggregate exposed	Rough surface
Vertically deflected pipe	ID < 700 mm	≥ ID	ID = 1/2 ID	< 1/2 of ID
	ID 700 – 1650 mm	≥ 1/2 of ID	1/2 ID - 1/4 ID	< 1/4 of ID
	ID ≥ 1650 mm	≥ 1/4 of ID	1/4 ID - 1/8 ID	< 1/8 of ID

[14] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

2.2.4.3. Testing Criteria

A maintenance engineer should judge what counter measures are applied for inspected sewers in accordance with Table 1.10[15].

Table 2-9 Testing criteria for sewer[16]

Emergency level	Category	Testing criteria	Criteria for measure
I	Important	(A)s are more or (a)s are more in the testing results	Prompt measures are necessary
II	Medium importance	(A)s are less frequent and (B)s are more, or (a)s are less and (b)s are more in the testing results	Necessary actions may be taken by provisional measures and proper measures will be implemented within 5 years
III	Minor importance	(A)s, (B)s are few, (C)s are many, or (a)s, (b)s are few, and (c)s are many in testing results	Actions may be taken by provision measures, if required

According to the criteria in Tables above, emergency level I refers to a situation that requires an immediate response.

Emergency level II denotes that radical actions may be taken during the next five years, along with basic responses.

Additionally, emergency level III denotes partial implementation of a basic response and response selected by operation and maintenance.

2.2.5. Record Keeping

The test results for operation and maintenance of piping facilities should be recorded and stored in the format shown here.

2.2.5.1. Inspection Sheet

Once inspections and examinations are done, inspection record and sheets should be prepared as per the formats.

2.2.5.2. Logbook

For field data collection, including but not limited to samples, measurements, and observations, dedicated bound logbooks will be used. Logbook entries should be factual, objective, and devoid of any subjective judgments or terminology that might be deemed inappropriate.

To avoid information loss, all relevant field activity data shall be concurrently captured as it is observed or gathered. Daily work results that can be employed in the operation and maintenance of piping facilities should be recorded in the logbook. Then, monthly reports should include a summary of the daily record.

[15] https://openjicareport.jica.go.jp/pdf/12367207_04.pdf
[16] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

MANHOLE INSPECTION REPORT[17]

MH NO.: __________ DATE: ______________ TIME: ______________ INSPECTOR: ________

ELEVATION: ________________ DEPTHTO INVERT: __________ CLEANLINESS: ______________

TYPE CONSTRUCTION: _______________________ STREET REFERENCES: ________________________

DEFECTS:

(Cover,frame,grout,steps,shelf,pipes,or channels)

1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

(USE REVERSE SIDE FOR ADDITIONAL DEFECTSTO BE NOTED.)

	PIPE SIZE	LENGTH	TO MH#	EST.FLOW	TYPE FLOW
A.					
B.					
C.					
D.					

REMARKS:(Include need for repairs)

____

[17] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

Table 2-10 Inspection sheet[18]

<table>
<tr><td colspan="4">Inspection Sheet</td><td>No.</td></tr>
<tr><td colspan="2">Location
(Manhole No. etc.)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td rowspan="5">Inspections Items</td><td>• Manhole cover</td><td colspan="3">Abrasion, backlash, difference in level, invaded pavement, damaged, location unknown</td></tr>
<tr><td>• Inside of manhole</td><td colspan="3">Damaged floor, corrosion of metallic steps, penetration, deteriorated pipe end, rubbish, odor</td></tr>
<tr><td>• Pipe</td><td colspan="3">Corrosion, damage, coupling displacement, inadequate inclination, infiltration, roots of trees, earth, sand and mortar, road subsidence</td></tr>
<tr><td>• House inlet</td><td colspan="3">Cover (no damage), difference in level, corrosion, damage, damaged invert, earth and sand, location unknown, odor</td></tr>
<tr><td>• Lateral</td><td colspan="3">Damage, displacement, earth and sand, road subsidence</td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td colspan="2">Inspection Result</td><td colspan="3"></td></tr>
<tr><td colspan="2">Follow up actions</td><td>• Necessary
• Not necessary</td><td colspan="2">• Contracted
• Self</td></tr>
<tr><td colspan="2">Date of order</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of schedule</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of completion</td><td colspan="3"></td></tr>
<tr><td colspan="2">Remarks</td><td colspan="3"></td></tr>
</table>

[18] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

Table 2-11 Daily report[19]

Daily Report													Date			Weather
		Receipt No.	Receipt date	location:	Work Description					Inspector		Tool Material		Remarks		
Response to complaint breakdown	1.															
	2.															
	3.															
	4.															
Trunk cleaning	Diameter(mm)													No. of cleaned Area District:		Daily total
	Crew A															Person
	Crew B															Person
	Removed sand Volume															m3
	Cleaned Distance													System No.		M
Manhole	Direct works		Name of Place Repaired		No. of drainage Area		System No.	Entrusted Works		Name of place repaired		name of drainage area		System no.	Tool	Daily total
	Work description							Work Description								

[19] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

Table 2-12 Monthly report[20]

Monthly Report: **Date:** **Weather:**

Response to complaint breakdown	**category**	**1.Lateral**	**2. Inlet**	**3. Manhole**	**4.Ground Subsidence**	**5.Odour**	**6.Others**	**Total**
	Number							

Trunk cleaning		**1.Lateral**		**2. Inlet**		**3. Manhole**			**4.Ground Subsidence**		**5.Odour**			**6.Others**			**Total**
	Diameter(mm)																
	Direct crew																
	Entrusted crew																
	Removed sand																
	Cleaned Distance																

Manhole Repair	**Manhole type**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Special**	**Direct**	**Entrusted**	**Total**
	Corer replaced											
	Ring repaired											
	Barrel Repaired											
	Noise											

[20] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter2.pdf

3. CLEANING OF SEWER

3.1. Protection of Sewer Systems

If other infrastructure is constructed next to or at the cross section of a sewer, such as a water pipe or an electric cable, the sewer may be harmed. Changes brought on by ground excavation, including piles, subsurface water drops, and pile methods, can be particularly detrimental.

The maintenance engineer should take these steps to prevent sewer damage:

- Gather all pertinent data regarding the construction projects centered on the sewer location,
- Provide suggestions for effective building techniques to reduce the impact on sewers
- If necessary, ask the responsible authorities to take sewer protection measures before work is started.

Typical protective measures are as follows:

- Temporary sewer pipe laying to protect an existing sewer system
- Changing sewer materials in advance.

3.2. Safety Practices

The frequency of accidents in the sewer cleaning industry as a whole is higher than in any other sector. The obligation to provide a safe workplace for employees falls on the shoulders of the employer.

However, the employee is ultimately responsible for making sure the workplace is secure. Only by continually considering safety and working safely can this be possible.

By developing safety protocols for the plant and then making sure they are implemented, the worker has the duty to protect not just himself but also all other plant staff or visitors. He must learn to identify potentially dangerous behaviors or conditions and train himself to examine tasks, work locations, and processes from a safety standpoint. In the event that a hazard is identified, he must act right away to fix the situation. If repair is not possible, prevent the hazard by using warning signs and devices correctly, developing and adhering to safety procedures, and so on. The supervisor is personally responsible for any accidents that result in injuries or property damage due to his carelessness.

Keep in mind that "accidents don't happen—they're caused!" Every accident had a series of circumstances that culminated in an unsafe conduct, an unsafe environment, or both. Common sense, adherence to a few fundamental safety guidelines, and thorough familiarity with the risks particular to the plant supervisor job can all help prevent accidents.

3.2.1. Safety measures on sewer facilities

3.2.1.1. Traffic Hazzard

- Study the work area and make a strategy before beginning any project on a street or other high-traffic area.
- High-level signs placed far in advance of the job site may serve as a warning to traffic.
- To direct traffic, traffic cones, signs, or barricades placed around the construction site are suitable, as well as a flagger.
- If at all possible, position your work vehicle between the area being worked on and the approaching traffic.
- Wear a bright safety vest when working near roads.

3.2.1.2. Manhole

All employees who are required to enter sewer manholes should be given the appropriate safety gear, as suggested here.

1. Properly calibrated approved four gas detector
2. Safety harness
3. Fresh air blower
4. Tripod support
5. Half face masks
6. Approved hard hat
7. Safety shoes and goggles

Before entering the manhole, following guidelines may be adopted to ensure safety in manhole:

- In the small manhole, measured at all levels, the oxygen content must be at least 19.5%. (Bottom, middle and top). If the oxygen concentration is between 19.5% and 21%, it is deemed safe. If the oxygen level is below 19.5 percent, no one should go under the manhole.
- Open at least two or three manholes on both the upstream and downstream sides of the sewage line where the work is to be done to allow for ventilation. When there are insufficient blowers for ventilation sewers, this is required. At least an hour before the commencement of the procedure, the manholes should be opened. To protect anyone, especially youngsters, from unintentionally slipping into the sewer, the opening manhole must be adequately gated or walled. It is possible to employ a wire-net or -welded fabric dummy cover.
- As much as possible, a fresh air blower ventilation system should be used. It is preferable to run blowers for at least 30 minutes before to beginning and throughout the cleaning process.
- Utilize a detector to determine the gas flammability in manholes.
- Before a person enters a manhole or sewage line, as well as periodically throughout lengthier activities, it may be examined for the presence of harmful gases.
- Before accessing the sewage system, all employees must wear a safety harness and lifeline. Each person entering the manhole must have at least one support person waiting for them at the top. Throughout the duration of operation, the person entering the manhole or sewage line must be watched using a signal, camera, CCTV, etc.
- Before entering the manhole, the stairs or rungs must be checked for structural safety. Where necessary, a portable aluminum ladder must be accessible during the work duration. During operation, the portable ladder must be correctly fastened or seated.
- Make sure that there are no items or tools close to the edge that could fall into the manhole and hurt the workers.
- In a bucket secured with rope and a pulley, lower all the tools to the workers.
- The lighting apparatus used for sewer cleaning must be both fire- and explosion-proof.
- Open manholes must have warning signs posted around them while construction is underway.
- Smoking, using open flames, and using spark-producing devices shall be forbidden both inside the manhole and in the vicinity of an open manhole.
- All employees who enter the manhole must have the necessary tools and safety gear. The use of

portable tools and equipment must be strictly regulated.

- For respiratory protection, personnel must have access to gas masks. The proper use of the gas masks must be taught to the employees.
- A big sewer system may require the use of specialized equipment to penetrate. The equipment may include alarm-equipped atmospheric monitoring systems.

An emergency escape breathing equipment (EEBA) with at least a 10-minute air supply should be worn for escape in the case of a rapid or unanticipated atmospheric change.

3.2.2. Safety measures before sewer cleaning

3.2.2.1. Highly toxic components of sewer gas

- Hydrogen sulfide, methane, carbon dioxide, sulfur dioxide & Carbon mono oxide.
- Symptoms of headache, nausea, dizziness, or drowsiness may indicate exposure to an odorless gas like methane or carbon monoxide, or to hydrogen sulfide, which smells of rotten eggs.
- Anyone experiencing severe symptoms should seek immediate medical care.

a) Gases of main concern in sewer

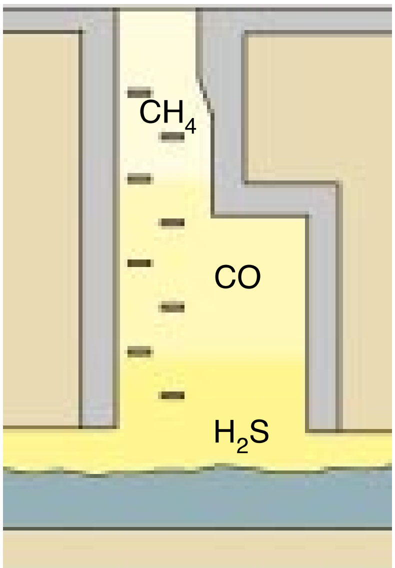


Figure 3-1 Gases of main concern in sewer

b) How are these gases formed?

- The end products of anaerobic decomposition include gases like hydrogen sulphide, ammonia, methane, etc. $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$
- Aerobic decomposition is caused in the presence of air or oxygen which is available in sewage in the dissolved form. During this process, organic matter is broken up and oxidized to form stable and non-objectionable end products such as carbon dioxide, nitrates, sulphates, etc.

c) Hydrogen sulphide (H2S) and Carbon monoxide (CO)

d) Hydrogen sulphide (H2S)

Hydrogen sulfide has been reported as the leading cause of sudden death in the work place. At concentrations in air of approximately 300 ppm, H2S can be immediately deadly.

At concentrations above 100 ppm, hydrogen sulphide has a paralysing effect on the sense of smell.

It is absorbed primarily through the lungs, but can also be adsorbed to a limited extent through the skin and mucous membranes (eyes, ears, nose, mouth etc).

e) Carbon monoxide (CO)

The lethal colorless and odorless gas – carbon monoxide

Exposure to carbon monoxide at concentrations over 350 ppm can cause confusion, fainting on exertion and collapse. An airborne concentration of carbon monoxide above 1,200 ppm is immediately dangerous to life or health.

f) Methane (CH4) & CO2

- Methane is a simple minimally toxic gas and displaces oxygen, but does not itself cause significant physiological responses.
- It is a colorless, extremely flammable and explosive gas that can cause fire and explosion.
- Carbon dioxide is a simple asphyxiant (displaces oxygen) and a stimulant for the respiratory system. A concentration of 5% may produce headaches and shortness of breath. Background concentrations of carbon dioxide in air range from 300 to 400 ppm.

Safety equipment used for sewer cleaning

Choose easy operated Four gas detectors

Figure 3-2 Four gas detector

Figure 3-3 Half face mask

Figure 3-4 Breathing equipment & Full body harness

Figure 3-5 Tripod and ventilating arrangement

Figure 3-6 Fresh air should be supplied to the working location and the blower fan must be carefully located to avoid sucking in contaminated air.

g) Protective clothing

There are four primary types of disease-causing organisms that can affect humans and are found in sewage — bacteria, protozoa, viruses and parasitic worms. PPE can help ensure that these contaminants are kept off of the human body and keep the worker free from scrapes, cuts, scratches and other bodily harm.

Figure 3-7 Protective clothing

3.3. Sewer Cleaning

3.3.1. Sewer & manhole cleaning procedures suitable for MCs

I. Manual

II. Mechanical

To operate and maintain a sewer collection system to function as intended, the maintenance engineer should try to strive towards the following objectives:

- Minimize the number of blockages per unit length of sewer, and
- Minimize the number of odour complaints.

For this purpose, sewer cleaning using hydraulic or mechanical cleaning methods needs to be done on a scheduled basis to remove accumulated debris in the pipe such as sand, silt, grease, roots, and rocks. If debris is allowed to accumulate, it reduces the capacity of the pipe and blockage can eventually occur resulting in overflows from the system onto streets, yards, and into surface waters. Roots and corrosion also can cause physical damage to sewers.

3.3.2. Cleaning Equipment and Procedures

Sewer cleaning works require usual implements like pick axes, manhole guards, tripod stands, danger flags, lanterns, batteries, safety lamps, lead acetate paper, silt drums, ropes, iron hooks, hand carts, plunger rods, observation rods, shovels etc.

In addition, sewer cleaning work calls for the following special equipment and devices like a portable pump set running on either diesel or petrol engine, rope and cloth balls, sectional sewer rods, a sewer cleaning bucket machine, a dredger, a rodding machine with flexible sewer rods and cleaning tool attachments such as augers, corkscrews, hedgehogs and sand cups, scraper, and hydraulically propelled devices such as flush hags, sewer balls, wooden bail and sewer scooters, sewer jetting machine, gully emptier and pneumatic plugs.

3.3.2.1. Manila Rope and Cloth Ball

The most common way of cleaning small diameter sewers up to 300-mm diameter is by the use of a manila rope and cloth ball. Flexible bamboo strips tied together are inserted in the sewer line by a person on top. If necessary, another person inside the manhole helps in pushing the rod through the sewer line. When the front end of the bamboo strip reaches the next manhole, a thick manila rope, with cloth ball at one end, is tied to the rear end of the bamboo splits. The bamboo splits are then pulled by another person in the downstream manhole and pushed through the sewer line. As the rope is pulled, the ball sweeps the sewer line and the accumulated grit is carried to the next manhole where it is removed out by means of buckets. This operation is repeated between the next manholes until the stretch of sewer line is cleaned.

3.3.3. Manual cleaning

i. Long strips from bamboo stem are taken and tailored to use as sewer cleaning rod between two consecutive manholes.

ii. Ventilate the manhole and test for toxic gases, explosive gases, and oxygen level

iii. Determine the depth of the manhole

iv. Assemble sufficient rod portion to firmly rest in the sewer and leave enough protruding above the street level to allow for working conditions, usually about 18 to 24 inches

3.3.4. Mechanical cleaning

3.3.4.1. Bucket Machine (Winch Machine)

Source: EPA, 2003

Figure 3-8 Power bucket machine setup

The bucket machine consists of two powered winches with cables in between. For cleaning a section of sewer; the winches are centered over two adjacent manholes. To get the cable from one winch to the other, it is necessary to thread the cable through the sewer line by means of sewer rods or flexible split bamboo rods. The cable from the drum of each winch is fastened to the barrel on each end of an expansion sewer bucket fitted with closing device, so that the bucket can be pulled in either direction by the machine on the appropriate end. The bucket is pulled into the loosened material in the sewer until the operator feels that it is loaded with debris. The winch is then thrown out of gear and the opposing winch is put into action. When the reverse pull is starts, the bucket automatically closes and the dirt is deposited in a truck or a trailer. This operation is repeated until the sewer is cleared. Various bucket sizes are available for sewers of 150 mm to 900 mm in size. The machine is also used along with other scraping instruments for loosening sludge banks of detritus or cutting roots and dislodging obstructions.

i. Two machines are positioned over the respective manholes
ii. The lower manhole roller is lowered into the manhole.
iii. To thread the sewer, a synthetic rope is used
iv. To this rope attach a nylon parachute designed for such use and allow this parachute to float downstream to the working manhole
v. The clearing bucket is now ready to be attached to the cable

vi. As the bucket is pulled upstream into the material deposited in the sewer, a definite resistance can be noticed when the bucket is full

vii. When the bucket is full, pull the loaded bucket back out of the sewer

viii. Final cleanup is performed with special care given to washing down and completely cleaning the entire area

3.3.4.2. Velocity Cleaners (Jetting Machines)

Figure 3-9 Sewer high pressure jetting machine

1. The high velocity sewer cleaner makes use of high velocity water jets to remove and dislodge obstructions, soluble grease, gut and other materials from sanitary, storm and combined sewerage systems. It combines the functions of a rodding machine and gully emptier machine. Basically, it includes a high-pressure hydraulic pump capable of delivering water at variable pressure up to about 8 MPa through a flexible hose to a sewer cleaning nozzle. The nozzle has one forward facing hole and a number of rear wards facing holes. The high-pressure water coming out of the holes with a high velocity breaks up and dislodges the obstructions and flushes the materials down the sewer. Moreover, by varying the pressure suitably, the nozzle itself acts as a jack hammer and breaks up stubborn obstructions. (A separate suction pump or air flow device may also be used to suck the dislodged material).
2. The entire equipment is usually mounted on a heavy truck chassis with either a separate prime mover or a power takes off for the suction device. The high-pressure hose reel is also hydraulically driven. The truck also carries fresh water tanks for the hydraulic jet and a tank for the removed sludge and the various controls grouped together for easy operation during sewer cleaning. The manufacturer's operating and servicing manuals should be carefully followed for best results in the use of the machine.

   The items of the most importance in performance of these machines is listed below. Maintenance will be easier and staff will be happy if these specifications are taken care of:

Table 3-1 Important specs

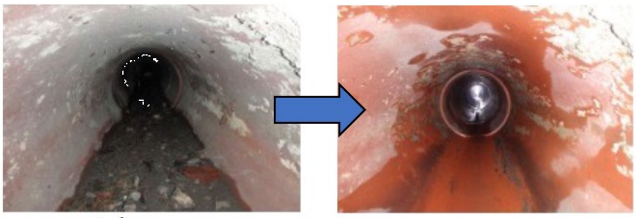
High pressure plunger pump	Pressure should not be less than 190 bar
Strength of hose	Should be minimum of 7500psi
Tank capacity	Should not be less than 8000 liters

Image of water nozzle

From above

From side

Image in pipes(Before and After)



Before cleaning

After cleaning

Figure 3-10 Pressure nozzle

3.3.4.2. Sludge suction machine

Suction units create the vacuum required for siphoning of mud, slurry, grit and other materials from sanitary, storm and combined sewerage systems. The vacuum elevated is such as to siphon the materials from the deep manholes catch-pits etc., having depth ranging from 1 m to 8 m in normal cases with an option to suck an additional 4 m with the help of special accessories for the purpose. The unit can be vehicle or trolley mounted.

Silt and heavy particles settled at the bottom can be agitated and loosened by pressurized air with the help of the pump and then sucked in a tank. Once the silt tank is full, the effluent is discharged in the nearby storm water drain or manhole and the operation is repeated until the silt is cleared off the manhole. The silt deposited in the tank is then emptied at the predetermined dumping spot.

Figure 3-11 Sludge suction machine

The items of the most importance which, are matter of concern for maintenance staff are:

Table 3-2 Important specifications

Vacuum pressure	Should not be less than -90 Kpa at sealing temperature of 15C
Air Flow	Should not be less than 30m^3/min
Tank capacity	Should not be less than 4500 liters

3.3.5. Maintaining record of cleaning

Records of all cleaning operations should be entered and filed for future reference. These records should include the data, street name or number, line size, distance, and manhole numbers or identification. Also, the kind and number of materials removed, wastewater flow, and auxiliary water used should be noted. If particular problems were encountered, these too should be noted, especially the exact location of obstructions. A record form sample is shown in Figure below.

During the routine cleaning operations, many manholes should be opened and used for high-velocity cleaning or flushing of sewer. Manhole Inspection form detailing its location, condition, and any problems observed should be completed. If this is done each time a manhole is opened during cleaning operations, over time the database for these structures will include up-to-date information on a high percentage of them and allow better decisions to be made in regard to routine maintenance, repair, or rehabilitation.

If pieces of broken sewer are removed, a TV inspection may be needed and repairs may need to be made on the broken sections of pipe.

Recording traffic patterns at a site can be very helpful next time the equipment is set up at the location. Car park (such as over manholes), traffic volume during rush hours, and whether police traffic control should be called for help before going to the site, should be indicated.

Computers are being used in many aspects of operation, maintenance, and recordkeeping of collection system. Computer software packages are available for scheduling preventive maintenance activities, issuing work orders for repairs, keeping track of where work is done, who did the work, when, and the labour and materials required. With the correct software, any information in the computer's records can be recalled for future use. Computers are also used to keep spare parts inventories and to order spare parts when the supply runs low and before they are needed for scheduled maintenance and repairs.

When marking out records, remember that you or someone else will be referring to them. The more complete the record, the easier the next operation becomes since you have a history of this sewer.

Record keeping and reporting is proposed as below:

3.3.5.1. Daily cleaning record

Table 3-3 Daily cleaning record

Office	Record	Machines used	Record
Location of work		Condition of flow before cleaning	
Size of sewer		Condition of flow after cleaning	
Length cleaned/desilted		Kind of material removed	
No. of M/H cleaned		Time spent on cleaning	
Supervisor		Pictures taken?	

Office	Record	Machines used	Record
Sewer men deputed			

Pictures of cleaning may be maintained as below:

Table 3-4 Pictures for cleaning

DESILTING OF SEWER AT ----------------			
Picture before desilting		**Picture after desilting**	

3.3.5.2. Annual record

Table 3-5 Annual cleaning record

Size of sewer	Desilted length	Frequency	Remarks
9 inches			
12 inches			
15 inches			
18 inches			
21 inches			
24 inches			
27 inches			
30 inches			

3.4. Protection Against Infiltration and Exfiltration

Infiltration and inflow, while overlooked in many collection systems for decades, have now gained recognition as major defects that can cause failure of a collection system. In most cases, this failure results in hydraulic overloads (too much water) of the collection system or the sewage treatment plant.

In the case of a collection system, hydraulic overloads result in surcharged manholes, overflowing manholes and exposure of community to diseases and pollutants carried by the wastewater in a collection system. This type of failure is also known as a sanitary sewer overflow.

In the case of an STP, infiltration and inflow can result in plant loads exceeding the plant capacity. Bypassing raw sewer to the environment has been the only answer in the past, but this practice is no longer allowed.

3.4.1. Measures Against Infiltration of Rainwater

Inflow detection and collection depend upon the type and source of inflow causing the problem. Inflow is water that is not polluted and should not be in a wastewater collection system. Inflow is water that enters a sewer as a result of a deliberate illegal connection or by deliberate drainage of flooded areas into a wastewater collection system.

In many areas the main line portion of the collection system is relatively tight. A major source of infiltration in this situation can be the house service lines. They can be tested for leaks using smoke tests and by development of small cameras and robotic equipment.

Collection or elimination of inflow/ infiltration depends on the type and location of the source of problem. Typical solutions to inflow/infiltration problems include:

a) Manholes

- Raise rim elevation by use of grade rings if not located in streets (inflow). Install watertight covers where needed (inflow).
- Install inflow protection covers (inflow).
  Seal covers (inflow).
- Seal or repair barrels (infiltration).

b) Sewer Pipes (Infiltration)

- Seal segment of damaged pipes and joints.
- Dig up and replace damaged pipes and joints.
- Line sewer with a plastic liner and/or fiber liner material.

3.4.2. Measures Against Exfiltration of Untreated Sewage

Exfiltration is the leakage of wastewater out of the collection system through broken or damage pipes and manholes. All wastewater collection systems, except some constructed in recent years, have many leaks. These systems may exfiltrate wastewater through defective pipe joints and cracks. The wastewater that does exfiltrate may contaminate shallow wells or open ditches where children and pets play. To make an old collection system airtight would be extremely expensive and not very cost-effective. Major points of infiltration or exfiltration in a collection system can be identified by the use of television or smoke testing and can then be corrected.

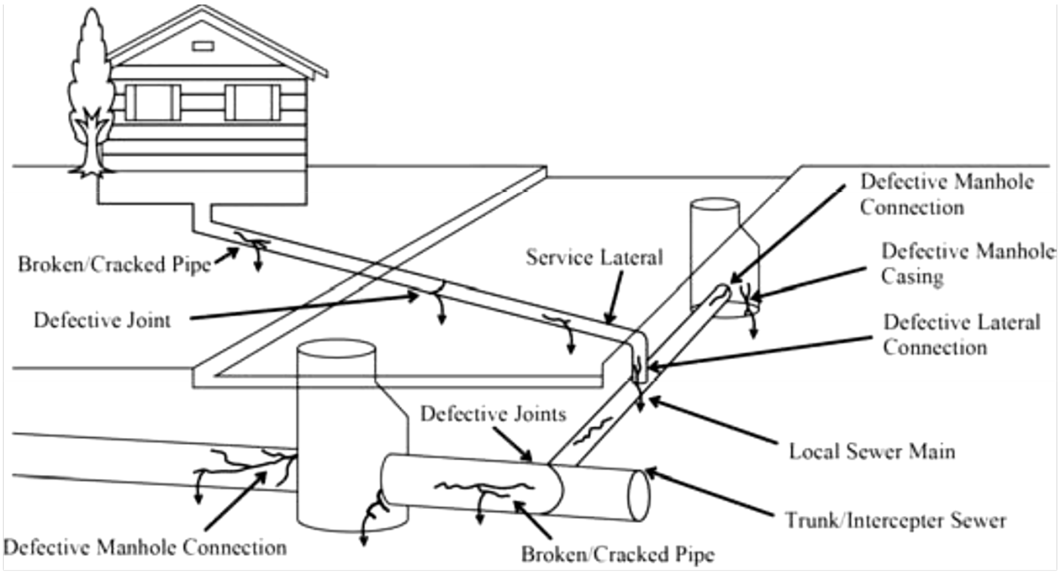


Figure 3-12 Sewerage leaking locations

The proper selection of corrective or rehabilitation methods and materials depends on a complete understanding of the problems to be corrected, as well as the potential impacts associated with the selection of each rehabilitation method. Pipe rehabilitation methods to reduce exfiltration (and simultaneously infiltration) fall into one of the two following categories:

- External Rehabilitation Methods
- Internal Rehabilitation Methods

Certain conditions of the host pipeline influence the selection of the rehabilitation method. It is therefore necessary to assess these factors to prepare the pipe for rehabilitation. Rehabilitation is proceeded by surface preparation by cleaning the pipes to remove scale, tuberculation, corrosion, and other foreign matter.

The concerned departments, corporation, urban local bodies, etc. have to participate in the total sanitation program. These departments should be part of a co-ordination committee constituted at a local level and are required to meet half yearly to plan appropriate co-ordination specific to total sanitation. These meetings, however, can be more frequent during specific items such as drought, floods, etc.

3.4.2.1. External Sewer Rehabilitation Methods

External rehabilitation methods are performed from above the ground surface by excavating adjacent to the pipe, or the external region of the pipe is treated from within the pipe through the wall. Some of the methods used include:

External Point Repairs
Chemical Grouting (Acryl amide Base Gel and Acrylic Base Gel) Cement Grouting (Cement, Micro fine Cement, and Compaction)

3.4.2.2. Internal Sewer Rehabilitation Methods

Internal sewer rehabilitation methods are the same as infiltration measures.

3.5. Manholes And Appurtenances

Because they are part of the collection system, manholes require the same attention as the rest of sewer network. When located in streets, these structures are subject to vibrations and pounding of vehicle traffic. Manholes may settle at a different rate than connected sewer, creating cracks in joints. Determine the proper elevations or grades around the lid, to confirm that the lid is not buried, and to examine structural integrity (look for cracks) of the manhole and its functional capacity. The condition of the pipelines coming into a manhole may be known merely by observing the content and volume of flows from a specific direction.

3.5.1. Checking the current situation

Manhole examination is made by visually inspecting the condition of the cover and the internal parts.

Manhole inspection should be carried out together with the inspection and examination of sewer. It is generally carried out together with the cleaning of the sewer.

Before entering any manhole, adequate safety measures should be taken.

Safety measures during the work should be formulated giving consideration to traffic safety, oxygen deficiency, poisoning due to toxic gas such as hydrogen sulphide, and so on.

3.5.2. Damage or wear

Damage or wear in the manhole cover obstructs passage and is a risk. The facility manager should inspect the manhole cover for damage, wear, play, non-coincidence of heights of cover and road surface, offset of manhole block, and so on.

Wear of cover | Offset of manhole block | manhole damaged

Figure 3-13 Damage to manholes

3.5.3. Conditions Inside Manhole

Manhole is an essential facility for operation and maintenance of sewer pipes; it helps operation and maintenance to be performed safely and easily. For smooth flow of wastewater through the

sewer pipe, the following are to be properly inspected: scouring of sewer bottom, differential settlement, manhole block, crack in side wall, sediments and condition of mouth of connected sewer pipe.

Inspection should be performed on ground, while examination should be performed by the relevant person entering the manhole and working inside.

Table 3-6 Manholes Check items[21]

Item inspected		Description of inspection
Exterior condition	Ground surface	a. Check for crack, subsidence, and cave-in b. Check for overflow stream c. Check for any invaded pavement d. Check surrounding condition
	Manhole cover	a. Visual check for backlash, abraded surface, and corrosion (Check if any mark on external or internal surface of cover is erased.) b. Check for any malfunction of float preventive function, locking device, fall preventive function, etc. c. Others (damage on rising spacer, difference in grade of cover and grade ring, damaged grade ring, caved in manhole cover, offset, etc.)
Interior condition	Flow and sediment	a. Check for stagnant water or flow b. Check for any accumulation of sand and soil, pieces of wood, and mortar including remains of construction works and illegal disposals. c. Check for appearance of inverts such as scouring, damage, etc.
	Damage	a. Check steps for corrosion, rattling, and missing items (No.). b. Check blocks for damage, crack, corrosion, gap, and deteriorated caulking. c. Check barrel and base for damage, crack, and corrosion. d. Check for any improper joint of main sewers and laterals. e. Check for any irregular subsidence.
	Infiltration	a. Check for infiltration
Others		a. Check inflow for unacceptable or inferior quality. b. Check for toxic gases or odour.

3.6. House Service Connection

House connections or service connections to the public or municipal sewer should preferably be approved by the Maintenance Engineer. It is necessary to ensure that the fittings and pipes in the houses are according to the byelaws or rules or regulations in force. If such byelaws, rules or regulations do not exist, then reference may be made to the relevant IS code of practice. House connections may be of minimum size of 150 mm in diameter and should preferably be connected to the Municipal or Public sewer through a manhole. When “Y or T” connections are allowed, extreme care must be taken when breaking the sewer pipeline and inserting the “Y or T” saddle.

Similarly, the connection to the manhole must be properly done and closed. Care has to be taken so that the brick bats or other materials of construction are not allowed to fall and lie in the manhole. This extraneous material is largely responsible for persistent clogging of the sewer lines.

It should also be ensured that the house fittings are properly trapped not only to prevent the ingress of sewer gases into the houses but also to ensure that large objects do not find their way into the sewers. Similarly, it should be ensured that any liquid or material which is likely to be injurious to the material of the sewer line or to prejudicially interfere with its contents or be a hazard to the workmen engaged in the maintenance of the sewer lines, like very hot water, acids, chemicals, etc., are not allowed.

3.6.1. Examination of house connection

Inspection of lateral sewer and house inlet (household) should be carried out if deemed necessary from documents and data, and cross connections and mains should be studied. Clogging of lateral sewer and sedimentation of house inlet are the items to be inspected.

[21] JASCOMA, 2007

3.7. Accidents related to Sewer Facilities

3.7.1. Need for Traffic Control

The primary function of streets is to provide for the movement of traffic. A common secondary use within the right-of-way of streets is for the placement of public and private utilities such as sanitary sewers. While the movement of traffic is very important, streets need to be constructed, reconstructed, or maintained, and utility facilities need to be repaired, modified, or expanded Consequently, traffic movements and street or utility repair work must be regulated to provide optimum safety and convenience for all.

Working in a roadway represents a significant hazard to a collection system operator as well as pedestrians and drivers. Motor vehicle drivers can be observed random things like reading, talking on cell phones, etc., rather than concentrating on driving. At any given time of the night or day, a certain percentage of drivers can be expected to be driving while under the influence of drugs or alcohol. Given the amount of time collection system operators' work in traffic while performing inspection, cleaning, rehabilitation, and repairs, the control of traffic is necessary if we want to reduce the risk of injury or death while working in this hazardous area. The purpose of traffic control is to provide safe and effective work areas and to warn, control, protect, and expedite vehicular and pedestrian traffic. This can be accomplished by appropriate and prudent use of traffic control devices.

Most states, counties, and cities have adopted regulations to control traffic and reduce the risk under different circumstances. This section illustrates examples of traffic control which may or may not meet the specific requirements of the laws in your geographical area but should serve to make you aware of various aspects of traffic control.

At any time, traffic is affected, appropriate authorities in your area must be notified before leaving for the job site. These could be state, country or local depending on whether it is a state, country or local street. Frequently, a permit must be issued by the authority that has jurisdiction before traffic can be diverted or disrupted. In some cases, traffic diversion or disruption may have an impact on the emergency response system in your area, such as access by fire or police, and so these agencies may be involved as well in most cases, you will need to plan ahead to secure permits and notify authorities. This may mean only a phone call or two or it could mean several days' or weeks' advance planning if you need to make extensive traffic control arrangements.

Upon arrival at the job site, look for a safe place to park vehicles. If they are to be parked in the street to do the job, route traffic around the job site before parking vehicles in the street. If practical, park vehicles between oncoming traffic and the job site to serve as a warning barricade and to discourage reckless drivers from ploughing into operators.[22]

[22] https://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter7.pdf
moud_manual_on_sewerage_and_sewage_treatment_part_b_operation_and_maintenance_2012

4. O&M OF DISPOSAL PUMPING STATIONS/LIFT STATIONS

4.1. Introduction

Typical Flow Diagram

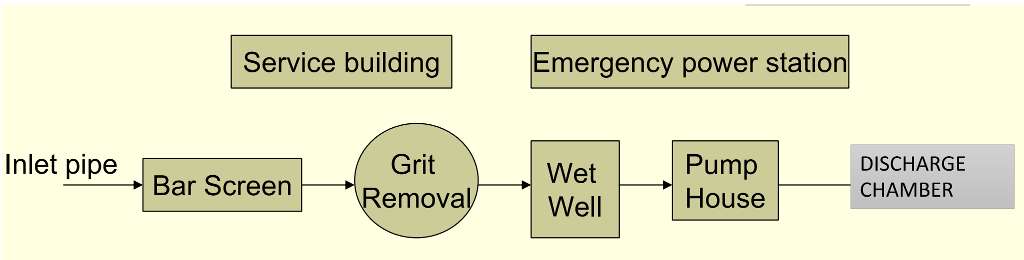


Figure 4-1 Typical flow diagram

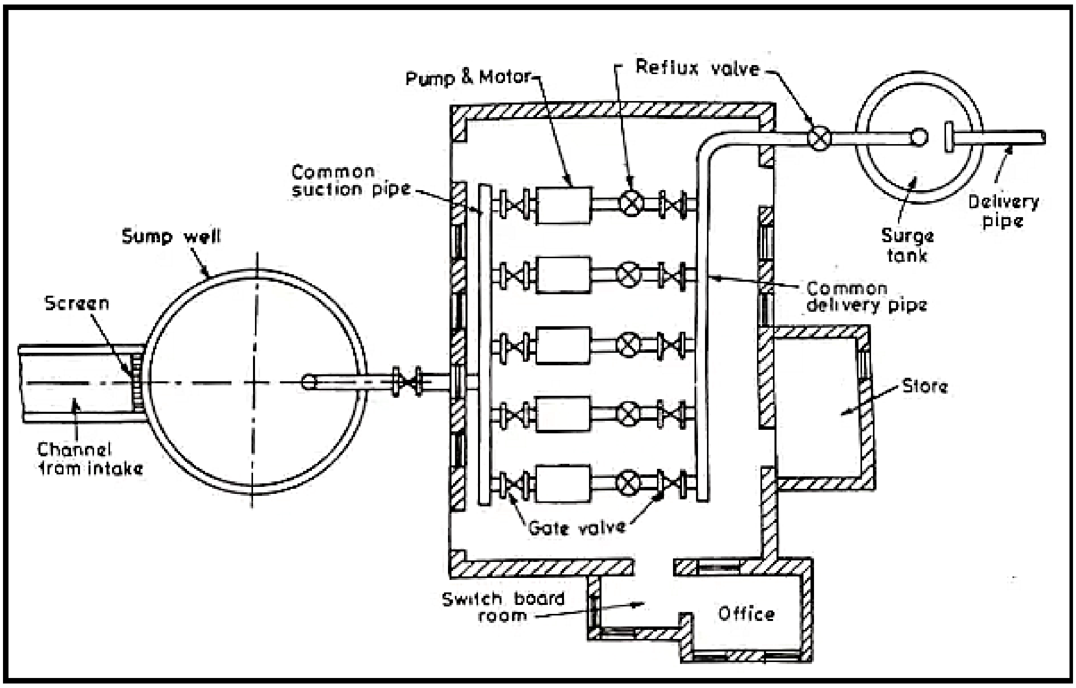


Figure 4-2 General components of a disposal station

4.2. Typical design of a disposal pump station

4.2.1. Influent Chamber & Channels

The influent chamber will receive the incoming sewers and divide the flow as necessary to the influent channels and wet wells. There will be more than one influent channel and wet wells, to facilitate repairs and cleaning without shutting down the pump station operation. Manually operated or motor driven sluice / penstock gates should be provided at the sluice gate to shut down the sewage flow.

4.2.2. Pump Station Overflow

An overflow and emergency discharge conduit will be provided for each sewage pump station, for use if the pump station must be shut down, where required to prevent immersion damage to electric motors, switch gear, and/ or other equipment. The overflow will be located at the influent chamber or a conventional upstream chamber to and will discharge by gravity to the nearest drainage channel.

4.2.3. Influent Channels and Bar Screens

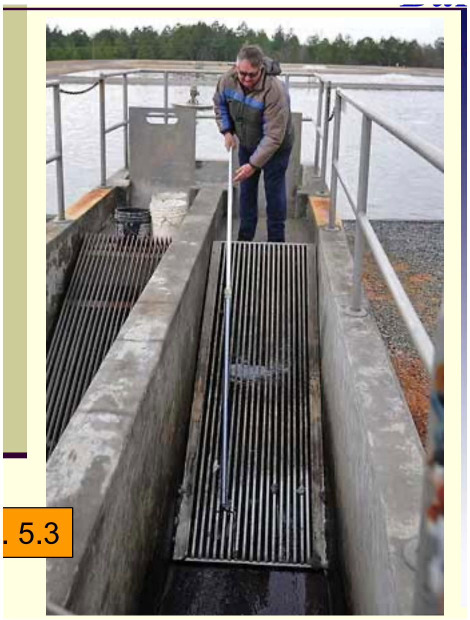


Figure 4-3 Bar screen

Normally there should be two influent channels, each designed to carry half the flow from the influent chamber. Each chamber will have a manually / mechanically cleaned bar screen of mild steel or stainless steel properly designed with spacing of bars to match pump requirement.

4.2.4. Wet Wells

Normally wet wells should at least be provided in duplicate. This will permit isolation and shutdown of one side during cleaning or maintenance work in the wet well area, while keeping the other side in service for continuity of pump station operation. The effective capacity of the wet well should provide a holding period not to exceed 10 minutes for the average sanitary (dry weather) flow. For the ultimate anticipated flow conditions, it is suggested that an effective wet well capacity be selected to provide a holding time of approximately 5 minutes at average sanitary design flow. The wet well floor shall be hopper shaped. The horizontal area of the hopper bottom shall be no larger than needed for proper installation of the sewage pump suction pipes and other wet well appurtenances.

4.2.5. Pumping station capacities

Sewage pumping station are designed to have pumping capacity to handle total design flows i/c storm water. If the area development is likely to be extensive, it is advisable to design the pumping station so that additional pumping units can be added at a later stage along with leaving space in both wet well and pumping chamber including provision of additional rising mains / force mains. Following conditions should be met in the design of pumping stations:

a) cycle time must not be less than 5minutes.

b) Each pump must run at least 2 minutes.

c) Detention time should not be more than 10-20 minutes to avoid septic conditions.

4.2.6. Wet Well Design

4.2.6.1. Storage and holding Capacity of wet well

- The effective capacity of the wet well should provide a holding period not to exceed 10 minutes for the average sanitary (dry weather) flow.
- For the ultimate anticipated flow conditions, it is suggested that an effective wet well capacity be selected to provide a holding time of approximately 5 minutes at average sanitary design flow.

4.2.6.2. The primary variables for sizing the wet well are:

- number of pumps,
- pump bell diameter,
- pump bay width,
- minimum distance to trash rack, and
- minimum distance to inlet invert.
- Effective Volume = $V = [Q_{max} \times t(min)]/4$
- Detention time of wet well=wet well volume/average discharge

  Cycle Time for Minimum and Average Flow. It should be greater than 2 minutes

  $t = V/(P-Q_{min})$
- CYCLE TIME for average flow = $t = (V/(P-Q)) + (V/Q)$
- Pumps will be selected for minimum, average and peak flow.

- **Cycling Sequence and Volumes**
- Cycling is the starting and stopping of pumps, the frequency of which must be limited to prevent damage and possible malfunction. The wet well must be designed to provide sufficient volume for safe cycling, or sufficient volume must be provided outside the wet well. However, to keep sediment in suspension, the wet well should not be oversized. The volume required to satisfy the minimum cycle time is dependent upon the characteristics of the power unit, the number and capacity of pumps, the sequential order in which the pumps operate and whether or not the pumps are alternated during operation.

Storage and holding Capacity of wet well

- The effective capacity of the wet well should provide a holding period not to exceed 10 minutes for the average sanitary (dry weather) flow.
- For the ultimate anticipated flow conditions, it is suggested that an effective wet well capacity be selected to provide a holding time of approximately 5 minutes at average sanitary design flow.

4.2.6.3. There are two basic cycling sequences:

- One will be referred to here as the "common off elevation." In this sequence, the pumps start at successively higher elevations as required; however, they all stop at the same off elevation. This is advantageous when large amounts of sediment are anticipated.
- The other sequence uses a "successive start/stop" arrangement in which the start elevation for one pump is also the stop elevation for the subsequent pump; i.e., the start elevation for Pump 1 is the stop elevation for Pump 2, the start elevation for Pump 2 is the stop elevation for Pump 3 (see Figure below). There are countless variations between these two sequences.

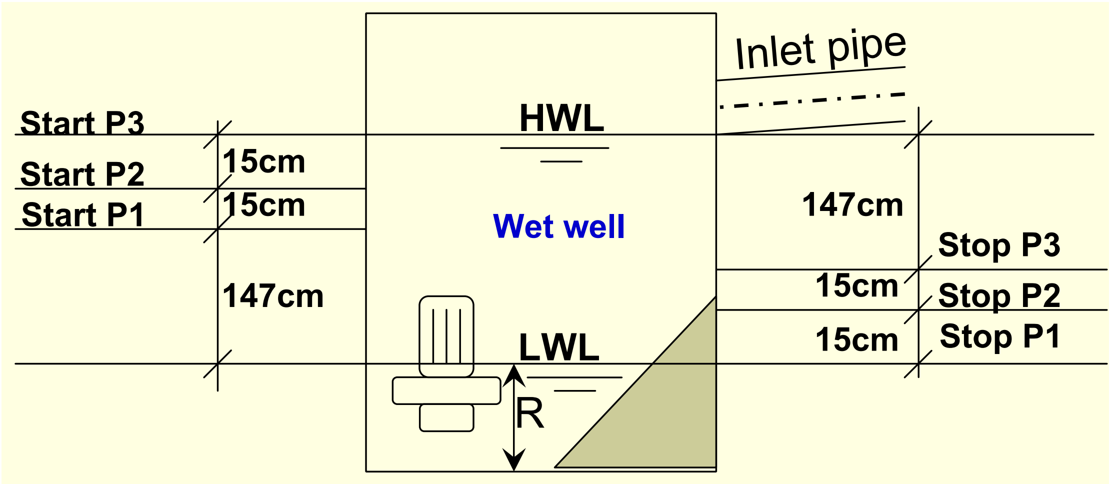


Figure 4-4 Wet well showing sequence of pumps

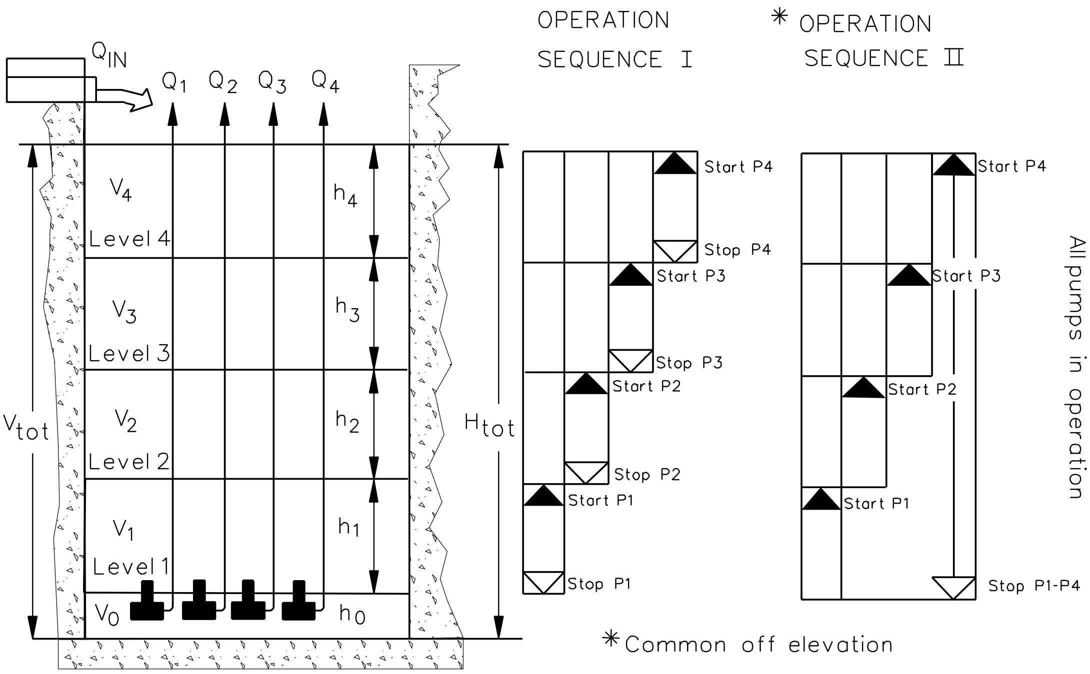


Figure 4-5 Pump Sequences

I. *Decreasing sump volume by pump alternation. Pumps starting in sequence and stopping in reverse order.*
II. *By designing the control system for pump alternation, the sump volumes can be reduced and distribute the pump operating time more evenly between the four pumps.*
III. *This system works for any number of pumps in a station.*
IV. *For example, when four pumps are installed in the same station and if the inflow is less than the capacity of one pump, pump number one would, without alternation, do all the work.*
V. *With alternation, pump number one starts and draws down. Next start would call pump number two. This means that, with four pumps of the same size and operating in an alternating sequence, each pump is called on to pump down the sump volume, V1, every fourth time. The cycle time of each pump will be four times longer than the cycle time offilling and emptying of V1.*

(a) Lowest Pump "Off" Elevation

The Hydraulic Institute recommends that the lowest pump "off" elevation be no lower than the invert elevation, unless plan dimension constraints dictate that the station floor be lowered to obtain the necessary cycling volume. This recommendation is based on the fact that it is usually less expensive to expand a station's plan dimensions than to increase its depth. This elevation represents the static pumping head to be used for pumping selection.

(b) Pump "On" Elevations

These should be set at the elevations that satisfy the individual pump cycling volumes (V_x). Starting the pumps as soon as possible by incrementing these volumes successively above the lowest pump-off elevation will maximize what storage is available within the wet well and the collection system. The depth required for each volume is computed as follows:

$H_x = V_x$/plan area

In theory, the minimum cycle time allowable to reduce wear on the pumps will occur when the inflow to the usable storage volume is one-half the pump capacity. Assuming this condition, cycling time can be related to usable volume.

$t= V_t/(Q_p - Q_i)+V_t/Q_i$

where: t = minimum cycle time

V_t = minimum required volume for pump cycling, ft^3

Q_p = individual pump rate, ft^3/s

The time in minutes for all pumps is computed as follows:

$t_{min} = V_{min}/15Q_p$
where: V_{min} = minimum required cycle volume, ft^3

the following limits may be used for estimating allowable cycle time during preliminary design:

Table 4-1 Cycling time

Motor kW	Cycling Time (t), min
0 – 11	5.0
15 – 22	6.5
26 – 45	8.0
48 – 75	10.0
112 – 149	13.0

Knowing the pumping rate and minimum cycling time, the minimum necessary allowable storage, V, to achieve this time can be calculated by: $V = 15Q_pt$

Having selected the trial wet well dimensions, the pumping range, Δh, can then be calculated. The pumping range represents the vertical height between pump-start and pump-stop elevations. Usually, the first pump-stop elevation is controlled by the minimum recommended bell submergence criteria specified by the pump manufacturer or the minimum water level, H, specified in the design. The first pump- start elevation will be a distance, Δh, above H.

Where the only storage provided is in the wet pit, the pumping range can be calculated by dividing the allowable storage volume by the wet pit area:

Δh = V/wet pit area

This distance between pump starts may be in the range of 1 ft to 3 ft for stations with a small amount of storage and 0.25 ft to 0.5 ft for larger storage situations.

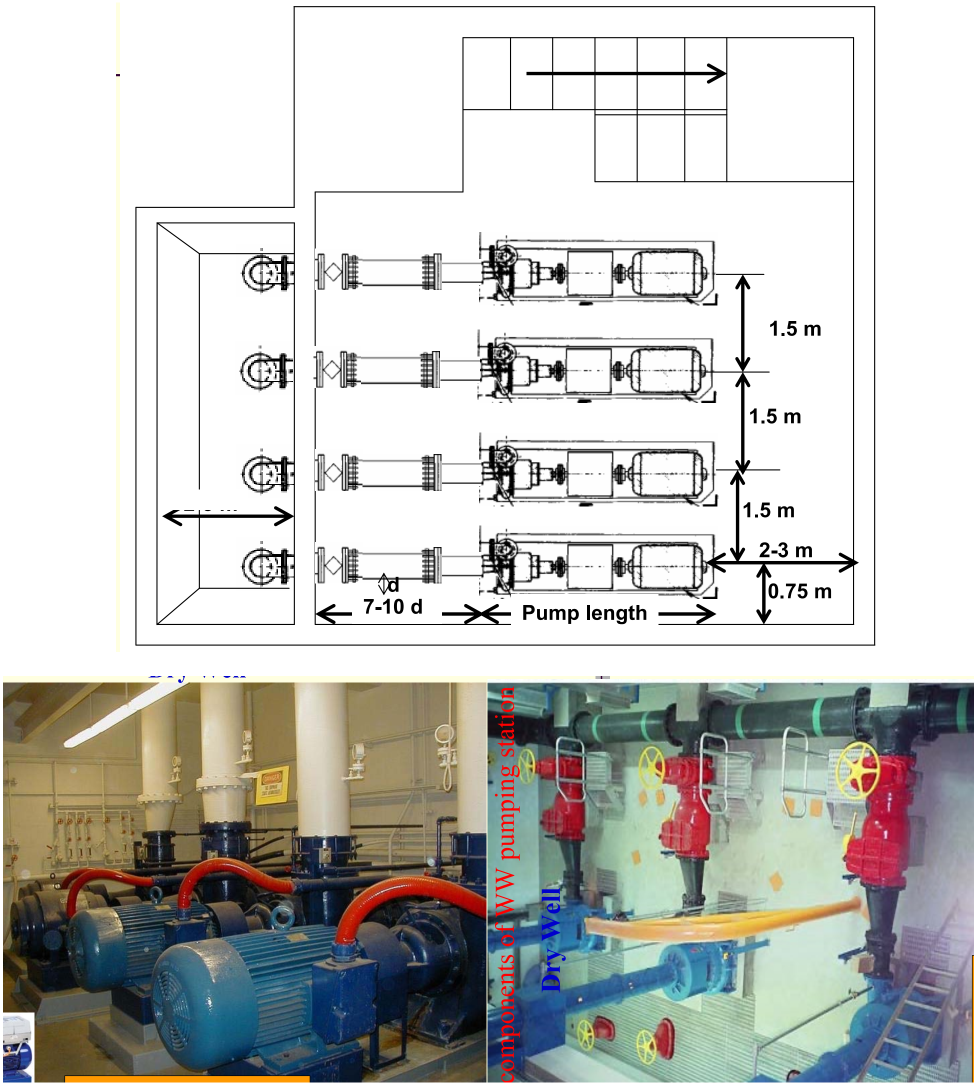


Figure 4-6 Inside and outside dry well or pump house[23]

4.2.7. Suction and Discharge Piping

All pump suction and discharge piping with- in the pump station wet well and dry well should be cast iron or ductile iron, with flanged joints. A separate suction pipe will be provided for each sewage pump, including a flange and flare intake elbow, wall casting, shutoff valve and necessary connecting pipes and fittings. Suction piping will be sized adequately to avoid high flow velocities under the normal design conditions. Velocities should preferably be within a range of 2 to 4 ft/sec at the flare inlet and 4 to 8 ft/second in the suction pipe. The discharge line from each sewage pump will include a flexible connection, a swing type check valve, a shutoff valve, and necessary connecting pipes and fittings. Velocities should preferably be within a range of 6 to 10 ft/second in the discharge pipe. Ample supports will be provided for suction and discharge piping, to prevent loads from reaching the sewage pumps and to resist hydraulic thrust. Force mains may be cast iron pipe (CI), Ductile iron pipe (DI) or fabricated steel pipe. Flow velocities in the force main should be within a range of 6 to 10 feet per second, preferably in the lower part of the range. High points in force mains, where air locking might occur, should be avoided.

[23] Source: Dr. Fahid Rabah: Pumping Stations Design UDOT Manual of Instruction

A delivery pipe is the pipe that connects the pump with the manifold. The diameter of this pipe is determined using the Continuity equation:

Dia of delivery pipe= (4*Q/π V) ^0.5

D = pipe diameter, m

Q $_{pump}$ = discharge of one pump when operation alone, m^3/s

V = flow velocity, m/s

The velocity in delivery pipes is usually assumed in the range of 2-2.5 m/s.

Q pump is the determined from the intersection between the system curve and The characteristic curve of a single pump in operation.

Figure 4-7 Force main and header

In case of multiple discharge lines, one single discharge of bigger diameters should be installed that will carry flow from all sewage discharge lines. This saves financial burden as less pipe cost is involved and also reduces head losses in pipe due to larger diameter hence easy maintenance.

4.3. Understandings Centrifugal Pumps

4.3.1. Understanding Suction Lift of the pump

Suction lift deals with the maximum distance to the intake of a pump. Fire pumps and others may lift about 5' to 10' of suction. You must lower the pump continually towards the water to keep them pumping. This creates a water risk, and when they put it back in, it pumps for a while, and if it quits again, then the same process must be repeated until it is pumping properly. Pumps operating at a negative minimum inlet pressure are capable of creating a suction lift (non-self-priming). The suction capacity is approximately equal to the level of the negative minimum inlet pressure minus a 1 m safety factor.

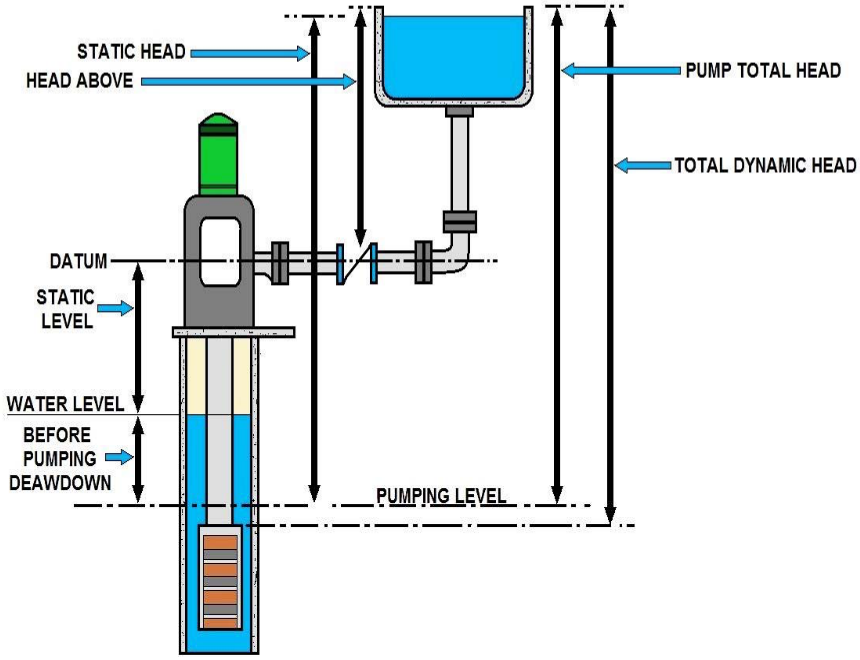


Figure 4-8 Total dynamic head

Total Dynamic Head = Total discharge head + Total Suction Lift
Total Suction Lift = static + friction

Depending on how the measurement is taken suction lift and head may also be referred to as static or dynamic. Static indicates the measurement does not take into account the friction caused by water moving through the hose or pipes. Dynamic indicates that losses due to friction are factored into the performance. The following terms are usually used when referring to lift or head.

4.3.1.1. Static Suction Lift

The vertical distance from the water line to the centerline of the impeller.

4.3.1.2. Discharge Head

The vertical distance from the discharge outlet to the point of discharge or liquid level when discharging into the bottom of a water tank.

4.3.1.3. Dynamic Suction Head

The Static Suction Lift plus the friction in the suction line. Also referred to as a Total Suction Head.

4.3.1.4. Dynamic Discharge Head

The Static Discharge Head plus the friction in the discharge line. Also referred to as Total Discharge Head.

4.3.1.5. Total Dynamic Head

The Dynamic Suction Head plus the Dynamic Discharge Head. Also referred to as Total Head.

4.3.1.6. Suction Lift Chart

The vertical distance that a pump may be placed above the water level (and be able to draw water) is determined by pump design and limits dictated by altitude. The chart below shows the absolute limits. The closer the pump is to the water level, the easier and quicker it will be to prime.

4.3.1.7. Suction Lift at Various Elevations

Table 4-2 Suction lift at various altitudes

Altitude	Suction Lift in Feet
Sea Level	25.0
2,000 ft.	22.0
4,000 ft.	19.5
6,000 ft.	17.3
8,000 ft.	15.5
10,000 ft.	14.3

4.3.2. Understanding Pump Performance

4.3.2.1. NPSH - Net Positive Suction Head Section

If you acknowledge that a pump can create a partial vacuum and atmospheric pressure forces water into the suction of the pump, then you will be able to find NPSH a simple concept.

NPSH (A) is the Net Positive Suction Head Available, which is calculated as follows:

NPSH (A) = p + s - v - f

Where:
'p'= atmospheric pressure,
's'= static suction (If liquid is below pump, it is shown as a negative value) 'v'= liquid vapor pressure
'f'= friction loss

NPSH (a) must exceed NPSH(r) to allow pump operation without cavitation. (It is advisable to allow approximately 1-meter difference for most installations.) The other important fact to remember is that water will boil at much less than 100 degrees C^O if the pressure acting on it is less than its vapor pressure, i.e., water at 95 degrees C is just hot water at sea level, but at 1500m above sea level it is boiling water and vapor.

The vapor pressure of water at 95 degrees C is 84.53 kPa, there was enough atmospheric pressure at sea level to contain the vapor, but once the atmospheric pressure dropped at the higher elevation, the vapor was able to escape. This is why vapor pressure is always considered in NPSH calculations when temperatures exceed 30 to 40 degrees C.

NPSH(r) is the Net Positive Suction Head Required by the pump, which is read from the pump performance curve. (Think of NPSH(r) as friction loss caused by the entry to the pump suction.)

The formula for calculating NPSHA:

NPSHA
Term = HA ± HZ - HF + HV - HVP

Table 4-3 NPSH terms

HA	The absolute pressure on the surface of the liquid in the supply tank (wet well)	• Typically, atmospheric pressure (vented supply tank), but can be different for closed tanks. • Don't forget that altitude affects atmospheric pressure (HA in Denver, CO will be lower than in Miami, FL). • Always positive (may be low, but even vacuum vessels are at a positive absolute pressure)
HZ	The vertical distance between the surface of the liquid in the supply tank and the centerline of the pump	• Can be positive when liquid level is above the centerline of the pump (called static head). • Can be negative when liquid level is below the centerline of the pump (called suction lift). • Always be sure to use the lowest liquid level allowed in the tank.
HF	Friction losses in the suction piping	• Piping and fittings act as a restriction, working against liquid as it flows towards the pump inlet.
HV	Velocity head at the pump suction port	• Often not included as it's normally quite small.
HVP	Absolute vapor pressure of the liquid at the pumping temperature	• Must be subtracted in the end to make sure that the inlet pressure stays above the vapor pressure. Remember, as temperature goes up, so does the vapor pressure.

4.3.2.2. Suction Lift

A pump cannot pull or "suck" a liquid up its suction pipe because liquids do not exhibit tensile strength. Therefore, they cannot transmit tension or be pulled. When a pump creates a suction, it is simply reducing local pressure by creating a partial vacuum.

Atmospheric or some other external pressure acting on the surface of the liquid pushes the liquid up the suction pipe into the pump.

Atmospheric pressure at sea level is called absolute pressure (PSIA) because it is a measurement using absolute zero (a perfect vacuum) as a base. If pressure is measured using atmospheric pressure as a base it is called gauge pressure (PSIG or simply PSI).

Atmospheric pressure, as measured at sea level, is 14.7 PSIA. In feet of head, it is:

Head = PSI X 2.31 / Specific Gravity

Head = 14.7 X 2.31 / 1.0 = 34 Ft

Therefore, 34 feet is the theoretical maximum suction lift for a pump pumping cold water at sea level.

No pump can attain a suction lift of 34 feet; but well-designed ones can reach 25 ft. quite easily.

You will note, from the equation above, that specific gravity can have a major effect on suction lift.

4.3.2.3. Cavitation - Two Main Causes:

A. NPSH (r) exceeds NPSH (a)
Due to low pressure the water vaporizes (boils) and higher pressure implodes into the vapor bubbles as they pass through the pump, causing reduced performance and potentially major damage.

B. Suction or discharge recirculation. The pump is designed for a certain flow range, if there is not enough or too much flow going through the pump, the resulting turbulence and vortexes can reduce performance and damage the pump.

4.3.2.4. Discharge head defined.

It is the vertical distance between the intake level of a water pump and the level at which it discharges water freely to the atmosphere. The energy per unit weight of fluid on the discharge side of a pump.

The centrifugal pump pumps the difference between the suction and the discharge heads. There are three kinds of discharge head:

- **Static head.** The height we are pumping to, or the height to the discharge piping outlet that is filling the tank from the top. Note: that if you are filling the tank from the bottom, the static head will be constantly changing.
- **Pressure head.** If we are pumping to a pressurized vessel - like a boiler- we must convert the pressure units (psi. or Kg.) to head units (feet or meters).
- **System or dynamic head.** Caused by friction in the pipes, fittings, and system components. We get this number by making the calculations from published charts.

  Suction head is measured the same way.

  - If the liquid level is above the pump center line, that level is a positive suction head. If the pump is lifting a liquid level from below its center line, it is a negative suction head.
  - If the pump is pumping liquid from a pressurized vessel, you must convert this pressure to a positive suction head. A vacuum in the tank would be converted to a negative suction head.
  - Friction in the pipes, fittings, and associated hardware is a negative suction head.
  - Negative suction heads are added to the pump discharge head; positive suctions heads are subtracted from the pump discharge head.

Total Dynamic Head (TDH) is the total height that a fluid is to be pumped, taking into account friction losses in the pipe.

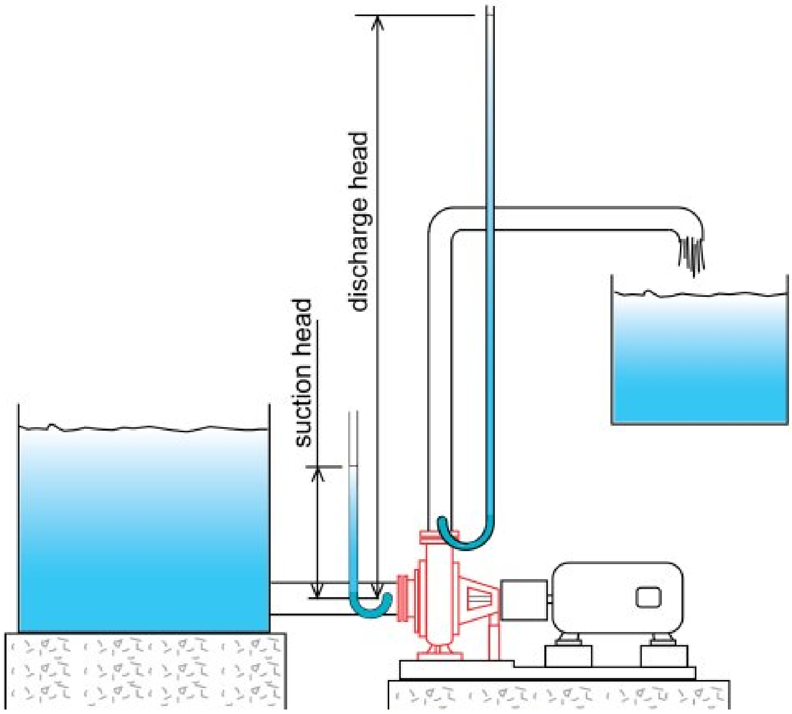


Figure 4-9 Head of pump

TDH = Static Lift + Static Height + Friction Loss

where:
Static Lift is the height, the water will rise before arriving at the pump (also known as the 'suction head').

Static Height is the maximum height reached by the pipe after the pump (also known as the 'discharge head').

Friction Loss is the head equivalent to the energy losses due to viscose drag of fluid flowing in the pipe (both on the suction and discharge sides of the pump). It is calculated via a formula or a chart, taking into account the pipe diameter and roughness and the fluid flow rate, density, and viscosity.

4.3.2.5. Pump Performance and Curves

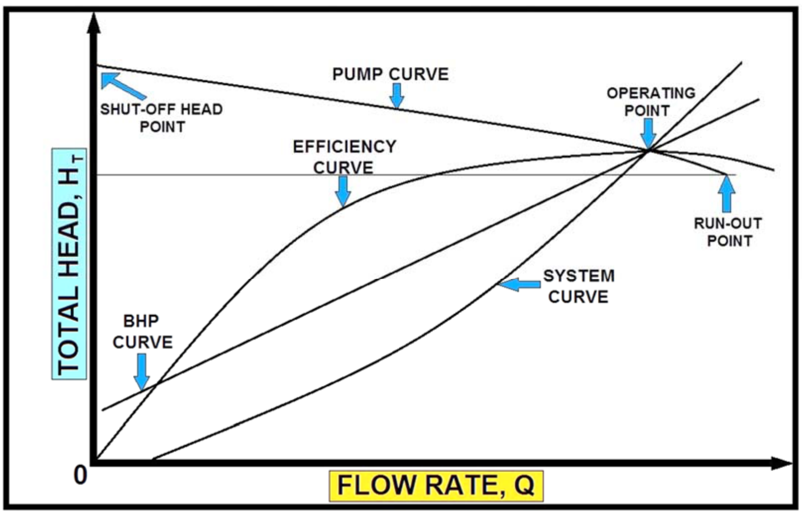


Figure 4-10 Pump performance curve

4.3.2.6. Pump performance curve

When selecting a centrifugal pump, one should match the performance of the pump to that needed by the system. To do that, an engineer would refer to a pumps composite curve. A typical composite curve includes the pump performance curves, horsepower curves and NPSH required.

4.3.2.6.1 Head and flow curve:

A pump performance curve indicates how a pump will perform in regards to pressure head and flow. A curve is defined for a specific operating speed (rpm) and a specific inlet/outlet diameter. In our example below, these curves show the performance at 1450 rpm for a 3” inlet/2” outlet. Several curves on one chart indicate the performance for various impeller diameters. In the example below, the impeller size ranges from 6.3” to 8.7”. These curves also tell you the possible conditions that the pump could be modified to meet in the future by installing a different impeller size.

Flow is indicated on the x-axis while pressure/head is indicated on the y-axis. In this example, if pumping against a head of 40 ft using an impeller size of 7.9”, you could pump at a rate of 140 gallons per minute. Typical centrifugal pumps will show an increased flow rate as head pressure decreases. The curve also shows the shut off head or the head that the pump would generate if operating against a closed valve. In our same example, the shutoff for the 7.9” impeller is 45 ft of head.

The pump performance curve also provides efficiency curves.
These efficiency curves intersect with the head-flow curves and
are labeled with percentages. The efficiency varies throughout
the operating range. In our same example with the 7.9”
impeller, we can see that at 140 gallons per minute, the pump is operating at 72% efficiency.

Some curves will also mark the Best Efficiency Point (B.E.P.). This is the point on a pump's performance curve that corresponds to the highest efficiency and is usually between 80-85% of the shutoff head. At this point, the impeller is subjected to minimum radial force promoting a smooth operation.

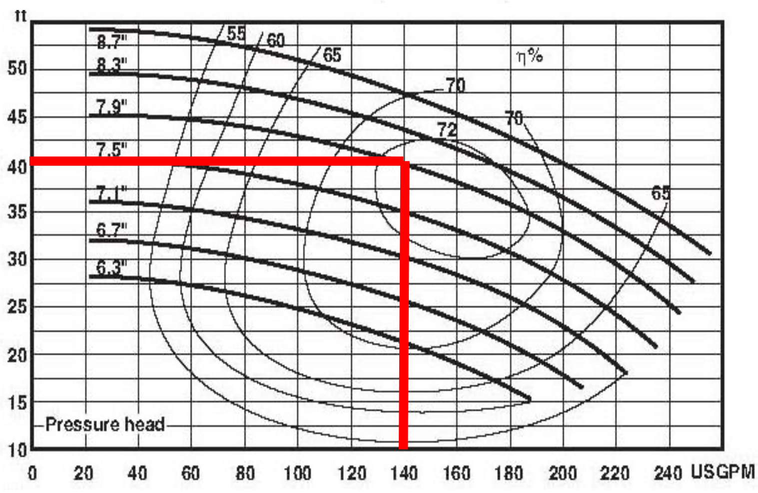


Figure 4-11 Head and flow curve

4.3.2.6.2 Power curve:

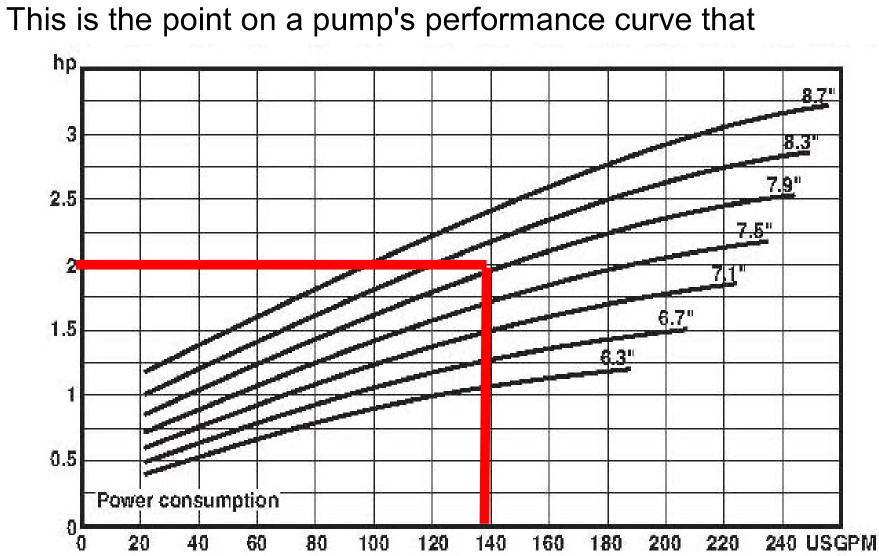


Figure 4-12 Head and flow curve

If we take our same example of a flow of 140 gpm using the 7.9” impeller, the power demand is 2 hp.

When sizing a motor, the total current and future demand should be considered to make sure that the motor is the correct size. The motor is typically sized not at the peak efficiency point but by the maximum power draw that will be needed. It is common practice to size the motor for the End of Curve (EOC) horsepower requirements. In the example shown, even though 2 hp is required for a flow of 140 gpm with 40 ft head, the end of curve horsepower requires a 2.5 hp motor be used.

4.3.2.6.3 NPSHr Curve

The 3rd part of the pump curve is the Net Positive Suction Head Required (NPSHr) curve. The NPSHr curve provides information about the suction characteristics of the pump at different flows.

The x-axis is still measured in flow units (gallons per minute), but the y-axis is now measured in feet of NPSHr. Each point along the curve identifies the NPSHr required by the pump at a certain flow to avoid cavitation issues that would be damaging to the pump and would have a negative impact on overall pump performance. In other words, the NPSH available must be greater than the NPSHr to avoid cavitation. Looking back at our example design flow of 140 gallons per minute, we can see that this pump will require approximately 2.5 ft of NPSHr at that condition.

Generally speaking, NPSHr does not vary dramatically between variations in impeller trim which is why we do not see separate curves for the minimum and maximum impeller trims. Those curves are actually present, but they are overlaid by the design- trim NPSHr curve.

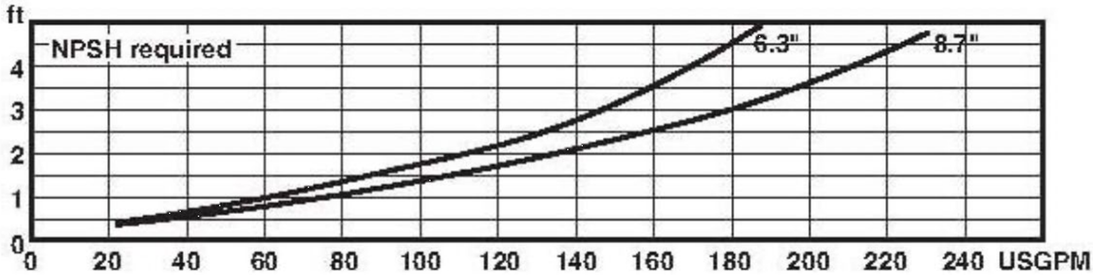


Figure 4-13 NPSHR curve

4.3.2.6.4 Composite or Quick Selection Curve

Often, an entire line of pumps of one design can be shown in a composite curve to give a complete picture of the available head and flow. These charts provide flow, head and pump size only. For more specifics, you must then refer to the specific performance curve for impeller diameters, efficiency and other details.

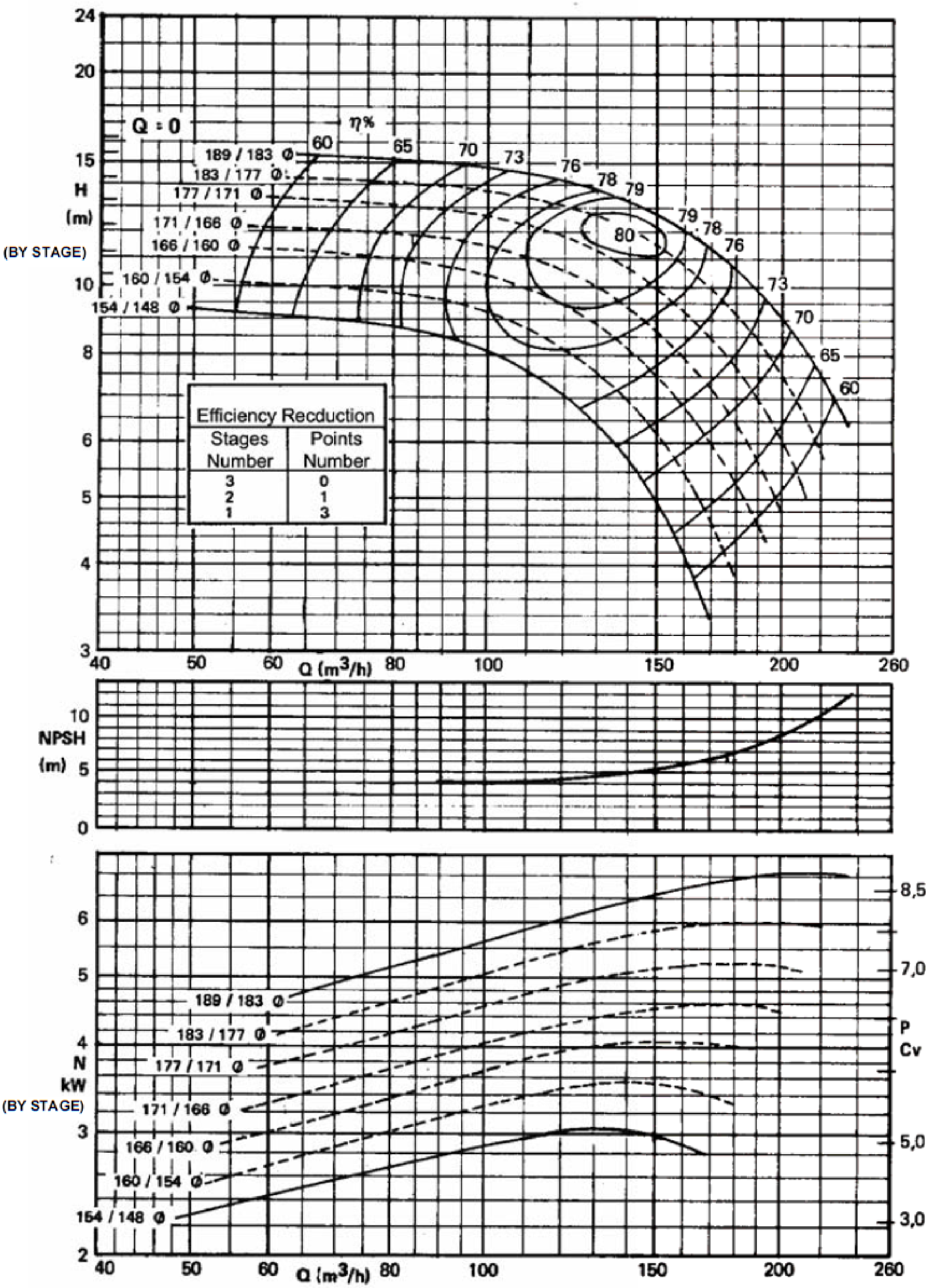


Figure 4-14 composite curves

4.4. Affinity Laws - Centrifugal Pumps

If the speed or impeller diameter of a pump changes, we can calculate the resulting performance change using:

Affinity laws

i. The flow changes proportionally to speed i.e.: double the speed / double the flow

ii. The pressure changes by the square of the difference i.e.: double the speed / multiply the pressure by 4

iii. The power changes by the cube of the difference i.e.: double the speed / multiply the power by 8.[24]

4.4.1. Wastewater Pumps used in current project of PMDFC

Centrifugal pumps are recommended for the sewerage systems of the project Cities. Submersible pumps shall not be used because these take much more time in repair and are damaged frequently in our environment of excessive solid waste in the sewage. The sewage pumps shall be vertical, centrifugal, non-clog type suitable for installation in a dry well with the drive motor located above on a separate motor floor at the new pump stations and horizontal centrifugal, non-clog type suitable for installation in a dry well for existing disposal stations. RPM of the pumps having less than 10 cusec capacity will be about 960 and above 10 cusecs will be 750.

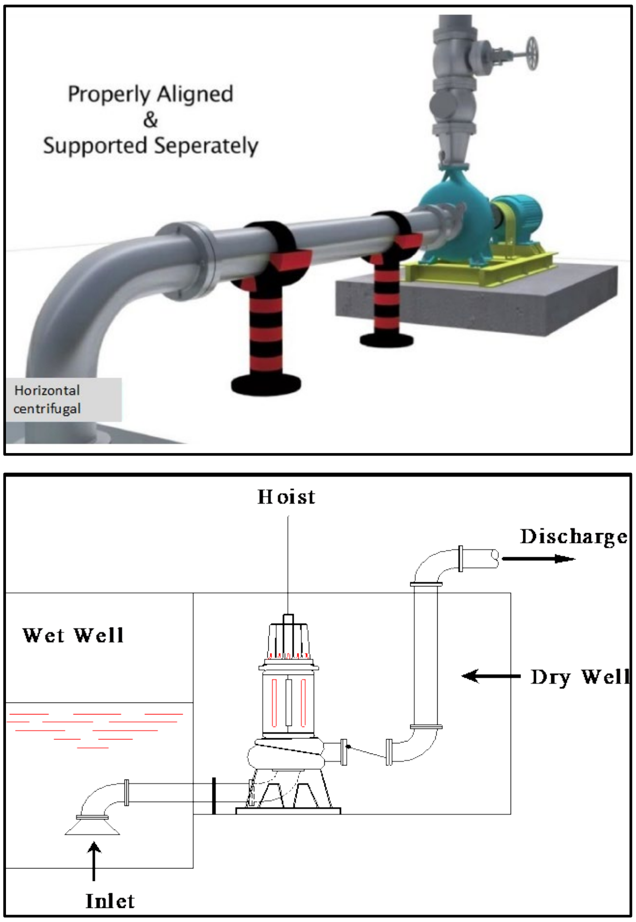


Figure 4-15 Above horizontal and below Vertical pump

Shafting

[24] Pumping Principles: http://www.ABCTLC.comdownloads/PDF/Pumping%20Ass.pdf

Intermediate shafting between pump and motor shall be having suitable couplings, bearings and supports.

Motors

The drive motors shall be vertical/horizontall, Open, drip proof, solid shaft, squirrel cage, induction type design.

Pump Priming and Intake

The pump shall be installed so that it will operate under a positive suction head under normal operating conditions. Each pump should have an individual intake and the wet well should be designed to avoid turbulence near the pump intake.

4.4.2. Supervision of operation

- Do not operate the pump with the outlet and/or inlet valve completely closed.
  Any maintenance work on the pump must be done only when the pump is not running.
- If the packing Seal starts to leak while the pump is operating, tighten the backup Packing Rings through the Gland Bolts, to reduce the leakage. This should give the operator some time to schedule a shut down for the pump and replace the Mechanical Seal.

  Reverse rotation of the pump through improper electrical wiring connection can cause the Impeller to spin off the Shaft and possibly damage any or all of the following parts:
  a. Pump Shaft
  b. Impeller Casing
  d. Stuffing Box Cover

  e. Wear Pad
- Pumps should be operated only within the recommended range of the head-discharge characteristics 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 recirculation within the pump, resulting in overheating of water in the casing and consequently, overheating of the pump.
- Voltage during operation of pump-motor set should be within ±10% of 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. The time lag should be adequate to allow the head on the pump to stabilize, as indicated by a pressure gauge.
- The stuffing box should allow a drip of leakage to ensure that no air passes into the pump and that the packing gets adequate water for cooling and lubrication. When the stuffing box is sealed with grease, adequate refill of the grease should be maintained.
- The running of the duty pumps and the 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, unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.
- 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 contact. 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 is all the truer when too much grit is likely to come into the sewage pumping stations from sewages at monsoon time, which is difficult to handle. Hence sewer collection system should not be allowed to collect any storm water from the roads.

4.4.3. Increased wear due to dry running Damage to the pump set!

- Never operate the pump set without liquid fill.
- Never close the shut-off element in the suction line and/or supply line during pump operation.

4.4.4. While the pump is in operation, observe and check the following points:

- The pump must run quietly and free from vibrations at all times.
- Check the correct functioning of any auxiliary connections.
- Monitor the stand-by pump.
  To make sure that the stand-by pumps are ready for operation, start them up once a week.
- Check the flexible elements of the coupling or belts and replace them, if required.

4.4.5. Visual inspection through the inspection hole

If there are problems with clogging, the inside of the casing and the impeller can be checked via the inspection hole.

4.4.6. Risk of injuries, damage to the pump!

- Check that the inside of the pump is free from any foreign objects. Remove any foreign objects.
- Never insert your hands or any other objects into the pump, if the pump set has not been disconnected from the power supply and secured against unintentional startup.

4.4.7. Undesirable Operations

- The following undesirable operations should be avoided.
- a. 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 water 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 normally low so such an operation is also inefficient.
- b. Operation at lower head

If a pump is operated at a lower head than the recommended minimum head, 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 both pressure gauge and ammeter. Efficiency at a lower head is normally low, so such an operation is also inefficient.

4.4.7.1. 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 water into vapour. These vapour 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 due to pitting, pump discharge also reduces drastically. Typical damage to impeller and sometimes to the casing is shown in Figure below.

Figure 4-16 Typical cavitation damage of an impeller

4.4.7.2. Operation of the pump with low submergence

Minimum submergence above the bell-mouth or foot valve is necessary so as 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, the lowest permissible water level should be marked on the water level indicator. Usually, the pump manufacturer indicates the minimum height of submergence.

4.4.7.3. Operation of pumping units at keeping free water fall in collecting tanks

Design of Free fall vertical drops at wet wells of Disposal stations is not recommended by Hydraulic Institute specs ANSI/HI 9.8-2012 and 2018. Because Entrained air can influence efficiency, create cavitation and lead to corrosion of the impeller and vibration.

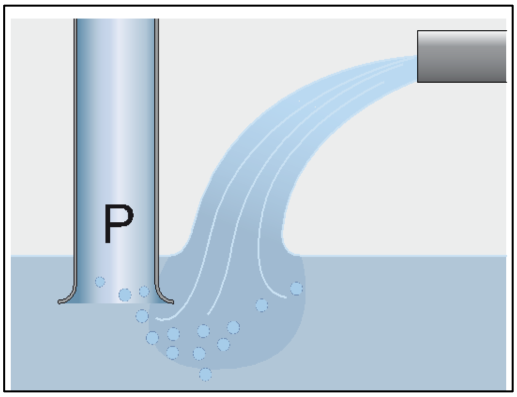


Figure 4-17 Free fall not recommended by HI

Minimum level of wet well should be such that there is no free fall rather steady flow to avoid air entrainment.

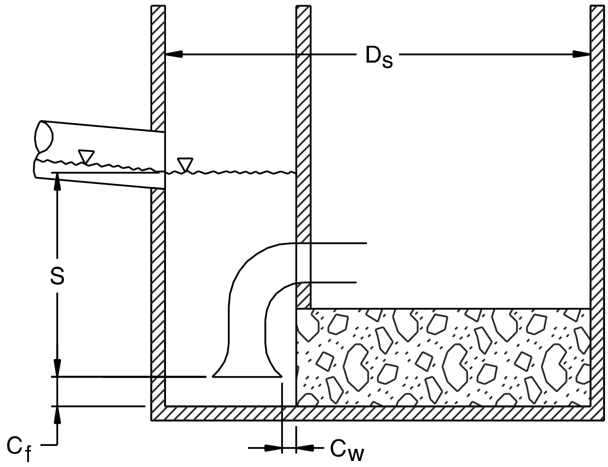


Figure 4-18 Minimum submergence level

S is the minimum submergence level of suction bell for dry pit pumps.

The Hydraulic Institute recommends minimum submergence of suction bell at the inlet velocity of 5.5 ft/s. This minimum level of wet well is where 1st pump is started and it is at the bottom line of inlet pipe.

A few examples are given below:

For 10 cusec capacity pump submergence is recommended 4.2 ft, for 6 cusecs=3.5 ft

And for 4 cusec 3.3 ft

4.5. Maintenance of Pumping Station

Maintenance as follows shall be carried out for screens, penstock/gate, sump/intake/well and pump house including civil works.

4.5.1. O&M of Bar Screen

The following are important for O&M of manual bar screen:

Our sewage contains excessive floating material because the MC staff and general public thinks that sewage can also carry solid waste. Cleaning and maintenance of screens is of utmost importance which, unfortunately our operational staff normally ignore and thinks that it will not result in any major breakdowns. In fact, poor screening is one of the major causes of pump breakdown. Any object (especially the ropes and any wrapping object can seize the impeller.

i) Screen should be cleaned at a frequency depending on ingress load of floating matters. The frequency in monsoon season shall be more than that in fair season.

ii) Care should be taken to remove and dump the screening far away from the pump house.

iii) Lubricate wheels and axle of wheel burrows.

iv) The screen, catch tray and screen handling arrangement shall be thoroughly inspected once in six months and any item broken, eroded, corroded shall be rectified.

Figure 4-19 Bar screen and a chocked impeller

Even shopping bags frequently choke t suction pipe of the pumps and reduce the discharge. This results in reduced output and energy inefficiency.

Screens must be cleaned in, at least two shifts. This cleaning process should continue without any break if we want to avoid any pump breakdown.

4.5.1.1. Regular maintenance on a daily basis and repairs

- Verify that the screen rods have not broken loose.
- Verify that the cleaning rake is well washed in running water after each use.
- Verify that gum boots are kept inside a locker covered with mesh.
- Verify that disposable gloves are available for all 3 shifts and a stock of one month is available.
- Verify that helmet is available. Operation
- 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.
- If all items are in order, do the cleaning once in four hours in each shift.
- 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.
- 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.
- Push the screenings with the rake to the side of the platform to drop them into the tipper positioned there.
- Move the tipper to the vermin compost site, dump the contents in the pit and cover with earth **"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, which should be prevented from direct rainfall and also flow of overland rainwater.

4.5.1.2. Weekly Preventive maintenance

- Check whether the standing platform is at least 2 m wide with the first 1 m as slotted. As an example of a risky platform, in which there is no space for the operator to stand after he has lifted and dumped screenings on it. Because of the lack of space, the operator 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, the operator has to bend forward. The rear side of the platform should have handrails. If handrails are not provided, enter this point in the site book.

- Check the condition of ladders and paint them periodically. Verify that there are no broken metal parts that protrude outside. Once a month check the rigidity of handrails. Verify the platform for its sturdiness by gently setting the foot on it.
- The lighting is not in front or behind the operator. It should be above the operator, at high and mounted on the sidewall.
- Verify that the operator platform and slotted platform have 3-m head room and roof so that the operator is not drenched and he can lift the cleaning rake freely.

4.5.2. Cleaning of wet well

Normally cleaning of wet well is not required daily if screens of disposal station are working satisfactorily and labour clean the screens in two shifts. Unfortunately, importance of cleaning of screens is not well understood. Everywhere it is considered a routine activity whereas this cleaning provides lifeline to pumps. A large number of breakdowns occur due to blockage created by floating material in the suctions and impellers of pumps.

There are two reasons of accumulation of solid waste in the wet well:

- The design of screens is not satisfactory to fulfil the requirement.
- Cleaning staff is unable (due to less labour available for this job) to remove large quantity of screenings therefore, they make a wide gap between the bars so that solid waste pass the screens easily and they are saved of excessive cleaning.
- The present condition of wet wells in almost all the MCs is such that it requires daily cleaning as a part of screen cleaning is what was to be stopped and removed there.

Figure 4-20 Cleaning of wet well with clamshell excavator

4.5.2.1. Desilting of Wet well

Desilting of wet well may be carried out once in a year.

Necessity of Wet well desilting

- Cleaning is necessary to avoid suction bells of pumps from chocking and reduced output due to difficulty in lifting of wastewater.

There are Two methods of desilting:

- Manual
- Mechanical

(a) Manual desilting:

- Wet well will be isolated by closing of penstock gate.
- Wet well be emptied from wastewater as much as possible. Remaining wastewater may be discharged out through a potable submersible pump.
- contractor may be hired for the job who will arrange sufficient labour and safety belts, manila rope and long safety shoes and gas masks.
- He will also arrange T&P for removal and lifting of silt and dumping it on a truck or trolly.
- A truck/Trolly may be arranged for transportation of silt to dumping place.

Assessment of volume of silt:

Measure the dia of wet well

Measure the depth of silt

Volume of silt=Pie/4$(d)^2$ * depth of silt, from volume of silt one can estimate the rounds of a trolly.

(b) Mechanical Desilting

Mechanical desilting is easily carried out with the help of a clamp shell dragline excavator or if depth of wet well is not so much the normal excavator with clamshell arrangement may be used

Figure 4-21 Clamshell dragline excavator and a simple excavator having clamshell bucket

Precautions with Mechanical Desilting

Desilting with clamshell machine may damage the suction pipes, wet well structure and other allied items if the operator does not know about geometry of wet well therefore, he may be completely briefed before start of work.

4.5.3. Penstock / Sluice Gate

A sluice gate is traditionally a metal plate which slides in grooves in the sides of the channel. Sluice gates are commonly used to control wastewater levels in sewerage disposal pumping stations. They have a key importance in controlling the flow especially the repair of pumps is not possible when sluice gates at inlet channel of disposal station are defective along with gate valves on suction pipe of the pump because sewage flows round the clock and no control is possible when both are jammed due to non-maintenance.

Figure 4-22 Penstock gates

4.5.3.1. Reasons of sluice gate not working properly

- Rust on frame
- Deflection of leaf
- Lack of lubrication
- Specifications not suitable
- Specifications do not fulfill the requirement of a trouble-free gate.

Attention should be paid to the following points for proper operation:

4.5.3.2. Maintenance of penstock gates

i. **Monthly maintenance**

The penstock/sluice gate normally remains in open position and closed only when inflow is to be stopped. Since floating matters may adhere to the gate and may accumulate in the seat, it should be operated once in a month. In order to ensure that gate remains free for operation

ii. **Yearly maintenance**

- The gate should be thoroughly inspected once in a year preferably after monsoon and components found worn out shall be replaced. Particular attention shall be paid to the seats of the frame and gate.
- The gate should be closed to check the leakages. For this purpose, the sump/intake shall be partly dewatered so that differential head is created on the gate and leakage test at site can be performed.

4.5.4. Sump/Intake well Maintenance

- All foreign floating matters in the sump/intake shall be manually removed at least once in a month and shall be disposed of away from pump house.
- Desilting of intake/sump shall be carried out once in year preferably after monsoon. Care should be taken to dump the removed silt away from pump house.

- It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in monsoon. The intake should be disinfected.
- The sump/intake should be fully dewatered and inspected once in a year.
- It is advisable to undertake leakage test of sump once in a year. For this purpose, the sump shall be filled to FSL and drop in water level for reasonably long duration (2-3 hours) should be observed. If leakage is beyond limit, rectification work shall be taken.

4.5.5. Pump House Maintenance

- The pump house should be cleaned daily. Good housekeeping and cleanliness are necessary for pleasant environment.
- Entire pump house, superstructure and sub-structure shall be adequately illuminated and well ventilated. Poor lighting, stale air etc. create unpleasant environment and have an adverse effect on will of the staff to work.
- Wooden flooring and M.S. grating wherever damaged should be repaired on priority.
- It is observed that at many places, roof leaks badly and at times the leakage water drips on the panel/motor which is dangerous and can cause short circuit and electric accidents. All such leakages should be rectified on priority.
- All facilities in sub-structure i.e., staircase, floors, walkways etc. should be cleaned daily.
- Painting of civil works should be carried out at least once in two years.

4.5.6. Tools And Testing Instruments

The pumping installation should be equipped with all necessary tools, testing instruments and special tools required for repairs and testing. Their quantity and special tools depend on size and importance of installation. Generally following tools and testing instruments shall be provided.

a) Tools

- Double ended spanner set, and ring spanner set.
- Box spanner set
- Hammers (of various sizes and functions)
- Screwdriver set
- Chisel
- Nose plier, cutting plier
- Flies of various sizes and smooth/rough surfaces
- Adjustable spanner
- Pipe wrenches
- Bearing puller
- Torque wrench
- Clamps for column pipes, tube and line shaft.
- Specials tools such as grinder, blower, drilling machine.
- Tap and die set.

- Bench vice
- Special tools for breakers
- Crimpling tool
- Heating stove for heating sleeves.

b) Test instruments

- Insulation tester
- Tongue tester
- A VO meters
- Test lamp
- Earth resistance tester
- Wattmeter, CT and PT
- Dial gauge
- Tachometer

4.5.6.1. Lifting and Material Handling Aids

Following lifting and material handling aids shall be kept in the pump house.

- Chains
- Wire rope
- Manila rope
- Chain pulley block and tripod.
- Other lifting equipment
- Hand cart
- Ladder

4.5.7. Pumps Maintenance:

- Sealing
- lubrication
- Vibration
- Electric control panel

4.5.7.1. Packing Seals

How can we prevent the water from leaking along the shaft?
A special seal is used to prevent liquid leaking out along the shaft. There are two types of seals commonly used:

- This leakage must be controlled for two reasons:
    1) to prevent excessive fluid loss from the pump, and
    2) to prevent air from entering the area where the pump suction pressure is below atmospheric pressure.

- The amount of leakage that can occur without limiting pump efficiency determines the type of shaft sealing selected. Shaft sealing systems are found in every pump. They can vary from simple packing to complicated sealing systems.
- Packing is the most common and oldest method of sealing. Leakage is checked by the compression of packing rings that causes the rings to deform and seal around the pump shaft and casing. The packing is lubricated by liquid moving through a lantern ring in the center of the packing. The sealing slows down the rate of leakage. It does not stop it completely, since a certain amount of leakage is necessary during operation. Mechanical seals are rapidly replacing conventional packing on centrifugal pumps.

4.5.7.2. Gland packing is commonly used in as seals.

Figure 4-23 Shaft of pump worn out at sleeve due to gland packing

- ❖ The shaft sleeve is a sacrificial component that protects the more expensive pump shaft.
- ❖ Because packing needs to contact the shaft it will eventually wear a groove into it, which can be costly to repair or replace.
- ❖ Inspect every 150 hours of operation for excessive leakage. Adjust as required

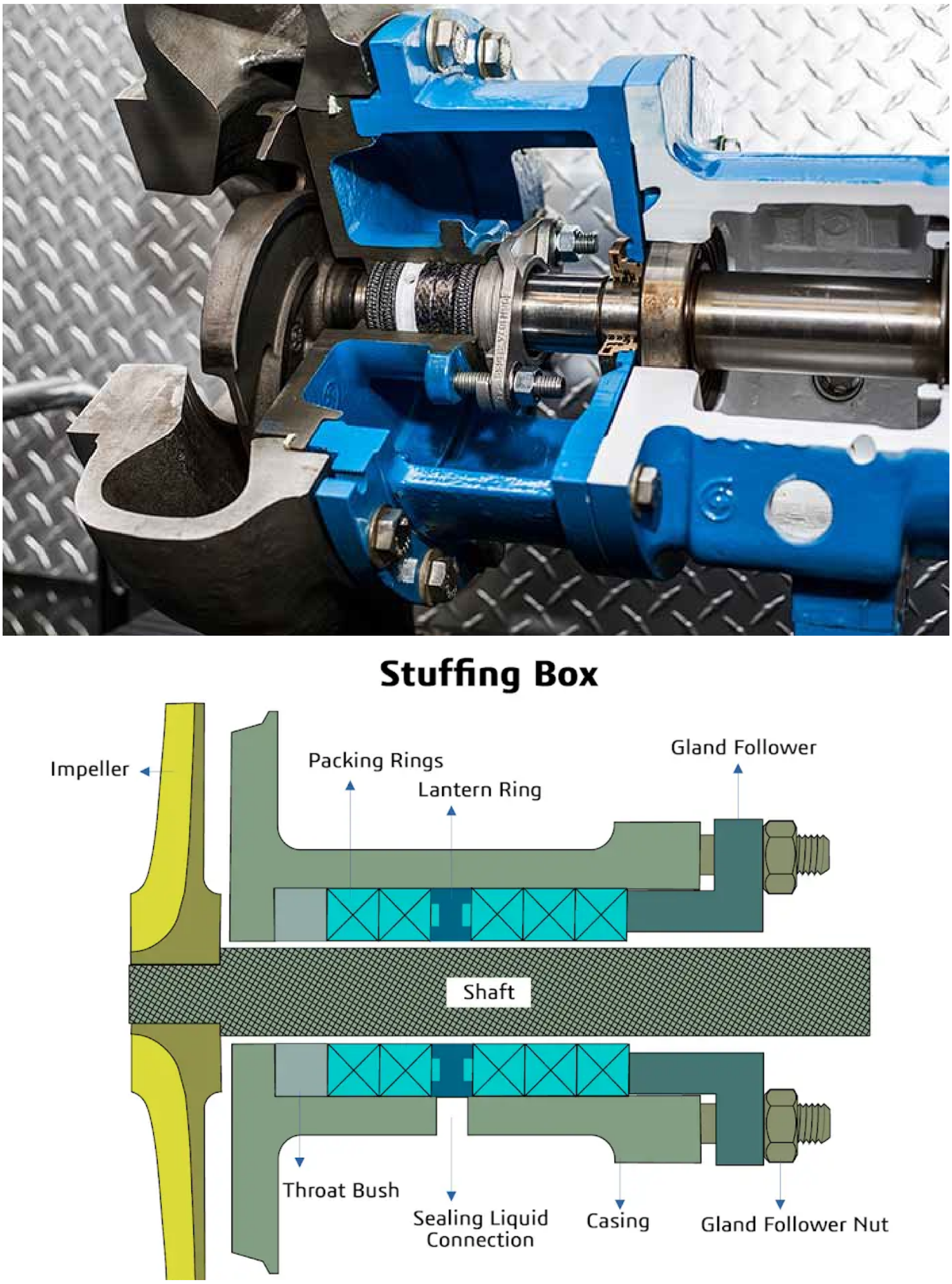


Figure 4-24:Parts related with gland packing seal

a) Stuffing Box Bushing

Installed in the bottom of the stuffing box to prevent packing from extruding through the bottom of the stuffing box.

b) Lantern Ring

The lantern ring is grooved and drilled with holes to allow lubrication and distribute cooling water to all packing rings as well as keep the stuffing box clean of containments

c) How to size Gland packing?

Simply measure the inner diameter of the bore of the stuffing box and subtract from it the outside diameter of the shaft. The figure obtained be divided by 2 to get your gland packing size.

d) Standard sizes

Generally, the following sizes of the gland packing are recommended for the different shaft sizes as follows:

- For shafts of size 50 to 75 mm diameter the gland packing of size 12.5 mm is used
- For shafts of size 75 to 120 mm diameter the gland packing of size 16 mm is used

e) Lubrication

- Lubrication of the pump packing is extremely important.
- The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes.
- Be sure there is always a slight trickle of water coming out of the stuffing box or seal.
- Rapid wear of the packing will be caused by roughness of the shaft sleeve.

4.5.7.3. Mechanical seal

Some of the reasons for the use of mechanical seals are as follows:

1. Leaking causes bearing failure by contaminating the oil with water. This is a major problem in engine-mounted water pumps.
2. Properly installed mechanical seals eliminate leak off on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings.

4.5.7.4. Motor-Pump alignment

It should be an important part of any maintenance program. Most pump distress events or failures) have their root cause in the misalignment of the pump to motor. Misaligned pumps can even consume up to 15% more energy input than well-aligned pumps.

Even small pumps can generate big losses when shaft misalignment imposes reaction forces on shafts, even if the flexible coupling suffers no immediate damage. The inevitable result is premature failure of shaft seals and bearings.

Performing precise alignment, therefore, pays back through preventing the costly consequences of poor alignment. Indeed, using precise alignment methods is one of the principal attributes of a reliability focused organization.

Good alignment has been demonstrated to lead to:

- Lower energy losses due to friction and vibration
- Increased productivity through time savings and repair avoidance
- Reduced parts expense and lower inventory requirements
- Further, in order to ensure good alignment, the alignment must be checked and correctly set when:
- A pump and drive unit are initially installed (before grouting the baseplate, after grouting the baseplate, after connecting the piping, and after the first run).

After a unit has been serviced.

- The process operating temperature of the unit has changed.
- Changes have been made to the piping system.
- Periodically, as a preventive maintenance check of the alignment.

4.5.7.4.1 Operating procedures for scheduled checks or maintenance.

Proper shaft alignment is achieved by moving the motor. The motor is shimmed vertically to achieve the proper elevation to align it to the pump, both parallel (offset) and angular. The motor is them moved horizontally to achieve proper horizontal placement for aligning the shaft centerlines, both parallel and angular. The motor is moved horizontally by the use of jacking bolts, or by the use of pry bars, hammers, or other tools.

Motors are normally easier to move, since the motor is not piped into a process system. A short run of flexible conduit is most often used to run the electrical wiring from a local disconnect, or a rigid conduit, to the motor termination box. This allows for ease of movement of the motor.

Motor-Pump alignment is critical for these reasons:

- It minimizes the forces of misalignment acting upon the bearings and seals of both components.
- It minimizes wear of the coupling.
- It can help reduce energy costs.
- It maximizes the life of the machine components by minimizing wear, increasing time between failures, and reducing vibration.

4.5.7.4.2 The pump coupling serves two main purposes:

- It couples or joins the two shafts together to transfer the rotation from motor to impeller.
- It compensates for small amounts of misalignment between the pump and the motor.

  Remember that any coupling is a device in motion. If you have a 4-inch diameter coupling rotating at 1800 rpm, its outer surface is traveling about 20 mph.

  There are three commonly used types of couplings:

4.5.7.4.3 Rigid, Flexible and V-belts.

a) Rigid Coupling

Rigid couplings are most commonly used on vertically mounted pumps. The rigid coupling is usually specially keyed or constructed for joining the coupling to the motor shaft and the pump shaft. There are two types of rigid couplings: the flanged coupling, and the split coupling.

b) Flexible Coupling

The flexible coupling provides the ability to compensate for small shaft misalignments. Shafts should be aligned as close as possible, regardless. The greater the misalignment, the shorter the life of the coupling. Bearing wear and life are also affected by misalignment.

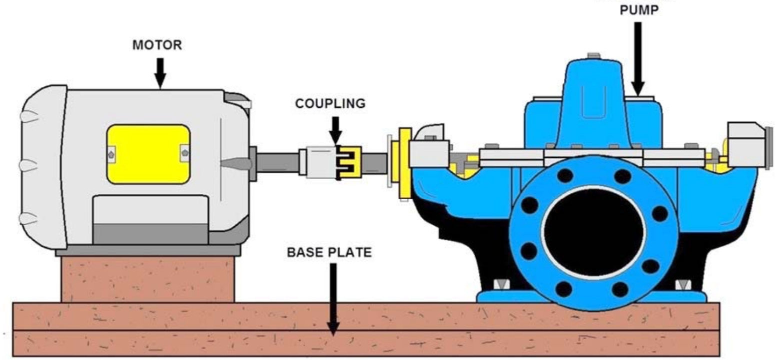


Figure 4-25 Closed coupled pump

4.5.7.4.4 Alignment of Flexible and Rigid Couplings

Both flexible and rigid couplings must be carefully aligned before they are connected. Misalignment will cause excessive heat and vibration, as well as bearing wear. Usually, the noise from the coupling will warn you of shaft misalignment problems.

Three types of shaft alignment problems are shown in the pictures below:

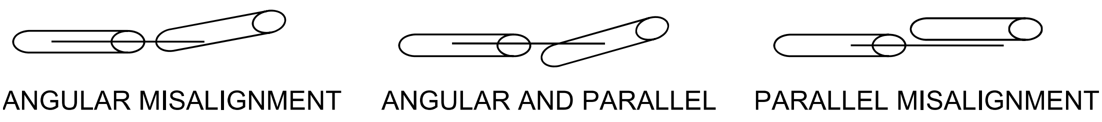


Figure 4-26 Alignment positions

Different couplings will require different alignment procedures. We will look at the general procedures for aligning shafts.

1. Place the coupling on each shaft.
2. Arrange the units so they appear to be aligned. (Place shims under the legs of one of the units to raise it.)
3. Check the run-out, or difference between the driver and driven unit, by rotating the shafts by hand.
4. Turn both units so that the maximum run-out is on top.

Now you can check the units for both parallel and angular alignment. Many techniques are used, such as: straight edge, needle deflection (dial indicators), calipers, tapered wedges, and laser alignment.

Shaft misalignment is responsible for as much as 50 percent of all costs related to rotating machinery breakdowns.

4.5.7.5. Worn Wear Ring/ Wear Plate

Device used to seal the pressure leakage of the liquid between the inlet of the impeller and the pump casing.

Excessive Clearances: If clearances are too wide for the type of fluid pumped, excessive slip will occur.

Figure 4-27 Wear ring[25]

[25] http://www.ABCTLC.comdownloads/PDF/Pumping%20Ass.pdf

4.5.7.6. Electric control panel

Auto star delta electric control panels are being used with the squirrel cage induction motors for this project in all MCs. It has following items:

Sizing and setting of Contactors & Overload Relay: Whenever somebody requires replacement of parts of panel the capacity may be calculated as under:

Full line current in an induction motor flc = KW X 1000/ (400*1.732*0.80)

Over Load Relay Setting

- The overload should be sized according to Main Contactor
- Relay Min (70% of FLC Phase)
- Relay Max (120% of FLC Phase) or
- Relay Setting (100% of FLC Line)

Making / Breaking Capacity of Contactors:

- Main Contactor (58% of FLC Line):
- Delta Contactor (58% of FLC Line):
- Star Contactor (33% of FLC Line):

Figure 4-28 ASD panel

4.5.7.7. Bearings:

The most important part in pump failure is bearing. There are various studies showing high rate of failures due to defects in bearings. Some of them are illustrated below:

a) The study carried out as *"Main Oil Line Pump Seal Failure Prevention; Advanced Simulation and Case Study. by A.M. Khalaf, A.M. Al Omari, A.H. AL-Sherif, A. Toubar, ADMA-OPCO I. Barsoum, The Petroleum Institute.A. Karrech, The University of Western Australia"* Their report is summed up in below graph.

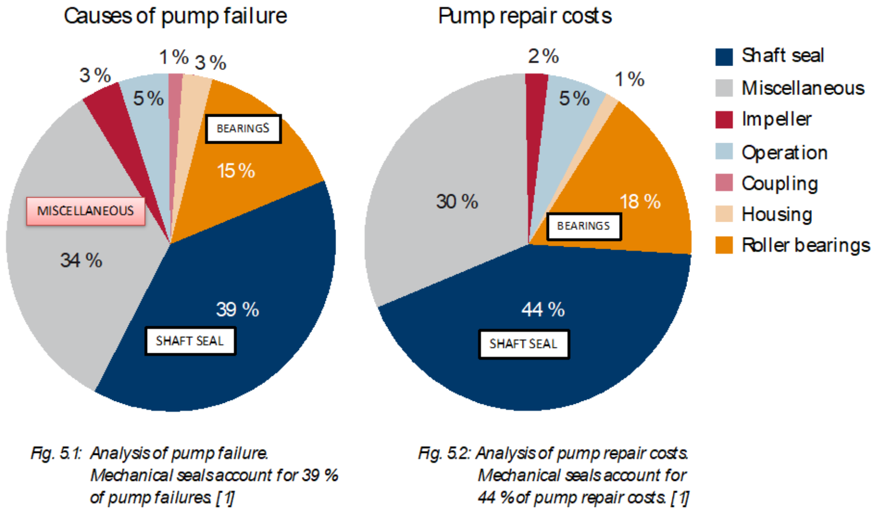


Figure 4-29 Causes of pump failure

According to a survey bearing failures occur due to Improper lubrication. Major causes of Bearing Failure are listed below:

i. The wrong lubricant type 20%.
ii. Too much lubricant; Too little lubricant 15%.
iii. Aged lubricant 20%.
iv. Contamination of the grease/oil by objects or
v. water 25 %

b) AESSEAL, 2015 According to (AESSEAL, 2015), an equipment reliability study conducted at a major refinery has published statistics on causes of rotating equipment failures and found that 40% of rotating machinery failures were due to bearing defects. The study further estimated that 48% of all bearing failures were due to contamination.

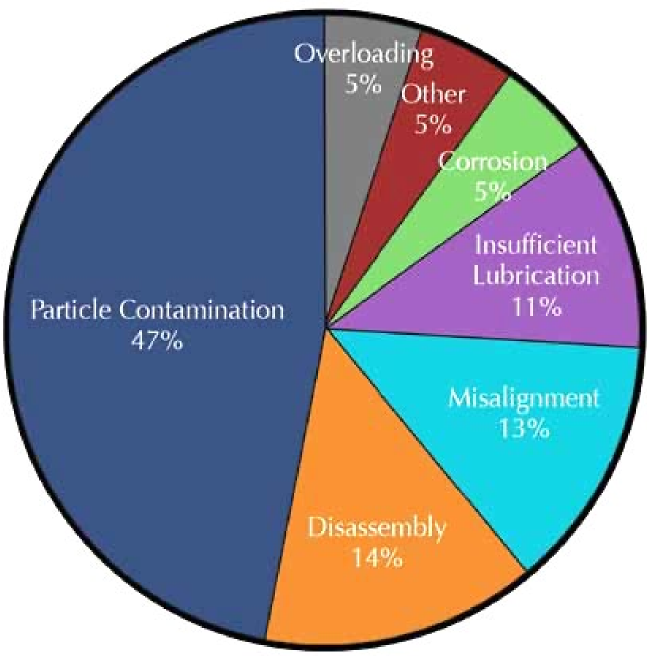


Figure 4-30 Pump failure due to bearings failure
Credit SKF

c) Study carried out by Science Direct: “Bearing fault diagnosis under various conditions using an incremental learning-based multi-task shared classifier”.[26]
Their findings are: “Rotating machinery has applications in aerospace, automotive, energy, and transportation fields. Rolling bearings are critical components of such machines. Approximately 40% of significant machine failures originate from bearing defects; this figure increases to approximately 90% for small machines. Such failures cause safety issues, economic loss, and system breakdowns. An effective, automatic fault diagnosis method is urgently needed”.

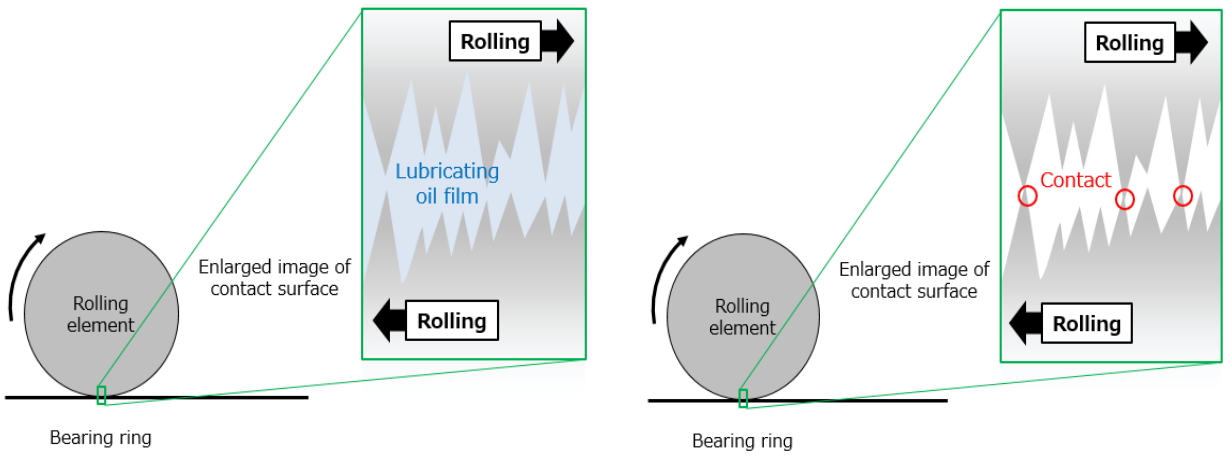
a) Types Of Bearings Commonly Used

There are three types of bearings commonly used: ball bearings, roller bearings, and sleeve bearings. Regardless of the particular type of bearings used within a system--whether it is ball bearings, a sleeve bearing, or a roller bearing--the bearings are designed to carry the loads imposed on the shaft.

Bearings must be lubricated. Without proper lubrication, bearings will overheat and seize. Proper lubrication means using the correct type and the correct amount of lubrication. Similar to motor bearings, shaft bearings can be lubricated either by oil or by grease.

b) Lubrication is required

The surfaces of bearing rolling elements and rings (inner ring and outer ring) are finished extremely smooth. But however smooth they are their surfaces still have unevenness. When a bearing rotates, the convex regions of the bearing rings and the rolling elements come in contact with each other. This contact between the convex regions leads to friction and wear, inhibiting the smooth rotation of the bearing. In order to prevent this friction and wear, oil or some other substance is applied between the contact regions. This is called "lubrication



No contact between a bearing ring and a rolling element (with lubricant)

No contact between a bearing ring and a rolling element (with no lubricant)

Figure 4-31 Purpose of lubrication

The surfaces of bearing rolling elements and rings (inner ring and outer ring) are finished extremely smooth. But however smooth they are their surfaces still have unevenness.

[26] Pengcheng Wang, Hui Xiong, Haoxiang

When a bearing rotates, the convex regions of the bearing rings and the rolling elements come in contact with each other. This contact between the convex regions leads to friction and wear, inhibiting the smooth rotation of the bearing.

In order to prevent this friction and wear, oil or some other substance is applied between the contact regions. This is called "lubrication.

c) Purpose of lubrication

- To reduce friction and wear on the components of the bearing
- To carry away the heat generated by friction inside the bearing, and decrease the temperature
- To prolong the bearing fatigue life by maintaining the proper oil film on the rolling contact surface at all times
- To prevent corrosion during use of the bearing
- To remove contaminants that penetrate into the inside of the bearing

d) How lubrication be carried out?

- Lubricate pump bearings every year of operation. Frequent lubrication is not required
- Many applications call for only a ¼ to ½ ounce of grease every month, which translates to;
- "One or two strokes on a standard grease gun. (Annually 0.17 KG per bearing or 0.34 KG per pump)"
- A general way to determine how much grease to replenish is to multiply the outside diameter of the bearing in millimeters by the bearing width in millimeters, then multiply by 0.005. This will give you the re-lubrication amount expressed in grams.

4.5.7.7.1 Factors Causing High Bearing / Lubricant Temperatures

- The load on the bearing: High relative bearing loads will increase bearing temperature. Factors that can increase the bearing load include:
  a. The pump flow rate.
  b. Misalignment of the bearings.
  c. Heat from the pumped fluid expanding the shaft into the bearing inner race.
  Higher oil viscosity increases oil and bearing temperatures, so the oil grade should not be higher than necessary. Synthetic oils will often allow lower oil grades. Higher oil viscosity also increases the power loss from the bearings, which slightly increases life cycle costs.
- Oil level too high: The oil level should not be above the center line of the lowest ball/roller, to prevent overheating of the oil.
- Too much grease: Greased bearings will generally run hotter than oil lubricated bearings, and over-greasing will increase the bearing temperature even further.
- Higher speed pump operation increases the bearing temperature.

4.5.7.7.2 What if bearings are exposed into water due to leakage in dry well?

Figure 4-32 Contaminated bearing with water

Water contamination

If bearings are dipped into leakage water in the pump house, cooling of the housing with water will restrict the expansion of the bearing outer race, increasing the internal bearing load and overheating.

4.5.7.7.3 Other Lubrication Factors Impacting Bearing Life

- Prevent abrasive dirt from entering the lubricant before it reaches the pump, with proper storage and handling. Keep reservoir hatches closed, use air filter-breathers on all reservoirs, and clean reservoirs before installing new oil. Further, filter all oil introduced into the reservoirs/sumps with the use of a filter cart or off-line filtration.
- Ascertain that bearing fits comply with specifications.
- Ensure that the approved grades of oil or grease are used.
- Do not permit oil levels to go higher than the center of the lower ball.
- Do not mix incompatible greases.
- Use synthetic lubricants.

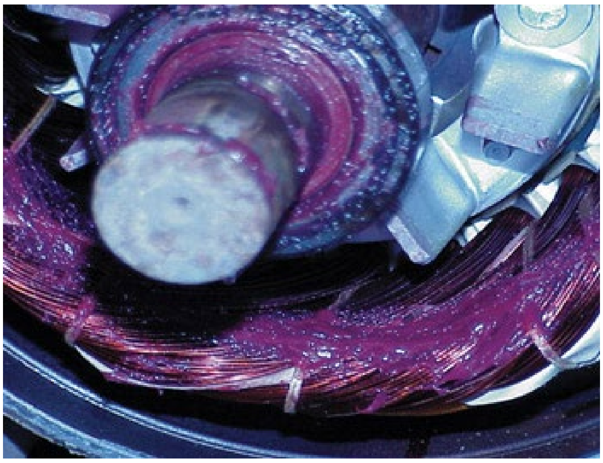


Figure 4-33 Over greasing

Over greasing can lead to high operating temperatures, collapsed seals.

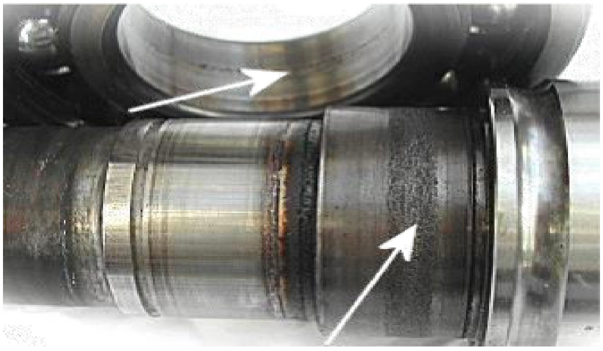


Figure 4-34 Bearing surface damaged due to vibration[27]

Bearing surfaces damaged by fretting (vibration) wear

4.5.7.7.4 Factors affecting life of pump bearings

- Wrong fitting (loose or tight fit)
- Stuffing box leakage on bearings
- Low quality greasing
- Over greasing
- Shaft vibrations
- Sinking of pumps in leakage water
- Swear vibration jerks due to sudden blockages and delayed stopping of pumps.

4.5.7.8. Piping and Appurtenance Maintenance

- Properly maintaining pumping-station pipelines and other appurtenances can minimize pump loads. Excessive head losses on either the suction or 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 side of 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 on the 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 the pump and physically open out the valve head, remove the blockage. In smaller pumps, it is easier to remove the entire valve, disassemble and remove blockage, reassemble and refit. During such time, 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.).

4.5.8. Trouble shooting

4.5.8.1. Pump problems and possible causes

a) Causes Of Pump Vibration

[27] https:// www.watertechonline.com › wastewater › article

- Misalignment
- Bent shaft
- Clogged, eroded, or unbalanced impeller
- Insufficient suction pressure
- lack of rigidity in the foundation

b) Causes of Pump requires excessive power

- Misalignment
- Bent shaft
- Wrong wearing ring
- Shaft bearing worn
- Gland too tight resulting in no flow of liquid to lubricate gland
- Bearings rusted up due to flooding of water in dry well
- Excessive grease

c) Causes of Stuffing box leaks excessively

- Misalignment
- Pump (impeller) shaft bent
- Shaft or shaft sleeves worn or scored at the packing
- Gland packing improperly installed
- Incorrect type of gland packing for operating conditions
- Shaft running off center because of worn bearing or misalignment
- Rotor out of balance, causing vibration
- Failure to provide cooling liquid to water cooled stuffing boxes

d) Causes of Pump not delivering any liquid

- Insufficient priming

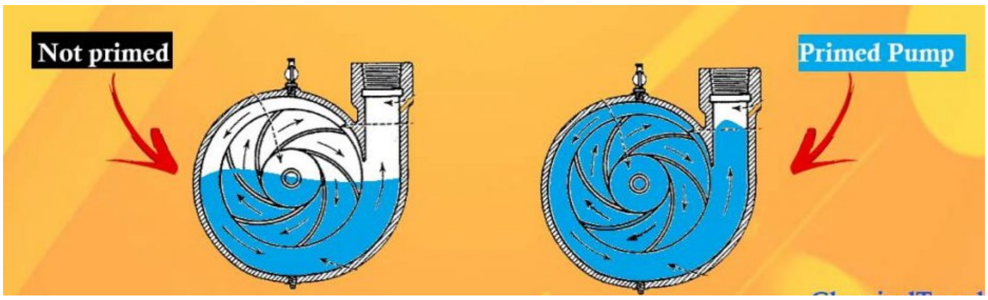


Figure 4-35 Insufficient priming

- Partially closed valve or some other obstruction in the discharge line
- Excessive suction lift

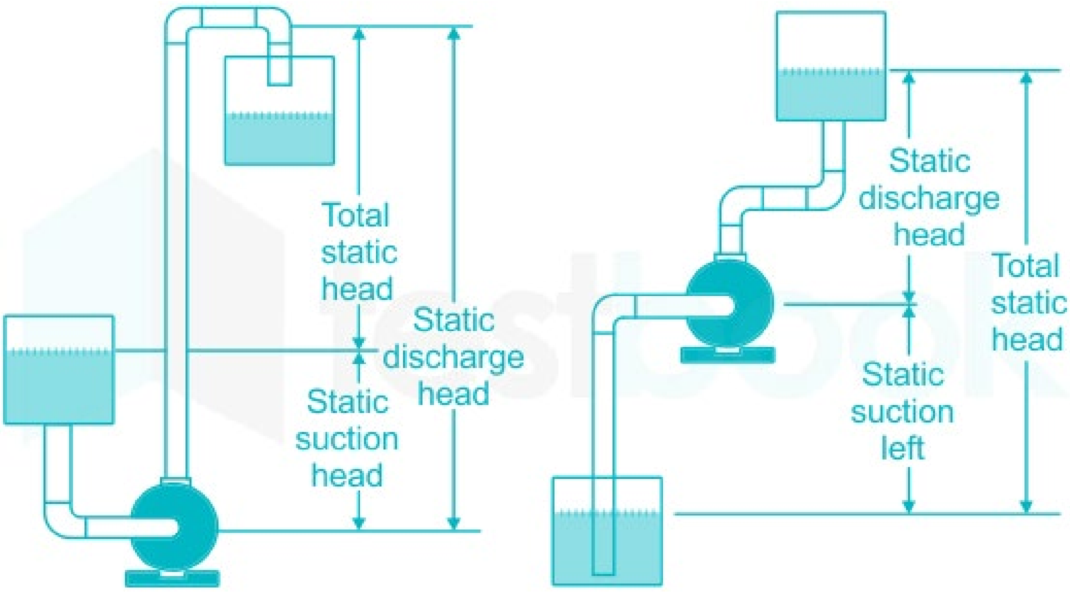


Figure 4-36 Suction lift

- Clogged impeller
- Wrong direction of rotation
- Clogged suction
- Ruptured suction line

e) Insufficient Discharge

- Air leak into suction pipe
- Air leak into pump through gland packing
- Concentric reducer in suction line causing air pocket (Replace with eccentric one)
- Casing not air-tight and therefore breathing in
- Total head of system higher than design head of pump
- Pump main clogged
- Line valve malfunctioning
- Impeller locking pin loose

f) Pump vibrates or is noisy at low flow

- Pump not fully primed
- Check clogging on suction side
- Suction lift too high
- Suction bell mouth insufficiently submerged

4.5.8.2. The most common causes of motor failure

- Electrical Overload (Overcurrent): This can be caused by a low supply voltage, short circuited conductors. Install effective overcurrent protection relay
- Low Insulation Resistance
- It is caused by the degradation of the insulation of the windings due to overheating, corrosion, or physical damage and Moisture.
- Over-Heating
- Around 55% of insulating failures in motors occur due to overheating caused by poor power quality (low voltage), or a high temperature operating environment.
- Contamination

- Contamination from dust, dirt and chemicals is one of the leading causes of motor failure. Foreign bodies can dent bearing raceways and balls
- Vibration
- The motor positioned on an uneven or unstable surface often causes vibration. Vibration can also be a result of loose bearings, misalignment, or corrosion.
- Poor lubrication

4.5.8.1.1 Insulation Resistance

- *For insulation resistance, A general rule-of-thumb is 10 Mega ohm or more*

Figure 4-37 Measuring resistance

4.5.8.1.2 Motors Insulation Classes

Generally, Class-F insulation is used in Electric motors installed with pumps. This class has more temperature tolerance (155°C) than class-B (130°C), therefore more safety and more life.

4.5.8.2. Trouble Shooting for Electric Motor

Table 4-4 Motor trouble shooting

Sr No.	Trouble	Cause	Remedy
1	Hot bearings	• Misalignment • Oil too heavy or too light • Insufficient oil level	• Straighten or replace shaft. • Correct coupling alignment. • Use recommended oil.
		• Bearing loose on shaft or in bearing housing • Insufficient grease • Deterioration of grease or lubricant contaminated • Excessive lubricant • Overloaded bearing	• Replace bearings. • Remetal shaft/housing or replace shaft or bearing housing. • Remove old grease, wash bearings thoroughly with kerosene and replace with new grease. • Reduce quantity of grease. Bearing should not be more than two-third filled. • Check alignment

Sr No.	Trouble	Cause	Remedy
	Motor dirty	• Ventilation passage blocked. Windings coated with fine dust or lint. • Rotor winding coated with fine dust/cement	• Dismantle entire motor and clean all windings and parts by blowing off dust, and if necessary, varnish. • Clean and wash with cleaning solvent. • Clean and polish slip ring. Clean rotor and varnish
3	Motor stalls	• Motor overloaded • Low voltage • Open circuit • Incorrect control resistance of wound motor • Mechanical locking in bearings or at air gap.	• Check any excessive rubbing or clogging in pump • Correct voltage to rated value. • Correct voltage to rated value. Fuses blown, check overload relay, starter and push button.
4	Motor does not start. Wrong rotation	• No supply voltage or single phasing or open circuit or voltage too low. • Motor may be overloaded • Starter or switch/breaker contacts improper • Initial starting torque of load too high. • Rotor defective • Mechanical locking in bearings or at air gap. • Wrong sequence of phases	• Check voltage in each phase. • Start on no load by decoupling. Check for cause for overloading. • Examine starter and switch/breaker for bad contact or open circuit. • Remove end shields, check • end connections. Dismantle and repair. • Inter change connections of two leads at motor or at switchboard for two phases.
5	Motor overheats while running	• Check for overload • End shields may be • clogged with dust, preventing proper ventilation of motor. • Motor may have one phase open. • Motor may have one phase open. • Unbalanced terminal voltage	• If overloaded, check and rectify cause for over loading. • Blow off dust from the end shields. • Check to make sure that all leads are well connected. • Check for faulty leads, connections from transformer. • Check insulation resistance, examine and revarnish or change insulation. • correct voltage of the extent possible. • Replace worn bearings.
6	Motor vibrates	• Motor misaligned • Weak foundations or holding down bolts loose • Defective ball or roller bearings Rotor unbalanced • Single phasing • Excessive end play	• Realign • Strengthen base plate/ • foundation; tighten holding down bolts. • Replace bearing • Rotor unbalanced • Single phasing • Unbalanced terminal voltage. • Motor may be overloaded.
7	Leakage of oil or grease on winding	• Thrust bearing oil seal damaged • Excessive oil, grease in bearing.	• Clean the spilled oil on winding. Replace oil seal. • Reduce quantity to correct extent.

Sr No.	Trouble	Cause	Remedy
			• Grease should be filled up to maximum half space in bearing housing.

4.5.8.3. Maintenance of Valves

4.5.8.3.1 Gate Valves

Figure 4-38 Gate valve

Gate valves are simply a shut-off device used on force mains to allow for pump or valve removal. These valves should not be used to throttle flow. They should be either totally open or totally closed.

Maintenance as follows shall be carried out.

- As time goes by, the steel gate valve will start to get stuck. Periodically lubricate the stem of the valve wheel.
- **Be watchful of rust: It can stick the disc.**
- Use wire brush to scrape the rust off of the metal
- Check gland packing of the valve at least once in a month. It should be ensured that packings inside the stuffing box are in good trim and impregnated with grease. It may be necessary to change the packing as often as necessary to ensure that the leakage is within limit.
- Grease should be applied to reduction gears and grease lubricated thrust bearing once in three months.
- Check tight closure of the valve once in 3 months.
- A valve normally kept open or closed should be operated once every three months to full travel of gate and any jamming developed due to long disuse shall be freed.
- Inspect the valve thoroughly for flaws in guide channel, guide lugs, spindle, spindle nut, stuffing box etc. once in a year.
- Important DON'T for valve is that it should never be operated with oversize handwheel or cap or spanner as this practice may result in rounding of square top and handwheel or cap or spanner may eventually slip.

- An important DON'T for valve is that it should never be operated under throttled i.e. partially open condition, since such operation may result in undue chatter, wear and failure of valve spindle.

4.5.8.3.2 Check Valves

Figure 4-39 Check valve

Check valves are watertight and are required to prevent backflow on force mains that contain sufficient water to restart the pumps. They also effectively stop backflow from reversing the direction of pump and motor rotation. They must be used on manifolds to prevent return flow from perpetuating pump operation. Check valves should be "non-slam" to prevent water hammer. Types include swing, ball, dash pot and electric.

Maintenance of check valves

- Check proper operation of hinged door and tight closure under no-flow condition.
- once in 3 months.
- The valve shall be thoroughly inspected annually. Particular attention should be paid to hinges and pins and soundness of hinged door.
- Condition of dampening arrangement should be thoroughly examined once in year and necessary maintenance and rectification as per manufactures' instructions shall be carried out.
- In case of dampening arrangement, check for oil leakage and replace oil once in a year.

4.5.8.3.3 Air/Vacuum Valves

Figure 4-40 Air valve

Air/vacuum valves are used to allow air to escape the discharge piping when pumping begins and to prevent vacuum damage to the discharge piping when pumping stops. They are especially important with large-diameter pipe. If the pump discharge is open to the atmosphere, an air-vacuum release valve is not necessary. Combination air release valves are used at high points in force mains to evacuate trapped air.

Table 4-5 Air/vacuum valves maintenance

Operation	Year 0.5	Year 1	Year 1.5	Year 2	Year 2.5	After 5 years
Verify degassing function using the control valve	Yes	yes	Yes	Yes	Yes	Inspection two times for year
Verify the seal of filling orifice	Yes	yes	Yes	Yes	Yes	Control at every inspection
Verify the clamping of bolts of flanges	Yes	yes	Yes	Yes	Yes	Control at every inspection

- Verify of the degassing function: If the degassing orifice is well working when opening the control valve, only a little quantity of air must go out. If the flow of air is long, it means that the float is embedded in closed position and there's a big sack of air in the valve. In this case it's necessary to: - Close the isolating device; - Remove the cover of air valve; - Clean the internal parts and verify the integrity of various components; - If there's some relevant wear sign it's necessary to replace the gasket seal or the float; - Close the valve with its cover and re-open the isolating device.
- In case of failure of hydraulic seal This anomaly can be caused by the deposit on the seat of material suspension that builds-up during the functioning or it is caused by the blocking of float on the guides. In this case it's necessary to: - Close the isolating device; - Remove the cover of air valve; - Clean the internal parts and verify the integrity of various components; - If there's some relevant wear sign it's necessary to replace the gasket seal or the float; - Close the valve with its cover and re-open the isolating device.

4.5.8.3.4 Butterfly valves

Butterfly valve is a shut-off valve. It is also used for regulating flow. Basically, the disk is operable up to 90 degrees and that’s why it is called a quarter-turn valve.

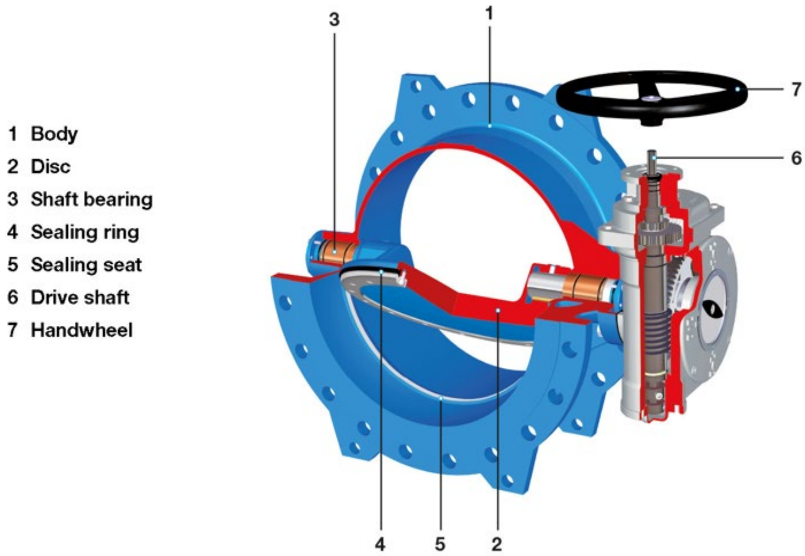


Figure 4-41 Butterfly valve

- Check seal ring and tight shut-off once in 3 months.

- Lubricate gearing arrangement and bearing once in 3 months.
  Inspect the valve thoroughly including complete operations once in a year. Change oil or grease in gearing arrangement once in a year.
- Operate bypass valve wherever provided once in 3 months.
- Flange adapter/dismantling joint provided with valve shall be loosened and retightened once in 6 months to avoid sticking.

4.5.8.4. Maintenance of starters. Breakers etc.

Circuit diagram of starter/breaker should be pasted on door of switch gear and additional copy should be kept on record.

i. **Daily**

- Clean the external surface.
- Check for any spark or leakage current. 1 Check for overheating.

ii. **Monthly**

- Blow the dust and clean internal components in the panel, breaker and starter.
- Check and tighten all connections of cable, wires, jumpers and bus-bars. All carbon deposits shall be cleaned.
- Check relay setting.

iii. **Quarterly**

- Check all connections as per circuit diagram.
  Check fixed and moving contacts and clean with smooth polish paper, if necessary.
- Check oil level and condition of oil in oil tank. Replace the oil if carbon deposit in suspension is observed or color is black.
- Check insulation resistance.
- Check condition of insulators.

iv. **Yearly**

- Check and carry out servicing of all components, thoroughly clean and reassemble.
- Calibrate voltmeter, ammeter, frequency meter etc.

Figure 4-42 Motor starter and breaker

4.5.8.5. Trouble Shooting for Starters, Breakers and Control Circuits

Table 4-6 Trouble shooting starters and breakers

Sr. No.	Trouble	Cause	Remedy
1	Starter/breaker not switching on	• Non availability of power supply to the starter/breaker • Overcurrent relay operated. • Relay reset not operating • Castle lock is not locked properly	• Check the supply. • Reset the relay. • Clean and reset relay • Remove lock and lock it properly
2	Starter/breaker not holding on ON-Position	• Relay contacts are not contacting properly. • Latch or cam worn out	• Check and clean the contacts. • Readjust latch and cam.
3	Starter/breaker tripping within short duration	• Overcurrent relay setting incorrect. • Moderate short circuit on outgoing side. • Sustained overload • Loose connection	• Check and reset to 140-150% of normal load current. • Check and remove cause for short circuit. • Check overcurrent setting. • Check for short circuit or • earth fault. • Examine cause of overload and rectify. • Clean and tighten.
4	Starter/breaker not tripping after overcurrent or short circuit fault occurs	• Lack of lubrication to mechanism • Mechanism out of adjustment • Failure of latching device • Mechanical binding. • Relay previously damaged by short circuit. • Heater assembled incorrectly. • Relay not operating due to: * Blown fuse * Loose or broken wire • Relay contacts damaged or dirty	• Lubricate hinge pins and mechanisms. • Adjust all mechanical devices i.e., toggle stops, buffers, springs as per manufacturer's instructions. • Examine surface, clean and adjust latch. If worn or corroded, replace it. • Replace overcurrent relay (and heater, if provided) • Replace overcurrent relay and heater. • Review installation instructions and correctly install the heater assembly. • Replace fuse.

Sr. No.	Trouble	Cause	Remedy
5	Overheating	• Poor condition of contacts. • • Contacts out of proper Alignment • Contacts burnt or pitted • Loose power connection. • Sustained overcurrent • or short circuit/earth fault.	• Clean and polish contacts. • Align the contacts. • Clean the contacts with smooth polish paper or if badly burnt/pitted, replace contacts. (Contacts shall be cleaned with smooth polish paper to preserve faces. File should not be used.) • Tighten the connection. • Check cause and rectify.
6	Contacts chatter	• Low voltage • Poor contact in control circuit • Defective or incorrect coil.	• Check voltage condition. Check coil voltage rating. • Check push button station, (stop button contacts), auxiliary switch contacts and overload relay contacts and test with test lamp. • Check for loose connections in control circuits. • Replace coil. Rating should compatible for system nominal voltage.
7	Noisy magnet (humming)	• Defective coil • Magnet faces not mating correctly. • Dirt oil or foreign matter on magnet faces. • Low voltage	• Replace coil • Replace magnet assembly. • Hum may be reduced by • removing magnet armature and rotating through 180. • Clean magnet faces with carbon tetrachloride. • Check system voltage and voltage dips during starting.

4.5.8.6. Trouble Shooting for Cables

Table 4-7 Trouble shooting cables

Sr. No.	Trouble	Cause	Remedy
1	Overheating	• Cable size inadequate.	• Provide a cable in parallel to existing cable or higher size cable • Increase clearance between cables.
2	Insulation burning	• Improper termination in lug termination	• Check size of lug and whether properly crimpled and correct. • Check whether only few strands of cable are inserted in lug. Insert all strands

Sr. No.	Trouble	Cause	Remedy
			using a new or higher size lug if necessary.

4.5.8.7. Power Factor Improvement

- Electric motors consume two types of power
- Power used to rotate the pump (useful work)
- Power used to magnetize or produce the flux within the motor called reactive power (wasteful power).

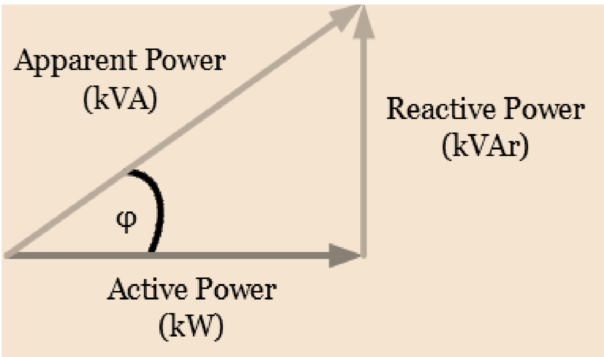


Figure 4-43 PF

- This reactive power can be supplied by capacitors. It is measured in KVAR.
- A power factor of -0.7 for example, indicates that only 70% of power supplied to your motor is being used effectively and 30% is being wasted.
- So, you are using 70% of power but Power Companies are supplying you100 % (70+30%) of power that's why they charge penalty for the power wasted by your system but not reflected in your consumed KWH units.
- For example, if a motor of 60 KW has 0.7 power factor, it will draw current as I=60x1000/1.732 x400 x0.7=123.7 A say=124 amperes
- But if power factor is 0.95the motor will draw current as 91 amperes
- So, 33 A current is reduced by improving PF from 0.7 to 0.95

a) Simplest way to calculate required KVAR of a capacitor

- Check the existing power factor (Either by direct checking with meter, reading name plate or with formula)
- Formula: Existing PF=KW/KVA
- Normally KW & PF is given on the name plate of motor.
- However, you can calculate the KVA by following formula; KVA=√3x V x I
- Suppose a 100 KW motor is drawing 90 A.
- KVA=1.73 x400 x90/1000= 62.35

- Existing PF= 50/62.35=0.8
- Check the table against existing and required PF.
- Multiply Factor from the table with power of the motor
- Required=0.95
- From table MF =0.421
- Required rating of capacitor will be=50 x 0.421=21 KVAR

Table 4-8 PF improvement table

	Factor K (kvar/kW)												
	final cosφ												
initial cosφ	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
0.60	0.583	0.714	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.549	0.679	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.515	0.646	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.01 5	1.062	1.123	1.265
0.63	0.483	0.613	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.581	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.419	0.549	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.388	0.519	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.358	0.488	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.328	0.459	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.299	0.429	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.70	0.270	0.400	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.242	0.372	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.344	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.316	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.159	0.289	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.262	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.235	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.079	0.209	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.052	0.183	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.026	0.156	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.80		0.130	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81		0.104	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82		0.078	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83		0.052	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84		0.026	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85			0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86			0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87			0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88			0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89			0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.90				0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484

4.5.8.7.1 Operation and Maintenance of power factor improvement panel

a) The supply voltage at the capacitor bus should always be near about the rated voltage. The fluctuations should not exceed + 10% of the rated voltage of the capacitor.

b) Frequent switching of the capacitor should be avoided. There should always be an interval of about 60 seconds between any two switching operations.

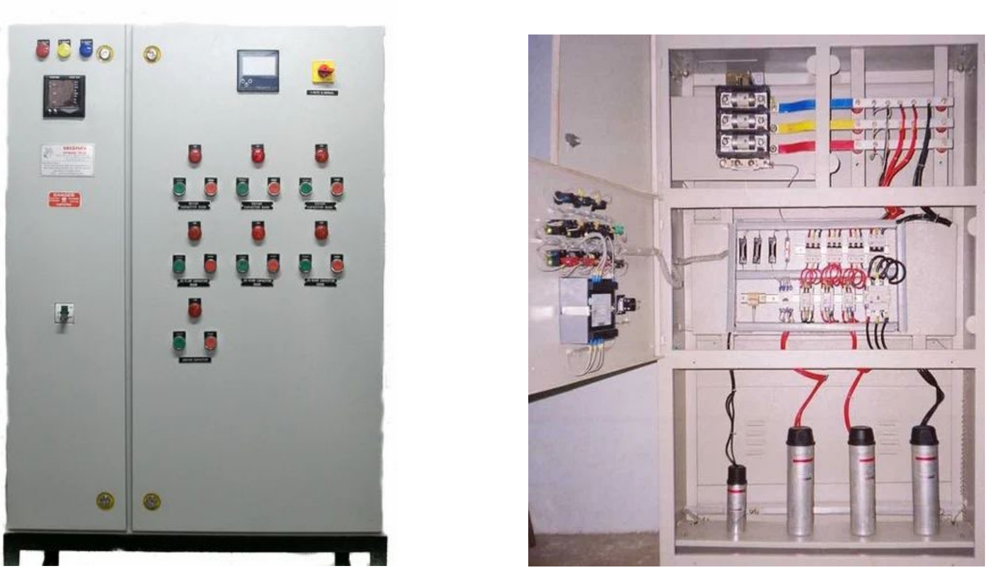


Figure 4-44 PFI panel

c) The discharge resistance efficiency should be assessed periodically by sensing, if shorting is required to discharge the capacitor even after one minute of switching off. If the discharge resistance fails to bring down the voltage to 50V in one minute, it needs to be replaced.

d) Leakage or breakage should be rectified immediately. Care should be taken that no appreciable quantity of impregnant has leaked out.

e) Before physically handling the capacitor, the capacitor terminals shall be shorted one minute after disconnection from the supply to ensure total discharging of the capacitor.

f) Replace capacitor if bulging is observed.

4.5.8.7.2 Trouble Shooting for PFI Panel

Table 4-9 Troubleshooting PFI panel

Sr. No	Trouble	Cause	Remedy
1	Overheating of unit	• Poor ventilation • Over voltage	• Arrange for circulation of air either by reinstalling in a cooler and ventilated place or arrange for proper ventilation. • Reduce voltage, if possible, otherwise switch off capacitors.
2	Current below normal value	• Low voltage • Element fuses blown • Loose connections	• Correct the voltage. • Replace capacitor • Tighten carefully
3	Abnormal bulging	• Gas formation due to internal arcing	• Correct the voltage. • Replace capacitor • Tighten carefully
4	Cracking sound	• Partial internal faults.	• Replace the capacitor

5	HRC Fuse blowing	• Short, external to the units. • Over-current due to over • voltage and harmonics • Short circuited unit. • kVAR rating higher.	• Check and remove the short. • Reduce voltage and eliminate • harmonics. • Replace the capacitor. • Replace with bank of • appropriate kVAR.
6	Capacitor not discharging	• Discharge resistance low	• Correct or replace the discharge resistance.
7	Unbalanced current	• Insulation or dielectric failure.	• Replace capacitor unit.

4.5.8.8. Lifting Equipment

Figure 4-45 Lifting gantry

Relevant points in the maintenance schedule as follows shall be applicable for lifting equipment's, depending on the type of lifting equipment i.e., chain pulley block, monorail (travelling trolley and chain pulley block), manually operated overhead crane and electrically operated travelling crane.

a) Quarterly:

- Check oil level in gear box and top up if required.
- Check for undue noise and vibration.
- Lubricate bearings and gear trains as applicable.
- Check insulation resistance of motors.

b) Half yearly:

- Clean limit switches.
- Clean all electrical contacts.

c) Yearly:

- Change oil in gear box.
- Conduct load test of crane for rated load or at least for maximum load required to be handled.

- All fast-moving components which are likely to wear should be thoroughly inspected once in a year and if necessary, shall be replaced.[28]

[28] https://www.seattle.gov/documents/Departments/SPU/Engineering/11PumpStationsFinalRedacted.pdf