Module 9 : Sewage And Storm water Pumping Stations

Lecture 11 : Sewage And Storm water Pumping Stations

9.1 Introduction

There are certain locations where it is possible to convey sewage by gravity to a central treatment facility or stormwater is conveyed up to disposal point entirely by gravity. Whereas, in case of large area being served with flat ground, localities at lower elevation or widely undulating topography it may be essential to employ pumping station for conveyance of sewage to central treatment plant. Sewage and stormwater is required to be lifted up from a lower level to a higher level at various places in a sewerages system. Pumping of sewage is also generally required at the sewage treatment plant.

Pumping of sewage is different than water pumping due to polluted nature of the wastewater containing suspended solids and floating solids, which may clog the pumps. The dissolved organic and inorganic matter present in the sewage may chemically react with the pump and pipe material and can cause corrosion. The disease causing bacteria present in the sewage may pose health hazard to the workers. Sedimentation of organic matter in the sump well may lead to decomposition and spreading of foul odour in the pumping station, requiring proper design to avoid deposition. Also, variation of sewage flow with time makes it a challenging task.

Pumping stations are often required for pumping of (1) untreated domestic wastewater, (2) stormwater runoff, (3) combined domestic wastewater and stormwater runoff, (4) sludge at a wastewater treatment plant, (5) treated domestic wastewater, and (6) recycling treated water or mixed liquor at treatment plants. Each pumping application requires specific design and pump selection considerations. At sewage treatment plant pumping is also required for removal of grit from grit chamber and pumping may be required for conveying separated grease and floating solids to disposal facility.

Generally pumping station should contain at least three pumping units of such capacity to handle the maximum sewage flow if the largest unit is out of service. The pumps should be selected to provide as uniform a flow as possible to the treatment plant. All pumping stations should have an alarm system to signal power or pump failure and every effort should be made to prevent or minimize overflow. Flow measuring device such as venturimeter shall be provided at the pumping station. In all cases raw-sewage pumps should be protected by screens or racks unless special devices such as self cutting grinder pumps are provided. Housing for electric motors should be made above ground and in dry wells electric motors should be provided protection against flooding. Good ventilation in dry well should be provided, preferably of forced air type, and accessibility for repairs and replacements should be ensured.

The site selection for the pumping station is important and the area selected should never get flooded. The station should be easily accessible in all weathers. The stormwater pumping station should be so located that the water may be impounded without causing damage to the properties. Location of the pumping station should be finalize considering the future expansion and expected increase in the sewage flow. There need to be enough space in the pumping station to replace low capacity pump with higher capacities as per the need in future. The capacity of the pumping station is based on the present and future sewage flow. Generally design period up to 15 years is considered for pumps. The civil structure and the pipelines shall be adequate to serve for the design period of 30 years.

9.2 Types of Pumps

Following types of pumps are used in the sewerage system for pumping of sewage, sewage sludge, grit matter, etc. as per the suitability:

a. Radial-flow centrifugal pumps

b. Axial-flow and mixed-flow centrifugal pumps

c. Reciprocating pistons or plunger pumps

d. Diaphragm pumps

e. Rotary screw pumps

f. Pneumatic ejectors

g. Air-lift pumps

Other pumps and pumping devices are available, but their use in environmental engineering is infrequent.

Radial-Flow Centrifugal pumps: These pumps consist of two parts: (1) the casing and (2) the impeller. The impeller of the pump rotates at high speed inside the casing. Sewage is drawn from the suction pipe into the pump and curved rotating vanes throw it up through outlet pipe because of centrifugal force. Radial-flow pumps throw the liquid entering the center of the impeller out into a spiral volute or casing. The impellers of all centrifugal pumps can be closed, semi open, or open depending on the application. Open impeller type pumps are more suitable because suspended solids and floating matter present in the sewage can be easily pumped without clogging. These pumps can have a horizontal or vertical design. These pumps are commonly used for any capacity and head. These pumps have low specific speed up to 4200.

Axial- flow Centrifugal pumps: Axial-flow designs can handle large capacities but only with reduced discharge heads. They are constructed vertically. The vertical pumps have positive submergence of the impeller. These are used for pumping large sewage flow, more than 2000 m^3/h and head up to 9.0 m. These pumps have relatively high specific speed of 8000 – 16000. The water enters in this pump axially and the head is developed by the propelling action of the impeller vanes.

Mixed flow pumps: These pumps develop heads by combination of centrifugal action and the lift of the impeller vane on the liquid. They are having single impeller. The flow enters the pump axially and discharges in an axial and radial direction into volute type casing. The specific speed of the pump varies from 4200 to 9000. These are used for medium heads ranging from 8 m to 15 m.

Most water and wastewater can be pumped with centrifugal pumps. They should not be used for the following:

- Pumping viscous industrial liquids or sludges, where the efficiencies of centrifugal pumps are very low, and therefore positive displacement pumps are used for such applications.
- Low flows against high heads. Except for deep-well applications, the large number of impellers needed is a disadvantage for the centrifugal design.

The rotational speed of impeller affects the capacity, efficiency, and extent of cavitation. Even if the suction lift is within permissible limits, cavitations can be a problem and should be checked. Centrifugal pumps are classified on the basis of their specific speed (Ns) at the point of maximum efficiency. The specific speed of the pump is defined as speed of the impeller in revolution per minute such that it would deliver discharge of 1 m^3/min against 1.0 m of head; and it is determined using the following equation:

$$Ns = \frac{3.65 n \sqrt{Q}}{H^{0.75}} \tag{1}$$

Where, Q = flow in m^3/min; H = Head in m; and n = speed in rpm.

The pumps with low specific speed are suitable for more suction lift than the pumps with high specific speed. The axial flow pumps with high specific speed will not work with any suction lift; rather these pumps require positive suction head and some minimum submergence for trouble free operation. It is advisable to avoid suction lift for the centrifugal pumps. Hence pumps are generally installed either to work submerged in the wet well 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.

Positive displacement pumps: These pumps include reciprocating piston, plunger, and diaphragm pumps. Almost all reciprocating pumps used in environmental engineering are metering or power pumps. A piston or plunger is used in a cylinder, which is driven forward and backward by a crankshaft connected to an outside driving unit. Adjusting metering pump flow involves merely changing the length and number of piston strokes. A diaphragm pump is similar to a reciprocating piston or plunger, but instead of a piston, it contains a flexible diaphragm that oscillates as the crankshaft rotates. Plunger and diaphragm pumps feed metered amounts of chemicals (acids or caustics for pH adjustment) to a water or wastewater stream. These are not suitable for sewage pumping because solids and rugs present in the sewage may clog them. These pumps have high initial cost and very low efficiency.

Rotary Screw Pumps: In this type, a motor rotates a vane screw or rubber stator on a shaft to lift or feed sludge or solid waste material to a higher level or the inlet of another pump. These are used in the square grit chamber for removal of grit.

Air Pumps: These pumps include pneumatic ejectors and airlifts. In pneumatic ejector wastewater flows into a receiver pot and an air pressure system then blows the liquid to a treatment process at a higher elevation. The air system can use plant air (or steam), a pneumatic pressure tank, or an air compressor. This pumping system has no moving parts in contact with the waste; thus, no clogging of impeller is involved. Ejectors are normally maintenance free and operate for longer time. Airlift pumps consist of an updraft tube, an air line, and an air compressor or blower. Airlifts blow air at the bottom of a submerged updraft tube. As the air bubbles travel upward, they expand reducing density and pressure within the tube. Higher flows can be lifted for short distances in this way. Airlifts are used in wastewater treatment to transfer mixed liquors or slurries from one process to another. These pumps have very low efficiency and can lift the sewage up to small head.

9.3 Efficiencies of Pumps

Efficiencies of the pumps range from 85% for large capacity centrifugals (radial-flow centrifugals and axial-flow and mixed-flow centrifugals) to below 50% for many smaller units. For reciprocating pistons or plunger pumps efficiency varies from 30% onward depending on horsepower and number of cylinders. For diaphragm pumps, efficiency is about 30%, and for rotary screw type, pneumatic ejectors type and air-lift pumps it is below 25%.

9.4 Materials for Construction of Pumps

For pumping of water using radial-flow centrifugals and axial-flow and mixed-flow centrifugal type pumps normally bronze impellers, bronze or steel bearings, stainless or carbon steel shafts, and cast iron housing is used. For domestic wastewater pumping using radial-flow centrifugals and axial-flow and mixed-flow centrifugal type pumps similar material is used except that they are often made from cast iron or stainless steel impellers. For industrial wastewater and chemical feeders using radial-flow centrifugal or reciprocating piston or plunger type pumps, a variety of materials depending on corrosiveness are used. In diaphragm pumps the diaphragm is usually made of rubber. Rotary screw type, pneumatic ejectors type and air-lift pumps normally have steel components.

9.5 Pumping System Design

To choose the proper pump, the environmental engineer must know the capacity, head requirements, and liquid characteristics. This section addresses the capacity and head requirements.

9.5.1 Capacity

To compute capacity, the environmental engineer should first determine average system flow rate, then decide if adjustments are necessary. For example, when pumping wastes from a community sewage system, the pump must handle peak flows roughly two to five times the average flow, depending on community size. Summer and winter flows and future needs also dictate capacity. Population increase trends and past flow rates should also be considered in this evaluation. The capacity of the pumping station should be so determined that the pump of minimum duty should also run for at least 5 min. In addition, the capacity of the well should be such that with any combination of inflow and pumping, the cycle of operation for each pump will not be less than 5 min and the maximum detention time in the wet well will not exceed 30 min at average flow.

The capacity of the pumps installed should meet the peak flow rate with about 100% standby. Two or more number of pumps should be provided. The size and number of pumps for larger pumping station is so selected that variation in the flow rate can be adjusted by manipulating speed of the pump or throttling the delivery valve, without starting or stopping the pumps too frequently. The general practice is to provide three pumping sets in small stations consisting of one pump of capacity equal to dry weather flow (DWF), second pump with capacity of 2 times DWF and third pump of capacity 3 times DWF. For larger pumping stations five pump sets are provided with capacities of 2 units of 0.5 DWF, 2 pumps of 1 DWF and one pump of 3 DWF.

9.5.2 Head Requirement

Head describes pressure in terms of lift. The discharge head on a pump is a sum of the following contributing factors:

1) Static Head (h_d) - The vertical distance through which the liquid must be lifted i.e. the lowest water level in wet well and highest point on the discharge side.
2) Friction Head (h_f) - The resistance to flow caused by friction in the pipes, valves, and bends. Entrance and transition losses shall also be included. The loss of head in friction in the pipes is estimated from the well known equation $h_f = fLv^2/(2gD)$
3) Velocity Head (h_v) - The head required to impart energy into a fluid to induce velocity. Normally this head is quite small and can be ignored unless the total head is low. This is estimated as $v^2/2g$.
4) Pressure Head (h_p) - The pressure differential that the pump must develop to deliver water on the delivery side under higher pressure. The pressure on water in sump well is usually atmospheric pressure, whereas when pumping into sewers there would be potential head at the point of delivery, against which the pump have to deliver. Thus, this is the difference between pressures on the liquid in the wet well and at the point of delivery.
Total Head (H) of pumping is thus expressed by the following equation:

$$H = h_d + h_f + h_v \pm h_p \qquad (2)$$

9.5.3 Suction Lift

The amount of suction lift that can be handled must be carefully computed. It is limited by the barometric pressure (which depends on elevation and temperature), the vapor pressure (which also depends on temperature), friction and entrance losses on the suction side, and the net positive suction head (NPSH) - a factor that depends on the shape of the impeller and is obtained from the pump manufacturer.

9.5.4 Horsepower

The horsepower required to drive the pump is called brake horsepower (BHP). The following equation determines the brake horsepower:

$$BHP = (w.Q.H)/(75.\eta_p.\ \eta_m) \qquad (3)$$

Where, Q = discharge (m^3/s); H = head of water (m); w = Density of water (kg/m^3); η_p = Efficiency of the pump; and η_m = efficiency of the driving motor.

9.6 Types of Pumping Stations

Pumping stations can be configured in a wide variety of arrangements, depending on size and application. The classifications for such pumping-station configurations are: wet well/dry well, wet well only with submersible pumps, and wet well only with non-submersible pumps.

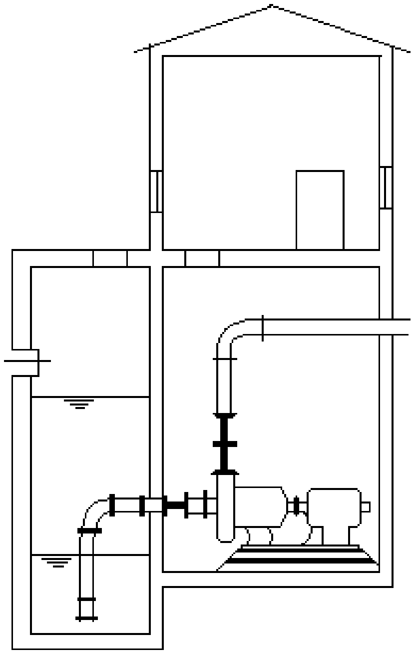
Wet well and dry well: In this configuration, two pits (wells) are required: one to hold the fluid, and one to house the pumps and appurtenances (Figure 9.1). This is required for fluids that cannot be primed or conveyed long distances in suction piping, this option is typically used to pump large volumes of raw wastewater, where uninterrupted flow is critical and wastewater solids could clog suction piping. While construction costs of this type may be higher and a heating, ventilation, and cooling (HVAC) system is necessary due to installation below ground. This configuration is best for operation and maintenance activities because operators can see and touch the equipment.

Wet well with submersible pumps: In this configuration, one well holds both the pumps and the wastewater being pumped. The pump impeller is submerged or nearly submerged in the wastewater. Additional piping is not required in this type to convey the wastewater to the impeller. This option is common worldwide, and the submersible centrifugal pumps can be installed and operated cost-effectively. When vertical pumps are installed the driving motor is mounted on the floor above the ceiling of the wet well.

Wet well with non-submersible Pumps: In this configuration, one well holds the wastewater. The pumps are installed above the water level in wet well. This option is used in areas where the wastewater can be "pulled" through suction piping e.g., treated or finished water or where shutdowns or failures would not be immediately critical e.g., a package plant's raw wastewater lift stations, equalization of secondary treated wastewater, etc.

In selecting the best design for an application, environmental engineers should consider the following factors:

- Many gases are formed by domestic wastewater, including some that are flammable. When pumps or other equipment are located in rooms below ground level, the possibility of explosion or gas buildup exists, and ventilation is extremely important.
- When wastewater is pumped at high velocities or through long lines, the hammering caused by water can be a problem. Valves and piping should be designed to withstand these pressure waves. Even pumps that discharge to the atmosphere should use check valves to cushion the surge. Coarse bar screens shall be provided ahead of pumping station when centrifugal pumps are installed.
- Most of the places dry-well design is preferred. The pumping station must be able to adjust the variation of wastewater flow. The smallest capacity pump should be able to pump from the wet well and discharge at a self cleansing velocity of about 0.6 m/s. Pumping stations typically include at least two pumps and a basic wet-well level control system. One pump is considered a "standby" pump, although the controls typically cycle back and forth during normal flows so they receive equal wear.



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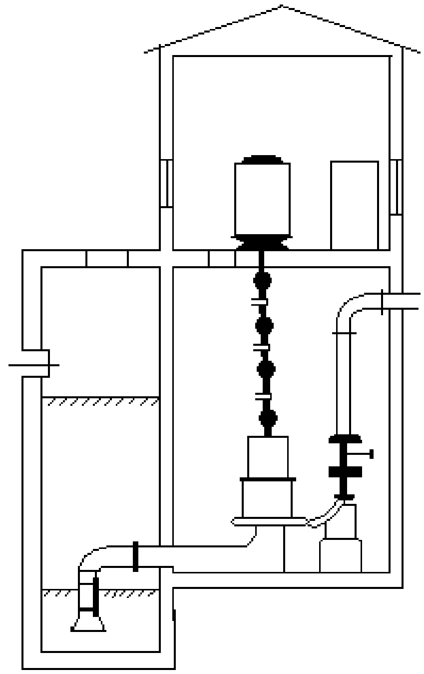

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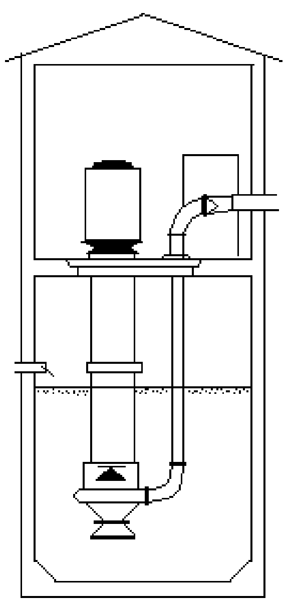

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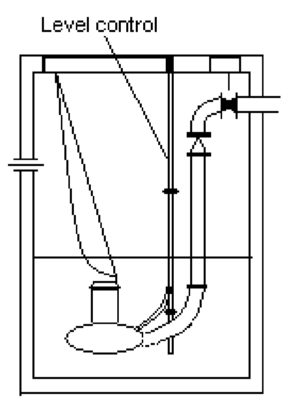

(d)

Figure 9.1 Pumping stations (a) Pumping station with horizontal pumps installed in dry well, (b) Pumping station with vertical pump in dry well, (c) Pumping station with vertical pumps in wet well, and (d) Wet well with submersible sewage pump

Example: 1

A per capita water demand of a township is 200 LPCD having total population of 50000 persons. The sewage generated from this town is required to lifted for 10 m of static head and 100 m distance. Consider loss of head in bends and valves of 0.4 m. Determine (a) size of the sump well, (b) horsepower required for the pump, (c) diamter of the rising main. Assume suitable data required.

Solution

Estimation of sewage flow considering sewage generation equal to 80% of the water supply

Average sewage flow = 50000 x 200 x 0.8 x 10^{-3} = 8000 m^3/d = 0.093 m^3/s

Peak sewage flow, considering peak factor of 3 = 0.278 m^3/s

Considering velocity of 1 m/s in rising main, diameter required

$$D = \sqrt{\frac{0.278x4}{\pi}} = 0.595 \text{ m}$$

Provide diamter of 0.6 m, hence actual velocity = 0.278*4/(πD^2) = 0.984 m/s

Design of sump well

Desing the sump for minimum time of 15 min for any pump to run continuously.

Quantity of sewage = 0.278 * 60 * 15 = 250.2 m^3

Quantity of sewage in rising main = (πD^2)*L/4 = π * 0.6^2 * 100/4 = 28.26 m^3

Net storage capacity of the sump = 250.2 + 28.26 = 278.46 m^3

Provide 3 sump units, two for storage of sewage and one as standby, with effective water depth of 3.0 m. Hence the surface area of each sump = 250.2/(2 * 3) = 41.7 m^2

Provide circular or rectangular shaped three sump wells each having surface area of 41.7 m^2 and depth of 3.0 m.

Check for detention time of sewage in the sump at average inflow = volume/flow

=41.7 * 3/(0.093 * 60) = 22.42 min (less than 30 min, hence acceptable)

Check for minimum duration of pumping

If pump with the maximum discharge of 0.278 m^3/s (peak flow) is operated,

The maximum duration of storage at average flow = 30 min

Volume of sewage collected at average flow = 0.093 x 60 x 30 = 167.4 m^3

Hence duration of pumping for maximum capacity pump = 167.4 / (0.278 x 60) = 10 min

Hence, for lower capacity pump the continuous duration of operation will be more than 10 min, which is greater than minimum operation duration of 5 min.

Power of pump

Considering friction factor of 0.04, the frictional head loss = $h_f = fLv^2/(2gD)$

$= 0.04 * 100 * (0.984)^2/ (2 * 9.81 * 0.6)$

= 0.33 m

Velocity head = $v^2/2g = (0.984)^2/ (2 * 9.81) = 0.05$ m

Total head of pumping = 10 + 0.33 + 0.4 + 0.05 = 10.78 m

Considering efficiency of pump = 65% and efficiency of motor = 75%; hence HP of motor required for highest capacity pump (to be able to pump peak flow) = 0.278 x 1000 x 10.78 / (75 x 0.65 x 0.75) = 82 HP

Provide minimum 3 pumps one with 82 HP to handle peak flow alone and other two pumps of capacity to handle of 1 DWF and 2 DWF. The power required for these pumps need to be calculated considering discharge for each pump, and hence the change in velocity and head loss, and following the similar procedure as mentioned above.

Questions

1. Describe when pumping station will be required in sewerage scheme.
2. How pumping of sewage is different than pumping fresh water?
3. Write short notes on pumps used in sewage pumping and capacity of pumps required to be installed at pumping stations.
4. Prepare short notes on specific speed of the centrifugal pumps.
5. Describe the criteria for selection of site for pumping station. What are the facilities/ accessories required in the pumping station?
6. Describe different types of pumping stations and the types of pumps used in each. What is the basis for deciding the capacity of the wet well?