

Design of Industrial/Commercial Sewage Pumping Stations

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Industrial/commercial sewage pumping stations are designed to serve a given industry and, generally, pump to the public sanitary sewers. They are usually owned and operated by the industrial or commercial facility. This article will provide guidelines for designing industrial/commercial sewage pumping systems.

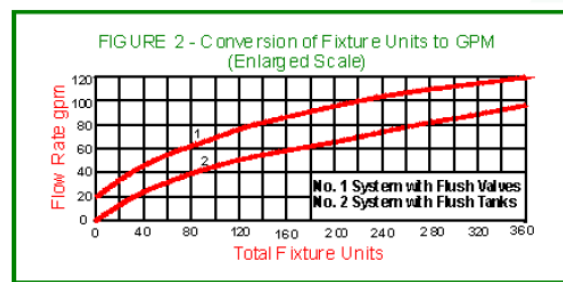
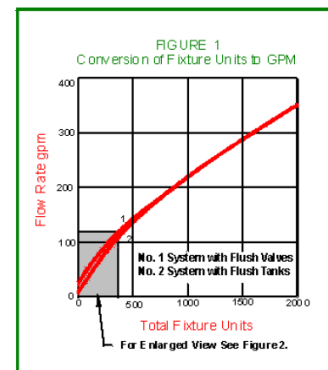
Throughout the country, several standards are used to design sewage pumping stations. All of them, generally speaking, use the same principal but have differences that need to be addressed. The engineer should become familiar with the standard on which the local/state plumbing code is based. The guidelines which follow describe a total system that is reliable and requires little maintenance.

The location of the pumping station will be a function of its size, but even medium to small stations require access by maintenance crews and equipment. Ease of access should always be considered.

DETERMINING FLOW

For industrial/commercial applications, the fixture units method is the most commonly used method to determine the peak flow rates. A fixture unit (FU) is an arbitrarily chosen scale that allows all of types of plumbing fixtures to be expressed in common terms. The sole purpose of the fixture unit concept is to make it possible to calculate the design load on the system when the system is composed of different kinds of fixtures, each having a loading characteristic different from the others. Fixture unit values are designed for application in conjunction with the probability of simultaneous use of fixtures to establish the maximum permissible water supply and drainage load.

Most local plumbing codes have design requirements on how to determine the fixture load for a commercial application. Once the total fixture unit value has been calculated, Figure 1 can be used to determine the peak flow rate into the sewage lift station. Past experience has shown that the fixture unit method is a conservative method of estimating the peak flow rate for a pumping station.



Once the peak flow rate of the drain line into the sewage lift station has been determined, pump capacity should be equal to that flow. If it is always critical that fixtures be kept in operation, a duplex pump station should be specified in lieu of a simplex station. In case of a pump failure, the other pump could carry the load while the failed pump is being repaired.

FORCE MAIN SIZING, MATERIAL

Once the peak flow rate has been determined, the force main can be sized. The velocity in the force main should be a minimum of 2 feet per second (fps) and a maximum of 5 fps. This will keep solids in suspension without generating a large head loss.

Minimum pipe size should be 4 inches when wastewater pumps are used that have at least a 2-1/2 inch solids passing capacity in order to minimize clogging of the force main.

Force mains can be constructed from several materials. PVC and polyethylene are being used more often in both buried and building force mains. The construction of force mains should be similar to water lines in that thrust restraints and blocks should be provided at bends and tees. Air release valves should be provided at high points to prevent air locking and siphoning. Vacuum valves shall be provided, as needed. Consideration should also be given to clean outs so that locations at which clogs may develop can be cleaned; typically, low spots.

SYSTEM HEAD CURVE ANALYSIS

Once the force main has been sized, the system head curve can be determined. All elbows, pipe fittings, and lengths of pipe run should be used to determine a total equivalent pipe length.

The two elements of the system head curve are: 1) the static head and 2) the friction head.

Static head is the vertical lift of the fluid that the pump has to overcome. It is assumed to be a constant head after the station is put into operation for a baseline of the system head curve. It is defined as the following:

Static Head = Highest elevation opened to the atmosphere* minus the system's low point**

*This will typically be the pipe outlet.

**All pumps off elevation (Suggestion: Use the average elevation between the "lead pump on" and "all pumps off". This will give the midpoint of the pump operation range.)

Static head will vary during the pump down of the wet well as noted above because it changes during the pumping cycle.

Force main friction losses can be based on the Hazen-Williams equation. Knowing the force main size, material and equivalent length, the system head curve can be determined.

In a given system, the friction head will vary with the flow rate, as defined by the following equation:

$$H_L = 10.4397 (L) \frac{(Q)^{1.85}}{(C)^{1.85} (d)^{4.8655}}$$

where, HL= Total friction head loss, feet of water

L=Length of equivalent pipe length of diameter di ft

C = Hazen-Williams flow coefficient (see Table 2) Q= Flow rate, gallons per minute (gpm)

d = Internal pipe diameter, inches (in)

The head loss through the system should be determined for each section of the system separately based on pipe material, pipe diameter, and amount of flow. If multiple pumps of the same size are to be operating at the same time, then the flow rate from the pump to the common force main is assumed to be equal to one divided by the number of pumps running.

A general rule of thumb is to generate the system head curve with approximately 10 points from 50 percent to 150 percent of the design flow. A separate system head curve is generally required to determine the total capacity of a multiple operating pump station. The system's head curve can then be plotted on the pump curve to determine the operating point of the pump.

Table 1 - Values of Hazen-Williams Coefficient C(1)	
Pipe Material	C
Asbestos-Cement	140
Brass	130
Brick Sewers	100
Cast Iron:	
New	130
5 Yrs. Old	120
10 Yrs. Old	100
Concrete (regardless of age)	130
Copper	130
Galvanized iron	120
Polyethylene	140
PVC	150
Riveted Steel, New	110
Vitrified Clay	110
Welded Steel, New	120
Wood Stave (regardless of age)	120

(1) Louisville and Jefferson County Metropolitan Sewer District (MSD) Design Manual, Table 5-2.

WET WELL SIZING

"Design of Wastewater and Storm water Pumping Stations" Water Pollution Control Federation, Manual of Practice No. FD-4, 1981, p. 18, indicates that the wet well shall be sized so that the cycle time for each pump will not be less than five minutes or that the average cycle time will not be more than 30 minutes. The shortest operating cycle occurs when the inflow equals to one-half the pump discharge rate. Therefore, if:

V = drawdown volume, gal

q = Pump discharge rate, gpm

Q = Inflow rate into the wet well, gpm

t = Minimum time of one pumping cycle in minutes, start to start $t = (\text{time to fill}) + (\text{run time})$

$$\text{then } t = \frac{V}{Q} + \frac{V}{q-Q}$$

When $Q = q/2$,

$$\text{then } t = \frac{V}{q/2} + \frac{V}{q-(q/2)}$$

which is reduced to the operating volume where

$$V = \frac{tq}{4}$$

With the operating volume, the vertical distance between the lead pump on and all pumps off floats can be determined for various wet well sizes. Between the operating volume and emergency storage requirement, the wet well size can be determined. Emergency storage volume will be dependent on the required response time and the average inflow.

After the size of the wet well has been determined, then the distance between the floats for lead pump on and all pumps off floats can be determined. This would be a function of wet well size and the operating volume requirement. The vertical distance between the common stop elevation and the bottom of the wet well is a function of the pump selected. The common stop elevation shall not be less than the top of the pump housing or as the manufacturer specifies, whichever is greater.

The distance between the lead, lag, and high water levels are generally a function of the local requirement. If mercury floats are utilized, then these should not be spaced less than six inches apart, with the high water alarm level being at or lower than the lowest incoming sewer line.

These settings will determine the depth of the wet well which will allow the buoyancy calculations to be completed. The buoyancy analysis on the wet well will determine whether additional methods of restraint will be necessary. Mechanical equipment, water weight, and other temporary loads should not be included in the analysis. The soil angle of repose should be assumed to be zero degrees, unless soil analysis determines that another value is warranted.

The buoyancy force equals the displaced volume of the wet well and bottom slab multiplied by the unit weight of water.

The opposing force is equal to the weight of the wet well, bottom slab, top slab, and the soil over the bottom slab extension, if applicable. The safety factor is equal to the opposing force divided by the buoyancy force. The safety factor should be > 1.5 .

FORCE MAIN PRESSURE AND WATER HAMMER CALCULATIONS

Water hammer is an increase in pressure in the pipe caused by a sudden change in the velocity. The velocity change usually results from the closing of a check valve. Most valves and fittings used in plumbing systems are designed for a normal maximum working pressure of 150 psi. Therefore, unless the shock pressures can be reduced to less than 250 psi., serious damage to the valves, fittings and other components of the piping system may occur. If the operating head of the system is greater than 35 feet, the check valves should be spring loaded, or lever and weight check valves used.

There are several design considerations that have not been covered, but are critical in some applications. They will be described briefly:

The following are several design considerations that have not been covered, but are critical in some applications.

- 1) Odor Control - Generally speaking, if the detention in either the wet well or force main based on the average flow is less than 30 minutes, then there should be very few problems.
- 2) Net Positive Suction Head (NPSH) - In small to medium submersible pump stations, if the pump housing is submerged and the wet well is vented to the atmosphere, there should be few problems. When there are high flows, cavitation could be a major consideration.

- 3) Air/Vacuum Valves - Depending upon the profile and size of the force main, air or vacuum pressure could be a major factor in the life cycle of the system. Air entrapment can cause an excessive head requirement that the pump cannot overcome. Large down grade profiles that open to the atmosphere can cause excessive negative head that could collapse the force main or over run the pump, causing it to overheat and burn out.
- 4) Safety - The design of a pumping station requires a review of the components of the system to assure that the system is safe to operate. The access ladder for the wet well and valve vault, a hoist for lifting out the pump, ventilation to remove dangerous gases and security for the electrical system are the major safety items that need to be considered in the design.
- 5) Wet Well Dead Zones - In all wet wells, there are areas that will allow solids to drop out of suspension. These areas need to be eliminated or a method provided to re-suspend the solids so that they are moved along.