CHAPTER 4 DESIGN AND CONSTRUCTION OF SEWAGE PUMPING STATIONS AND SEWAGE PUMPING MAINS

4.1 GENERAL CONSIDERATIONS

Pumping stations handle sewage either as in-line for pumping the sewage from a deeper sewer to a shallow sewer or for conveying to the STP or outfall. They are required where sewage from low lying development areas is unable to be drained by gravity to existing sewerage infrastructure, and / or where development areas are too remote from available sewerage infrastructure to be linked by gravity means.

4.1.1 Design Flow

Refer Chapter 3 of this manual.

4.1.2 Location and Configuration

The proper location of the pumping station requires a comprehensive study of the area to be served, to ensure that the entire area can be adequately drained. Special consideration has to be given to undeveloped or developing areas and to probable future growth. The location of the pumping station will often be determined by the trend of future overall development of the area. The site should be aesthetically satisfactory. The pumping station has to be so located and constructed such that it will not get flooded at any time. The storm-water pumping stations have to be so located that water may be impounded without creating an undue amount of flood-damage, if the flow exceeds the pumping station capacity. The station should be easily accessible under all weather conditions. Pumping stations are typically located near the lowest point in a development. However, the siting and orientation of each pumping station shall be considered individually and based on the following criteria:

- Local topography as slope of the ground and above and below ground obstructions
- Proposed layout of the particular development and of future developments
- Proximity of proposed and/or existing sewerage infrastructure
- Size and type of the pumping station
- Access considerations for O&M needs including operators health and safety issues
- Visual impact, particularly the vent tube, odours, noise problems, etc.,
- Availability of power, water, etc.,
- Vulnerability of the site for inundation
- Compatibility to neighbouring residences by suitable dialogues.

Of these, the inundation is the key and can result in major environmental and health problems in case raw sewage is flushed to the surface due to flooding of the wet well, or because of failure of the system due to a partially/fully submerged switchboard. Inundation may also result in severe scouring around structures, particularly around the wet well, valve chamber, and possibly cause damage to the critical components such as the electrical switchboard. Accordingly, the designer shall establish the levels of the top of the wet well wall, top of valve chamber walls and top of the plinth supporting the electrical cubicle, so that those structures cannot be inundated by a flood of a 1 in 100-year recurrence interval.

Preferred method will be the formed ground level to be at the 1 in 100 -year flood level and building plinth and top of wet wells etc. shall be at 0.45 m above.

Ditch drain shall be mandatorily provided all around and if it is not possible to drain by gravity to the nearby natural drain. Drain pump sets shall be installed with 100% standby to pump out rain water and connected to the standby power. Rain-water harvesting shall not be provided in sewage pumping stations to avoid ground water pollution by raw sewage due to accidental spillage.

Minimum number of wet wells shall be two, irrespective of the volume of sewage to be pumped out and the structures shall be as far possible circular in plan to facilitate simpler and economical construction, besides the possibility of removing accumulated grit from one of the wells at a time without interrupting the pumping out.

4.1.3 Measures for Safety and Environment Protection

1. Railing shall be provided around all manholes and openings where covers may be left open during operation and at other places, where there are differences in levels or where there is danger for people falling.

2. Guards shall be provided around all mechanical equipment, where the operator may come in contact with the belt-drives, gears, rotating shafts or other moving parts of the equipment.

3. Staircases shall be provided in preference to ladders, particularly for dry well access. Straight staircases shall be provided as against spiral or circular staircases or steps. The steps to be provided in the staircase shall be of the non-slippery type.

4. Telephone is an essential feature in a pump-house, as it will enable the operator to maintain contact with the main office. In case of injury, fire or equipment-difficulty, the telephone will provide facility to obtain proper assistance as rapidly as possible.

5. Fire extinguishers, first-aid boxes and other safety devices shall be provided at all SPS.

6. A system of colours for pipes shall minimize the possibility of cross-connections.

7. To prevent leakages of explosive gases, the wet well should not be directly connected by any opening to the dry well superstructure.

8. All electrical equipment and wiring should be properly insulated and grounded and switches and controls should be of non-sparking type. All wiring and devices in hazardous areas should be explosion-proof.

9. All pumping stations should have potable water supply, washroom and toilet facilities and precautions taken to prevent cross connections.

10. Hoisting equipment shall be provided for handling of equipment and materials, which cannot be readily lifted or removed by manual labour. Hence, in large pumping stations, gantries of adequate capacities shall be provided to lift the pumps, motors and large piping.

11. Fencing shall be provided around the pumping station to prevent trespassing.

12. The station should be landscaped to make it blend with the surroundings and to add to the aesthetic effect, particularly when residential areas are in the near vicinity of the station.

13. Adequate lighting is essential at the plinth and all locations of the pumping station and glares and shadows shall be avoided in the vicinity of machinery and floor openings.

4.1.4 Design Suction Water Level

The suction elevation should be preferably below the invert of the incoming sewer to facilitate air passage through the sewer in the reaches closer to the pump station. A preferable drop of 50 cm to 100 cm below the invert of the incoming sewer is desirable to safeguard against problems of choking of sediments in sewers due to stagnations.

4.1.5 Design Discharge Level

The water surface elevation in the receiving structure decides the static lift when compared to the suction level. However, friction losses and free-fall at receiving chamber are to be added to this to get at the design discharge level. As a rule, if needed this has to be increased such that the hydraulic grade line does not cut the longitudinal section of the ground level along the pumping main. This is achieved by raising the discharge elevation by means of a raised delivery line ending up in a goose-neck before dropping the flow into the receiving chamber such that the hydraulic grade line moves upwards in its terminal end and thus becomes free of the ground level.

The hydraulic grade line shall be at least 1 m above the highest ground level or the top most crown of the pumping main.

4.1.6 Selection of Power Source

The power source will be the local electricity grid. A dedicated feeder from the nearby substation is recommended and in large pumping stations two such independent dedicated feeders from two different substations is to be considered. Drawing off a nearby power cable is permissible for small pumping stations handling less than 1 MLD of DWF.

4.2 SCREEN AND GRIT CHAMBER

4.2.1 Gate

It is necessary to insert a penstock gate at the entry of the sewer into the wet well. The gate shall close by lowering the gate by either hand driven or motorized gear wheel.

4.2.2 Screens

These are needed to trap the floating matters like sachets, plastic milk packets, grocery bags, etc., which otherwise can lump in the impeller. The travelling mechanized endless screen is recommended so that man entry is totally avoided. For this purpose, it is necessary to restrict the width of flow to a rectangular profile in plan with the upstream length as at least three times the width and downstream length as at least two times the width. It is difficult to design and construct such a rectangular structure at deep depths. Hence, the recommended procedure is to construct the circular well first and fill up the arc sections with partitioned mass concrete to get at the rectangular passage. The design is invariably governed by equipment manufacturers who use the DWF and peak flows as the basis. In large pumping stations, it pays to have two successive screens: one coarse and the other fine, the idea being to have a back-up, in case one of them is in downtime. In small stations where the depth of incoming sewer is just about 3 m or so, a hand operated screen facility can be provided as in Figure 4.1.

The screen champer consists of two individual screens hung from a common wire rope gliding over a pulley lined with Teflon to avoid friction and avoid need for oil or grease to get over the friction. When one screen is in operation, the other is in raised position to facilitate cleaning. This relative movement can be got either by manually rotating the pulley wheel or mechanically doing this through a motor and limit switch. Each screen has an L shaped tray with perforated sheet at the bottom and when raised, the cleaning between the screens by a manual rake disturbs the screenings which will fall into the tray from where it is scooped out by a push of the spade over it and emptying directly into the trolley at ground level.

Figure 4.1 Typical Hand operated Screen Facility at Shallow Sewers in Pumping Stations

4.2.3 Amount of Screenings

Refer Section 5.6 of Chapter 5.

4.2.4 Configuration, Number of Grit Chambers and Method of Degritting

Grit shall be removed at the SPS to safeguard the same from causing wear to the pump impeller and inside of especially RCC pumping mains. In case of HDPE and PVC pipeline, the material of the wall does not succumb to erosion as long as velocities are between 1 m/s and 3 m/s and moderate grit content can be even pumped out directly to the STP. For almost all other pipelines the grit will erode the wall thickness and the pipes may collapse after some time. All the same, it is best to remove the grit before pumping.

The grit well shall be an independent well upstream of the wet well. A reliable grit removal system shall be a simple submersible pump set. The system shall be designed such that the floor of the wet well is depressed below the level of the incoming and outgoing sewers. The depression shall be minimum 0.6 m deep at one end and 1.0 m at the opposite end and such end finished flat for 1 m diametrical distance to house submersible pump sets. These pump sets shall be operated at the beginning of each eight-hour shift to pump out the grit laden sediments to a filtering masonry unit at GL and its filtrate let back into the grit well. The filtering masonry unit shall follow the designs of the sludge drying beds as in chapter 5 of this manual. The pump out rate shall be equal to the volume of the depressed portion pumped out in 10 minutes. The filtrate will be returned by gravity to the wet well. The pumped out sewage grit mixture can also be put through vortex separators (see Chapter-5 sub section on grit) installed above ground level and the grit collected in a trolley and the overflow degritted sewage can flow back to the well itself. The grit at the bottom can be further handled in screw classifiers like in detritors and elevated to fall into a stationary trailer. The system will be an enclosed and compact system eliminating human contact. There are many such integrated systems but these are patented. Hence specifying design criteria is difficult. However, these can be procured on competitive basis.

4.2.5 Amount of Grit

Refer section 5.6 in Chapter 5 of this manual.

4.2.6 Treatment and Disposal of Screenings and Grit

If land area is available, the screenings can be segregated to remove non-biodegradable components and blend it with grit and compacted. If not, it can be made a secure fill into an elevated HDPE container to be transported to the STP as and when it fills up. The removed plastics will be disposed into the municipal solid wastes.

4.3 MACHINERY ROOM

This room will house both switches, for switching 'on' and 'off' and the control gear and shall be a dedicated room with no other occupant and well ventilated with two entries/exits. The height of the room shall be the typical 4.5 m and the roof shall be a permanent structure of masonry. Timber products shall be totally avoided in the construction and fixtures and furniture in this building.

4.4 MEASURES AGAINST ODOUR

The best method is to provide good aromatic plants around and not trees. Artificial room sprays can be used, but not inside the electrical control room.

4.5 PUMPS

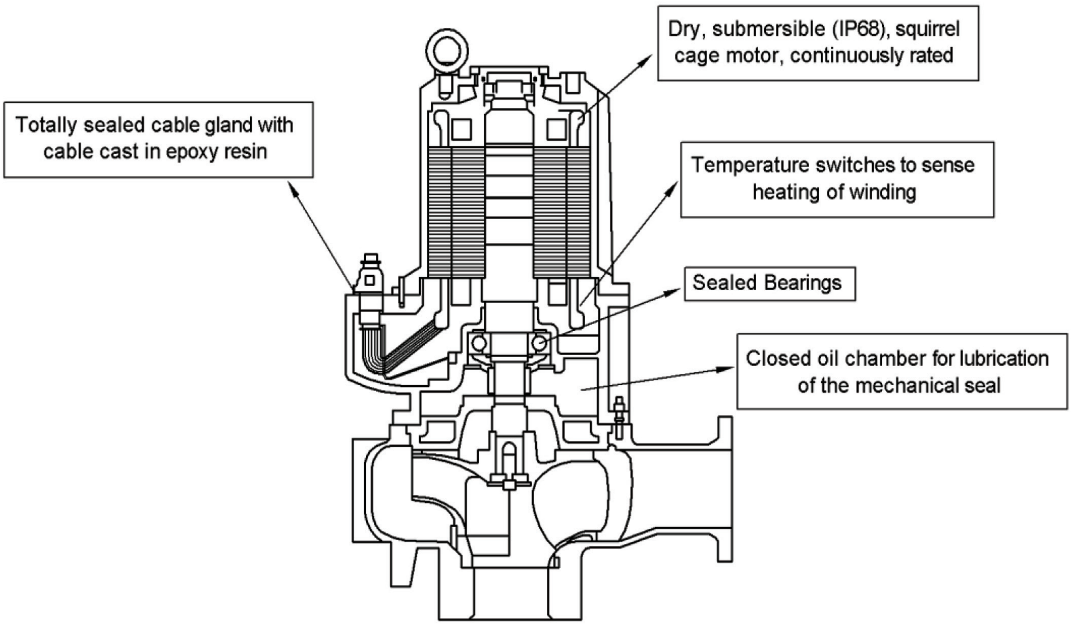
4.5.1 Types of Pumps

Historically, the sewage pumps are of two types, namely, horizontal axis driven with impeller rotating in the vertical plane or vertical axis driven with impeller rotating in the horizontal plane. Both these are centrifugal pumps. The vertical axis driven pump has the advantage that the pump can be at a lower elevation and the motor can be at a higher elevation and connected by a vertical shaft, which permits the pump at the floor of the wet well and the motor on top of it above the MFL. If horizontal axis driven pump is used, the motor and pump are close coupled and can be installed in dry well at the same depth of wet well. The suction pipe driven through the wall or erected above the MFL and the vacuum pump set is used to create the vacuum in the pumping arrangement called negative suction with priming. In general, this negative suction and its vacuum priming are to be avoided altogether in sewage.

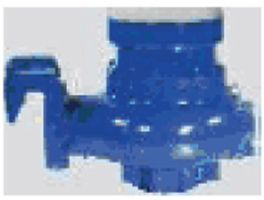
The later entrant of submersible pump sets are with integral motor and pump in the same casing and the assembly is water tight to the motor compartment and functions on vertical axis. Unlike the individual motor coupled pump sets, where the heat of the motor is dissipated by the air circulation brought about by the fan driven by impeller shaft blowing the air over the motor surface, the submersible pump sets require to be kept submerged in sewage at all times and the cooling of the motor is achieved through the surrounding sewage.

The recent entrant of immersible pump sets is with a seal of oil around the motor and which takes care of its cooling. Thus, theoretically, it is possible to pump out the wet well contents to almost the mid height of the pump and this saves considerable construction costs. These are otherwise similar to the submersible pump sets.

A typical section of a submersible pump set is shown in Figure 4.2.



TYPICAL SECTIONAL VIEW OF SUBMERSIBLE SEWAGE PUMP



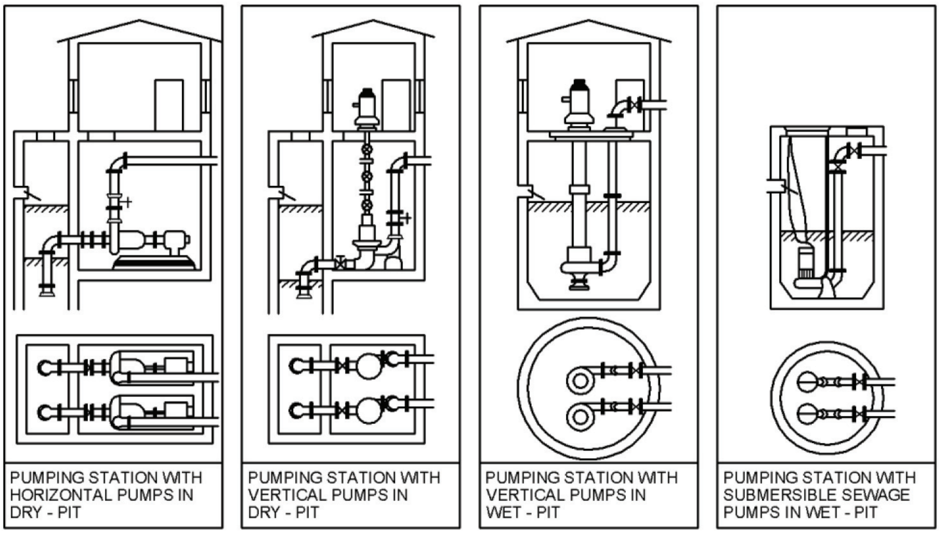
SELF-LOCKING CLAMP TO SEAL THE PUMP DELIVERY TO THE PIPE BRANCH

Figure 4.2 Arrangement of internals in a submersible pump set

In all cases, the free passage between the impeller and casing is called the ball passing size and is to be preferred as minimum of 80 mm.

4.5.2 Types of Pump Stations

This is shown in Figure 4.3 and is self-explanatory.



Source: CPHEEO, 1993

Figure 4.3 Typical dry-well and wet-well installations

4.5.3 Screw Pump Stations

There is yet another type known as immersible pump set where the cooling is made by an oil chamber filled with specific oil around the motor in the same arrangement as the submersible pump set and in this case, there is no need to keep the minimum depth of sewage submergence. There is also the Archimedean screw pump set which is shown in Figure 4-4 and which can only be used for lift stations as the delivery will be at atmospheric conditions .

The open impeller screw picks up and lifts the sewage on the screw and discharges at the top of the screw. The rotational speed is generally about 20 to 30 rpm. The motor is mounted at the top with a gearbox kept inclined and thus driving the impeller axially. Depending on the speed of rotation the quantity lifted varies. There is no piping or valve. The material is carbon steel. Photo courtesy CMWSS Board, Koyambedu STP-Chennai

Source: CMWSSB, Chennai

Figure 4.4 Archimedean screw pump.

4.5.4 Number of Pumps

The capacity of a pump is usually stated in terms of Dry Weather Flow (DWF), estimated for the pumping station. The general practice is to provide 3 pumps for a small capacity pumping station comprising (a) 1 pump of 1 DWF, (b) 1 of 2 DWF and (c) 1 of 3 DWF capacity. For large capacity pumping station, 5 pumps are usually provided, comprising (d) 2 of 1/2 DWF, (e) 2 of 1 DWF and (f) 1 of 3 DWF capacity, including standby.

Alternatively, the number of pumps can also be chosen to be in multiples of DWF flow and provide a 100% standby capacity for peak flow. This will permit easier inventories, cannibalization and uniformity in electrical control systems and switchgear except that the civil structure may need a larger footprint. In this alternative, it is also possible to defer the actual pump installations till the commensurate volume of sewage arises in due course.

A combination of vertical submersible screw, centrifugal impeller pump and a vortex inducing arrangement at the pump pit floor is stated to induce a spin of the incoming sewage depending on the flow rate and thus producing a flow variation commensurate to the incoming flow variation, while the pump is in constant speed of rotation. Right now, it is a patented make. It will be useful to take up pilot project of this and such other technologies and evolve a system so that it can help reduce the costs of civil works and multiples of pump set machinery for future pump stations.

4.5.5 Selection of Pump Stations

Where suction lifts are about 3 m to 5 m only, the horizontal foot mounted centrifugal pump stations should be explored in view of the ease of repairs from local resources and the fact that motors and pumps can be independently taken out for repairs. In addition, where space limitations are constricting, submersible pump stations could be preferred. Archimedean pumps are rugged in operation, but have a limitation on the efficiency, which is only about 25% and are to be preferred in dealing with high volumes of raw sewage to be lifted over a short height. As otherwise, their application in sewage is very little except return sludge in STP where they are ideal.

4.6 Wet Well

Wet well pumping stations usually contain larger pumping units than those required for submersible type pumping stations. The pumping units are installed in the dry well whilst the sewage is stored in the adjacent wet well. To ensure that the centrifugal pumps are always primed, the pumps are located below the level of sewage in the wet well. In respect of submersible pump sets, the top of the pump set shall be such that the pump set is fully submerged at minimum level of sewage flow and the required wet volume is satisfied by the volume of wet well below the invert level of the incoming sewer and an additional allowance of 50 cm below it. Conventional stations are often equipped with multi-stage pumps.

Wet wells shall be designed and constructed to be as hazard free as possible, and corrosion resistant materials shall be used throughout. No junction boxes shall be installed in the wet well. Float cables and bubbler tubes shall be placed in a covered case that shall extend from the control panel to the wet well.

These shall be in 2 parallel wells, each catering to 50% of the volume or in case of large flows, a single well with two compartments which can be hydraulically connected by a penstock in the partition wall.

4.6.1 Structure

Sewage pumping-station wet wells shall be constructed of brickwork duly plastered or reinforced concrete and shall be circular. Wet wells that are installed below the groundwater table shall be adequately designed to prevent uplift pressure without the use of hydrostatic pressure relief valves. Wet well size and depth shall be as required to accommodate the influent sewer, provide for adequate pump suction pipe or pump submergence as recommended by the pump manufacturer and to provide adequate volume to prevent the frequent start and stop of pumps. Partitioning the wet well to help accommodate future growth requirements may be practiced.

4.6.2 Interior Linings and Waterproofing for Old Wells

Wet well interior walls shall be lined with a material that is suitable for prolonged immersion in sewage. The lining shall be completely resistant to hydrogen sulphide and sulphuric acid. The liner shall be easily cleanable and sufficiently durable so that it can be washed with a high-pressure water hose and shall be light in colour. Wet wells that are anticipated to be below the groundwater table shall also have a waterproofing system installed on the exterior of the wet well. Regardless of the elevation of the water table, all joints in the concrete and all penetrations through the concrete shall be grouted with non-shrink grout on both sides of the joint or penetration.

4.6.3 Floor Slopes

In the case of wet well and dry well type with horizontal food mounted centrifugal pumps in the dry well, the floor should have benching like a hopper with a minimum slope of 1 vertical to 1 horizontal to enable suspended solids to drain into the hopper and pumped out without depositing on the entire flow. In the case of submersible pump / immersible pump, the floor shall be horizontal to permit easy installation of present and future pumps.

4.6.4 Lighting

The interior of pump stations, whether at grade or below grade, shall have a lighting system specifically designed to provide illumination best suited for the station layout, which may include suspended, wall, or ceiling mounted. Energy efficient fluorescent fixtures are preferred. Lighting shall be at levels adequate for routine service inspections and maintenance activities.

4.6.5 Ventilation

Pump stations shall be provided with a separate ventilating system and shall be sized to provide a minimum of 10 air changes per hour. Ventilation systems shall be capable of matching inside air temperature to outside air and shall be automatic. Ventilation shall be accomplished by the introduction of fresh air into the pump station under positive pressure. The air shall be filtered to remove particulates inside the pumping station.

4.6.6 Wet Well Design Criteria

Size of the wet well should be based on the following:

1. Flow from proposed development and any associated future development
2. Capability to receive flows from surrounding areas as determined by the authorities

The volume of wet well is given by

$$V = T \times Q/4 \tag{4.1}$$

where,

V	:	Effective volume of wet well (in cubic meters)
T	:	Time for one pump cycle (in minutes)
Q	:	Pumping rate (cubic meters per minute)

The value of T is related to the number of starts per hour and it is not advisable to exceed 6 starts per hour. Accordingly, the value of T in the design is to be taken as 10 minutes for smaller pump capacities but 15 minutes is desirable and hence, the denominator in the equation is to be used as a value of 4.

Ideally, this volume has to be provided below the invert of the lowest incoming sewer in accordance with section 4.1.4 of this manual. However, it may not always be possible especially in large sized pumping stations. In such a case, the volume in the sewers calculated at 0.8 times their total volume can be considered as the extended wet well volume. This is illustrated in Table 4.1.

Table 4.1 Illustration of wet well volume in sewer systems

Given,

Pumping capacity at peak flow	= 42 cubic meters per minute
Volume required	= 15 × 42 / 4 = 158 m^3
Possible depth below invert of sewer	= 2 m
Area needed	= 158 / 2 = 79 m^2
Diameter needed	= SQRT (4×79 /3.14) = 10 m

The depth of the wet well required is also governed by the depth of submergence needed for the submersible pump set. This is governed by the height of the submersible pump set and the floor clearance. Assuming the height of the pump set as 1.2 m and floor clearance as 0.3 m the minimum depth of the floor of the wet well below the invert of the sewer shall be 2 + 1.5 = 3.5 m.

It may be difficult to construct wet wells of 3.5 m deep below invert of incoming trunk sewers which themselves may be at a depth of about 5 m to 6 m below ground level. Moreover, designing and constructing the wet wells to be checked for cracking stress in high water table areas may be not only difficult but may give way to infiltration which will be a challenge to control later on. Thus, it becomes a problem of obtaining sufficient wet well volume at reasonable cost.

A solution to this is proposed in Chapter 6 titled pumps and pumping stations of the book "Wastewater Engineering, collection, treatment and disposal" by Metcalf & Eddy, TMH edition, 1974, which states, "The effective volume V of the wet well between "on" and "off" float switch settings includes the storage in the incoming sewers. If the "on" switch setting is below the sewer invert, no storage is available. This setting is wasteful of both the storage capacity and head available in sewers of appreciable size. It also wastes power and may require higher head pumps and larger horsepower motors. Where it is necessary to rely on the storage in the sewers to obtain adequate wet well volume for control, backwater curves should be computed to obtain the effective volume between the various float switch settings. This may amount to 50% of the volume in the wet well itself. Some stations have been built with practically no wet well and in the case of really large stations, the wet well volume within the station approaches insignificance. In these cases, the only volume available for control is the storage volume in the sewers."

It is also a matter for consideration to move on to immersible pump sets in future where the submergence in sewage is not needed and the motor winding cooling is provided by an internal oil chamber around it in the example above, this will mean reducing the height of wet well below the incoming sewer by 1.2 m.

An ideal type of wet well design can be as shown in Figure 4.5 overleaf.

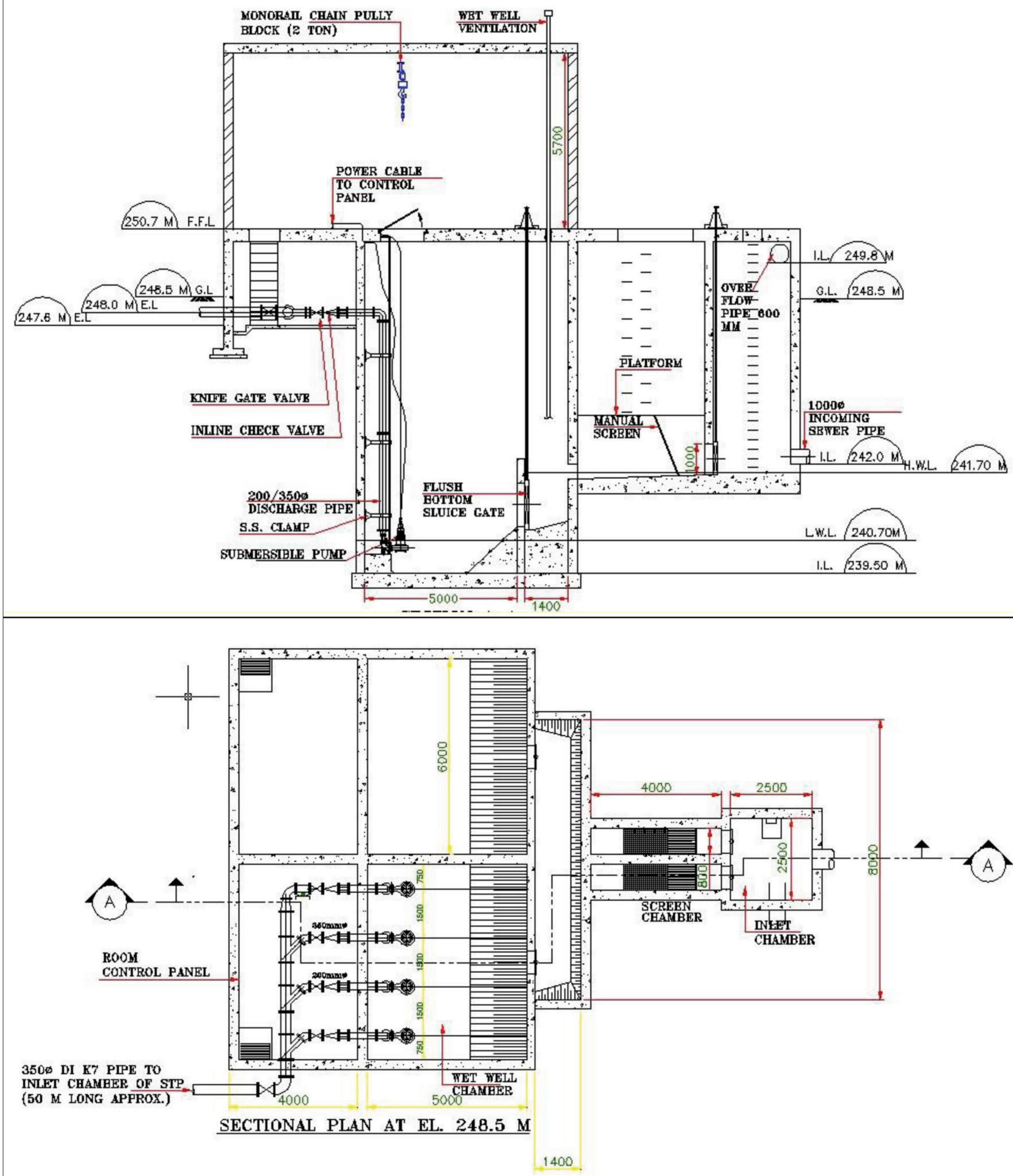
Following points should be considered while designing the wet well pumping system:

- Normal operating volume shall prevent any one pump from starting more than 3 times per hour.
- Level control is to be provided by ultrasonic level controller or submersible transducer.
- Provide high water and low water alarm activated by ultrasonic or submersible level control system and backup float switches.
- Locate level switch where flow from the inlet pipe will not interfere with the float.
- Design electrical service to handle the ultimate capacity of the pump station.

4.6.7 Structural Design Criteria

In respect of civil structural design, all wet wells shall be designed to withstand soil water pressure as though it is at ground level itself irrespective of actual water level, to take care of contingencies of flooding and marooning of the stations. In addition, the stability of the base slab shall be checked for resisting moment by considering the weight of the slab alone and neglecting the weight of the sidewalls. Pressure relief valves for soil water uplift should not be encouraged in wet wells and IS: 456 & IS: 3370 shall be followed. All civil works in contact with sewage shall be constructed with either brick work or RCC and in both cases sulphate resistant cement alone shall be used. In RCC, Fusion Bonded Epoxy coated reinforcement steel having not less than 175 to 300 microns shall be used for reinforcement.

Epoxy coating over the inner face of the screen well / grit well 1 m above the maximum sewage water level is recommended.



Illustrative wet well design for submersible pump set

The top of the pump set shall not be exposed to the atmosphere and shall be always submerged. The required wet well volume shall be provided preferably between the invert of the sewer and the top of the submersible pump set. This is achieved in this drawing. The wet well volume for large stations can also be compensated by the volume in sewers obtained at 0.8 of diameter and backwater curve.

Figure 4.5 Typical arrangements of a submersible pump set wet well

4.7 PUMP BASICS

Even though submersible pumps have become a generic name, the fact remains that the basics of pumps as applicable to centrifugal pumps apply to these also and accordingly, these are discussed herein.

4.7.1 Centrifugal Pumps

These are by far the most widely used in the country in the past in sewage pumping and are generally classified as radial flow, mixed flow and axial flow pumps based on the specific speed of the pump (n_s), which is obtained from the following formula:

$$n_s = \frac{3.65 n \sqrt{Q}}{H^{0.75}} \tag{4.2}$$

where,

n : Speed of the pump in rpm

Q : Flow rate in m^3/s

H : Head of the pump in m

The specific speed of the pump is akin to a shape number and forms the basis for the design of the impeller of a centrifugal pump. The shape of the impeller is identifiable by the relative proportions of the inlet size, outlet width and the outside diameter. Broader inlet size and outlet width are logical for larger flows. For higher head-to-speed ratio the impeller would be logically narrower than broader. Therefore, the specific speed is larger and the shape is broader. This is proportional to the flow-rate and inversely proportional to the head-to-speed ratio.

In a narrow and tall impeller, the flow through the impeller will be radial, i.e., across a plane perpendicular to the axis of rotation. Hence, these are called as radial flow pumps and are pumps of low specific speed, generally between 40 and 150.

In a broad and short impeller, the flow through the impeller will be partly radial and partly axial. Hence, these are called as mixed flow pumps and are pumps of specific speeds in the range from 150 to 350. If the impellers in the pumps has specific speeds higher than 350, the flow is more or less parallel to the axis of rotation and hence these pumps are called as the axial flow pumps. In a double-suction pump, the impeller is actually a composite impeller, with two identical flow-passages combined back to back. Each side is practically an independent impeller and each such impeller handles only half the flow. So, the specific speed for such pumps is calculated by taking only half the flow. By this, the specific speed of a double-suction pump is only 70% of what the specific speed would have been with a single-suction design.

Generally, pumps of low specific speed can work with more suction-lift than the pumps of higher specific speed. With the pumps of very high specific speed as that of the axial flow pumps, not only that they would not work with any suction-lift, instead they would need positive suction head or minimum submergence for trouble free working.

It is always advisable to avoid suction-lift for any centrifugal pump. In the SPS, the pumps are installed either to work submerged in the wet well itself like vertical pumps with motor above GL and the pump in the wet well connected by a rotary shaft or installed in the dry well at such a level that the impeller will be below the level of the liquid in the wet well.

The power-characteristics of the centrifugal pumps are also related to the specific speed. The radial flow pumps with low specific speed have such power-characteristics that the required input power to the pump increases as the capacity, i.e., the flow-rate of the pump increases.

In radial flow pumps, the power demand is minimum with zero flow, i.e., with the delivery valve closed. Since the pump should be started with the pump exerting the minimum load on the driver/ motor, the radial-flow pumps should be started with the delivery valve closed.

The power-characteristics of the mixed flow pumps are almost flat or with very little gradient so, the mixed flow pumps can also be started in the manner similar to that for the radial flow pumps. However, in the case of axial flow pumps, the power needed to put into the pump is maximum at zero flow. These pumps should hence be started with the delivery valve fully open.

The impellers of centrifugal pumps have vanes, which are either open or have shrouds. Open impellers have no shrouds. Semi-open impellers have only a back shroud. Enclosed impellers have both the front and the back shrouds. Axial flow pumps would have only the open impellers. The mixed flow pumps, especially of the higher specific speed would be generally semi-open. However, the impellers of radial and mixed flow pumps can be constructed in all the three types.

The centrifugal pumps are used more commonly for clean and clear liquids. The enclosed impellers are the most common in construction. The impellers are constructed of the semi-open or open type depending on the size of the solids and the consistency of solids to be handled. For handling large-size solids, the impellers are also designed with fewer vanes, which would however have less efficiency.

In the case of high head pumping, the total head is shared by more than one impeller in the multi-stage pumps. With very high head, for a single-stage pump the specific speed may become less than 40 and in turn so low that even the radial flow design would be too narrow. By making the head to be shared by more than one impeller, the specific speed for each impeller will be better. On the other hand, high head would be beyond the range of a single-stage, high specific speed mixed flow or axial flow pump.

Multi-staging would make the head attainable, as is typically seen in vertical turbine pumps. In multi-stage construction, the flow out of one impeller is carried to the suction of the next impeller, with some conversion of the kinetic energy into pressure-energy, in a bowl or a diffuser.

In single-stage pumps, the energy conversion is achieved in a volute casing around the impeller.

For ease of access to the internals the volute casing is often made of the axially split type. This facilitates accessing all the rotating parts for cleaning or repairs, without disturbing the fixation of the pump with the adjoining suction and delivery piping.

4.7.2 Computation of the Total Head of Pumping

The total head of pumping has to be calculated taking note of four factors.

Firstly, the differences between the static levels of the liquid in the suction sump, i.e., the wet well and the highest point on the discharge side makes the potential or static head.

Secondly, the rate of flow and the size of the discharge-mouth determine the velocity at the point of discharge and in turn the kinetic or the velocity head.

Thirdly, the difference in the pressures on the liquid in the suction sump and at the point of delivery makes the pressure head. On the suction side, the liquid in the wet well is open to the atmosphere, but on the delivery side when delivering into a closed conduit sewer, there would be a potential head at the point of delivery, against which the pump will have to deliver. Therefore, the delivery pressure will be higher than atmospheric. The pressure-differential will make the pressure head.

Lastly, the pump has to generate as much head as is needed to compensate for the frictional losses across the pipes, valves, bends and all such appurtenances both on the suction and delivery sides. This makes the frictional head.

With the pumps running, if the discharge of the pumps is more than the inflow, then the level of the liquid in the wet well would keep falling. By this, the potential head component in the total head would keep increasing. Converse will be the case when the inflow is more than the discharge by the pumps.

Throttling of the delivery valve causes a change in the rate of flow and in turn a change in the velocity head which varies in square proportion of the velocity, because the velocity head is computed as $V^2/2g$.

The frictional losses also vary in square proportion of the velocity or flow-rate. The formula for calculating the friction loss will be the Hazen Williams formula as in section 3.16.2 of this manual.

There will be losses in fittings of the pipe line which can be calculated as a function of the velocity head and as in Table 4-2 overleaf.

A typical calculation of the total friction factor for fittings is shown in Appendix A.4.1.

4.7.3 System Head

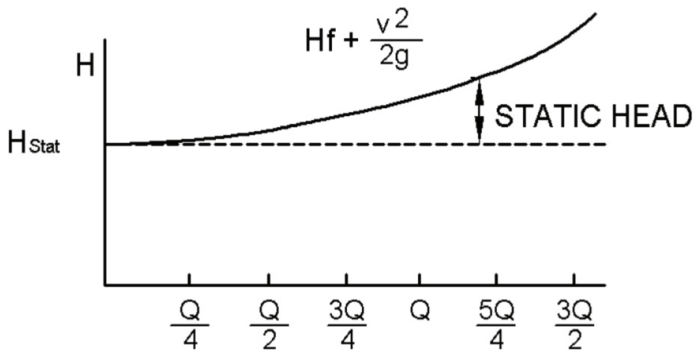
At the stage of planning, the method of computing the total head of pumping should be to estimate it over a range of flow-rates, for different variations in the static levels and for different options of piping sizes and layouts. This obtains the system head curve, as illustrated in Figure 4-6 overleaf.

With an increase only in the potential head, the new system head curve will be a curve shifted parallel upwards, as shown in Figure 4.7 overleaf.

For a smaller size of piping, the parabolic portion in the system head curve will be steeper, as shown in Figure 4.8.

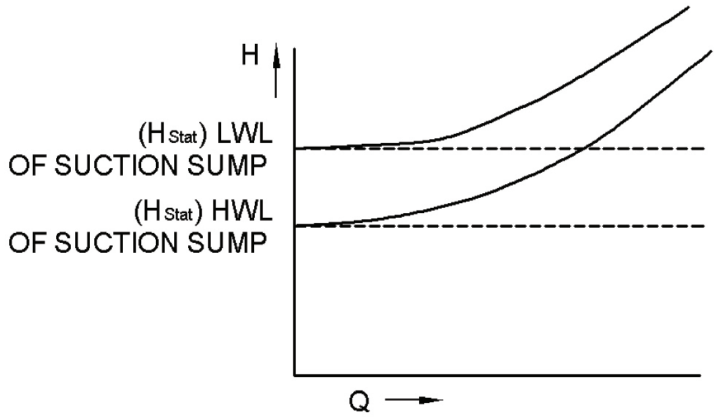
Table 4.2 Friction factor for fittings in pumping mains

No.	Type of Fittings	Factor
1	Sudden contraction	0.5
2	Entrance shape well rounded	0.5
3	Elbow 90 degrees	1.0
4	Elbow 45 degrees	0.75
5	Elbow 22 degrees	0.5
6	Tee 90 degrees	1.5
7	Tee in straight pipe	0.3
8	Gate valve open	0.4
9	Valve with reducer and increaser	0.5
10	Globe valve	10.0
11	Angle	5.0
12	Swing check	2.5
13	Venturi meter	0.3
14	Orifice	1.0



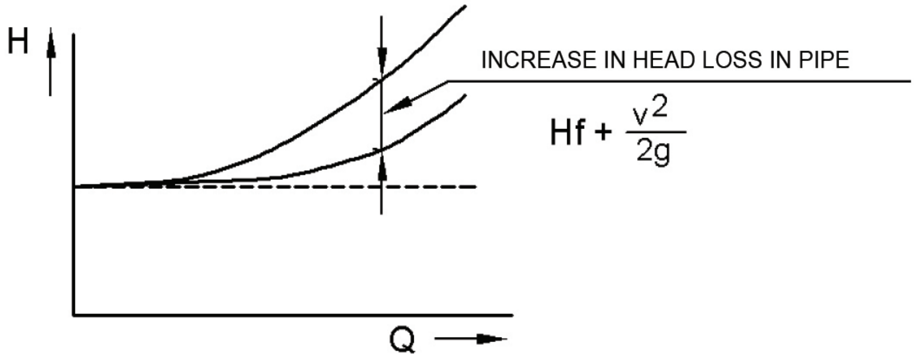
Source:CPHEEO, 1993

Figure 4.6 System head curve for a pumping system



Source:CPHEEO, 1993

Figure 4.7 System head curves for LWL & HWL in suction sump



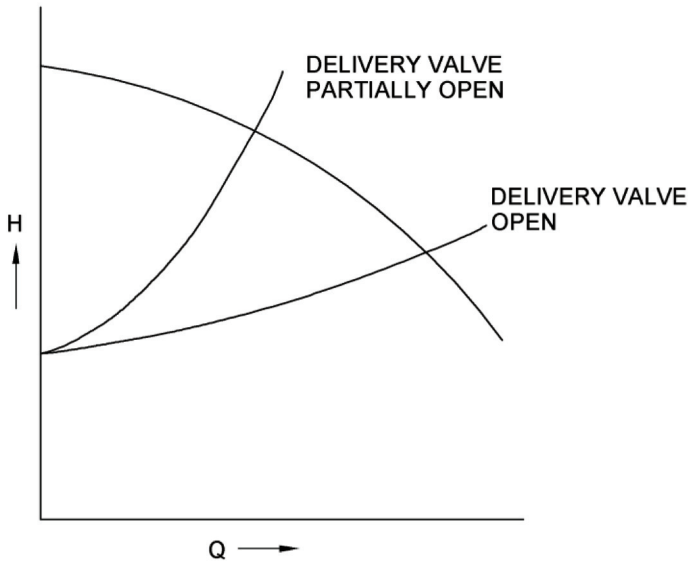
Source:CPHEEO, 1993

Figure 4.8 System head curves with change in pipe sizes

From the system head curves, one knows what the total head would be for an average operating condition, which then can be specified as the total head of pumping.

4.7.4 Operating Point of a Centrifugal Pump

The Head-Discharge (H vs. Q) characteristics of a centrifugal pump are a drooping parabola, with the pump discharge being less when the head is more. When the pump is put into a system, it meets the head as demanded by the system. The system demand is as per the system-head curve. The head met by the pump is as per its H-Q curve. For example, by throttling the delivery valve to close, the system head curve would become a steeper parabola and would intersect the H-Q curve of the pump at a point of higher head and less discharge, thus becoming the new operating point of the pump. This is illustrated in Figure 4.9.

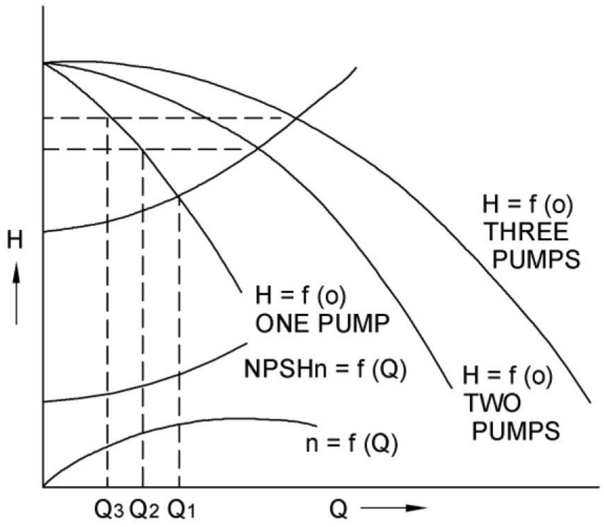


Source:CPHEEO, 1993

Figure 4.9 Change in operating point by operation of delivery valve

4.7.5 Parallel Operation

When more than one pump would be discharging into a common closed conduit or header, the performance characteristics of the pumps suffer mutual influences. Pumps discharging into a common closed header/conduit are said to be running in parallel. The flow obtained in the header is what is contributed by all the running pumps together. The combined characteristics of pumps running in parallel are obtained by reading against different heads; the values of the Q obtainable from the individual pumps and plotting the addition of the Q-values against respective heads, as illustrated in Figure 4.10.



No. OF PUMPS IN OPERN	FLOW OF EACH PUMP
1	Q_1
2	Q_2
3	Q_3

Source: CPHEEO, 1993

Figure 4.10 Operation of pumps in parallel

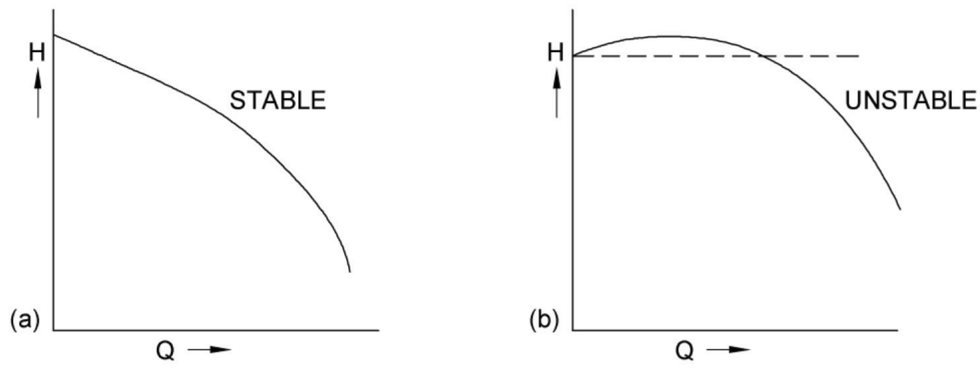
The operating point of parallel operation is the point of intersection of the combined H-Q curve with the system head curve. Because the point of intersection on the combined characteristics is at a head higher than that at the point of intersection on the H-Q curve of a single pump, the discharge at the operating point will be the intersection on the H-Q curve of a single pump.

From this, it is clear that two identical pumps put into parallel operation will give discharge less than double the discharge of only one pump operating. One must study what combination of pumps of different H-Q characteristics can give such combined characteristics as to have an intersection on the combined characteristics at the desired double discharge.

As seen from Figure 4-10, if there are two identical pumps running in parallel, individual pump would be contributing a discharge Qp. If one of the pumps would trip, the system would have only one pump running and giving a discharge Q1, which is more than Qp. At higher discharge, the pump would draw more power, which should not overload its motor. While putting the pumps into parallel operation, it is sound logic to provide that the discharge Qp in parallel operation would be somewhat to the left of the discharge at the best efficiency-point (b.e.p.) of the pump. This will aid in the event of tripping of any other pump, the higher discharge such as Q1 of the running pump will only be nearer to its b.e.p.

4.7.6 Stable Characteristic

It is possible that on the H-Q curve of a centrifugal pump, the shut-off head will not be the maximum head, as shown in Figure 4.11.



Source: CPHEEO, 1993

Figure 4.11 Stable and unstable characteristics of centrifugal pumps

Such H-Q curve is called unstable, because at heads higher than the shut-off head, the discharge of the pumps keeps hunting between two values, causing the pump's performance to be unstable. Such instability is prone to cause the pump to suffer vibrations. This becomes more hazardous in parallel operation, because the hunting of flow of the unstable pump causes the other pumps also to experience continuous change in their share and in turn hunting, instability and vibrations. Pumps to be put into parallel operation should hence be only of stable H-Q curve or care should be taken that the system head will definitely be safely less than the shut-off head of the pump with unstable curve.

4.8 CAVITATION IN PUMPS

The flow must reach the eye of the impeller with such absolute pressure-head, that it will be higher than the vapour-pressure and the net positive suction head required ($NPSH_r$) by the pump. The absolute pressure-head of the flow, as it reaches the eye of the impeller can be found by deducting from the pressure on the liquid in the suction sump. It is atmospheric in the case of an open sump such as the wet well, firstly, the static head between the liquid level in the suction sump and the centre-line of the pump, if the pump's centre line is above the liquid-level, i.e., if there is a suction-lift. If the centre-line of the pump is below the liquid level, i.e., if the suction is flooded, the static head will have to be added and not deducted. Next, the velocity-head, appropriate to the suction-size will have to be deducted.

In addition, the frictional losses up to the eye of the impeller will also have to be deducted. Even if the flow has a positive absolute pressure, after all the deductions, while reaching the eye of the impeller, the flow suffers from shocks, twists, turns and turbulences at the eye of the impeller. This tax on the energy in the flow is called as the net positive suction head required (NPSHr) of the pump. Therefore, the positive absolute pressure of the flow, as it reaches the eye of the impeller should be more than the vapour pressure (Vp) even after providing for NPSH.

This means:

(Pressure head at the eye of the impeller) > ($NPSH_r$ + V_p)

i.e., (Pressure head at the eye of the impeller − V_p) > ($NPSH_r$)

The value in the parenthesis now on the left is termed as the $NPSH_a$, i.e. Net Positive Suction Head available. $NPSH_a$ can hence be derived as follows:

$NPSH_a$ = Pressure on liquid in the suction sump ± Static head between the liquid level in the suction sump and the centre line of the pump − velocity head − frictional losses up to the eye of the impeller − vapour pressure

If the $NPSH_a$ be not greater than $NPSH_r$, vapour bubbles get formed, which while travelling along the flow, being compressible receive energy from the impeller, which builds up the pressure inside them and the resultant compression reduces their volume culminating in the collapse of the bubbles with sudden release of the energy. This causes impact and vibrations. This entire phenomenon is called cavitation and can cause very serious damages. The simple clue to avoid cavitation is to ensure that $NPSH_a$ will be more than $NPSH_r$. The formula given above for $NPSH_a$ suggests many possibilities of keeping $NPSH_a$ as high as possible.

4.9 PRIME MOVERS

Invariably the prime mover is an electrical driven motor. See section in Chapter 5 for further details.

4.10 SURGING OF PUMP AND WATER HAMMER

This may occur where the delivery is for a high head and there is a sudden shut off when the sewage in the delivery main surges back on the pump. In medium situations, this is taken care of by the non-return valves in the delivery main which itself is the surge control device, especially when the dashpot type is used wherein an air cushion is trapped inside a chamber and the surge force is absorbed and the flap does not bang against the valve seating. A sudden closure can lead to bursting of the pipeline and hence the surge analysis has to be made and evaluated for the normal operation of the pump station as well as for a power outage while the pump(s) are running. The modulus of elasticity of the pipe material shall be considered when evaluating water hammer effects and cyclic loadings. At a minimum, the following should be addressed in the surge analysis:

- Transient pressures due to water hammer and its effect on the entire system
- Cyclic loading of the force main
- Investigation of the pipeline profile to determine the possibility of water column separation
- Reverse rotation characteristics of the pumps
- Shut-off characteristics of all proposed pump control valves (if allowed), including check valves.
- Substantiation for the use of surge control valves and other surge protection devices, when necessary, listing recommended size and computed discharge pressures

The potential impact of water hammer shall be evaluated with special consideration given to cyclic loadings that are inherent in sewage force mains. All elements of the piping system must be designed to withstand the maximum water hammer in addition to the static head and cyclic loading. A minimum safety factor of 1.5 shall be used when determining the adequacy of all piping system components with regard to withstanding system pressure. A surge control device in lieu of strengthening piping system components may be used based on the life-cycle cost comparison.

The software for surge analysis is rather complicated and hence it is not promulgated in this manual. Suffice it to state that when the delivery heads exceed 25% of the horizontal length of the delivery pipeline, a surge analysis can be carried out by using the commercially available software or outsourced to institutions of repute.

Water hammer is an internal surge in pressure inside the pumping main when a pump suddenly stops or when a delivery valve in the pumping main is suddenly closed causing a reversal of the flow direction instantly and its forward and reverse oscillation. This phenomenon imparts a higher instantaneous pressure on the pumping main and can cause bursting depending on the magnitude which is almost entirely a function of the static lift. In general, sewage-pumping mains seldom encounter static lifts of more than about 20 m and this will not be a problem.

Moreover, soft-start starters shall be used to ameliorate the situation as also spring-check or dashpot type of non-return valves to be used instead of plain swing-check valves. There are also customized protection systems from appropriate equipment vendors.

4.11 PIPING AND VALVES

The suction and delivery piping of pumping stations are to be chosen between ductile iron and cast iron, in that order and the inside lining shall be with either high alumina cement mortar or polyurea and outside coated with epoxy. Joints shall be of O-ring spigot and socket and valve fixtures shall be through appropriate flanged joints. Next are the RCC pipes with high alumina cement or polyurea lining on the inside and a sacrificial concrete of 15 mm to 20 mm on both the inside and outside and in cases where the soil water has sulphates exceeding the limits for concrete, sulphate resistant cement shall be used in the manufacture itself. The use of MS pipelines is not advocated.

The preferred material of valves is cast iron body with disc of such material as desired by the user agency and relevant BIS code.

4.12 APPURTENANCES

4.12.1 Air-Release and Air/Vacuum Release Valves

Air release and air/vacuum release valves shall be specifically designed for sewerage services and be sized as per the manufacturer’s recommendations. Air release and air / vacuum release valves shall be required at pumps on the discharge pipe as close as possible to the check valve. The air and vacuum release valves will be contained in a vault and vented above ground. A manually controlled isolation valve shall be installed between the force main and the air release or air / vacuum release valves.

4.12.2 Drain Valves

There should be provision of at least one force main dewatering connection at the pumping station and dewatering connections at other major force main low points. Drains shall generally include a plug valve installed on a tee and drain piping to an existing sewer manhole or to a separate manhole that can then be pumped out.

4.12.3 Additional Appurtenances

Additional appurtenances at sanitary sewer pumping stations and force mains should be provided on a case-by-case basis.

4.12.4 Dry Well

This shall be designed in accordance with IS: 456 and IS: 3370 and the precautions stipulated in Subsection 4.6.7 shall apply here also.

4.12.5 Automatic Operation of Pumps and Equipment

Automatic operation of pumps is possible by pre-programmed logic controllers which start the specified pump set once the sewage level reaches a specified height and progressively brings in more pumps into operation and the same in reverse order with dropping of sewage levels. The input to this is the float switch with mercury contact in sealed float, which gets tilted to horizontal and floats when sewage level reaches the float and thereby closes an electronic circuit inside the float which generates a standard signal of 4 mA to 20 mA which is relayed to the control panel for activating the pump. When the sewage level falls, the circuit gets tripped and the signal vanishes and the pump is tripped. The key to the whole issue is to recognize the pre-set programming which may have to be validated for different seasons like monsoon, normal and drought. For this purpose, these controllers are referred to as programmable logic controllers (PLCs). These are custom designed.

4.12.6 Protective Equipment

Refer chapter 5 of this manual.

4.13 AUXILIARY POWER DEVICES

Refer chapter 5 of this manual.

4.14 ALARM SYSTEMS

Alarm is indicated when the pump is running dry and when the motor temperature exceeds the specified limit. In both cases, the method of instant detection is most crucial. The dry running of the pump is detected by the no flow reading in the flow meter. The temperature increase in the motor is detected by the built in temperature sensor which uses the bimetallic properties of dissimilar metals and a set point transducer. In both cases the signal generation is the standard 4 to 20 mA which is relayed to first trip the pump set and simultaneously raises a hooter and visual annunciation by appropriately coloured flashing lamps. Refer chapter 5 of this manual on instrumentation.

4.15 FLOW MEASUREMENT

4.15.1 Magnetic Flow Meters

Magnetic flow meters work on the principle of electromagnetic induction. The induced voltage generated by an electrical conductor in a magnetic field is directly proportional to the conductor's velocity. Thus, the sewage is the conductor and is suitable for all piping like, raw sewage, settled sewage, primary sludge, return activated sludge, waste activated sludge and treated sewage. These are non-invasive and used in almost all pipelines but of course initial calibration is needed. The output is the standard 4 mA to 20 mA signal which is relayed to the central monitoring system.

4.15.2 Ultrasonic Flow Meters

When ultrasonic impulses are released onto a pipe surface carrying sewage, the impulses are deflected along the flow direction based on the velocity of the flow before they impinge on the opposite sidewall of the pipe. The time taken is measured and is correlated to the velocity and then to the diameter of the pipeline and hence the flow rate is arrived at. Like magnetic flow meters these are also non-invasive and used in almost all pipelines but of course, initial calibration is needed. The output is the standard 4 mA to 20 mA signal which is relayed to the central monitoring system.

4.16 CORROSION PREVENTION AND CONTROL IN PUMP SETS

In general, when pipes are flowing full, corrosion does not arise. As such piping in pumping stations, as long as they are of DI or CI, will not exhibit corrosion inherently because they are of such a material and because there is no chances of sulphide corrosion on these metal castings. However, mild steel fixtures will immediately go into corrosion and will be totally avoided. The fasteners shall be of SS under all circumstances.

4.17 REHABILITATION / RECONSTRUCTION OF PUMPING STATION

These arise in contingent situations such as incoming sewage flow exceeding the capacity of the pump sets, or the pump sets are old or the civil works are beginning to crumble. When the inflow exceeds the capacity of existing pump sets, if the increase is marginal, it may be possible to use a variable frequency drive and increase the speed of the pump set, but this may not be a permanent measure. Installation of diesel pump sets in the open area and connecting the pumped sewage to the existing delivery main header is another option, but here again, may be to about the same 10% extra flow only as otherwise the pressure in the delivery main will increase and burst can occur.

A better option will be to switch over to near uniform pumping instead of using peak hour pump sets in the morning peaks whereby the no flow time slots and night-time slots can be brought into play beneficially. In fact, if the pumping is effectively managed in this way, the volume of the entire sewer system itself will buffer the morning peak flows till about noon time for stretched out pumping.

If the civil works start crumbling, the first thing is to construct another independent electrical control panel room and shift all electrical gadgets there. The next is to gunite the outer surface of the walls of the wet well to arrest leakages on both sides.

As for the bottom slab, it is difficult to examine its integrity and if it is only a wet-well with no submersible pump sets, under pinning technique can be used. If the well has installed submersible pump sets, a possibility will be to sink another wet-well and shift the pump sets and then attend to the old well.

4.18 LIFT STATIONS

In locations of high water table and rocky terrain, a typical conventional sewer design and more so its construction poses a series of challenges when depths of excavation exceeds about 3 m. Eventually, the depth of wet-well is also negatively influenced by this issue.

In such situations, it is advantageous to opt for intermediate lift stations, which are like “on line”. In general, these are submersible pump stations, which are interposed in the gravity sewer network.

The procedure is to sink a wet-well on the road shoulder or an acquired plot beyond the shoulder and divert the incoming deeper sewer to it and the submersible pump set therein will lift the sewage and discharge it to the next on line shallow sewer. As the sewer progresses, any number of such lifts can be inserted based on the location. These shall be connected to dedicated electricity feeders as installation and O&M of standby diesel pump sets etc., are not feasible in such locations.

A typical lift station is illustrated in Figure 4.12 overleaf.

4.19 INSTALLATION OF PUMPS

The procedure of installation depends upon whether the pump is to be mounted horizontally or vertically. Most pumps to be mounted horizontally are supplied by the manufacturers as a wholesome, fully assembled unit.

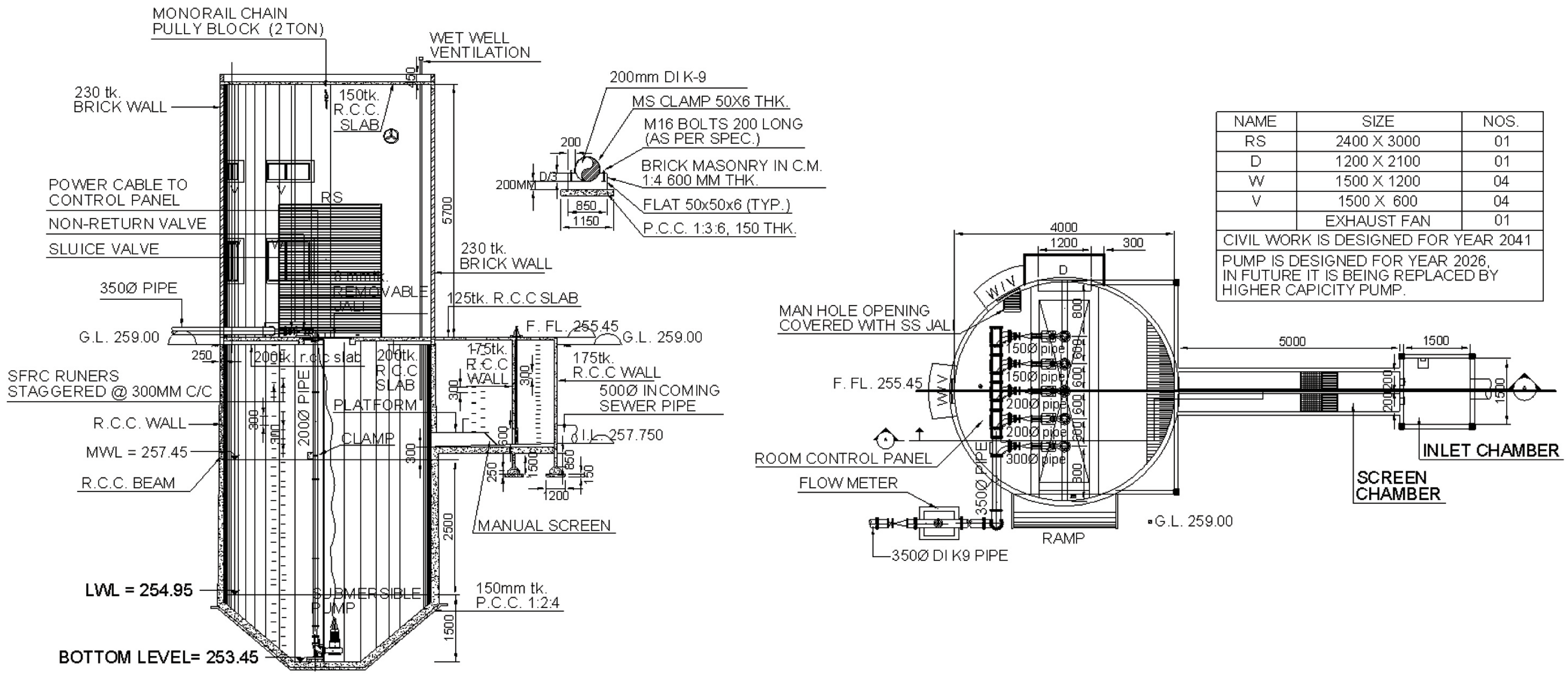
However, pumps to be mounted vertically are supplied as sub-assembled. For the installation of these pumps, the proper sequence of assembly has to be clearly understood from the drawing of the pump manufacturer.

The installation of a pump should proceed through five stages in the following order:

1. Preparing the foundation and fixing the foundation bolts
2. Fixing the pump on the foundation bolts, however resting on levelling wedges, which permit not only easy levelling but also space for filling in the grout later on
3. Levelling
4. Grouting
5. Alignment

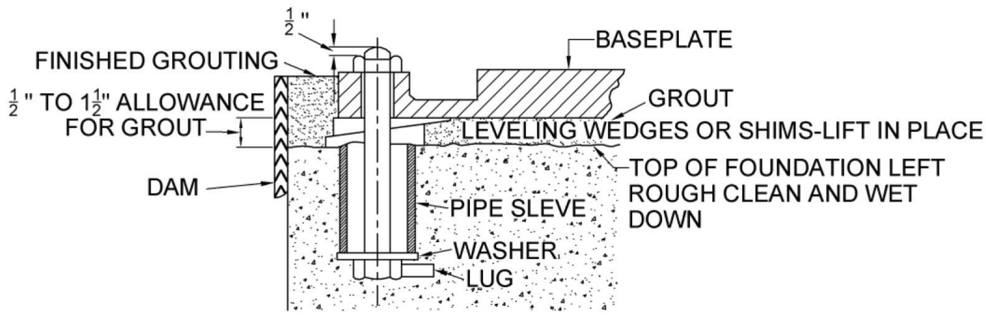
The foundation should be sufficiently substantial to absorb vibrations and to form a permanent, rigid support for the base plate.

A typical foundation is illustrated in Figure 4.13.



These are normally used for lifting the sewage in the sewers at intervals to save the ultimate depth of cut and laying sewers.
The wet well is finished as a bowl to collect and pump out the grit.

Figure 4.12 Illustrative drawing of lift stations



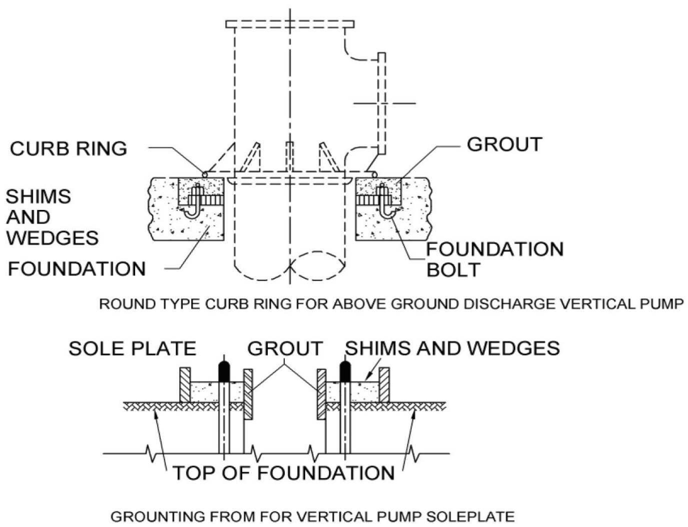
Source: CPHEEO, 1993

Figure 4.13 Typical foundation for a pump

The capacity of the soil or of the supporting structure should be adequate to withstand the entire load of the foundation and the dynamic load of the machinery. As mentioned in clause 6.2.2 and 6.2.3 of IS: 2974 (Part IV), the total load for the pump set and foundation shall include the following:

a) Constructional loads
b) Three times the total weight of the pump
c) Two times the total weight of the motor
d) Weight of the water in the column pipe
e) Half of the weight of the unsupported pipe, connected to the pump-flanges

If the pumps are mounted on steel structures, the location of the pump should be as nearest as possible to the main members (i.e., beams or walls). The sections for structural should have allowance for corrosion also. A curb-ring or a sole-plate with machined top should be used as a bearing surface for the support flange of a vertical wet-pit pump. The mounting face should be machined, because the curb-ring or sole-plate is used to align the pump. Figure 4-14 shows typical arrangement with curb-ring and with sole-plate. Pumps kept in storage for a long time should be thoroughly cleaned before installation.



Source: CPHEEO, 1993

Figure 4.14 Foundation for vertical pumps

Submersible pumps with wet type motors should be filled with water and the opening should be properly plugged after filling the water.

Alignment of the pump sets should be checked, even if they are received aligned by the manufacturer. The alignment should be proper, both for parallelism (by filler gauge) and for coaxiality (by straight edge or by dial gauge). During all alignment-checks, both the shafts should be pressed hard, over to one side, while taking readings. Alignment should be also checked after fastening the piping and thereafter, periodically during operation.

4.20 PUMPING MAINS AND DESIGN APPROACH

These are designed and constructed in the same way as any other water pumping mains. The exception being that the design practice of economical size of pumping mains in conjunction with the electrical energy of the pump sets as used in water pumping mains is not applicable in sewage pumping mains. This is due to varying rates of discharge through the 24 hours like low, average and peak flows through the same main at various parts of the day and night.

4.20.1 Design Formula

The Hazen Williams formula as detailed in Section 3.16.2 of Chapter 3 shall be followed.

There will be pressure losses in fittings which shall be accounted for as in Table 4.2 and illustrated in Appendix A.4.1.

4.20.2 Computation of Pump Kilowatt

This is a function of the static head, friction losses and incidental other losses as illustrated in Appendix A.4.2.

The usual efficiencies of pump sets for estimating the kW requirement can be taken as in Table 4.3.

Table 4.3 Efficiencies of pumps to be adopted for design purposes

No.	Type of Pump Set	Efficiency
1	Horizontal foot mounted centrifugal pump sets	0.85
2	Vertical shaft centrifugal pump sets	0.8
3	Submersible pump sets	0.65
4	Positive displacement pump sets	0.40

In actual practice based on the manufacturer’s pump curves and duty point, the figures may vary and here again, the figures will vary from manufacturer to manufacturer and hence, suffice to state that for design purposes, these figures shall be used.

The kW of a pump shall be calculated as

$$\text{kW required} = Q \times H / 100.5 / \acute{\eta} \tag{4.3}$$

where,

Q : Discharge in litres per second

H : Total head to be got over in m

ή : Efficiency of the pump

This is usually called the brake horse power. The actual horse power is to include the efficiency of the motor. This is about 0.95 for modern new motors and 0.9 for motors nearing their life cycle of 15 years. Thus, the actual kW needed shall be taken for design purposes as

Actual kW = Brake horse power in kW / 0.9

4.20.3 Velocity Considerations in Design of Pumping Mains

The US EPA suggests that pumping mains designed for velocities between 0.6 to 2.4 m/s are normally based on the most economical pipe diameters and typical available heads. For shorter pumping mains of less than 600 m and low lift requirements of less than 10 m, the recommended design force main velocity range is 1.8 to 2.7 m/s. This higher design velocity allows the use of smaller pipe, reducing construction costs. Higher velocity also increases pipeline friction loss resulting in increased energy costs.

The maximum velocity at peak conditions is recommended not to exceed 3 m/s. In the case of water pumping mains, economical size of pumping mains is calculated by trying out various sizes and finding out the net present value of the capital costs of pipeline and pumping machinery and capitalized electrical energy costs. In the case of sewage, this is not possible because of the complexity of varying pumping rates during lean flow, average flow and peak flows resulting in near impossibility of doing the economical size calculations.

Hence, the rule of thumb is recommended whereby the maximum velocity in peak flow does not exceed 2.7 m/s and the minimum velocity at low flows is not less than 1 m/s.

A judicious selection of the pipe diameter is implied in dealing with sewage pumping mains. The reason for recommending the minimum velocity as 1 m/s is based on the fact that sewage in India invariably brings in considerable grit and even though grit removal is provided in pumping stations, there can be times when either the equipment is under repair or the grit actually passes through at peak flows. When the peak flow tapers off it accumulates in the pipeline and reduces the sectional area and higher velocities are needed if the net pumping flow is the low flow conditions.

A case study of a pumping main evaluated by the WHO/UNDP at Chennai way back in 1979, itself using Fluorometer studies illustrates the theory as in Appendix A.4.3 and is a rare piece of literature. Sewage pumping mains of especially RCC can suffer corrosion by hydrogen sulphide gas, which forms and gets liberated inside these mains due to the velocity conditions.

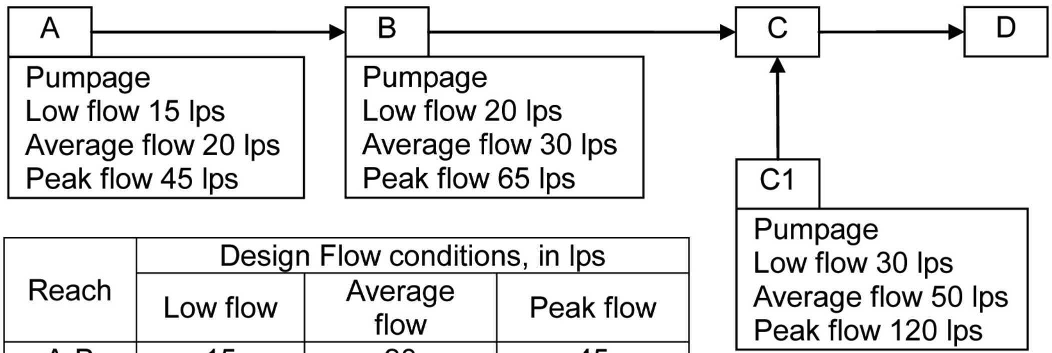
Whenever the velocities are too small, the organic materials get settled out and undergo anaerobic decay and release the sulphide, which later combines with the moisture and forms sulphurous and sulphuric acid.

The effect of velocity and relative sedimentation of organics and grit is shown in Appendix A.4.3. Thus, ensuring of velocities at not less than 0.8 m/s barest minimum and not exceeding 3 m/sec at any time has to be the criterion.

The example in Appendix A.4.4 explains the interpretations of these through the entire 30 years period by considering segments of each 10 years.

4.20.4 Injection and Relay Pumping Mains

Often sewage pumping mains themselves get injected one into another. This is designed on the same principles of design as in Appendix A.4.4 applied to each sequential section starting from the farthest origin of the pumping and add the respective low, average and peak flows for each successive section and arrive at the sizes of pipelines along the "spine" as shown in Figure 4.15.



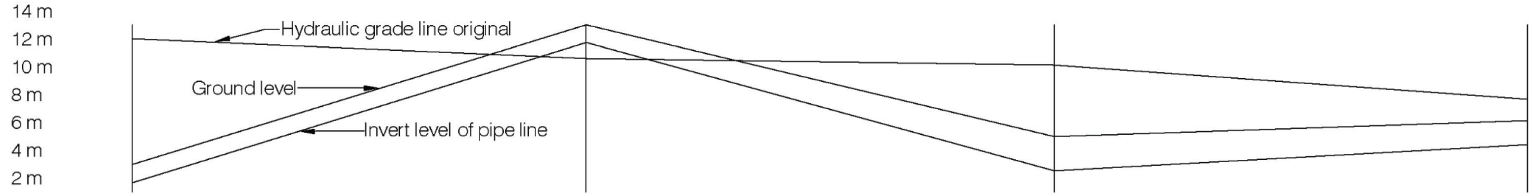
Reach	Design Flow conditions, in lps		
	Low flow	Average flow	Peak flow
A-B	15	20	45
B-C	35	50	110
C1-C	30	50	120
C-D	65	100	230

Figure 4.15 Illustration of pumping main hydraulics on serial pumping mains

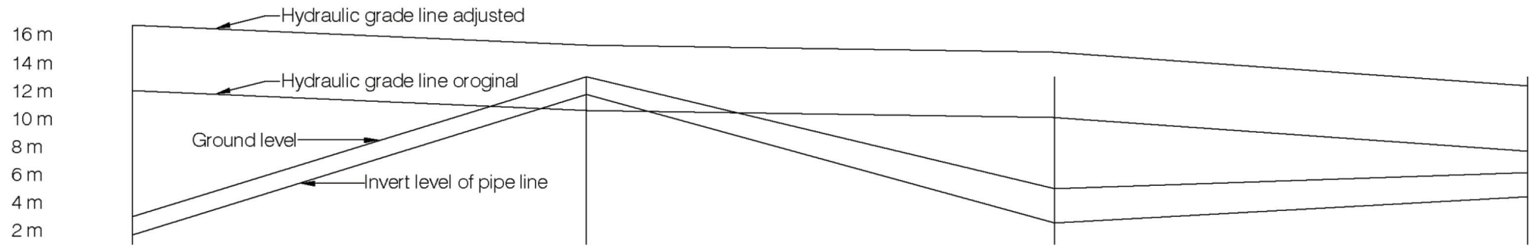
a) The first step is to calculate the friction loss and fittings loss in the "spine" pipe line which will be A-B-C-D with incrementing flows in each segment for a given pipeline diameter by using Appendix 4.4 for each segment and adding up all these from A to D and establish the preferred diameter from velocity considerations.

b) The next step is to plot the hydraulic head line, the ground level and invert level line on Y scale from A to D on a two dimensional scale on Y scale.

c) The next step is to mark the delivery level at D and connect backwards by the losses and verify the hydraulic grade line is above GL by at least 2 m and if not, raise it by 2 m above GL at the crown point. The hydraulic elevations at B, C and D are the delivery levels for pumps at A, B and C1. This is explained in Figure 4.16 overleaf.



Original condition				
Hydraulic Head	13-4=9	11.5-13=(-)1.5	11-6=5	8.5-7=1.5
Hydraulic level	13	11.5	11	8.5
Friction loss in the reach	1.5	0.5	2.5	
Delivery level				6.5
Invert of pipe, m	2.7	10.7	3.55	5.55
Earth cover in the reach, m	1	1	1	
Dia. of pipe in the reach, m	0.3	0.3	0.45	
Ground level, m	4	12	6	7
Location	A	B	C	D



Adjusted condition				
Hydraulic Head	16.5 - 4 = 12.5	15 -13 = 2	14.5 - 6 = 8.5	12-7=5
Hydraulic level	15 + 1.5 = 16.5	11.5+1.5+2=15m	15 - 0.5 = 14.5	14.5 - 2.5 =12.0
Friction loss in the reach	1.5	0.5	2.5	
Delivery level				6.5
Invert of pipe, m	2.7	11.7	3.55	5.55
Earth cover in the reach, m	1	1	1	
Dia. of pipe in the reach, m	0.3	0.3	0.45	
Ground level, m	4	13	6	7
Location	A	B	C	D

In the original condition the hydraulic grade line cuts into the ground level at location B by 1.5 m and leading to cavitation in the pipe line.
In the adjusted condition the hydraulic grade line is lifted by the 1.5 m to avoid cavitation and additional 2 m safety is introduced.

Figure 4.16 Illustrative hydraulics of relay pumping mains in Figure 4.15

4.21 ANTI VORTEX

A vortex is a phenomenon whereby when a liquid is sucked into a suction end of the pump set, air is also drawn due to a vortex formation. This can be caused in both vertically downward suction as well as vertically upward suction. The result is the pumped sewage will be having an air-sewage mixture and thus, in fact it will aid imparting oxygen to the sewage which is beneficial. However, the problem is because of the turbulence induced, dissolved gas like sulphide if already present in the sewage can get stripped and the discharged end may have a perceptible concentration which may be offensive. Hence, anti-vortex attachments are normally used in the suction end, which breaks up the formation of the vortex. The simpler version is the attachment of a circular orifice plate of sufficient annulus width for upward suction pipes as in Figure 4.17.

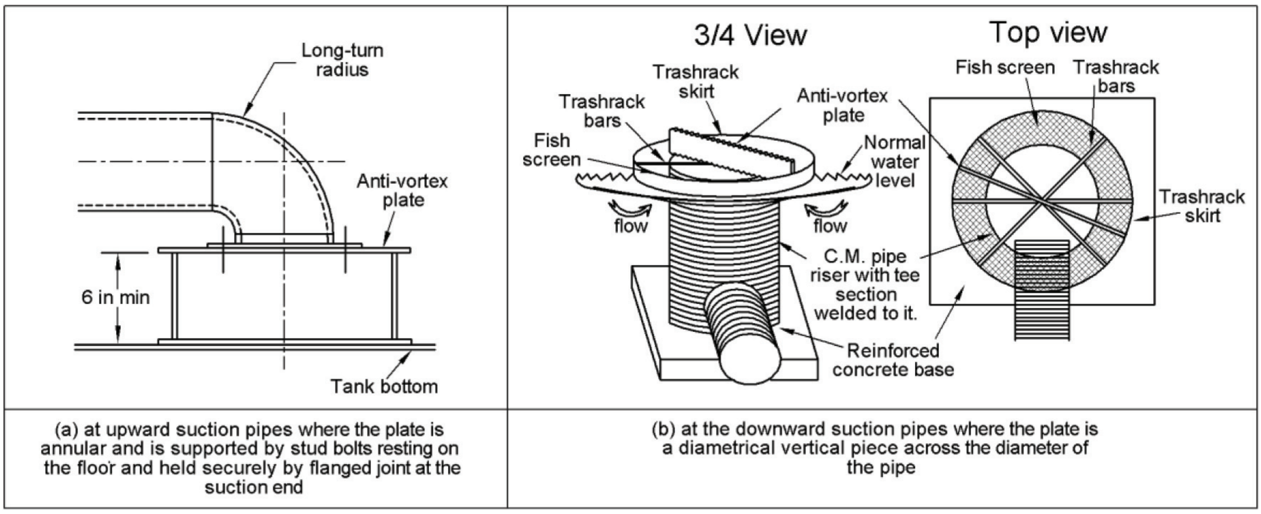


Figure 4.17 Typical anti vortex plate

There are many other variations and can be sourced from the market.