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Introduction to Wastewater and Storm Water Pumping Stations

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A. INTRODUCTION

The design of a wastewater or storm water pumping station requires consideration of several issues. Site selection, deciding on the type of pumps to be used, undertaking the necessary hydraulics, picking the most efficient pumps from the pump curves and perhaps, the most important facet, understanding the equipment available from manufacturers and suppliers. This course, touches on a number of the design issues, however, an informed designer will always avail himself of the information and material available from manufactures. Be sure to obtain several balanced opinions. The last thing factory engineers and manufactures representatives want is a poorly working pumping station.

Many similarities exist between storm water pumping stations and wastewater pumping stations. For that reason, much of the material presented herein can be addressed to both. However, the bulk of the material is addressed to the wastewater station because it presents the most difficult design problems.

Location, arrangement, type of equipment and structure, and external appearance all are basic considerations in the design of any pumping station. Most important is the proper location of the station. This means that a comprehensive study must be made to assure that the entire area to be served can be drained adequately. Careful attention should be given to probable future growth because the location of the pumping station will in many cases determine the future overall development of the area. In selecting the site good aesthetic judgment must be exercised so that the station will not be detrimental to the neighborhood.

Studies of the topography downstream from a proposed station should be made to determine whether the station could be eliminated feasibly by tunneling through or by providing conduits around high ground to obtain gravity drainage. All pumping stations require operation and maintenance, the cost of which, when capitalized, usually will justify a considerable first-cost expenditure to build a gravity sewer. Wherever possible, storm water pumping stations should be located in areas where water may be impounded without creating an undue amount of flood damage if the inflow should exceed the station capacity. Also, the ability to impound a part of the storm water inflow will reduce the effect of peak runoff to the station and consequently the overall pumping capacity required for any given storm.

The depth of incoming sewers or drainage channels, and sometimes foundation conditions, will determine the depth of the station below ground level. Surface conditions, neighboring buildings, land use, and relative elevations with reference to flooding will determine the level of the operating floor, the type of superstructure, and exterior finish. All stations must be designed to withstand flotation.

Where stations are located in built-up areas, the superstructure should be similar to that of adjacent buildings or structures. Descriptions of such designs may be found in the literature. When the location is isolated the type of structure may be left to the owner and engineer but the probable nature of future development in the vicinity of the site should not be overlooked. Isolated stations should be protected against vandalism and preferably not have windows or as few as architectural considerations will allow.

Underground stations may be either factory assembled or built in place and should conform to good design principles as outlined in this chapter. Locations beneath city streets should be avoided.

Dependability of equipment and power is mandatory in most pumping stations because failure of either can cause considerable damage. The types of drive and controls for pumping equipment should, for this reason, be weighed carefully. Electric stations, to be reliable, should have at least two independent incoming power lines with automatic switching equipment to transfer the load from the preferred line. Where this reliability cannot be obtained, standby engine-driven generators, standby engine driven pumping units, or all engine-driven pumping units may be required.

Careful attention should be given to the control of odors in the design of sewage pumping stations, especially when stations are located within 1,000 ft (300 m) of human habitation. However, if stale sewage is being handled, it is sometimes impossible to prevent odors emanating from the station unless the ventilating air is specially treated.

Two differentiating terms which apply to both sewage and storm water pumping stations have, by common usage, come to have certain general meanings: *(a)* lift (re-lift) station, in which the pumped liquid is released to atmospheric pressure a relatively short distance from the facility into a gravity sewer, open channel, or receiving body; and *(b)* pumping station, in which the liquid is pumped from the facility some distance, occasionally miles, in a pressure pipe. The term lift station is applied only in the first case while pumping station is applicable to both unless the two are being compared.

B. STATION CAPACITY

If the area is not developed fully, the designer will be obliged to establish an initial station capacity, which probably will meet the requirements for a reasonable time, customarily a period of not less than 10 yr. The initial flows under these conditions may not be as great as allowed in the design. The effects of the minimum flow conditions must be estimated to be sure that retention of the sewage in the wet well will not create a nuisance and that pumping equipment will not operate too infrequently. Allowances must be made for future requirements so that additional or larger pumps can be installed as required.

Obviously, station capacity must be adequate to meet the maximum rate of flow. It also is mandatory that this capacity must not exceed the capacity of receiving conduits or sewers. This sometimes is overlooked because it is assumed that the pumps will operate intermittently and that there will be no downstream difficulties.

Probable minimum inflows to the station also must be taken into account because such flows will affect the design of screen flow-through channels and the size of the wet well. Average flow conditions are of interest in that they indicate the conditions under which the station usually will operate. To obtain the least operating expense, pumping equipment should be selected to perform at maximum efficiencies under average conditions.

C. WET·WELL DESIGN

Storage capacity usually is required for all wastewater and storm water pumping stations where automatic controls and variable speed drives are not furnished to match pumping rates exactly with inflow rates. The selection of proper storage capacity is critical because it affects the time, which the liquid will be retained in the station and the frequency of operation of the pumping equipment. The storage effect of incoming sewers and channels and storm water overflows in low-lying areas all may be considered as part of the total station storage capacity, but usually is considered only in that portion of the capacity study relating to maximum flow conditions.

From a mechanical standpoint it is desirable to operate a pump for long periods if not continuously, but such performance is not compatible with the maintenance of aerobic conditions in the sewage when it results in long retention periods.

The shape of the wet well and the detention provided for sewage pumping stations should be such that deposition of solids is minimized and the sewage does not become septic.

Most design policies base detention on the average design rate of flow, but the maximum and minimum rates are the determining factors in sizing the wet well. The desired results can be attained with a minimum of objections except for large-capacity stations if the size of the wet well is such that with any combination of inflow and pumping, the cycle of operation for each pump will be not less than 5 minutes and the maximum retention time in the wet well will not average more than 30 min. Where large pumping units are involved, they should be operated continuously insofar as practical. It can be seen readily that to meet these requirements the design of the wet well must be coordinated with the selection of both the individual pumping units and the liquid levels at which the pumps are started and stopped.

It should be kept in mind that the longer the detention period, the greater the chance for the generation of objectionable odors from septic sewage and the accumulation of sludge in the bottom of the wet well, which in turn may increase the nuisance from odors and the frequency of pump stoppages. Accordingly, detention periods should be kept to the minimum compatible with proper operation of the pumping equipment.

The pump operates under suction lift conditions during drawdown to its cutoff level, a normal capability of the non-clog sewage pump of the radial-flow type. This practice requires that a means of automatically re-priming each pump after each drawdown be provided, for example, by an open venting line from the pump discharge nozzle discharging to the wet well. Such venting lines should use a minimum of bends, pass through the wet-well wall at a high level, be constructed of corrosion resistant tubing, and be of appropriate size to reduce clogging, but not less than 3/4 inch in diameter. Proof of pump output may be interlocked electrically with motor controls by means of a time delayed pressure switch on the unit discharge, or by a limit switch on the exterior arm of the check valve. Similarly, an air bound unit may be shut down by a temperature switch mounted on the pump case. It generally is accepted that the pump control levels in the wet well should be such that the incoming sewers to the station will not be surcharged and that velocities will be maintained which will prevent deposition of solids and, thus, the formation of sulfide-producing slimes.

Probably the most controversial point in the design of sewage wet wells is the bottom slope needed to minimize deposition of solids. A relatively large number of state regulatory agencies call for a minimum bottom slope of 1 to 1 to the pump inlet. Designs occasionally are encountered where the slope is less; and some are steeper. States requiring a minimum slope of 1 to 1 to the pump inlet also require a minimum slope of 1 horizontal to 1.4 vertical at the bottom of Imhoff tank flow-through compartments. Considerable deposition and accumulation of solids have been encountered in Imhoff tank flow-through chambers having slopes of 1 horizontal to 1.5 vertical or flatter. A minimum accumulation of solids occurs where the slope is 1 horizontal to 1.75 vertical or greater, indicating that hoppers in wet wells should be constructed with slopes not flatter than 1 horizontal to 1.75 vertical.

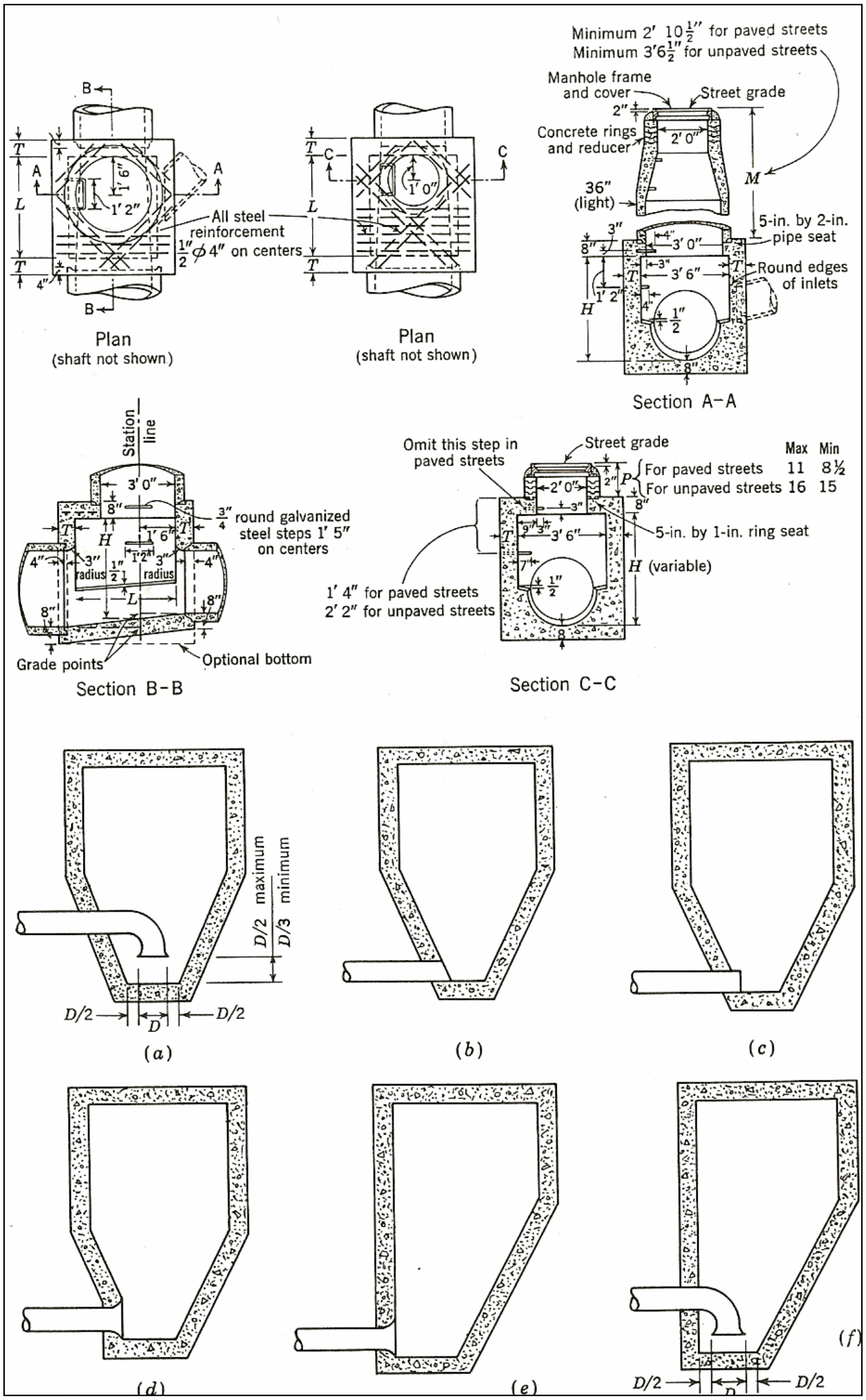


FIGURE 1

A number of pump suction pipe arrangements in sewage wet wells are shown below. Bellmouth inlets are far superior to the straight inlets. Both are shown in Figure 1. Flaring eliminates the sharp edges on which material may accumulate and also minimizes head loss. The inlets, Figure 1 *a* and *f,* are considered superior to any of the other arrangements illustrated since there is less possibility of vortices forming in the wet well.

Where turned-down bellmouth inlets are used, the bell should be not more than *D* /2 and not less than *D* /3 (in which *D* is the diameter of the suction pipe) above the floor of the wet well in order to obtain scouring inlet velocities and still obtain nearly optimum hydraulic entrance conditions.

The spacing between suction inlets in the wet well should be such that both hydraulic interference and deposition of solids between inlets are prevented insofar as possible. A spacing not more than two times the suction pipe diameter is required to prevent deposition of solids between suction inlets. However, this requirement cannot be satisfied, as a spacing of approximately four times the diameter of the suction inlets is required to prevent hydraulic interference.

The design of wet wells for storm water pumping stations requires careful study where vertical axial-flow or diffusion-vane pumps are installed, taking suction directly from the wet well. These pumps are very sensitive to inflow arrangements, spacing between the units, and clearances from the bottom and sidewalls. The recommended clearances for installation are shown in Figure 2, although variations sometimes are acceptable. The advice of pump manufacturers should be considered in the design and layout of wet wells. For large installations or unusual conditions, model tests may be advisable.

FIGURE 2

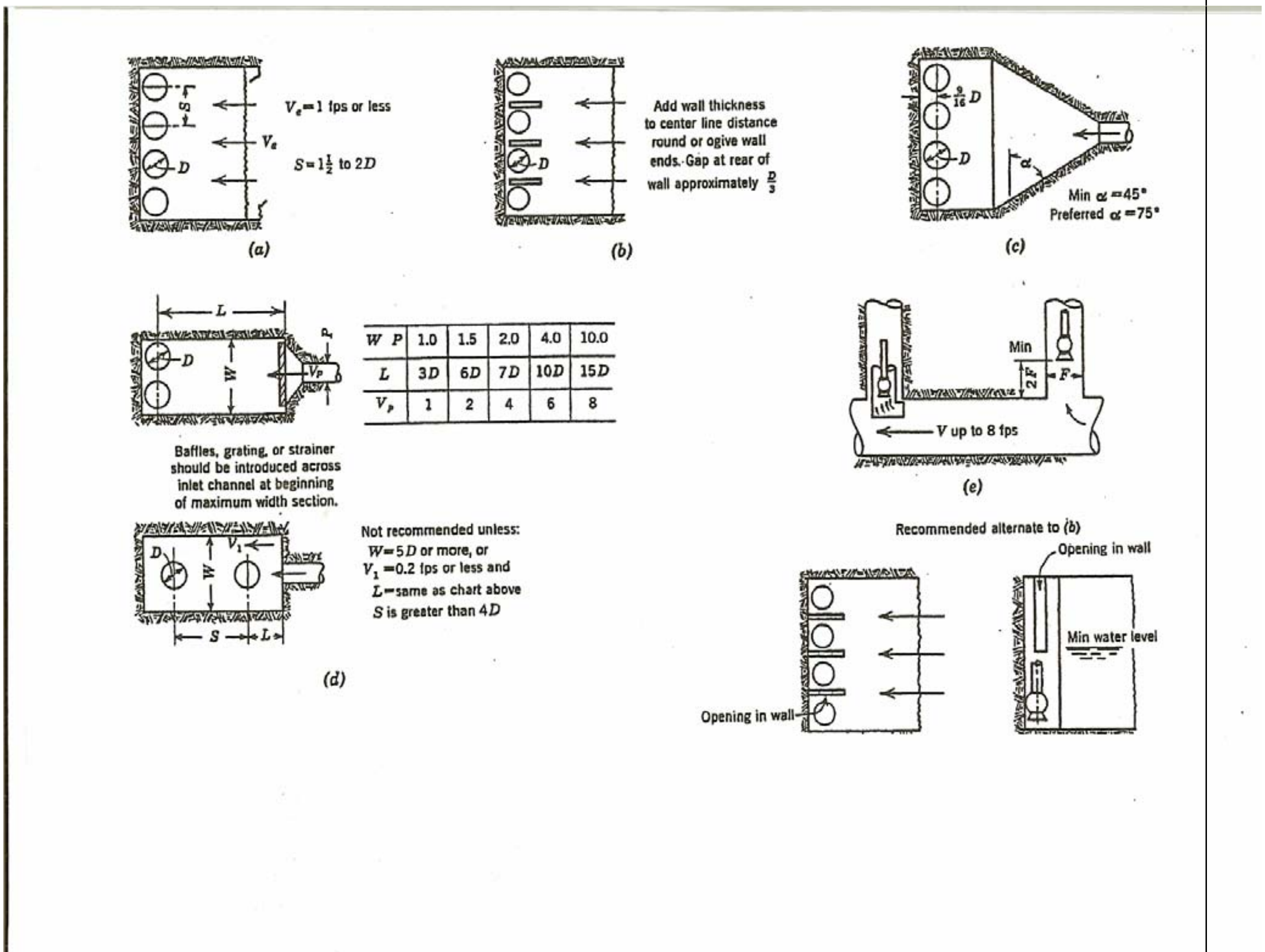


Figure 2

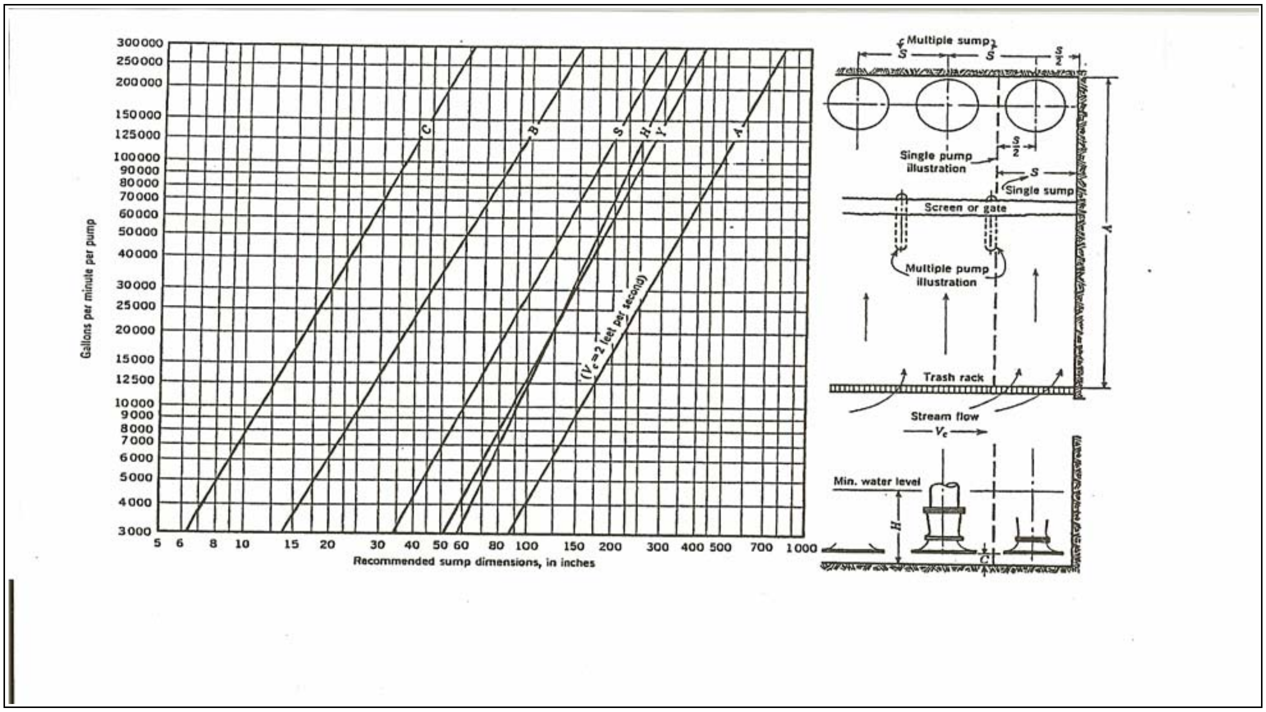


FIGURE 3

Provision should be made for adequate access to wet wells for inspection and cleaning. Stairways and walkway platforms should be furnished in the larger stations. Proper lighting and ventilating facilities also should be available whenever the wet well is entered for any reason. Suitable access openings and facilities are needed for the removal of accumulated solid matter. This material may be in the form of sand, gravel, or other trash in pumping stations serving storm or combined sewers, and in many cases, sanitary sewers. In the case of sanitary sewage, there may be a collection of grease balls or scum on the water surface and grease accumulations on the wet-well walls. Thus, provisions generally are required manual skimming.

Where wet wells are totally enclosed, adequate vents are needed to allow for entrance and exit of air as the liquid level in the sump rises and falls. Rooms located directly over wet wells, and having atmospheres common thereto, should be isolated from the rest of the station and be ventilated continuously by blowing air into them to provide a pressure slightly above atmospheric.

Bar screens are usually made of iron or steel bars. The space between the individual bars varies: clear space of 1-1/2 inch is customary for manual cleaned screens, and a 1-inch spacing for the mechanical type. Bar screens with relatively wide clearances are used for large pumping installations, depending on the ability of the pumps to pass solids.

At least 6 inch should be allowed in the hydraulics of a station for loss through the bar screen, and a greater loss should be allowed where manually cleaned screens are used, especially where they will receive relatively little attention. The floor of the screen channel should be placed at least 6 inches below the invert of the incoming sewers to allow for some accumulation of screenings without affecting the flow in the sewers.

Screenings should be disposed of by burying, burning, or shredding. In the last case, the screenings may be returned to the wet well. The handling and disposal of screenings are important design features. Moreover, inadequacies in this phase of pump station operation will create a nuisance.

(a) Manually Cleaned Bar Screens -Manually cleaned screens are usually of the basket or bar rack type. Basket screens are applicable only to smaller pumping stations and generally are in the form of a box with one open side facing the incoming sewer. Facilities are provided for hoisting the basket to the surface where the screenings may be removed.

Manually cleaned bar screens are placed in the entrance channel at angles varying between 30 and 45 degrees from the horizontal. Because of the difficulty of cleaning by hand, manually cleaned bar screens are applicable only to channels of relatively shallow depths. Fabrication of the rack should be such that except for the toe all cross bracing is attached only to the rear edge of the bars. This provides an uninterrupted path for the rags, which tend to slide up the bars in the form of a wad when raked.

Adequate headroom is required to manipulate a hand rake of suitable length. A depressed pocket and drain should be provided in the operating floor adjacent to the top of the screen. Wet-well lighting should include at least one fixture located to illuminate directly the face of the screen.

Where appreciable quantities of screenings are to be removed, for example, immediately upstream of wastewater treatment processes, the bar screen should be sized so that the velocity through the clear openings will not exceed 2.5 fps under all flow conditions. However, low velocities can have a detrimental effect in that rags tend to drift into the rack, rapidly blanketing the screen, and causing an undesirable surcharge in the influent sewer. Thus, where maximum screening efficiency is not the objective, higher velocities may be preferred in that they tend to reduce this blanketing effect by causing a single rag either to pass through or to stream out over a single bar. This method of operation provides the desired pump protection from oversized objects while at the same time maintains proper velocities in the sewer. The higher velocities are achieved by depressing the screen channel minimum of 6 inches below the sewer invert, depressing the channel several inches again immediately downs below the toe of the screen.

(b) Mechanically Cleaned Bar Screens -Mechanically cleaned bar screens are basically either front- or rear-cleaned, with the bars making an angle with the horizontal varying from 60 to 90 degrees. Mechanical cleaning is accomplished by traversing the bar screen with a rake, although some manufacturers offer a rotary comb which not only traverses the bar screen but also shreds the screenings. The rake is moved either by means of endless chains or by cables, which lower it to the bottom of the channel and then pull it vertically along the bars.

The front-cleaned type can be placed in a channel of almost unlimited depth. But since the cleaning mechanism is on the upstream side of the bars, objects may wedge between the cleaning mechanism and the bottom of the channel so that the machine is disabled. This disadvantage is overcome in the back-cleaned unit where all the cleaning mechanism is behind the bars. Cleaning is done by the teeth of the rake which project through the bar screen to the extent that they engage the screenings and elevate them to the surface. The back-cleaned bar screen does have one disadvantage; it can be installed only in channels with limited depths of flow because the individual bars in the screen must be supported from the bottom of the channel.

Close attention should be given to the resulting hydraulic effects of mechanically cleaned screens. Some equipment includes a gravel guard to protect the foot shaft assembly, which causes a damming effect of up to 12 inch in depth. Similarly, some equipment requires a controlling weir downstream to insure a minimum water level for submergence of the water-lubricated foot shaft and sprocket bearings. These factors, together with head loss through the screen, must be considered in designing the channel to avoid undesirable surcharges upstream. Consideration of minimum velocities is important to prevent deposition of debris, which would jam the mechanism, particularly during storm runoff when the screen is most needed.

In cold climates screens must be housed in heated spaces to keep solids from freezing to the rakes during off periods. In storm sewer systems and large combined systems, it is customary to protect mechanical screens with coarse trash racks having openings of 3 to 6 inches. Their purpose is to prevent logs, timbers, or other large objects from jamming and damaging the mechanism.

Where mechanically cleaned screens or comminutors are installed it is customary to provide at least two channels, both of which may be equipped with mechanical equipment. If only one channel is so equipped, a manually cleaned bar rack or basket screen usually is placed in the auxiliary channel. In any case, both should be provided with means for isolation, such as sluice gates, slide gates, stop plates, or wooden stop logs.

2. Comminutors

A comminutors is essentially a circular bar screen placed in the incoming channel which is traversed by a rotary rake that serves as a cutter to engage and shred the accumulated debris. Thus, screening and shredding are accomplished in one operation. Shredded solids are returned to the sewage flow, eliminating equipment and labor for separate handling, shredding, and disposal. Slot width of the screen usually varies from 1/4 to 3/8 inch. The life of the equipment can be extended if grit removal precedes it.

3. Water Supply

A water supply isolated by an air gap or other suitable means should be provided, if possible, at all screening installations in order to maintain cleanliness. Shredders for screenings require a water supply.

E. PUMPING EQUIPMENT

I. Types in General Use

Pumping equipment used in sewage and storm water stations may be classified into two general types: centrifugal pumps and pneumatic ejectors. The latter are used only in the small installations where centrifugal pumps, if used, would be too large for the application.

2. Centrifugal Pumps

Centrifugal pumps fall into three general classifications:

(a) Axial-flow or propeller pumps;
(b) Mixed-flow or angle-flow pumps; and
(c) Radial-flow pumps (commonly referred to as centrifugal pumps).

The classification into which a pump falls usually can be determined by its specific speed (Ns) at the point of maximum efficiency. The specific speed of an impeller may be defined as the speed, in revolutions per minute (rpm), at which a geometrically similar impeller would run if it were of such size as to deliver 1 gpm against 1 feet of head. The formula for specific speed is as follows:

$$N = \frac{rpm \sqrt{gpm}}{H3/4}$$

in which H is in feet.

(a) Axial-Flow Pumps -Axial-flow or propeller pumps develop most of their head by the propelling, or lifting, action of the impeller vanes on the liquid. They are characterized by a single inlet impeller with the flow entering axially and discharging nearly axially into a guide case and are customarily used for large, low-head installations in capacities greater than 10,000 gpm and for heads below 30 feet. This type of pump was developed primarily for flood control and irrigation work and is adapted particularly to storm water pumping installations where the head-capacity relationship is within their range of this type of unit. The pumps are generally of the vertical wet-pit type, although they can be obtained for horizontal dry pit installation.

Axial-flow pumps have relatively high specific speeds, usually ranging between 8,000 and 16,000 rpm. It is desirable that vertical units have positive submergence of the impeller for proper operation. Units can be obtained that will operate with a suction lift.

(b) Mixed-Flow Pumps - The head is developed by mixed-flow pumps partly by centrifugal force and partly by the lift of the impeller vanes on the liquid. This type of pump has a single inlet impeller with the flow entering axially and discharging in an axial and radial direction, usually into a volute-type casing. These units are applicable for medium-head applications of 25 to 50 feet and for medium to large capacities. Mixed-flow pumps fall into a medium range of specific speeds, usually between 4,200 and 9,000 rpm. They generally require positive submergence, although, with proper selection of rotative speeds, they may be used for limited suction-lift applications.

(c) Radial-Flow or Centrifugal Pumps -The head in radial-flow pumps is developed principally by the action of centrifugal force. Pumps of this type may be obtained with either single suction or double suction inlet impellers; the flow leaves the impeller radially and normal to the shaft axis. The majority of all pumps installed are of this type, and they may be obtained in almost any range of head and capacity. Centrifugal pumps are characterized by relatively low specific speeds, usually below 4,200 rpm for single inlet impellers and below 6,000 rpm for double suction units. Single suction pumps normally are used for sewage or storm water pumping since they are less subject to clogging.

(d) Relative Characteristics -A comparison of the characteristics of the axial-flow, mixed-flow, and centrifugal pumps is shown in Table 1.

(e) Impeller Types -Impellers for centrifugal pumps may be classified into three general types:

1. Enclosed (front and back shroud)
2. Open (no shrouds)
3. Semi-enclosed (back shroud)

Enclosed impellers with shrouds generally are specified for pumps, which are to handle sanitary sewage. Not only are they less subject to clogging but they also pass stringy materials better than other types.

Open or semi-enclosed impellers sometimes are used in storm water pumps, especially for handling large volumes and for intermittent service.

(f) Casings -Two types of pump casings are common: the volute and the turbine or diffusion type. The primary difference is that with the volute case the velocity leaving the impeller is transformed to head by gradually increasing the area of the water passageway in a spiral-shaped scroll; whereas in the diffusion-vane case the velocity leaving the impeller is transformed to head by means of curved vanes. Dry-pit pumps generally are furnished with volute cases. Vertical wet-pit pumps used for storm water pumping are usually of the turbine or diffusion-vane type.

Description	Axial Flow	Mixed Flow	Radial Flow
Usual capacity range	10,000 gpm	5,000 gpm	Any *
Head range	0 to 30 ft	25 to 50 ft	Any *
Shutoff head above rated head †	About 200 percent	165 percent	120 to 140 percent
Horsepower characteristic	Decreases with capacity	Flat	Increases with capacity
Suction lift	Usually requires submergence ‡	Usually requires submergence	Usually not over 15 ft
Specific speed	8,000 to 16,000	4,200 to 9,000	Below 4,200—single suction; below 6,000—double suction
Service	Used where space and cost are considerations and load factor is low	Used where load factor is high and where trash and other solid material are encountered	Used where load factor is high and high efficiency and ease of maintenance are desired.

* Heads of radial-flow sewage pumps may be limited.
† Maximum efficiency point.
‡ Lift limited.
Note: gpm × 0.0631 = l/sec; ft × 0.3048 = m.

Table 1 - Characteristics of centrifugal pumps

Either type of casing may be split axially or radially to obtain access to the impeller for cleaning.

(g) Pump Construction -Most pump casings are made of cast iron. Although for special applications where gritty or corrosive liquids are handled, other materials sometimes are specified. Pumps used for handling sanitary sewage usually are specified with cast iron impellers; most manufacturers furnish trash pumps with this construction as standard.

Sleeves should be provided on shafting through stuffing boxes and preferably should be of chromium steel or other abrasion-resistant material. Where possible, clear water flushing should be provided for pump stuffing boxes. If this is not possible, provision should be made to apply grease under pressure to the stuffing box at all times when the pump is in operation. Mechanical seals have become quite popular with some engineers in recent years. Where they are used, a cooling and lubricating liquid must be applied to the seal. Brief operation without the lubricant can cause immediate damage. Where mechanical seals are used, spare seals should be kept available, since they cannot be repaired after they fail. Pump bearings may be either the anti-friction or sleeve type. Although advocates of each point out their relative merits, proper application of either type should result in successful operation.

(h) Non-Clog Pumps -Actually, no pump has been developed that cannot clog. Experience shows that rope, long stringy rags, sticks, cans, rubber goods, and grease are objects most conducive to clogging. For pumps smaller than 10 inches in size, which handle sanitary sewage, non-clog units are used almost exclusively. Pumps smaller than 4 inches in size are not recommended for this kind of service. Non-clog pumps differ from conventional units in arrangement, size, smoothness, and contour of channels and impellers to permit passage of clogging material. If efficiency is not the prime concern, passages are sometimes only one size smaller than the discharge pipe. Where coarse screening or comminution is done, the passages may be limited to approximately 1 inch greater than the clear openings between bars in the screen but not less than 2 ½ inches. The pump casing is a simple volute with a so-called end suction inlet to the impeller eye. The conventional non-clog impeller contains two blades and is fastened securely with a minimum overhang on a heavy shaft with at least one radial and one radial-thrust bearing. The radial bearing is placed as close to the stuffing box as is feasible, within a heavy supporting frame. Impeller blades should have smooth easy curves designed to prevent solids from agglomerating around the shaft between the impeller and back head or casing.

The leading edges of the impeller blades are rounded generously so that rags tend to slide off. Impeller wearing rings seldom are specified for pumps smaller than 10 inches. Both case and impeller rings can be obtained for larger pumps where it is desired to maintain both axial and radial clearances. Most sewage pumps include a feature to allow field adjustment of the pump shaft to restore impeller end clearance without disassembly of the pump.

3. Pneumatic Ejectors

Pneumatic ejectors are used largely for lifting sewage from the basements of buildings and in small lift stations where their advantages outweigh their low efficiency, which is limited to about 15 percent. Their advantages are: (a) sewage is completely enclosed and consequently no sewer gases can escape except through the vent; (b) operation is fully automatic and the ejector goes into service only when needed; (c) the relatively few moving parts in contact with sewage require little attention or lubrication; and (d) ejectors are not clogged easily.

A pneumatic ejector consists essentially of a closed tank into which sewage flows by gravity until it reaches a certain depth. Then enough air under pressure is admitted into the tank to discharge the liquid. The inlet pipe check valve prevents sewage from leaving the tank except through the outlet pipe check valve, which also prevents backflow into the tank. Ejectors and compressors should be installed in duplicate to assure that service will not be interrupted either for reason of mechanical failure or lack of regular maintenance.

The following is an empirical formula for the approximate capacity of air required to operate an ejector:

$$V = \frac{Q\,(H+34)}{250}$$

in which V is the volume of free air required in cfm, H is the total head in feet, and Q is the rate of sewage discharged in gpm.

To allow for expansion of air in the storage tank as the sewage is displaced, the volume of the air storage tank and the characteristics of the air compressors selected should be adequate to provide the proper volume of air at a pressure at least 40% higher than that required to raise all sewage the maximum compute lift.

4. Pump Selection

The number of pumps to be installed in the station will depend largely on the station capacity and range of flow. It is customary to provide a total pumping capacity of at equal to the maximum expected inflow with at least one of the largest units out of service. Two units sometimes are considered our of service in large stations in determining firm capacity. At least two pumps should be installed in any station.

In small stations two pumps are installed, normally with each unit having sufficient capacity to meet the maximum inflow rate. The size and number of units for large stations should be selected so that the range of inflow can be met without starting and stopping pumps too frequently and without requiring excessive wet-well storage capacity. Variable-speed drive are provided in many cases to match the pumping rate with inflow rate. Pumping station in close proximity to treatment works should be designed with consideration for the adverse effects of sudden or wide-ranging variations of flow.

Before describing procedures for selecting pumping equipment it is appropriate to define various standard terms used to describe pump characteristics. The definitions, which follow, are given in the Standards of Hydraulic Institute.

a) Datum: All reading for suctions lift, suction head, total discharge head, and net positive suction head are taken with reference to the datum which, in the case of horizontal shaft pumps, is the elevation of the pump center line and in the case of vertical shaft pumps is the elevation of the entrance eye of the suction impeller.

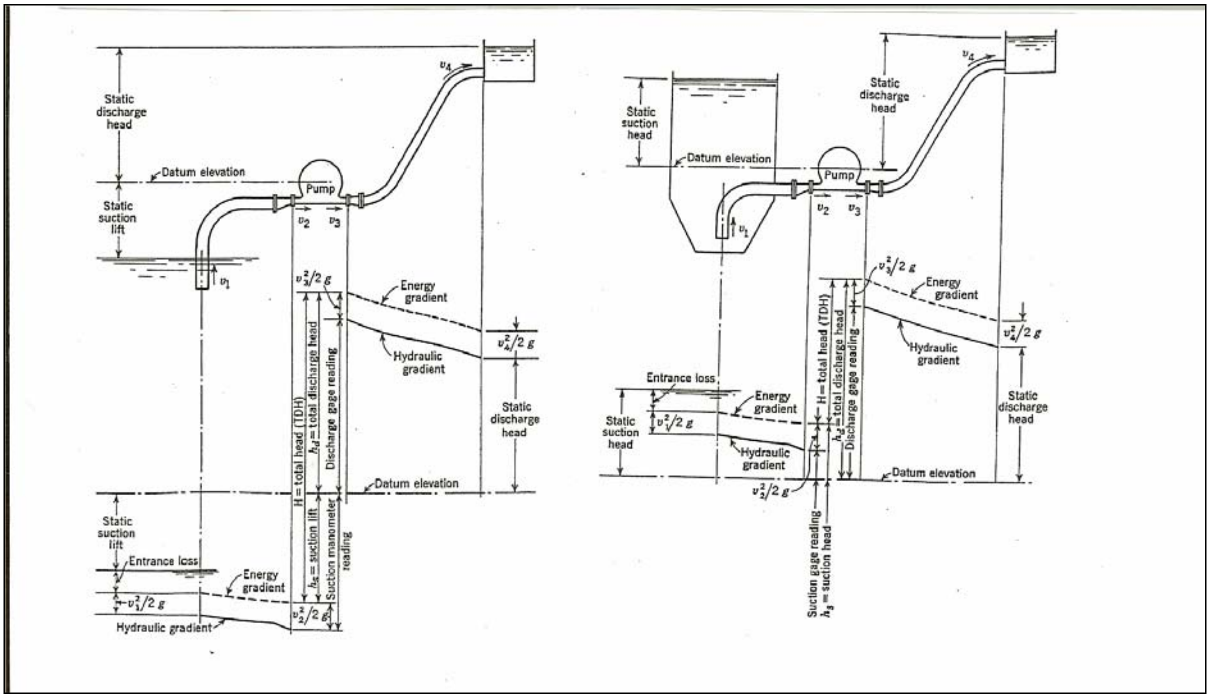
b) Suction Lift: Suction lift exists where the total suction head is below atmospheric pressure. Total suction lift, as determined on test, is the reading of a liquid manometer at the suction nozzle of the pump converted to feet of liquid and referred to datum, minus the velocity head at the point of gage attachment.

c) Suction Head: Suction head exists when the total suction head is above atmospheric pressure.
    a. As determine on test, it is the reading of the gage at the suction of the pump converted to feet of
    b. Liquid and referred to datum, plus the velocity head at the point of gage attachment.

d) Total Discharge Head: Total discharge head is the reading of a pressure gage at the discharge of the pump, converted to feet of liquid and referred to datum, plus the velocity head at the point of gage attachment.

e) Total Head: Sometimes referred to as Total dynamic head or TDH. Total head is the measure of the energy increase per pound of liquid imparted to it by the pump and is therefore the algebraic difference between the total discharge head and the total suction head. Total head as determined on test where suction lift exists, is the sum of the total discharge head and total suction lift, and where positive suction head exists, the total head is the total discharge head minus the total suction head.

f) Net Positive Suction Head (NPSH) – The net positive suction head is the total suction head, in feet of liquid absolute, determined at the suction nozzle and referred to datum, less the vapor pressure of the liquid, in feet absolute. Graphic representations of pump-head relationships are shown in the Figure 4 below.



Pump-head relationships with suction lift. Pump-head relationships with suction lift.

FIGURE 4

Pumps should be selected having head-capacity characteristics, which correspond as nearly as possible to the overall station requirements. This can be accomplished by the preparation of a system curve showing all conditions of the head and capacity under which the pumps will be required to operate. The head-capacity curve is developed using standard hydraulic methods for determining friction losses. Several available methods for calculation pipe friction losses are described in most standard hydraulic textbooks. Friction losses in straight piping usually are calculated using the Hazen-Williams formula. They also may be estimated by extracting loss of head values directly from tables. Losses of head in valves and fittings (excepting increasers) may be approximated using the following formula:

$$Hl = (K)\ \frac{V}{2g}$$

in which Hl is the head loss in ft; V is the velocity in the fitting in fps; g is acceleration due to gravity; and K is the resistance coefficient from Table 2, or from appropriate manufacturer's tables.

Loss of head due to increasers may be computed using the following relationship:

$$Hl=(K)\ \frac{{V1\ -\ V2}^{2}}{2g}$$

in which Hl is the head loss in ft; and K is the resistance coefficient from Table 2.

These coefficients represent average losses in fittings and valves 4 inch in diameter and larger. Where headloss in fittings represents a major part of the total system loss, especially in rating pumps, an analysis should be made to determine the minimum and maximum possible using more accurate methods.

Table 2

Fitting	K
Standard elbow	0.30
Long radius elbow	0.20
45-deg elbow	0.20
90-deg bends in flumes	1.50
Tees:	
Straight through	0.20
Branch to line	0.50
Line to branch	0.80
Entrance	
Inward projecting	0.78
Sharp cornered	0.50
Bellmouth	0.04
Gate valves	0.20
Check valves:	
Swing	2.50
Tilting disk	0.34
Butterfly valve	0.30

In such cases a hydraulics handbook and manufacturers' data on losses through valves should be consulted.

The procedure outlined above for estimating loss of head in valves and fittings may be described as the "resistance coefficient" method. Another procedure known as the "equivalent length" method may be sufficient where loss through fittings is a relatively small component of total dynamic head. There are available in hydraulics texts and manufacturers' literature for the various types and sizes of valves and fittings, an equivalent length in ft (or in pipe diameters) of pipe of the type normally used with the particular valve or fitting. The equivalent lengths so determined are added to the actual pipeline length and losses through them determined concurrently as a part of the overall system loss.

In the design of long force mains, it is difficult to predict accurately the changes in total friction loss that may occur over an extended period of time. It has been reported from some localities that friction losses in sanitary sewage force mains do not increase substantially with time, regardless of the type of pipe material used. Where this is observed as a normal local condition, the designer frequently uses a Hazen-Williams C of 130 or 140. In areas where the friction loss is known to increase with time, it is customary to use the more conservative Hazen-Williams C of 100. These considerations will affect materially the designer's selection of pumps and pipe sizes, as well as the capacity of the pumping units and their successful operation. System curves, for this reason, should be developed to show the possible maximum and minimum friction losses to be expected in the pipeline during the lifetime of the pumping units.

When a system head study is being considered in which two or more pumps will discharge into a common discharge header and pressure main, it is normal practice to construct a system head curve on which may be superimposed the head-characteristic curves of some specific pumps being considered. The system head curve is constructed, for the full range of desired station capacity, by plotting against pumping rate the sum of the static head and the hydraulic losses in the system for the given pumping rate. Since the wet-well levels fluctuate considerably, it is usual to plot two system head curves, one for minimum level in sump (maximum static head) and one for the maximum level (minimum static head). Further, additional system head curves may be plotted using different friction factors. Only the losses in that part of the system common to all pumps normally are included in the system head curve computation. This provides a modified system curve reflecting performance at the station header (including static head) but temporarily excluding the variable of losses in individual pump suction and discharge piping, which losses depend solely on the flow rate through the individual pump.

The individual pump curves next are superimposed on the system curve. However, the losses in individual pump piping previously deleted from the system curve now are considered. They are computed for each pump from the suction inlet to the station header, for varying pumping rates, and subtracted from the pump characteristic curve. The resulting data are plotted as a modified pump curve. Combined modified pump curves then plotted by adding the capacities (from the individual modified pump) for points of equal head to determine the output capacity of multiple pump operation in parallel.

The Figure 6 below shows a typical set of system curves together with representative individual pump characteristic curves, modified pump curves, and combined modified pump curves showing multiple pump operation in parallel. The intersection of the modified pump curves and the combined modified pump curves with the system head capacity curves shows the station pumping capacity for the several conditions of operation. The figure below shows four system curves, two for a Hazen-Williams C of 100 and two for C of 140 for maximum and minimum water levels in the sump. These coefficients usually can be considered as the maximum and minimum, which will obtain in sewage force mains.

It is good practice to select pumps, which will deliver the station capacity at the maximum head. However, this capacity and head will not necessarily be the point of maximum pump efficiency. Pumps should be selected with maximum efficiency at average operating conditions. In the Figure below, assuming that the total station capacity is to be obtained by operating Pumps 1, 2, and 3 in parallel, the total head required at the station discharge header would be approximately 51 ft (15.5 m), with maximum sump level and C = 100 in the discharge line.

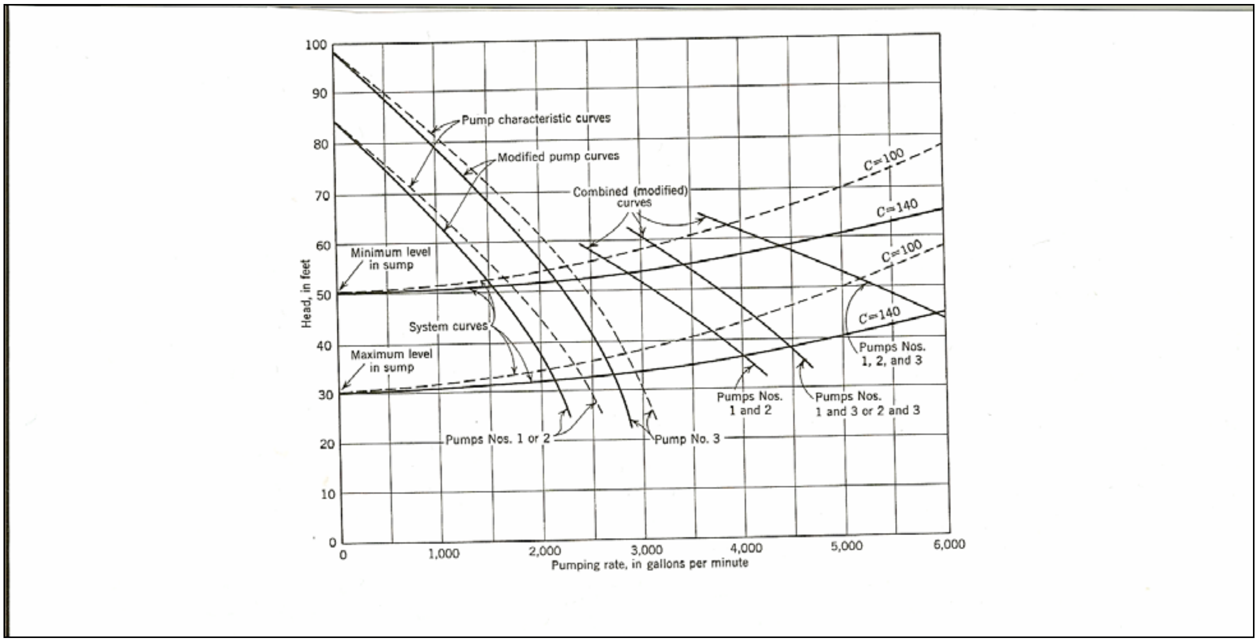


FIGURE 6

If this point is projected horizontally to the individual modified pump curves and thence vertically to the pump characteristic curves, the required head for Pumps 1 and 2 would be 54 feet, and for Pump 3, approximately 57 feet. The difference between the head required at the station header and the head required for each pump is the head loss in the suction and discharge piping to each individual pump and is portrayed graphically as the vertical distance between the pump characteristic curve and the modified pump curve. The minimum head at which each individual pump will operate also is indicated above.

From the intersection of the modified pump curve and the system head curve for maximum sump level and 0=140, a vertical projection to the pump characteristic curve shows the minimum head in the case of Pumps 1 and 2 is approximately 39 feet. For Pump 3 it is approximately 42 feet. These minimum heads are important and should be furnished to the pump manufacturer since they usually will determine the maximum brake horsepower required to drive the pump and the maximum speed at which the pump may operate without cavitation.

The relatively large passageways of the non-clog impellers somewhat limit the practical heads against which they can operate. For this reason, the series operation of two standard sewage pumps occasionally has been employed to meet the requirements of some installations having higher than normal heads. The designer should examine closely, with the manufacturer, all factors relating to such installations, including the ability of the pump cases to handle the interior pressures. The performance of the series operation may be approximated by plotting the sum of the heads of the individual pumps for points of equal capacity.

It must be remembered that the capacity of a centrifugal pump is a variable, which depends on the total head at which the unit operates. When a pump is referred to as having a certain capacity, this capacity applies only to one point on the characteristic curve and will vary depending on the actual head conditions.

Pump sizes usually are designated by the size of the pump discharge nozzle. The size of a pump for a given set of performance characteristics will vary with individual manufacturers. There has been a tendency in some cases to decrease the size of the suction' and discharge nozzles to the extent that excessive nozzle velocities are obtained. It is, therefore, reasonable in purchasing pumps to specify the minimum size of suction and discharge nozzle, which will be considered. For smaller installations it is recommended that no sewage pump be installed less than 4 inches size or unable to pass a 2-1/2 inches sphere. It has been found that excessive clogging occurs in pumps smaller than 4 inches when handling sewage. This means that a pump having a greater capacity than actually is required will sometimes be installed; satisfactory operation is more important than matching actual station requirements. Pneumatic ejectors are probably the best solution for installations where flows are such that a 4-inch pump would be too large.

The maximum speed at which a pump should operate is determined by the net positive suction head available at the pump, the quantity of liquid being pumped, and the total head. The limiting suction requirements for pumping units are shown in Figure 7. When specifying pumps, especially those that are to operate with a suction lift, the speed at which the pumps will operate should be checked against these charts, which are based on sea level conditions and a temperature of the liquid of 85 degrees F. Conditions different from these must be taken into account when selecting the proper speed. For a given pump, damaging cavitation will occur if it is installed where the permissible maximum suction lift (or minimum suction head) determined from Figure 7 is exceeded. For a given head and capacity, a pump of low specific speed will operate safely with a greater suction lift than one of higher specific speed.

It generally is not good practice to operate sewage or storm water pumping units at speeds over 1,800 rpm. Although sewage pumps are operated between the general limits of 200 rpm, for large capacity low-head units, and 1,800 rpm, for small capacity high-head units, there is a tendency among some engineers and owners to keep operating speeds as low as practical. This tends to increase considerably the life span of the unit.

The general trend for storm water pumping units, especially in the larger sizes, has been toward the vertical diffusion-vane type since the pumps require a minimum of space and in the larger sizes are considerably more economical. Close coupled, submerged pumping units are used in many cases for pumping storm water from small drainage areas, such as highways or railroad underpasses and where it is desirable to keep pumping stations below ground level.

Sewage or volute-type pumps for storm water pumping are available in both horizontal and vertical units. Most installations now being built use vertical pumps since they require less space. And, where the pump pit may be flooded, the pump drives can be mounted high enough to keep them out of the water. The determination of whether or not to use vertical or horizontal units must be governed by the individual conditions as no general rule can be established. Horizontal units are basically more stable than close-coupled vertical units, since the motors for the former are mounted separately from the pumps. Extended shafting for vertical units presents problems of alignment and maintenance, especially in large installations, and must be weighed against the disadvantage of horizontal units with the drives usually mounted in the pump pit and consequently subject to flooding. For small and medium-sized vertical units with motors mounted on the upper floor, the most popular shafting is the hollow type, having universal joints at the pump, motor couplings, and the intermediate steady bearings, and including a slip spline at the pump end.

This combination allows the shaft to be disconnected quickly and swung aside for pump servicing. Minor shaft misalignment is compensated for automatically when proper installation is used. It is good practice to mount the vertical motor on a high ring base, rather than on the flat motor room floor, and to provide 1 to 3 inches of grout under the base.

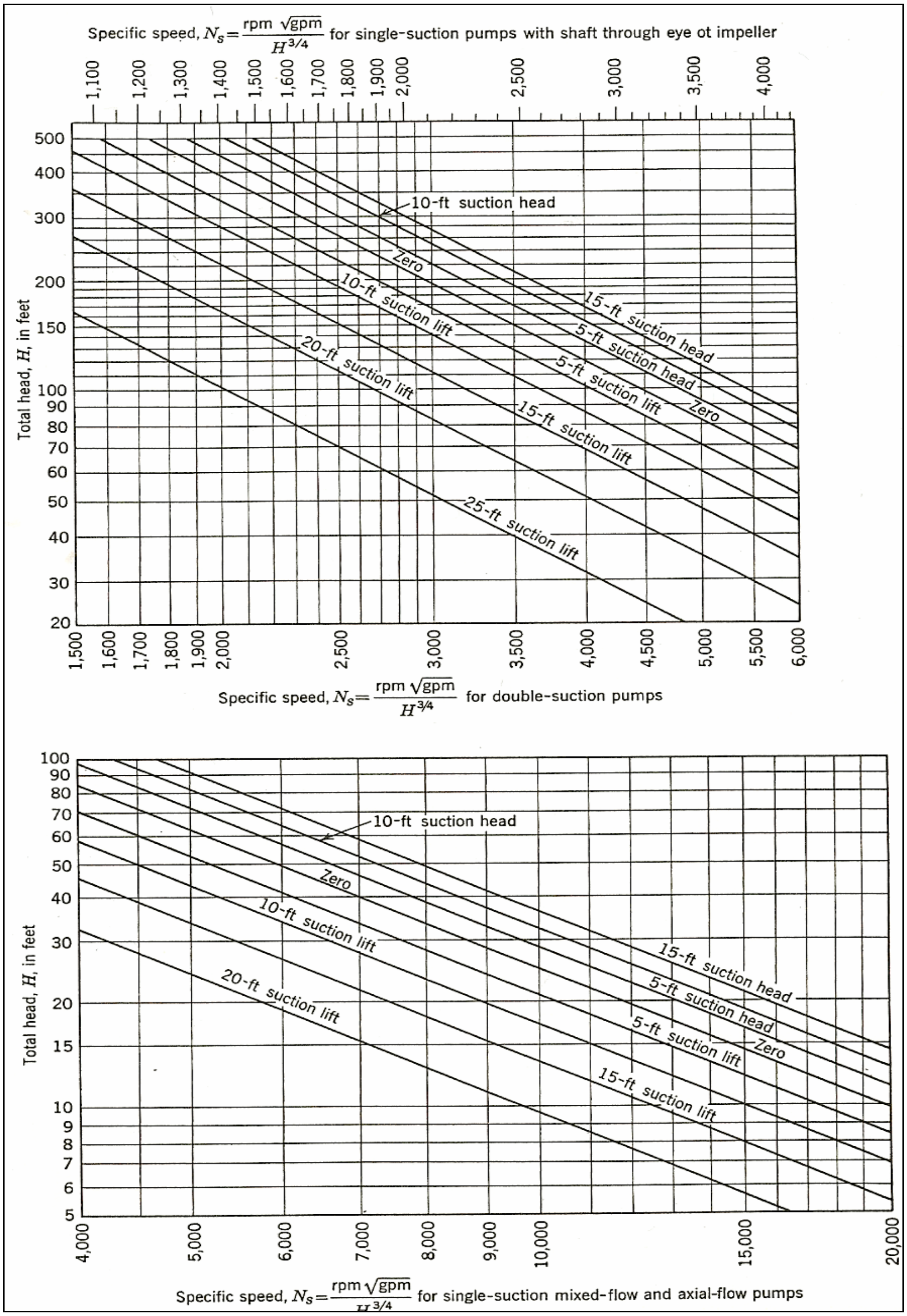


FIGURE 7 – Upper limits of specific speeds for clear water pumps at sea level and 85 degrees F.

5. Pump Drives

In modern sewage and storm water pumping stations, pumps are driven by either electric motors or internal combustion engines. Where uninterrupted power and continuous duty are anticipated, electric motors usually prove more economical in first cost as well as in maintenance. Where firm power is not available or where the duty is such that the pumping will be at infrequent intervals (as in storm water pumping stations), gasoline, diesel, or gas engines may be the most economical. In deciding on the type of drive to be used, these objectives must be considered:

(a) Low cost;
(b) Suitable performance characteristics;
(c) Simplicity and ruggedness of construction
(d) Dependability.

The cost of a drive involves both initial and operating expense. The former comprises the purchase price and the cost of installation, including all mounting features such as floor supports, wiring and conduit, and special rigging. Operating costs, on the other hand, include the energy costs, demand charges and power-factor billing penalties, repair and maintenance costs, and extra operational labor expense, if any.

Electric motor drives may be classified into three general groups: constant-speed, multi-speed, and variable-speed. Constant-speed motors may be either the squirrel-cage induction, synchronous, or wound-rotor induction type. The squirrel-cage induction motor is the most widely used and for most applications will cost less to install. It also has the simplest controls of the three types listed and is the simplest to maintain. For those drives where the motor rating exceeds more than one hp/rpm, the synchronous motor may have lower initial cost. A comparison of constant-speed drive characteristics for electric motors is shown in Table 8.

Included in the control cost for induction motors is a standard primary starter both across the line and reduced voltage. For the wound-rotor and synchronous motors the cost includes both primary and secondary controls including the exciter for the synchronous motors. Quotations from manufacturers should be secured for analysis. Since unusual circumstances, other than cost, would be needed to justify the use of synchronous or wound-rotor motors instead of the induction type for drives below 100 hp.

Comparison of Constant Speed Motors Characteristics

Type of Motor	Full-Load Eff.	Full-Load Power Factor	Simplicity	Initial Cost
Squirrel-cage induction	1–3% less than synchronous	75–90% lagging	Simplest	Lowest
Synchronous	Highest	Unity or 80% leading	Least simple	Second
Wound-rotor induction	1–3% less than synchronous	75–90% lagging	Less simple	Highest

FIGURE 8

Multi-speed motors are a compromise between constant-speed and variable-speed drives. Because of pump characteristics, their application usually is limited to only two speeds. Both speeds, of course, are restricted to the available synchronous speeds, which may limit hydraulic capability.

A two-speed drive costs approximately twice as much as a single-speed motor of the same type and maximum ratings. But multi-speed motors have an advantage over variable-speed drives in that they will operate at a higher efficiency at lower speed than any form of variable speed drive.

Variable-speed electric drives also may be classified into three general groups: wound-rotor induction, brush-shift, and slip-coupling combinations. The wound-rotor induction motor is the most popular variable-speed drive used for pumping equipment. Brush-shift motors are limited at present to horsepower ratings of 75 and less. Slip couplings used on pumping equipment are of either the hydraulic or magnetic type. Speed adjustment is obtained with the hydraulic coupling by changing the clearance between the vanes in the coupling or by changing the vane angles. Speed adjustment is obtained in the magnetic coupling by adjusting the excitation of the coupling. For those stations employing variable-speed pumps and in addition requiring standby generation, consideration should be given to the use of wound-rotor motors to limit the size of the generating set required. Standard wound-rotor controls can be arranged to limit the starting or inrush current to a value of 100 percent or less of normal full load running current, thereby allowing in most cases a generator set of much smaller capacity than that required for other types of motors.

Many speed controllers are available. In general, it may be said that for each one percent of speed change, one percent of drive efficiency (based on the brake horsepower at the reduced speed) is lost.

However, the variation in pump efficiency may tend to compensate for the drop in drive efficiency at reduced speeds and consequently, one may cancel the other. For this reason, the overall pump and drive efficiencies at the various operating speeds should be studied together with other methods of matching inflow requirements before deciding whether variable-speed or constant-speed drives are the better selection from an economic standpoint.

Enclosures for motor drives on sewage or storm water pumps are usually of the open drip-proof type, although in some installations protected or enclosed motors may be required. Motors and starting equipment for pumps, which operate infrequently well, may be equipped with heaters to prevent condensation during periods of idleness. For small- and medium sized installations it is good practice to select motors for the maximum load anticipated under adverse conditions.

Two general factors usually will determine the type of engine best suited to drive sewage or storm water pumps; first, the type of fuel available at the most economical price, and second, service to which the engine will be subjected, that is, continuous duty or infrequent service.

High-speed gasoline engine drives are probably the most economical from a first-cost standpoint for horsepower ratings of 500 or less. However, they are not used ordinarily for continuous duty because of high maintenance expense. Low-speed diesel or gas engines are best for continuous duty, considering all factors, including first cost and operating and maintenance expense. One advantage of engine drives is that variable speed may be obtained by controlling engine speed by a direct mechanical linkage from float controls. By this method, pumping rates can be varied over rather wide limits to match the sewage flow rate. Remote control of engines is more complex than remote control of motors.

The proper selection of a drive for pumping equipment requires a careful study of all factors concerned, including but riot necessarily limited to:

(a) First cost
(b) Availability and dependability of electric power
(c) Pump characteristics as to horsepower, torque, and speed under all operating conditions
(d) Total annual power cost considering not only the energy rate but also demand charges
(e) Maintenance costs
(f) Dependability of equipment

F. PIPING AND VALVES

Suction, discharge, and header piping in the station should be sized to handle the flows adequately. Proper sizing of piping is usually a matter of economics. Ordinarily, piping is sized so that the velocity in the suction line will not exceed 5 fps, and in the discharge piping, 8 fps. Piping less than 4 inches in diameter should not be used for conveying sewage. Valves should be provided on the suction and discharge side of each pump to allow proper maintenance of the unit. Where sewage check valves are used, they should be installed so that they are readily accessible for cleaning or repair without removal from the line. Check valves should be of the outside lever, spring or weight-loaded type and be installed only in horizontal lines. Pivoted valves, where the disk shaft is not clear of the flow, should not be used. Studies should be made and facilities provided to prevent excessive surges due to water hammer when starting and stopping the pumps where stations discharge into long force mains. This may require automatic valves coordinated with the pump motor controls.

Velocities previously mentioned should not be exceeded through valves, which usually require that increasers and decreasers be placed on each side of the pump. Reducers on the suction side of pumps should be eccentric and installed with top flat to prevent entrapment of air in the suction line. Sectionalizing valves should be installed in the station header to the extent that the firm capacity of the station may be maintained if it should prove necessary to take any of the station piping out of service. Pump discharge piping should not connect to the header piping from the bottom since solids will have a tendency to settle out from the header into any vertical riser. Suction piping should be arranged so that it can be dismantled readily for cleaning. Each pumping unit should have a separate suction line from the wet well.

Flexibility is essential in laying out flanged piping. It may be provided by using hub-end joints, flexible couplings, or other means so that tolerances in such piping may be taken up in the flexible joints. Cast-iron flanged pipe, flanged specials or flanged fittings should not be encased in concrete because a failure in the flange would be very difficult to repair. Rigid connections should not be provided between flanged piping and concrete walls or floors.

It is essential to provide proper hangers, braces, and supports for all piping to assure that no undue strains are induced. Particular attention must be paid to proper blocking and tying of pipe where hub-end or flexible joints are used. Small drain valves should be installed at all low points and air relief valves at all high points in the piping.

G. ELECTRICAL EQUIPMENT

I. General

The basic requirements for the electrical equipment at pumping stations are adequacy, reliability, and safety. Adequacy of the major equipment is determined largely by the continuous current requirements of the station loads and the available short-circuit capability of the power supply. The reliability of the equipment concerns the capacity of the electrical system to deliver power when and where it is required under abnormal, as well as normal, conditions. Safety involves the protection of plant personnel as well as the safeguarding of equipment under all conditions of operation and maintenance. None of these three requirements should be sacrificed for the sake of initial economy. The electrical system should be designed with enough flexibility to permit one or more components to be taken out of service at any time without interrupting the operation of the station.

The type of electrical equipment that is chosen for quite similar pumping stations may vary considerably in size, cost, and complexity because of the following differences: voltage, short-circuit capability, regulation, anticipated changes and reliability of the power source, the initial and ultimate station capacity, and the general appearance of the station.

2. Voltage Selection

A proper selection of voltages in the station electrical system is one of the most important decisions affecting overall system characteristics and plant performance.

The station main-bus voltage should be at the level most suitable for the pump motors, which constitute the major part of the load. If a choice is available in the voltage level of a purchased power supply, the desired voltage rating for the largest pump motors will dictate how the choice should be made.

From the viewpoint of service voltage, the purchased power supply for a user will come from one of the following:

(a) Substation owned and operated by the power company at the station site to provide a service voltage satisfactory for the pump motors
(b) Incoming voltage to the site satisfactory for the pump motors
(c) Main substation owned and operated by the user to produce a voltage satisfactory for the pump motors

The user has design control of the main-bus voltage for supplying the pump motors under the last kind of service arrangement. For the other two kinds of service, the user should make known to the power company the service voltage level which best suits his purposes. In residential areas, the power company may prefer to supply 220-v service for small pumping facilities with aggregate loads of 15 hp or lower, so that portions of the residential area may be served from the same transformer bank. In -this case, a penalty charge may be assessed to provide higher voltages. For aggregate loads between 15 and 100 hp, either 220- or 440-v service should be available without penalty. Some users, for safety or policy reasons, prefer service voltages of 220 for facilities up to an aggregate loading of 100 hp; others prefer to retain 220-v service until the largest single motor is rated 100 hp or larger.

3. System Selection

The equipment for a particular pumping station depends on the type of distribution system selected. These types vary not only in arrangement but also in operating characteristics and cost, depending on the following:

(a) Quality of service required

(b) Total load

(c) Magnitude of individual loads

(d) Location of station

(e) Size and arrangement of station

The simple radial system is the least expensive and most common. The secondary selective system is more expensive and may be provided with two full-capacity transformers so that either the primary feeder or its associated transformer may be out of service while continuous service to the station is maintained. Still more flexible and reliable yet even more expensive is the primary and secondary selective system, which permits either transformer or primary feeder to be out of service simultaneously while still maintaining continuous service.

Generally the equipment selected for the primary and secondary selective system will require the highest interrupting capacity of the three systems described. The interrupting capacity of the equipment selected.

4. Transformers

Transformers are either dry self-cooled, liquid-immersed self-cooled, or forced-cooled. Dry transformers are limited in size and generally are chosen of necessity for lower weight, elimination of liquid, or improved appearance. Dry units compare unfavorably with liquid-immersed transformers with respect to impulse strength. Their ability to withstand surge voltages is only about one-half that of a liquid-filled transformer of the same voltage rating. The use of the dry-type should, therefore, be avoided where the system may be hit by lightning. Liquid-filled units are available in nearly all sizes and are considered to possess the highest degree of reliability of any of the main components of a power system. Two general types of liquid-filled transformers are the oil filled and the non-flammable liquid filled. Oil-filled transformers may be used only outdoors or in special transformer vaults. Non-flammable, liquid-filled transformers are for indoor use or for outdoor installation at locations where fire hazards must be reduced.

5. Switchgear

The functions of switchgear in a distribution system include normal and fault switching operations and equipment protection. Motor-starting functions sometimes are vested in switchgear, but only when the required frequency of starting and stopping is low or in applications where the motors are of such magnitude that no other equipment is practical. The basic classifications of switchgear equipment are made according to their rated voltage and their rated-fault interrupting capacity. Successful fault handling extends beyond the selection of devices which will interrupt satisfactorily an abnormal over current; it also is important to prevent or minimize the damage, and perhaps hazard, that may appear in a cable, a motor controller, or other device during the clearing operation, even though the device itself was not initially in trouble. The problem is to choose equipment to withstand the duration and magnitude of faults and to operate selectively so that only a minimum of the system is disconnected in the event of trouble.

Outdoor metal-clad switchgear similar to the indoor type is used commonly for both medium and low voltages. All features of indoor switchgear are retained in the outdoor type, such as compartmentation, insulation levels, and removable and interchangeable breakers. Other added features include extra heavy base construction, planned ventilation, heaters, illumination, and weatherproof enclosures with weather resisting outdoor finishes.

6. Unit Substations

Transformers and switchgear or controls may be built integrally to combine into unit substations in modern distribution systems. Electrical and mechanical coordination of components provide a variety of benefits that assist in the planning, purchase, installation, and operation of the system. The total installed cost of unit substations is almost always lower than the total installed costs of the piecemeal components.

7. Motor-Starting Equipment

The full-voltage type starting equipment always is preferred from the standpoint of cost, floor space, and reliability. Experience has shown that full-voltage starting could be employed profitably to a much wider extent than it has been in the past; and each exception will warrant an investigation to see if full-voltage starting can be employed. Methods other than full-voltage starting are used broadly to improve an actual or imagined bad effect on system voltage from motor starting. In general use are the autotransformer type of starting, the reactor type, resistance type, and part winding. The objective of reduced-voltage starting is to minimize the disturbance on the electric system by limiting the starting kilovolt amperes; Most electric utilities have had definite restrictions on permissible starting kilovolt-amperes; however, it must be recognized that, as their system capacity increases, these permissible starting in rushes can become greater. As a rule, use of reduced-voltage starting equipment will approximately double the cost of the equipment. It also must be noted that any reduction in starting kilovolt-amperes supplied to a given motor, will be accompanied by a considerable reduction in locked rotor and accelerating torque.

Careful consideration should be given to the use of power circuit breakers as motor starting equipment where motors are not started more than two or three times per day. High-voltage, fused, motor controllers are better suited for repetitive operations as they have approximately 100 times longer mechanical life than circuit breakers operating under comparable duty. There are limitations, however, in the use of the fused high voltage starters, such as the interrupting capacity and maximum horsepower sizes that are available. The horsepower limitations are approximately 700 hp for oil-immersed contactors and 1,500 hp for air-break contactors used in the high-voltage, fused, starting equipment at 2,300 v.

Grouped motor control equipment assembled into integrally built control centers often offers such benefits as lower installation costs, better appearance, and the advantage of factory wiring, testing, and coordination of protective and interlocking devices.

Control centers can be combined and integrally built with transformers to comprise power centers having the advantages similar to those associated with unit substations.

8. Motor Overload Protection

A major cause of motor failure is attributed to the breakdown of the winding insulation. Motor overloads cause excessive heat, which is damaging to the insulation and is cumulative, i.e., each occasion of excessive temperature adds to the total deterioration. For this reason, the overload protection device should disconnect the motor before excessive heat can be generated. It has been customary to protect three-phase motors with overload protection in two of the three phases. In recent years, an increased trend toward overload protection in all three phases has been evident, particularly where the service is fed from wye-delta connected transformers.

Initially, the protection device should be sized or set for the stamped nameplate data of the motor it protects. The setting should follow a careful study of the ambient temperatures of the starter enclosure and that of the motor, as well as motor amperage, temperature rise rating, and service factor. Once properly selected, these settings rarely should be increased, though the operator may wish to reduce them when actual operating amperages are found to be substantially lower than motor nameplate ratings.

For motors of 300 hp and larger, consideration should be given to additional and more elaborate overload protection devices. Among these are time delay over current relays, phase protection relays, differential relaying, and temperature detectors imbedded in the motor windings.

9. Conduit and Fittings

Galvanized rigid metal conduit, ordinarily used in wastewater treatment works, may be used under nearly all atmospheric conditions. Aluminum conduit may be used in lieu of steel for exposed runs but should not be cast in concrete, because it causes spalling, or installed in soil. Epoxy resin or PVC-coated steel conduit or conduit made of special alloys is used where severely corrosive conditions are expected. Rigid metal conduit must be used in all hazardous locations.

PVC conduit is suitable in extremely corrosive, but not hazardous, atmospheres. PVC, asbestos-cement, and fibrous conduit are suited to underground service either direct buried or encased in concrete. These conduits are corrosion resistant, immune to electrolysis, non-inductive, and will not support combustion. Thin-wall fibrous conduits are designed for use where encased in concrete. Rigid or heavy wall conduits are designed to be buried or exposed.

Conduit fittings should conform to the requirements and be of the same material as the conduit. The use of two different metals in a conduit system should be avoided, especially in the presence of moisture, to prevent galvanic action.

H. PREFABRICATED PUMPING STATONS

Prefabricated or factory-built pumping stations are available in several basic types. One type includes conventional non-clog pumps, motors, controls, and piping mounted in a vertical cylindrical steel structure. Another comes fitted with pneumatic ejectors, compressors, and controls, but the most widely used factory-built pumping station is two or more submersible pumps mounted on slide-rails. The system is installed in precast concrete manholes, sized to hold the pumps and at the same time provide the function of a wet well. When lowered into the wet well, the pumps have a “slide connection” to the discharge piping.

Normally the cylindrical steel stations include dehumidification and ventilation equipment, sump pumps, and sometimes elevators where the depths are great. Air conditioning equipment may be supplied with the larger stations for the dissipation of the heat from motor operation. Cathodic protection in the form of a sacrificial anode normally is provided for the outer steel shell. The operating agency should keep a record of the anode's location so that it may be checked periodically and replaced as necessary.

I. APPURTENANCES

1. Wash Rooms

Washroom and toilet facilities should be provided in all stations, which are to be attended regularly. Foot operated valves should be used on lavatories. At least a washbasin and soap dispenser should be provided at every pumping station.

2. Meters and Gages

For medium-sized and large sewage pumping stations, it is desirable to have a flow meter, which indicates and records the discharge from the station and a recording and indicating gage, which shows the station header discharge pressure. This information is not only important from an operational standpoint but is of inestimable value if it should be necessary to enlarge the pumping capacity. It is helpful to have an elapsed-time clock mounted on each motor starter. If the facility is unattended, consideration should be given to the installation of monitoring equipment for the remote reporting of malfunctions to an operations center. As a minimum, an external alarm should be provided.

3. Water Supply and Water-Seal Equipment

A potable water supply is desirable in all pumping stations. A positive separation should be maintained between the potable system and any lines subject to contamination. Warning signs should be posted at all water taps not directly connected to the potable supply. Hose bibs are desirable in pump pits and screen rooms. Clear water should be provided for sealing stuffing boxes of volute-type pumps wherever possible.

4. Hoisting Equipment

Hoists should be provided in all stations for the handling of equipment and materials, which cannot be lifted readily or removed from the station by manual labor. It is advisable to provide overhead bridge cranes in larger stations. Moreover, it has been found in the larger stations that they usually pay for themselves in the handling of equipment and materials in the original installation. Hoists should be provided over basket screens and in other locations where it is necessary to lift pieces of equipment or containers, which cannot be handled by two men. The provision of heavy lifting eyes in the ceiling over pumps and heavy valves and equipment will ease materially the close handling of such equipment.

5. Fencing

Stations and station facilities should be fenced where necessary to protect against vandalism or hazard to persons who otherwise may come in contact with electrical transformers and switching equipment.

6. Landscaping

The station site should be landscaped as necessary to make the facilities fit in with the surrounding area. Appropriate landscaping is essential for stations located in residential areas. When a house is located extremely close, a buffer of closely planted shrubbery 6- to 8-feet high will reduce noise complaints materially and provide increased privacy to the residence.

7. Building Drainage

Adequate floor drains are a necessity and floors should be sloped to the drains a minimum of 1/8 inch per foot. Floor drains should be placed in sumps approximately 3 feet in diameter and depressed below the general floor elevation approximately 3/4 inch to provide positive drainage. For small- and medium-sized structures, good drainage may be obtained by providing 2-inch by 4-inch gutter along all four walls, draining to the sump. Floors should be sloped from the center of the room toward the gutters in this case.

Sump pumps almost always are required to remove drainage from the pit floor, and they should discharge above any possible high water in the station wet well to preclude backflow of sewage into the pump pit.

8. Safety Features

Railings should be provided around all manholes and openings where the covers may be left off during operation and at other locations where there are differences in levels or where there is danger of the operator falling.

Guards should be placed on and around all mechanical equipment where the operator might come in contact with belt drives, gears, chain drives, rotating shafting, or other moving parts of equipment.

Rubber mats of a suitable type should be provided in front of all electrical equipment where there is any hazard from electric shock. Electrical equipment and wiring should be insulated and grounded properly. Switches and controls should be of the non-sparking type. Adequate lighting should be provided in all locations, especially where there is moving equipment or openings in the floors. Wiring and devices, except polyphase motors, in hazardous areas should be explosion-proof. All receptacles should be of the three-wire grounding type outlet and a ground test of each conducted after installation. Portable power tools, extension cords, and trouble lights including their outlets should be of the three-wire grounding type. Lighting toggle switches should be "T" rated. When sump pumps are utilized with a flexible plug-in power cord, the cord and attachment cap should be of the three-wire grounding type; the attachment cap should be locked to the outlet with a locking device; and the outlet should be protected by a combination toggle switch having built-in overload protection (fractional hp manual starter). It is good practice to provide a prominent sign on the major gear stating the service voltage.

Stairways should be used in preference to ladders or manhole steps, with straight-run stairways preferable to the circular ones. Stair treads should be of the non-slip type. Vertical ladders should be provided with safety cages. Service elevators are desirable in larger stations with relatively deep pump pits. The use of manhole steps should be restricted to areas of infrequent use, and, if at all possible, to level changes not exceeding 8 feet. Grab bars should be provided approximately 4 feet above the level of the landing adjacent to the top step.

The possibility of slipping on oil or biological growths which may develop near leaks presents a considerable safety hazard. Thus, proper drainage is important.

Fire extinguishers of suitable type should be located strategically throughout the station. The use of carbon tetrachloride types should be avoided due to the toxicity of this liquid.

TYPICAL MUNICIPAL SPECIFICATIONS FOR PUMPING STATIONS

The following information is an excellent specification prepared by a municipality for pump stations being constructed within the City. It is evident that the City knows exactly what type of pumping systems and what type of equipment they want to see. If the City is to undertake maintenance of the pumping station, it should be of a type for which the City has spare parts and of a quality acceptable to them. Note the number of manufacturers names that appear in the specification. There is no doubt that this City Public Works Department is very knowledgeable relative to pump stations.

1.0 GENERAL

The following are the standard specifications for pump stations to be installed and connected to the City's sanitary sewer collection system. The purpose of these specifications is to provide a minimum standard for pump stations that complies with the guidelines set out by the State and incorporates the most cost effective and reliable design for maintenance and operation.

Sewage pump stations shall consist of a wet well, sewage pumps, control systems, electrical systems (normal and emergency), superstructures, site security, grading and access. The contractor shall be responsible for extending all necessary utilities to the pump station site (electrical, phone etc.).

Sanitary sewer pump stations will only be considered when the thorough study of all alternatives clearly indicate the impracticability of gravity collection and disposal.

All pump stations shall be equipped with a minimum of 8 hours of emergency storage or an emergency generator.

2.0 ENGINEERING REPORT

All pump station plans shall be accompanied by an engineering report. The following information shall be included in the report:

2.1 TITLE PAGE - Title page should include the project name, date, developer/owner's name and engineering firm preparing plans.

2.2 SEWER SYSTEM INFORMATION

A. Introduction

1. Type, location and size of development
2. Number of and range in size of lots or buildings to be serviced

B. Existing Sewer System

1. Location and type of gravity system the force main will discharge into.
2. Future of sanitary sewer service
3. State whether the entire development will be serviced by the proposed phase or if several phases will be involved.
4. State the number of lots this phase will encompass initially and finally if future phases are to be constructed.

2.3 PUMP STATION AND FORCE MAIN DESIGN CALCULATIONS

A. Nb = Number of specified types of buildings

Np = Number of persons per unit
Pe = Nb x Np

B. Average Daily Flow (ADF)

1. Average Daily Flow (GPD) = Per x 100 gal/person/day
2. Average Daily Flow (GPM) = Flow (GPD) /1440 (Min/Day)

C. Peak Daily Flow (PDF)

1. Peak Daily Flow (GPM) = PF X ADF (GPM)
2. Peak Daily Flow (GPD) = PF x ADF (GPD)

D. Total Dynamic Head (TDH)

1. Static Head (Hs)
Eh = Maximum force main elevation E1 = Wet well low water elevation Es = Eh - E1

2. Loss (Lf) due to friction in force main
Length = Total equivalent length of force main and piping within pump station
Lf = Length x Friction Factor

- Hazen-Williams C-factor of 120 shall be used for computation of friction losses.

3. TDH = Hs + Lf

E. Force Main

1. Volume of Storage (Vs)

2. Velocity Produced in Force Main

3. Maximum Operating Pressure

(a) Size air release valves (if applicable)

(b) Retention time of force main (at initial flows and at design flows)

F. Storage Requirements

1. Volume of storage (Vs)
Vs = ADF (GPD) x (hours of storage required /24 hours per day)

2.Dimensions of storage facility.

G. Buoyancy Checks - A buoyancy check shall be performed for the pump station wet well and the retention chamber.

2.4 CYCLE TIMES

A. Volume (Vr) of water in wet well needed to turn primary pump on

1. Elevation difference (E5) between primary pump on elevation (E3) and pump off elevation (E4)
E5 = E3 - E4

2. Volume (Vpf) of water per vertical foot in the wet well
A = the inside area of the wet well Vpf = A x 7.481 gal/ft3

3. Vr = E5 x Vpf

B. Cycle Time for ADF

1. Time (Tf) required for volume in wet well to reach Vr, Tf = Vr/ADF (GPM)

2. Time (Tp) required for pump to return water level to the pump off elevation

3. Total Cycle Time Pump

ON for Tp
Pump OFF for (2) Tf + Tp

C. Cycle Time for PDF

1. Time (Tf) required for volume in wet well to reach Vr, Tf = Vr/PDF (GPM)

2. Time (Tp) required for pump to return water level to the pump off elevation Tp = Vr/(CSR - PDF (GPM)

3. The pump is on for one pumping cycle of Tp and off for 2 storage cycles of Tf plus one pumping cycle of Tp because pumps alternate

D. Total Cycle Time:
Pump ON for Tp
Pump OFF for (2) Tf + Tp

2.5 LISTING OF RESULTS FROM THE DESIGN CALCULATIONS TO BE PRESENTED IN THE FOLLOWING ORDER:

A. Number of lots or Buildings

B. Population Equivalent

C. Average Daily Flow in GPM

D. Peak Daily Flow in GPM

E. The Volume of the Retention Chamber (8-hour minimum, may require 24 hours in some cases)

F. Static Head

G. Total Dynamic Head

H. The Pump Selected (including type manufacturer, model number, size, Hp, RPM, phase and GPM)

I. Total Cycle Time for Average Daily Flow
Number of Minutes ON (Pumping Time) Number of
Minutes OFF (Fill Time)

J. Total Cycle Time for Peak Daily Flow

Number of Minutes ON (Pumping Time) Number of Minutes OFF (Fill Time)

K. Size and length of Force Main

I. Velocity Maintained in Force Main

M. Force Main Retention Time (at initial flows and at design flows)

N. Air Release Valve Sizing Calculations (if applicable)

O. Maximum Force Main Operating Pressure

2.6 COST EFFECTIVE ANALYSIS

Consultant shall perform a cost effective analysis for all proposed pump stations and expansions of existing City-owned pump stations. Cost analysis shall compare the construction, operation and maintenance costs and any applicable salvage values over a 20-year period between proposed pump station and a reasonable gravity sewer alternative. Operation and maintenance costs that must be considered include: labor electrical, equipment replacement and routine maintenance.

Pump stations will only be considered a viable option if the cost analysis clearly shows that the gravity sewers are not economically feasible.

2.7 Pump performance curves shall be included with the engineering~ report.

3.0 PUMP REQUIREMENTS

At least 2 pumps shall be provided. If only 2 units are provided, they shall have the same capacity. Each shall be capable of handling flows in excess of the estimated daily: peak flow (GPM). Where more than 2 units are provided, each shall be designed to fit maximum flow conditions and must be of such capacity that with anyone unit out of service the remaining units will have capacity to handle maximum sewage flows.

3.1 GENERAL

A Sewage pumping stations may be either suction-lift type or submersible. When total suction lift exceeds 20 feet, only submersible-type pumps will be permitted.

B. Submersible-type grinder pumps will only be acceptable for pump stations utilizing 10-horse power pumps or smaller.

C. Pumps less than 2-horse power are not acceptable.

D. Pumps must be 3-phase.

E. The pump discharge piping diameter shall be determined as follows:

Individual Pump Output	Pipe Diameter
50 GPM and Below	2”
51 to 80 GPM	3”
81 GPM and Above	4” min.

F. The pump discharge piping diameter and material shall be uniform from the pump discharge base to the common header tee.

G. The common header and force main pipe diameter shall be sized to produce a minimum flow of 2 F.P.S. with one pump running and a maximum flow of 8 F.P.S. from the combined output of 2 pumps.

3.2 ACCEPTABLE MANUFACTURERS

A Suction lift-type pumps shall be Smith & Loveless, Gorman-Rupp, or approved equal.

B. Submersible non-clog solids handling pumps shall be Flygt, AB.S. Co., Myers, Fairbanks Morse, KSB or approved equal.

C. Submersible grinder pumps shall be manufactured by the Flygt Co., A.S.S. Co., Myers, Hydromatic, KSS or approved equal.

4.0 PIPING AND VALVES

4.1 DISCHARGE PIPING

The piping from the individual pump discharge bases, through the valving assembly and out to the force main, shall be in accordance with the following:

A. Four-inch Diameter Piping and Larger:

Piping - The discharge piping shall be ductile iron Class 53 or greater A.N.S.1. A-21.51 (AWW A C151) with rigid radius grooves for end preparation in accordance with AWWA C606.

2. Fittings - Fittings shall be ductile iron, ASTM A-536, Grade 65-45-12, or cast iron, ASTM A-48, conforming to the requirements of AWWA C110 for center to end dimensions AWWA C153 or AWWA 21.10/AWWA C110 for wall thickness, and AWWA C606 rigid radius grooving dimensions for end preparation. Fittings shall be cement lined and have a universal primer coating.

3. Mechanical Couplings - Mechanical couplings shall be ductile iron conforming to ASTM A536, Grade 65-45-12 with a universal primer coating as manufactured by Victaulic (style 31, style 75 or style 307), or approved equal. Couplings shall incorporate gaskets that are specially made to conform to ductile iron pipe surfaces and 304 stainless steel nuts

and bolts.

4. Transition Fittings:

(a) Grooved to Flanged - The connection of grooved pip and fittings to flanged pipe and fittings shall be facilitated with flange adapters as manufactured by Victaulic (style 341 Vie-Flange) or approved equal. The flange adapters shall be ductile iron conforming to ASTM A-536, Grade 65-45-12, with a universal primer coating. Gaskets shall have properties as designated by ASTM 0-2000 and shall be suitable for the required service. Use 304 stainless steel bolts and nuts on all flange adapters and flanged components.

(b) Force Main Connection - The ductile iron pipe shall be extended at least 4 feet from the outside of the valve vault. The force main shall then be connected to the ductile iron pipe with a mechanical coupling. The coupling shall be a MEGALUG Mechanical Joint Restraint or approved equal.

B. Three-inch Diameter Piping and Smaller:

1. Piping - The discharge piping shall be ASTM 1785 schedule 80 PVC roll grooved pipe in accordance with AWWA C606.

2. Fittings - Fittings shall be cast of ductile iron conforming to ASTM A-536, Grade 65-45-12, and have AWWA C606 grooving dimensions for end preparation. Fittings shall have a Tnemec or approved equal 140 outside coating and inside lining.

3. Mechanical Couplings - Mechanical couplings shall be rigid and cast of ductile iron conforming to ASTM A-536, Grade 65-45-12, alkyd enamel finish, with gaskets conforming to ASTM 0-2000 as manufactured by Victaulic (style 07, Zero Flex) or approved equal. Couplings shall utilize 304 stainless steel bolts and nuts.

C. Transition Fittings:

1. Grooved to Flanged - The connection of grooved pipe and fittings to flanged pipe and fittings shall be facilitated with flange adapters as manufactured by Victaulic (style 741 Vic Flange) or approved equal. The flange adapters shall be ductile iron conforming to ASTM A-536, Grade 65-45-12, with a universal primer coating. Gaskets shall have properties as designated by ASTM 0-2000 and shall be suitable for the required service. Use 304 stainless steel bolts and nuts on all flange adapters and flanged components.

2. Force Main Connection - The schedule 80 PVC pipe shall be extended at least 4 feet from the outside of the valve vault. The force main shall then be connected to the schedule 80 PVC pipe. The force main shall be connected to the schedule 80 pipe by means of a solvent well schedule 80 PVC coupling.

4.2 DISCHARGE RISERS

A. PVC - When plastic pipe is utilized for the pump discharge riser and the riser exceeds 6 feet in length, stainless steel support braces must be installed between the riser and wet well wall. The braces shall be placed at a maximum spacing of 6 feet.

B. DIP - When ductile iron pipe is utilized for the pump discharge riser and the riser exceeds 8 feet in length, stainless steel support braces must be installed between the riser and wet well wall. The braces shall be placed at a maximum spacing of 8 feet.

4.3 FORCE MAIN REQUIREMENTS

Force mains shall meet the following criteria:

A. Velocity - A cleaning velocity of at least 2 feet per second must be maintained when one pump is running and a maximum of 8 feet per second shall not be exceeded when both (all) pumps are running.

B. Air Release Valve - An automatic release valve shall be placed at high points in the force main to prevent air pockets.

C. Termination - Force mains shall discharge to a gravity sewer in a manner that smoothly directs the force main flow into the gravity sewer flow and minimizes turbulence. Force mains shall be connected to a gravity sewer as per the Standard Details.

D. Thrust Blocks - The force main shall be fitted with permanent thrust blocks at all bends, tees, plugs, fittings or other significant changes in direction. Thrust blocks shall be constructed as per the Standard Details. Thrust block locations shall be given on both plan and profile views on the construction plans.

E. Clean-outs - The need for clean-outs on the force main shall be determined during plan review by the City. As a general guideline, clean-outs will not be required on force mains under 1800 feet in length. If clean-outs are required, refer to the Standard Details.

F. Force Main Pressure Test - Contractor shall fill and pressure test the force main. The minimum required test pressure shall be the maximum force main operating pressure plus 50 psi. (City representative shall be present during this test).

G. Tracer Wire - A green-coated number 12 AWG copper tracer wire shall be installed the entire length of the force main as per the Standard Details. The tracer wire shall accessible from the surface at intervals not to exceed 1000. The tracer wire shall be extended into all valve vaults (pump station valve vault, air release vault, clean-out valves, etc.) a minimum of 5 feet, from each direction. If valve vault spacing exceeds 1000 feet, then tracer wire access vaults shall be provided as necessary. The tracer wire access vaults shall be constructed as per the Standard Details. The wire shall be neatly rolled and placed on a stainless steel hook so that it does not interfere with normal operation. When wet well-mounted pumps are utilized or when a pump station valve vault is not utilized, a tracer wire access vault shall be provided within 10 feet of the pump station wet well.

H. Utility Marking Tape - A detectable underground utility marking tape shall be installed the entire length of the force main as per the Standard Details. The tape shall consist of a 35 gauge (0.00035") solid aluminum foil core encased between 2 layers of plastic. The tape shall have an overall minimum thickness of 5.0 mil (0.005"). The aluminum foil must be visible from both sides. No inks or printing shall extend to the edges of the tape. All printing shall be encased to avoid ink rub off. Tape shall be green in color and conform to the following requirements:

Property	Method	Value
Thickness	ASTM 02103	5.0 mils (nominal)
Tensile strength	ASTM 0-882	22 Ibs/in width (4400 psi)
Elongation	ASTM 0-882	<50% at break
Printability	ASTM 02578	>40 dynes/cm^2

I. Pipe Material - The force main pipe shall have a pressure rating greater than the system's maximum operating pressure plus 50 psi. D.I.P., PVC and HOPE are acceptable materials. The project plans or specifications shall state the SDR Ratio, Pressure Rating and National Standard of the proposed force main material.

4.4 AIR RELEASE VALVES

An air release valve shall be installed on any high points or "knees" of the force main, as deemed necessary by the City Engineer. The air release valves shall be the short-body style and specifically manufactured for wastewater applications. The body and cover of the valve shall be constructed of heavy-duty cast iron that has a pressure rating greater than or equal to the force main pipe material. Bolts, pipe, nipples and plugs shall be stainless steel. Street elbows shall be stainless steel or bronze. Isolation and flush valves shall be threaded ball valves with bronze bodies, stainless steel ball and operating lever, and nylon seats.

Air release valves shall be attached to the force main by means of a stainless steel pipe nipple threaded to a cast-iron mechanical joint m.j. x m.j. x tap tee. (Air release valves on force mains smaller than 6 inches will require additional support.)

Air release valves shall be placed in a vault as per the Standard Details.

Acceptable air release valve manufacturers are Val-Matic, APCO Valve, Primer Corp. or approved equal.

4.5 PLUG AND CHECK VALVES

A. Approved shut-off and check valves shall be placed on the discharge line of each pump. The check valves shall be located between the shut-off valve and the pump. Approved shut-off valves shall be placed on the force main as necessary. The shut-off and check valves shall be installed horizontally and located in accordance with the Standard Details.

B. All valves shall be rated so as to withstand normal working pressure plus allowances for water hammer.

C. Shut-off Valves - The valves shall be located so that each pump may be isolated from the common discharge header.

1. 3 Inches and Larger - Shut-off valves 3 inches and larger shall be eccentric plug type valves with a resilient faced plug suitable for required service. Valves shall have self lubricating stainless steel bearings and bearing grit seals. The port shall be circular, have a minimum flow area of 81 % of the full pipe area, minimum 90% pipe diameter and be able to pass a cleaning pig when fully open. Flow direction shall be indicated on the valve body.

2. Body - The shut-off valves shall be cast iron body, ASTM A 126 Grade B or ductile iron per ASTM, Grade 65-45-12, and have a universal primer coating. The bonnet shall be ductile-iron material per ASTM A-536, Grade 65-45-12. Grooved valves shall comply with AWWA C-509 and AWWA C-606 requirements.

3. Plugs - Shut-off valve plugs shall be made of cast iron ASTM A 126 Class B or ductile iron ASTM A-536 covered with a Buna-N Rubber compound. The seats are to be a corrosion-resistant alloy such as 304 stainless steel. Flanged valves shall be in accordance with ANSI B 16.1 Class 125 standards. Grooved valves shall be in accordance with AWWA C606. Sleeve-type bearings shall be utilized in both the upper and lower trunnions. Bearings shall be corrosion resistant and have a low coefficient of friction.

4. Operators - 3-inch to 4-inch shut-off valves shall be provided with a 2 inch square operating nut and wrench head. Valves at the pump station and pump station valve vault that are larger than 4 inches shall be provided with a manual gear operator sized so that the maximum rim pull required is not more than 80 lbs. Valves installed on the force main that are larger than 4 inches shall be provided with a 2-inch square operating nut and wrench head.

5. Sealing requirements - Shut-off valves 3 inches to 6 inches shall provide positive and reverse flow sealing up to 175 psi Shut-off valves 8 inches to 12 inches shall provide sealing up to 175 psi and reverse sealing up to 50 psi. Shut-off valves larger than 12 inches shall provide positive sealing up to 150 psi and reverse sealing up to 50 psi. These valve~ have a preferred direction of shut off, and it is the responsibility of the contractor to see that they are properly installed.

   Acceptable manufacturers are Clow, Dezurik, Victaulic Series 365 Vie-Plug or approved equal.

6. Smaller than 3 Inches - Shut-off valves smaller than 3 inches shall be ball- type shut-off valves. The valve body shall be ductile iron, ASTM A-395, Grade 65-45-12. The ball and stem shall be Type 316 stainless steel. The valve shall be a standard port, end-entry valve designed for 600 psi, minimum. The valve shall provide a drip free seal. The valves must be provided with a 2-inch square operating nut and wrench head or a concentric tee handle. Acceptable manufacturers are Victaulic. or approved equal.

E. Check valves shall be of the swing check type with ASTM A-126 Class B cast-iron body. Check valves shall be either flanged or grooved end type. All fasteners shall be 304 or 316 stainless steel

   2 inches to 3 inches check valve - Acceptable manufacturers are Victaulic (Series 712) Val-Matic or approved equal.

   3 inches and larger check valves - Acceptable manufacturers are Victaulic (Series 317), Val-Matic or approved equal.

4.6 BY-PASS PUMP PIPING

All pump stations shall be equipped with a by-pass pump arrangement as per the Standard Details.

A. Pump stations with a force main that is 4 inches or smaller shall be equipped with a 3-inch by-pass arrangement.

B. Pump stations with a force main that is 6 inches or larger shall be equipped with a 6-inch by-pass arrangement.

4.7 VALVE CHAMBER DRAIN VALVE

A 4-inch drain pipe shall be installed from the valve vault to the pump vault. The drain pipe shall be ductile iron Class 53 or greater. A flapper-style backwater check valve shall be installed on the valve vault drain line as per Standard Details.

4.8 WET WELL VENT

The wet well structure shall be vented with a 4-inch Schedule 40 stainless steel or aluminum vent pipe (refer to detail drawings).

5.0 INTERIOR

5.1 SLIDE RAILS

All pump lifting slide rails shall be made of 316 or 304 stainless steel pipe. Slide rails shall be installed and sized per manufacturer's instructions. The slide rails shall be firmly braced to the wet well wall with stainless steel support brackets placed at a maximum spacing of 8 feet.

5.2 LIFTING CHAIN

Pump lifting chain, clevises and shackles shall be made of 316 or 304 stainless steel. The chain shall be sized to accommodate the installed pump weight, but shall not be sized smaller than 3/16-inch stainless steel diameter links.

5.3 BOLTS

All field installed bolts, nuts, and washers used inside either the pump or valve chamber shall be made of 316 or 304 stainless steel.

5.4 FASTENERS

All concrete fasteners used for installation of braces, brackets or boxes shall be stainless steel type stud anchors. Anchor holes shall be drilled to the manufacturer's recommended depth. Anchors shall be Hilti Quick Bolt Two or an approved equal. Pump base anchor studs shall be sized as per pump manufacturer's recommendation.

5.5 FLOATS AND SETTINGS

A. Pump floats shall consist of a mercury tube switch sealed in a corrosion resistant polypropylene housing with a minimum of 18 gauge, 2-wire, SJOW/A jacketed cable. The cable must be of sufficient length to reach the junction box with no splices and to allow removal of the float without entering the wet well. The level controls shall be suspended so that adjustment or replacement may be done without the use of any tools or without entering the wet well. The floats shall be UL/CSA listed.

B. Floats shall not be located near the flow of the incoming sanitary lines.

C. Sewage shall not rise to the level of the incoming gravity lines or the 8-hour retention pipe during normal pump operation for either single or double pump operation.

D. All floats shall be located away from the turbulence of the incoming flow.

E The following levels shall guide the setting of float levels.

1. Off Float -The pump shall have water covering the top of the pump volute at the off level.

2. First Pump - No Less than one foot above top of pump motor.

3. High Level Alarm - No less than 2 feet above the top of pump motor.

4. Lag Pump - No less than 2 feet above top of pump motor and no more than one inch below the 8-hour retention line.

F. Float leads and pump cords shall be suspended with stainless steel grips from the bracket supplied by the pump manufacturer. The bracket shall be attached to the wet well hatch frame or firmly bolted to the concrete immediately below the hatch frame. The bracket shall be positioned so that float leads and pump cords are easily accessible without entering the wet well.

G. Float wires shall be neatly routed away from the pump access hatch opening then through the chamber access conduit, without excessive wire strain or pull. Wire length on all float wires shall be such that each float may be adjusted to the bottom of the station wet well.

H. Installed pump top and bottom elevations as well as the float elevations shall be shown on the pump station interior drawing.

5.6 ACCESS HATCHES

All pump and valve chambers shall be provided with aluminum access hatches as follows:

A. The access hatches shall be of aluminum construction rated for a 300 Ibs. per square foot loading. Door size shall be as indicated on the drawings. The access frame and cover shall be flush with the top of the concrete with hinged and flush-locking mechanism, upper guide holder and level sensor cable holder. Frame shall be securely placed, mounted above the pumps. Hatches shall be equipped with form skirts, sized for the slab top thickness. Doors shall be provided with padlock lugs.

B. Hatches shall be Bilco Type PCM or PDCM, or Halliday model S1 S, or R1 R or approved equal.

C. All access hatch construction materials and appurtenances shall be manufactured from stainless steel, aluminum or brass.

5.8 PRESSURE SENSORS

Pressure sensors, if required, may be of the full-flange design with thru bolt holes or one piece wafer style with carbon steel flanges. Sensors shall clamp between standard ANSI pipeline flanges. All exposed surfaces to be epoxy painted or of a non-corrosive material. Sensor shall be flow thru design with flexible Buna-N elastomeric sensing ring around the full circumference.

Gauges to be 2 1/2-inch dial, Span Model 220 with 1/4-inch connection.

Pressure switches shall have Nema-7 Housings with Single Pole Double Throw, snap-action switching elements. Switches shall be wired normally closed, with adjustable pressure settings. The pressure range shall be specified for each specific installation. Switches shall be, "NEO-DYN Model 132P4-8C6."

Accessory piping to be 1/2-inch or 1/4-inch Parker Hex stainless steel with reducing fittings where necessary to connect instruments. Pressure sensors shall be "Red Valve" Series 40 flanged wafer sensors EVR type PES or approved equal.

5.9 PUMP CHAMBER INSPECTION

Following placement of the wet pit pumps and prior to allowing water in to the pump station, the pump station floor will need to be inspected by the City. The pit floor must be clean and dry for this inspection. The contractor/developer shall be responsible for arranging this inspection with the City.

6.0 STRUCTURAL REQUIREMENTS

6.1 STRUCTURE DESIGN

. The pump station structure shall consist of a wet well and a valve chamber, if required, constructed of either pre-cast or poured in place reinforced concrete design. All structure top elevations shall be located a minimum of one foot above the 100-year flood elevation if applicable.

6.2 CONCRETE SPECIFICATIONS

All requirements on cast-in-place concrete shall be in accordance with the City Street and Storm Drainage Specifications and Standards.

6.3 ACCESS HATCHES

Access hatches shall be cast in the top sections of each chamber.

6.4 PIPE & CONDUIT ENTRIES

"A-lock" or "Z-lock" gaskets embedded in the concrete castings is the preferred method of entry. Other methods may be allowed provided that:

A. Entry methods do not affect structural integrity.

B. All entries must be a minimum of one foot from section joints.

C. Areas around pipe shall be grouted as to be leak-proof.

6.5 WET-WELL FLOOR

A poured concrete invert shall be installed to minimize solids accumulation.

6.6 VALVE CHAMBER

A. Valve chambers are required on all pump stations that utilize submersible pumps.

B The valve chamber floor shall be sloped with a 3-sided invert towards the 4-inch drain pipe using a 2-inch fillet.

1. Valve chamber shall be sized and configured as per the Standard Details.

6.7 PIPING DESIGN

A. The standard pump station piping arrangements called out have proven themselves to be of sound design in typical pump station installations. Special bracing or water hammer protection devices have not been included or called for; however, when the surrounding terrain or station site is such that extreme hydraulic conditions may be created, it is the responsibility of the engineer to anticipate such conditions and design for the probability of excessive pressure, stress and/or movement in the piping system. The engineer shall be responsible for including whatever restraints, relief valves or surge protection, deemed necessary for the protection of the valve and piping system.

B. Valve Chamber Piping Supports - After discharge piping and valves have been installed in the valve chamber, adjustable pipe cradle jacks shall be placed under the valves and tee, so that they have a 1 Q-inch clearance between the floor and valve flanges. The supports shall be firmly bolted to the valve chamber floor.

6.8 RETENTION CHAMBER

An 8-hour minimum sewerage retention must be provided. Both the pump chamber and the incoming gravity system are not to be considered for the 8-houl calculations.

Retention shall be installed below ground with an access manhole located at the upstream end. The connection between the retention chamber and the wet well wall shall be made with an 8-inch PVC or ductile iron pipe. The retention tank must be a dedicated system, it may not be used as part of the gravity system. The retention chamber and connecting line shall be laid with a minimum 1 % slope.

7.0 ELECTRICAL

7.1 PUMP CONTROL PANEL

A. GENERAL SPECIFICATIONS: The intent of this specification is to provide a complete, integrated Pump Control System as described herein. It shall be factory assembled, wired and tested. The panel manufacturer shall supply 4 sets of AutoCAD As-Wired drawings upon completion of construction. Two copies of these drawings shall be provided inside the pump control panel and the other 2 sets given to the City's representative.

An equipment data tag shall be permanently affixed on the inside of the exterior door with the station designation, power source, pump horsepower, and pump full load amps. In addition to the label requirements of UL 508A, an engraved legend plate shall be permanently affixed on the inside of the exterior door with the name, address and telephone number of the service representative for the pumps and control panel.

The wet well is classified as a Class I, Division 1 or 2, Group D hazardous location per NFPA Article 820. All applicable installation procedures per NEC, ANSI, EPA, and all other codes and laws for this installation requirement shall be followed. Intrinsically safe barriers shall be provided for the float switches located in the wet well. All pump and control conduits entering or exiting the pump control panel shall have explosion proof conduit seals suitable for Class I, Division 1 or 2, Group D environments. These seals shall be provided and installed by the installing contractor.

1. Quality Assurance: The pump control panel shall be supplied by the pump manufacturer and fabricated by a current UL 508A Listed industrial control panel manufacturer. The panel manufacturer shall show its UL follow-up service procedure file number on submittals. All devices within the panel shall be UL listed and/or recognized where applicable and shall be mounted and wired in accordance with the most current edition of UL508 and NFPA. The panel manufacturer shall have a minimum of 5 years experience manufacturing systems specifically for wastewater applications.

   The pump control system(s) shall be fully tested by the factory prior to shipment. It shall include testing of both power and control devices as well as all control functions. A final inspection shall be performed prior to shipment and a copy of this form shall be provided with the panel.

   The panel shall be designed with the following features to operate the specified pumps. The pumps, pump control panel and related accessories shall be supplied by the pump supplier to insure compatibility and assure matching controls to pumps.

2. Basic Operation: The pumps shall be operated automatically or manually as a pump down,

lead/lag, common off system. Each pump shall be controlled primarily through a "Hand-Off-Auto" 3-position maintained selector switch. Control function requirements are further defined in the control section of these specifications.

3. Position Commands:

(a) OFF - In this position the applicable pump will not run under any circumstance.

(b) HAND - In this position the applicable pump shall run without regard for the level sensing commands and will rely on operator discipline to run and stop.

(c) AUTO - In this position both pumps shall be controlled by float switches. These switches will sense the appropriate level in the wet well and initiate, start and stop commands to the pumps. All floats shall be interposed with intrinsically safe UL. Listed relays installed per NEC Article 504, ANSIIISARP12.6 and all other applicable codes.

4. Pump Sequence: A total of 4 mercury level sensors shall be provided with sufficient length cord to run between the sensors and the junction box unspliced. The 4 levels shall act as:

LEVEL 4 - High Level Alarm
LEVEL 3 - Start Lag Pump; both pumps running
LEVEL 2 - Start Lead Pump; shall alternate on each call LEVEL 1 - Off; all pumps stop

5. Utility Power: Utility power to the panel shall be 480 volts, 3 phase, 60hz. It is the responsibility of the contractor to bring~
the necessary utility power to the pump station site.

6 Wet Well: The wet well is classified as a Class I, Division 1, Group D hazardous location as per NFPA Article *B20* recommendation.

B. CONTROL PANEL ENCLOSURE

1. General: A UL Listed and NEMA Type 4X enclosure properly sized to contain the required components shall be used. The enclosure shall be constructed of 14 GA stainless steel body and door(s) with continuous stainless steel piano hinge. A dripshield shall be welded on the top of the enclosure; screws to secure the dripshield shall not be allowed. Welded on mounting feet shall be provided; they shall be oversized to readily accommodate

mounting the
panel on 1 5/B-inch strut. All hardware shall be corrosion resistant. A 3-point latch with nylon rollers and padlock provisions on handle shall be provided. Oil-resistant door gasketing around all 4 sides of opening shall be applied. A painted white enamel steel mounting panel shall be provided for mounting of components. All hardware shall be corrosion resistant. Voltage identification labels and comprehensive warning labels shall be provided. To maintain the environmental rating of the specified equipment and enclosure, install in the openings only certified or recognized devices with the same integrity as the enclosure, in compliance with the installation instructions of the device. The enclosure with the installed inner swing door shall be NEMA Type 4X and UL Type 4X. The enclosure shall be designed specifically for municipal wastewater applications.

2 Enclosure Accessories: The enclosure shall also provide for and
Include the following mechanical and electrical facilities:

(a) Inner Swing Panel: Provision of a "dead front" feature shall
Be provided using a full size hinged inner door to mount all operator devices. Material shall be 0.125-inch aluminum with turned down flanges on all 4 sides for added rigidity. The inner door and components shall have a "dead back" feature in order to avoid accidental shock hazard. The inner door shall be large enough to fill the entire opening of the enclosure. The screws used to secure the inner swing door mounting hardware to the enclosure shall be UL and NEMA Type 4X rated/listed and shall not violate the environmental integrity of the enclosure. Mounting hardware which penetrates the enclosure and violates the environmental
rating of the enclosure shall not be allowed. All hardware shall be corrosion resistant. Quarter-turn latches shall be provided for securing the inner door in the closed position; captive screws are not acceptable. In addition, an inner door handle shall be provided for operator convenience.

(b) Condensation Heater: A 100 watt (minimum), 120 VAC
heater shall be provided to protect the enclosure from the harmful effects of condensation corrosion and low temperatures. The heater shall be complete with an adjustable thermostat. Branch protection shall be provided.

(c) Work Light: A 12-inch fluorescent work light with a safety
lens shall be mounted inside the top of the control panel without penetrating the panel outer skin with screws or fasteners. The light shall be operated with an on/off switch mounted on the inner door.

C. HIGH VOLTAGE SECTION

1. Main Lug Only: A power distribution block sized for the incoming power conductors shall be provided for the main power connection. A separate fused service entrance disconnect switch shall be provided and installed by the contractor. The disconnect switch shall be have padlock provisions.

2. Individual Branch Disconnect and Short Circuit Protection: Each pump motor shall be provided with a combination circuit breaker motor starter. Circuit breakers shall be thermal magnetic, "E" frame or better and rated for 14,000 AIC at 480 VAC. Starters shall be NEMA rated. Starters smaller than Size 1 and half sizes will not be allowed. Coils and contacts shall be replaceable without removing the motor starter from the enclosure. Overloads shall be ambient compensated, quick trip (Class 10) type. Overload reset operators shall be provided to reset the overloads without opening the enclosure door.

3. Power Distribution System: Associated with this installation will require the individual branch disconnect and short circuit protection to have a UL interrupting rating of 14 kA at 460 VAC.

4. Control Power: The 120 V AC, single-phase power shall be derived from a properly sized transformer.

   (a) Control power shall have an over current protection device suitable interrupting requirements of the system. Fused disconnect shall be provided in accordance with NEC and the system requirements.

5. Lightning Arrester: The system shall be protected by a lightning arrester for the electrical service and shall be capable of handling up to 600vac. It shall be parallel MOV design and provide protection for Category C Transient Surges as defined in ANS/IEEE C62.41 without degradation of components. The arrester shall provide protection between each phase line and the ground line. The arrester shall be UL listed as a secondary surge arrester, UL category OWHX. The enclosure shall be molded UV resistant polycarbonate or equal material. All electrical connectors shall be sealed in a UL component recognized epoxy to exclude moisture, dirt and corrosion. A 1/2-inch conduit nipple and lock nut shall be provided. Leads shall be color-coded and a minimum of 18 inches long. It shall be provided loose for mounting on the exterior of the utility service entrance disconnect by the installing contractor.

6. Ground Lugs: Ground lugs shall be provided for both incoming service and for each

motor.

7. Three-Phase Power Monitor: A.UL recognized 3-phase power monitor shall interrupt the control power in the event of phase loss, phase reversal, low voltage and phase unbalance. It shall have primary fuse protection. Contacts shall be rated for 15A resistive at 120 V AC. The 3-phase power monitor shall automatically reset when proper power is re-applied.

8. Components: Operator control devices shall be 22mm, NEMA and UL listed for Types 1, 12, 3R, 4 and 4X. Contact blocks shall be self-wiping and color- coded bridge type rated at 10A and must have a rated insulation of 600V. Terminal connections shall be suitable for two 14 AWG control wires. All control and time delay relays shall be DPDT rated 10A @ 120 VAC, 8-pin socket mount type. Sockets shall have pressure plate terminals that accept two 14 AWG wires and shall be rated a minimum of 300V. All terminal blocks supplied shall be box lug type rated at the proper voltage/amperage and shall accept two 14 AWG wires.

D. CONTROL SECTION

General: All control wiring shall be minimum 16 AWG, MTW and shall be color-coded in accordance with all applicable codes and laws. Spiral wrap, tie wrap, fasteners and wire duct shall be provided as required for aesthetics and safety.

All components mounted on the door shall be wired with insulated connectors (where "finger proof' terminals are not provided) to prevent accidental shock hazards. All components on the back panel shall be mounted on DIN rail or fastened via drilled and tapped screws to facilitate easy component replacement. Pop rivets shall not be allowed. Ammeter loops shall be provided between the disconnect switch and combination starter for better heat dissipation and an easy means of meter reading.

Self-adhesive Brady BMX-C + System vinyl cloth printed adhesive wire markers shall be supplied at both ends of every wire. All components on the back panel shall be identified by a Brady BMXC + System metallized polyester printed adhesive label. Dymo labels are not acceptable. These labels shall include all pertinent data applicable to ratings and sizes. Components on the door of the enclosure shall be identified with custom engraved plastic legend plates. Voltage identification labels and comprehensive warning labels shall also be provided.

2. Alternating Relay: An 8-pin socket mount DPDT alternating relay shall alternate each pump on

each successive start command. It shall be complete with LED indicating lights showing the status of the internal relay and a lead selector toggle switch which will allow the alternation to be canceled and omit a disabled pump. Contact~ shall be rated 1 OA at 120V AC.

3. Mode Select: Method of operation shall be by a 3-position green illuminated maintained "Hand-Off-Auto" selector switch for each pump which shall provide for mode selection and run indication.

4. Pump Thermal Trip and Seal Leak Detection: A temperature monitoring relay shall be supplied for all pumps. One relay shall b, provided for each pump. The relay shall monitor the stator temperature of the pump motor. Over temperature shall be detected by a normally closed low temperature switch mounted on the stator. An over temperature condition will cause immediate shutdown and the pump(s) shall remain locked out until manually reset. The over temperature function shall incorporate a relay that retains its position during power failures. LED's located on the relay shall indicate thermal trip.

   Seal leakage detection shall be provided for all submersible pumps. Seal leakage shall be detected by a resistive float switch in the seal cavity. Detection of a seal leak occurring within the motor chamber shall not shutdown or lockout the pump. LED's located O these relays shall indicate a seal leak condition.

   An over temperature pilot light and a seal failure pilot light shall be provided on the inner door for each pump.

5. Elapsed Time Meters(s): A 6-digit non-resettable type hour meter shall be provided for each pump to record hours of operation. These shall be wired with insulated connectors to prevent accidental shock hazards.

6. Intrinsically Safe Relay(s): ISR relays will be provided per Article 504 of the N.E.C. and ANSI/ISA-RP12.6. These relays shall be interfaced with each float switch. Intrinsically safe relays shall be UL 913 listed and shall be 8-pin socket mount style.

7. Convenience Outlet: A 15A GFI duplex outlet shall be provided. II shall be mounted on the inner swing door. A dedicated 15A circuit breaker shall be provided for this outlet.

8. Start Delay: A time delay relay shall be provided to delay the star of the lag pump. This relay shall be adjustable from 1 to 10 seconds and shall be an 8-pin socket mount type with contact ratings as previously specified.

9. Alarms: A weatherproof red flashing incandescent alarm light and a horn rated 90dS at ten feet

shall be provided to indicate a high level alarm condition. Alarm power shall be derived from the 120V control power and battery backup. They shall be mounted on the exterior of the pump control panel or fiberglass pump cover and shall be UL recognized for NEMA 4 to maintain the environmental rating of the enclosure. The alarm shall be activated by the level four mercury level sensor (high water sensor) or a power failure.

10. Dialer: An automatic phone dialer shall be provided and placed inside the control panel. The dialer shall be a solid state component capable of dialing from 1 to 8 phone numbers, each up to 30 digits in length. Unit shall have battery backup and be capable of utilizing standard pulse dialing or Touch Tone DTMF. If the control power fails, the dialer shall internally generate and automatically annunciate a power failure alarm. Unit shall be capable of being configured locally or remotely from a standard touch-tone phone.

A pump failure alarm shall occur if a pump is called and the motor starter does not energize within 5 seconds. A pump failure alarm shall also occur if the pump is operating and the motor starter de-energizes for any reason other than as required by the automatic level control. The pump failure timer shall be factory adjustable in one-second increments.

Acceptable manufactures are Microtel "D IALSTAT", Sensaphone model 1108 or approved equal.

(a) Phone Line: The dialer is to operate on a standard rotary pulse or Touch Tone "dial-up" phone line and is to be F.C.C. approved. A regular private line is to be provided by the contractor. Connection to the telephone is through an industry standard 4-pin modular jack (RJ-11).

(b) Power: Dialer shall be powered by a dedicated 15-amp circuit. Dialer shall have battery backup.

(c) Alarm Channels

(1) A minimum of 4 alarm channels is required
(2) Channel 1 shall indicate pump #1 failure
(3) Channel 2 shall indicate pump #2 failure
(4) Channel 3 shall indicate high wet well level
(5) Channel 4 - Spare or pump 3 fail if needed

E. CONTROL PANEL ACCESSORIES

1. Junction Box: A UL Listed NEMA Type 4X, Explosion Proof enclosure shall be provided for

connection of the floats and pumps. It shall contain tubular screw type terminal blocks for floats, pump power and control leads. In addition, it shall have intrinsically safe circuit provisions per NEC Article 504 and ANSI/ISA-RP12.6 and be provided complete with heavy wall fittings and sealing compound. This will be supplied mounted to the Mounting Rack and wired to the pump control panel. The appropriate seal packing and compound shall be provided loose for the installing contractor. The conduits between the pump control panel and the junction box and the wet well and junction box shall be sealed by the installing contractor AFTER start-up tests have been completed. The installing contractor must seal the conduit between the junction box and the wet well with a removable mechanical duct seal.

2. Transfer Switch: Pump stations that are not equipped with back up generators shall be provided with a thermal magnetic normal power main circuit breaker and emergency power main circuit breaker for transferring power between the utility and the portable generator. The 2 circuit breakers shall be mechanically interlocked to prevent both breakers from being in the "ON" position at the same time. The normal power circuit breaker shall be sized according to system load per the NEC. Generator size, generator receptacle size and system load shall be considered when sizing the emergency power main circuit breaker. Both circuit breakers shall be rated for a minimum of 10,000 AIC at 240 VAC or 14,000 AIC at 480 VAC.

   Pump stations equipped back up generators shall be provided with an automatic transfer switch to switch from utility power to generator power. The switch shall be properly sized for the load served as dictated by NEC and the manufacturer. The switch shall be certified to meet the latest adopted transfer switch standards as defined by UL Acceptable manufacturers are ASCO, Zenith, Russ Electric or approved equal.

3. Generator Receptacle: A generator receptacle shall be mounted on the side of the control panel. It shall have male contacts and include the required poles to properly interface with the generator system voltage requirements. The generator receptacle shall be suitable for connections in an outdoor environment. The generator receptacle shall be a model CROU ARE6425 RCPT ASSEM-S22 as manufactured by Crouse-Hinds.

7.2 THREE-PHASE MOTORS

All pumps shall utilize be 3-phase motors. Single-phase motors shall not be acceptable. Pump stations shall be served by utility supplied 3-phase power. The use of single phase power and a phase converter will only be considered when the cost of having 3-phase power brought to the pump station exceeds twice the cost of single phase power and a phase converter. If a phase converter is to be used, submitted plans shall detail the converter installation. All phase converter installations shall meet the following requirements:

A. Only converters using a static phase shift method of conversion will be acceptable. Rotary-type converters are unacceptable.

B. All wiring ahead of the 3-phase panel shall be protected with single phase fusing sized to meet the total single phase amperage; conductors shall be sized based on single phase amperage and fusing.

C. Converters shall be sized to operate the total installed pump station amperage with all pumps running.

D. The converter shall be a Ronk "Add-a-phase", manufactured by Ronk Electrical Industries, Inc. (or approved equal). The converter shall be housed in a locking NEMA-3R rain-tight stainless steel enclosure.

7.3 STATION INTERIOR WIRING

The following electrical requirements shall be followed for wiring installed in the station interior:

A. All pump power, control leads and level control float leads shall be hung with stainless steel grips from the bracket supplied by the pump manufacturer. The bracket shall be bolted to the inside of the wet pit hatch frame or firmly bolted to the concrete immediately below the hatch frame, immediately below the hatch cover. The bracket shall be located so as not to interfere with the pump chamber entrance steps. All wires shall be neatly passed from the bracket to the raceway.

B. Passage of the pump and float wires from the pump chamber to the junction box shall be made through a length of conduit installed between the junction box and pump chamber. The power lead for each pump shall be placed in separate conduit. All of the float leads shall be placed in one conduit.

C. There shall be no electrical connections made in the pump chamber. All wiring shall run unbroken from the pump chamber to the junction box through the conduit and spliced inside of the junction box.

7.4 FIELD WIRING SPECIFICATIONS

Control panel wiring shall be as follows:

A. All wiring installed on the line and load side of the electric meter shall be THHN copper wire.

B. Electric service to the station shall be sized to provide the maximum total station amperage with all installed pumps running under a fully loaded condition.

C. All pump station control panels shall be provided with a minimum 100amp service.

7.5 CONDUIT SPECIFICATIONS

A. All conduit installed between the pump chamber to the junction box shall be 2-1/2-inch diameter (minimum).

B. A separate conduit shall be provided for the power leads of each pump.
One conduit shall be provided for the float leads.

C. All conduit running to or from the control panel, should be run underground at a minimum depth of 30 inches below finished grade.

D. All below ground conduit shall be PVC schedule 80 conduit.

E. Conduit installed above grade may be PVC schedule 80 or stainless steel conduit. Galvanized steel conduit will not be acceptable.

7.6 MOUNTING RACK

The station pump control panel and junction box shall be mounted on one prefabricated stainless steel structure. The panel shall be placed as follows:

A. The structure shall be firmly anchored to the top of the pump chamber as shown in the Standard Details. The structure shall be anchored with six 3/8-inch stainless steel Wej-It type stud anchors. Anchor holes shall be drilled to the manufacturer's recommended depth. Anchors shall be Hilti Quick Bolt Two or approved equal.

7.7 EMERGENCY GENERATOR

A. Pump stations with pumps equal to or greater than 20 hp shall be equipped with a complete and operable emergency/standby electric generating system. The equipment shall be new, factory tested, and delivered ready for installation. The packaged engine generating system shall include, but not limited to, diesel engine, generator, main circuit breaker, controls, fuel tank, exhaust piping, exhaust silencer, batteries, battery charger and other miscellaneous items needed to provide a complete operational system that is capable of automatic start-stop operation. The generator shall be sized so that all the pumps and appurtenances contained in the pump station can run simultaneously.

B. Acceptable manufacturers are Caterpillar or approved equal.

8.0 FENCING

8.1 GENERAL

A galvanized chain-link fence surrounding the pump station site shall be provided as specified herein and as shown on the standard details. The fence shall be 7 feet high (minimum) with a 12-foot wide double-leaf gate.

Fencing shall be located so that:

A. There is a 10-foot space between all pump station equipment (control panel, pump vault, valve vault, emergency storage, emergency generator, etc) and the fence perimeter.

B. The access gate shall be located so that service vehicles have a direct and unobstructed path to the valve vault and pump chamber. Access gate shall not be placed over a manhole.

8.2 MATERIAL SPECIFICATIONS

A. Chain Link Fabric

1. Chain-link fabric shall be a 2-inch mesh woven from No.9 gauge aluminum-coated steel or aluminum-zinc alloy-coated steel conforming to ASTM A491 or A783. The fabric shall have a height of 72 inches, 20-1/2 diamond count, with the bottom selvage twisted and the top selvage knuckled. Aluminum-coated steel fabric shall be given a clear organic coating after fabrication. Aluminum zinc alloy coating on the steel fabric shall be not less than 0.47 ounce per square foot of uncoated wire surface.

B. Fence Framework

1. General: Galvanized steel, ASTM F1083 or ASTM A123, with not less than 1.8 ounces of zinc per square foot of surface, or steel conforming to ASTM A569 externally triple-coated with hot-dip galvanizing at 1.0 ounce per square foot,

chromatic conversion coating and clear acrylic polyurethane and coated internally with zinc-rich coating.

2. Fittings and Accessories: Unless otherwise noted, all fence fittings and accessories shall be galvanized according to ASTM A 153, with zinc weights per Table I.

3. Gate Posts: 2.875 inches O.O. at 5.79 pounds per foot.

4. End, Corner, Angle or Pull Post: 2.375 inches O.O. at 3.65 pounds per foot.

5. Line Post and Gate Frame: 1.9 inches O.O. at 2.72 pounds per foot.

. 6. Top Rail: 1.66 inches O.O. at 2.27 pounds per foot.

7. Braces:

(a) HORIZONTAL BRACE: 1.66 inches O.O. at 2.27 pounds per foot.

(b) DIAGONAL BRACE: 3/8-inch diameter rod equipped with adjustable tightener

C. Fasteners

The chain-link fabric shall be securely fastened to all terminal posts by a 1/4" x 3/4" tension bars with heavy 11-gauge pressed steel bands at 14inch maximum spacing, to line posts with 9-gauge wire clips at 14-inch maximum spacing, to the top rail with 9-gauge tie wires at 24-inch maximum spacing and to the bottom tension wire using 11-gauge galvanized hog rings at a 24-inch maximum spacing.

D. Barbed Wire and Supporting Arms

1. Barbed Wire: Barbed wire shall consist of 2 strands of 2wire aluminum-coated steel conforming to ASTM A585-81, Type I (with barbs spaced on 5-inch centers).

2. Supporting Arms:

(a) One supporting arm shall be placed on each line and pull post.

(b) Single arm at 45 degrees with vertical, sloping to outside of fence.

(c) Integral with post top and designed as a weather-tight closure cap.

(d) Constructed for attaching 2 rows of barbed wire to each arm.

(e) Designed for 200-pound minimum pull-down load.

(f) Malleable iron or pressed steel.

E. Bottom Tension Wire:

The bottom tension wire shall be a NO.7 gauge aluminum-coated steel conforming to ASTM A824, Type I. The tension wire shall be placed at the bottom of the chain-link fabric and stretched tight with galvanized turnbuckles.

F. Post Tops:

The post tops shall be designed as a weather-tight closure cap for the tubular posts.

G. Gates:

1. Framing:

(a) Frames shall be assembled by welding or watertight galvanized steel rigid fittings.

(b) Provide with the same chain-link fabric as for fence. Install fabric with stretcher bars at vertical and top and bottom edges.

(c) Provide a diagonal brace on each gate leaf to ensure frame rigidity without sag or twist.

2. Hardware:

(a) Hinges of pressed or forged steel, or malleable iron, nonlift-off type, offset to permit 180 degree gate opening, 3 per leaf.

(b) Plunger-bar type latch with flush-type gate stop shall be provided. Latch bar shall extend to full gate height and be designed to easily engage gate stop.

(c) Locking device and padlock eyes shall be an integral part of the latch.

(d) An automatically engaging gatekeeper shall be provided for each gate leaf which shall secure the free end of the gate in the open position.

H. Protective Electrical Ground

Continuous fence shall be grounded at each corner post and at intervals not exceeding 500 feet, as per the Standard Details.

I. Pump Station Sign

Each pump station shall be provided a sign in accordance with the Standard Details. The sign shall be securely fastened to the chain-link fence at a location clearly visible from the pump station access road and approved by the City.

8.3 INSTALLATION

A. FENCE

1. Follow general contour of ground and properly align.

2. Posts

a Set in concrete bases as indicated on Standard Details.

b. Temporarily brace until concrete base has set.

c. Install plumb and in straight alignment.

d. Install pull posts every 300 feet if no corner posts are encountered in that distance.

e. Install pull posts at changes in direction of 10 degrees to 30 degrees.

f. Install corner posts at changes in direction of 30 degrees or more.

g. Install pull posts at all abrupt changes in grade.

3. Post Bracing:

a Install braces for each end, pull and ate post and each side of each corner post.

b. Install after concrete has set.

c. Install so posts are plumb and in straight alignment when diagonal brace is under tension.

4. Tension Wire:

(a) Weave through the fabric and tie to each post with a minimum 9-gauge galvanized wire.

5. Chain-Link Fabric:

(a) Stretch taut with equal tension and each side of posts.

6. Stretcher Bars:

(a) Install at each pull, end and gate post and on each side of corner posts.

7. Barbed Wire:

(a) Attach 2 rows to each barbed wire supporting arm. Pull win taut and fasten securely to each arm.

(b) Install 2 rows above the fabric and on extended gate end members of swing gates.

8. Fasteners:

(a) Install nuts for tension bands and hardware bolts on inside face of the fence and peen ends of bolts or score threads t(prevent removal of nuts.

B. Gates

1. Install plumb and level.

2. Install all hardware, framing, supports, and appurtenances as required for gate.

3. Install keepers, ground-set items, and flush plate in concrete for anchorage as shown on Standard Details.

4. Adjust and lubricate as necessary for smooth operation.

C. Repairing Damaged Coatings

1. All damaged coatings shall be repaired in the shop or field by recoating with compatible and similar coating as per manufacturer's recommendations.

9.0 PAVING

9.1 STATION AREA

The entire area inside the pump station fence shall be paved with crushed aggregate on a 4-mil polyethylene sheeting placed over the entire enclosed area. This sheeting will have one-inch diameter perforations spaced not more than 2 feet in each direction. Prior to placing the aggregate, the ground surface shall be sloped so as to permit surface water to drain away from the station. The crushed aggregate pavement for the station area shall be in accordance to Section 9.3 of this specification.

9.2 STATION ACCESS ROAD

Any pump station located farther than 7 feet from the center of the pump chamber to the edge of a public street or road shall have a 12-foot wide paved access road provided to the station. The access road shall:

A. Be designed to limit the access road grade to a 12% maximum.

B. The access road will be required to have a turn around area as shown or the Standard Details when at least one of the following apply:

1. The access road exceeds 75 feet in length.

2. The access road exceeds a 3% grade.

3. The access road does not travel to the pump station in a straight line.

4. Access Road shall be constructed as per the Standard Details.

9.3 AGGREGATE

The pump station access road and the entire area inside the pump station fence shall be paved with 8 inches of crushed aggregate placed in 2 layers. The bottom 5 inches shall be 2 1/2-inch surface rock, as specified below. The top 3 inches shall be one-inch surface rock. The aggregate shall be composed of durable particles of rock and percentage of deleterious substances shall not exceed 12%. The aggregate shall comply with the following requirements:

Kind of Material	Percent Passing				
	Sieve Sizes				
	2 1/2"	2"	1"	3/8"	#10
1" surface			100%	65% max	5-25%
2 1/2 " Surface	90-100%	80-100%	20-55%		

1 0.0 INSPECTION/ACCEPTANCE PROCEDURES

10.1 Before final approval of or acceptance of any pump station by the City, there shall be field inspections made by the City's representative. The field inspections shall show that the pump station is fully operable and all necessary appurtenances have installed and constructed in accordance with the plans, designs and specifications approved by the Public Works Department before the start of the construction.

If requested by the City, representatives from the pumping equipment manufacturer and the installing electrical contractor shall be present at the pump station site for final inspection.

Upon completion and prior to acceptance of the installation, the contractor shall subject all the pumping equipment to operating tests as outlined in section 10.4 of this specification to demonstrate satisfactory performance of the equipment. I tests do not demonstrate satisfactory performance of the equipment, deficiencies shall be corrected and equipment shall be retested.

Since sufficient wastewater to test the pump may not be available when the water test is scheduled, the contractor shall arrange to obtain water, at the contractor's own expense, from the public water supply for the test. The minimum quantity of water to be pumped for the test is equivalent to 1.5 minute~ of continuous pumping at rated pump capacity for each pump operating alone. Each pump shall be tested a minimum of 2 times.

10.2 FINAL INSPECTION

The final inspection shall be arranged through the Public Works Department, Engineering Division. Pump stations shall only be considered as acceptable for operation and/or maintenance by the City upon written confirmation by the Public Works Department, Engineering Division.

10.3 FINAL GRADING AND SEEDING

All ground surrounding the pump station must be graded, seeded as per the Section 520 of the Sanitary Sewer Specifications and Standards for the City. Final acceptance of the pump station will not be given until this an effective erosion control has been demonstrated.

10.4 SITE TESTING

All pump station equipment shall be tested at start-up. At a minimum each pump started with the voltage, current and other significant parameters being recorded. The manufacturer shall provide a formal test procedure and forms for
recording data. The pump tests shall be performed by the contractor in the presence of City representatives. The City reserves the right to require representatives from the pumping equipment manufacturers to be present for these tests. The recorded data shall be submitted to the Public Works Department, Engineering Division in conjunction with the as-built electrical schematics before the pump station inspection is called for.

10.5 CONSTRUCTION, OPERATION AND MAINTENANCE

It is the responsibility of the developer to construct the pump station according to the approved construction plans. When the pump station has received construction approval and all operation manuals, specification literature, and electrical diagrams have been received, the pump station and related appurtenances will be accepted by the City for operation and maintenance.

10.6 WARRANTY

In addition to the equipment manufacturer's general warranties, the contractor shall warrant the pump station and related appurtenances to be free from defects in materials and workmanship for a period of not less than one year from the date of the City's final written acceptance of said pump station.

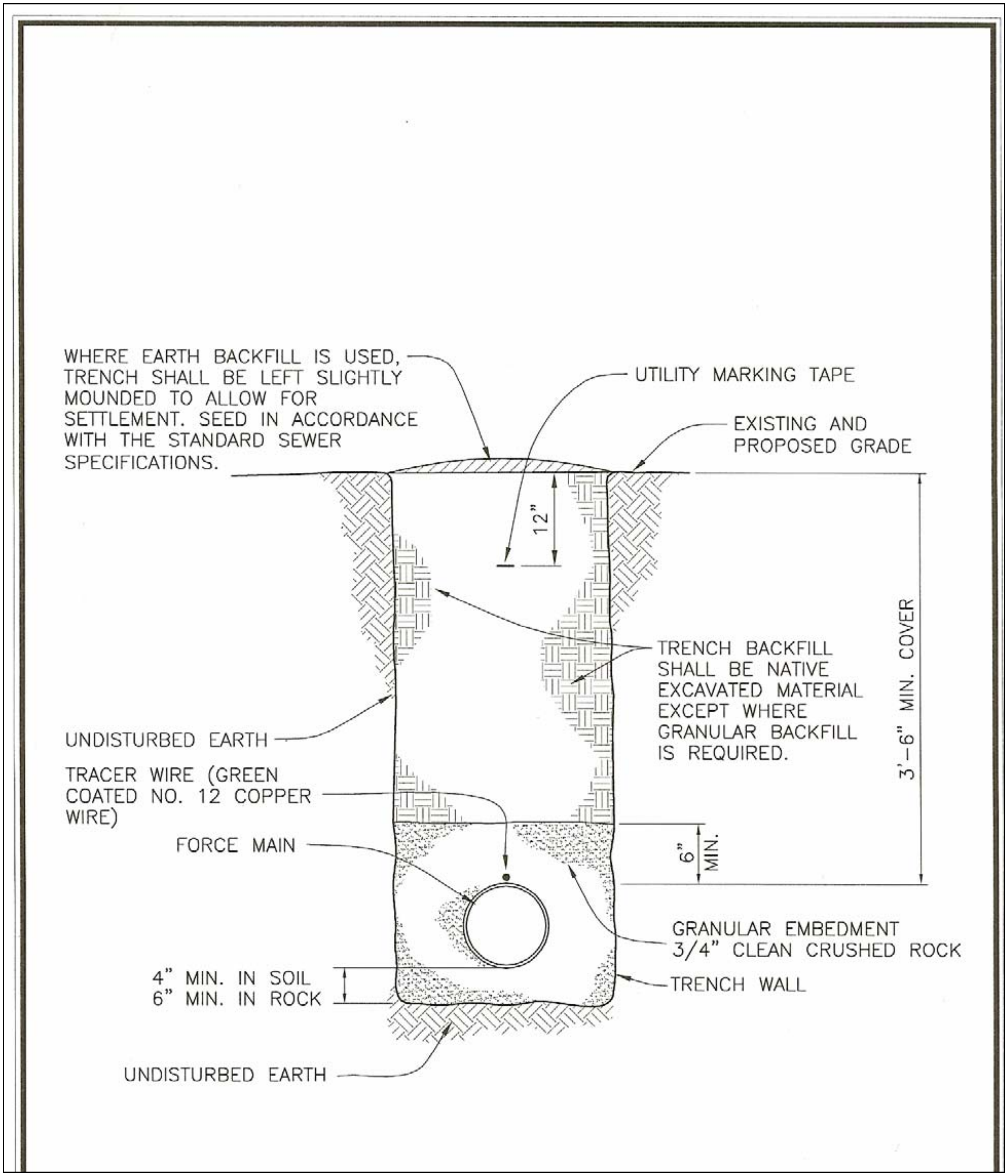
10.7 FINAL ACCEPTANCE

The following documentation must be submitted to the Public Works Department, Engineering Division before a final inspection will be scheduled:

- Four (4) sets of as-built wiring and piping schematics of the pump station site and any station access areas.
- Four (4) sets of operation and maintenance manuals.
- Warranty documents.

The City will not issue a written letter of acceptance or maintenance responsibility until such time that all of the above documentation has been preformed.

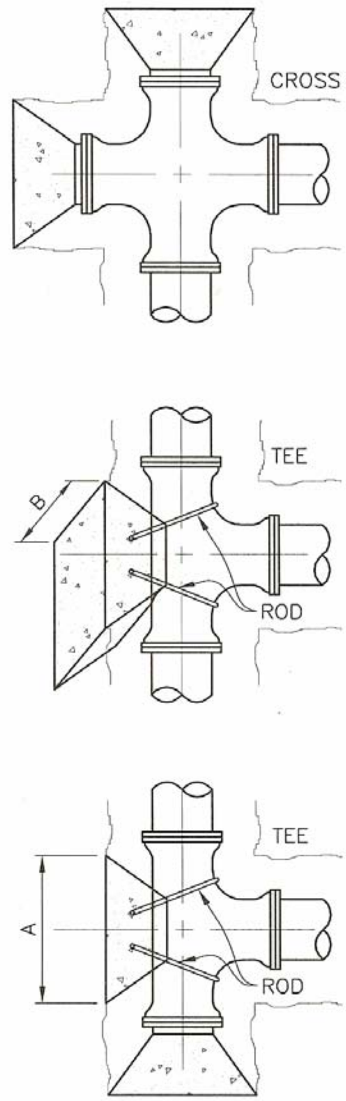
TYPICAL DRAWINGS AND DETAILS



FORCEMAIN INSTALLATION

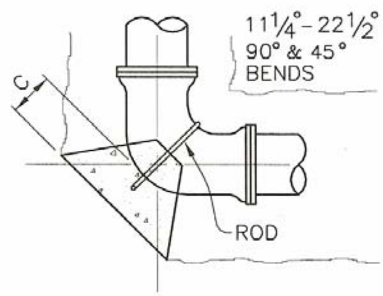
TABLE A

BEND		SIZE				
		4"& 6"	8"	10"	12"	16"
TEE OR PLUG	A	1'–8"	3'–2"	3'–6"	4'–2"	5'–5"
	B	1'–2"	1'–4"	1'–6"	1'–0"	2'–6"
	C	8"	9"	10"	1'–10"	1'–2"
11¼°	A	6"	7"	8"	8"	1'–3"
	B	1'–2"	1'–4"	1'–6"	1'–8"	2'–0"
	C	7"	8"	8"	8"	9"
22½°	A	8"	1'–4"	1'–5"	1'–10"	2'–8"
	B	1'–2"	1'–4"	1'–6"	1'–8"	2'–0"
	C	8"	9"	10"	11"	1'–2"
45°	A	1'–3"	2'–3"	2'–8"	3'–2"	4'–1"
	B	1'–2"	1'–4"	1'–6"	1'–10"	2'–6"
	C	8"	9"	10"	11"	1'–2"
90°	A	2'–3"	3'–7"	5'–0"	5'–10"	7'–7"
	B	1'–2"	1'–4"	1'–6"	1'–10"	2'–6"
	C	8"	9"	10"	1'–0"	1'–2"



NOTES:

1. ALL B&C DIMENSIONS TO BE AS REQUIRED TO REACH UNDISTURBED EARTH BUT NOT LESS THAN LISTED ON THRUST BLOCK TABLE.
2. CAST–IN–PLACE CONCRETE SHALL BE IN ACCORDANCE WITH THE "CITY OF COLUMBIA STREET AND STORM DRAINAGE SPECIFICATIONS AND STANDARDS," SECTION 250 CONCRETE STRUCTURES.
3. DIMENSIONS A, B, C, APPLY TO ALL BEND CONDITIONS SHOWN.
4. INSTALL PLUGS AT ALL RUNS OR BRANCHES DISCONTINUED FOR FUTURE SERVICES.
5. ALL BENDS, TEES, PLUGS, FITTINGS OR OTHER SIGNIFICANT CHANGES SHALL BE BRACED WITH POURED CONCRETE THRUST BLOCK AS SHOWN ON THIS DETAIL.
6. ALL PLUGS SHALL BE SEPARATED FROM THE CONCRETE THRUST BLOCK BY A 5 MIL LAYER OF PLASTIC SHEETING.



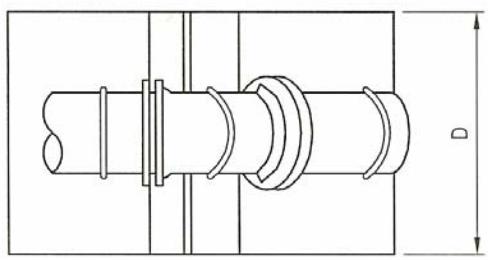
FOR HORIZONTAL ALIGNMENT

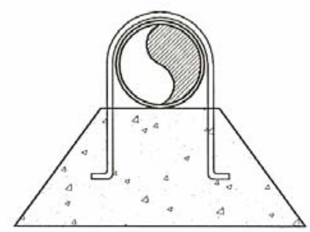
HORIZONTAL THRUST BLOCK

BEND		SIZE 4"& 6"	8"	10"	12"	16"
11¼°	D	1'-6"	1'-9"	2'-0"	3'-0"	3'-6"
	E	1'-3"	1'-6"	1'-9"	2'-0"	2'-3"
	F	2'-0"	2'-6"	2'-9"	3'-0"	4'-0"
22½°	D	2'-0"	3'-4"	3'-8"	4'-0"	4'-4"
	E	1'-9"	2'-3"	2'-6"	2'-6"	2'-6"
	F	2'-6"	2'-8"	3'-10"	4'-0"	5'-6"
45°	D	2'-6"	3'-0"	4'-0"	4'-6"	5'-2"
	E	2'-6"	2'-9"	3'-0"	3'-6"	4'-0"
	F	3'-0"	4'-0"	4'-6"	4'-9"	6'-6"

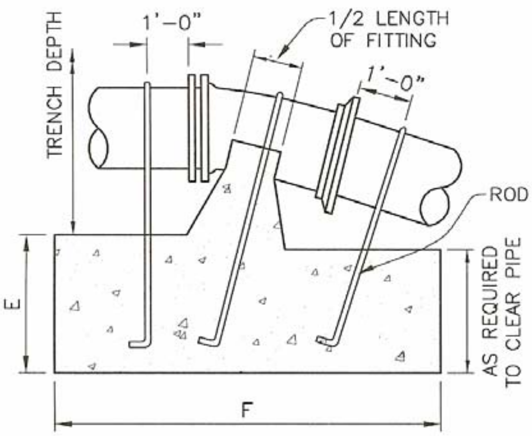
PIPE SIZE	ROD SIZE (IN) 45°	22½°	11¼°	NO. REQ'D.
4"& 6"	½	½	½	3
8"	½	½	½	3
10"	¾	¾	¾	3
12"	¾	¾	¾	3
16"	¾	¾	¾	3

THIS TABLE APPLIES TO VERTICAL & HORIZONTAL THRUST BLOCKS.





ROD DETAIL

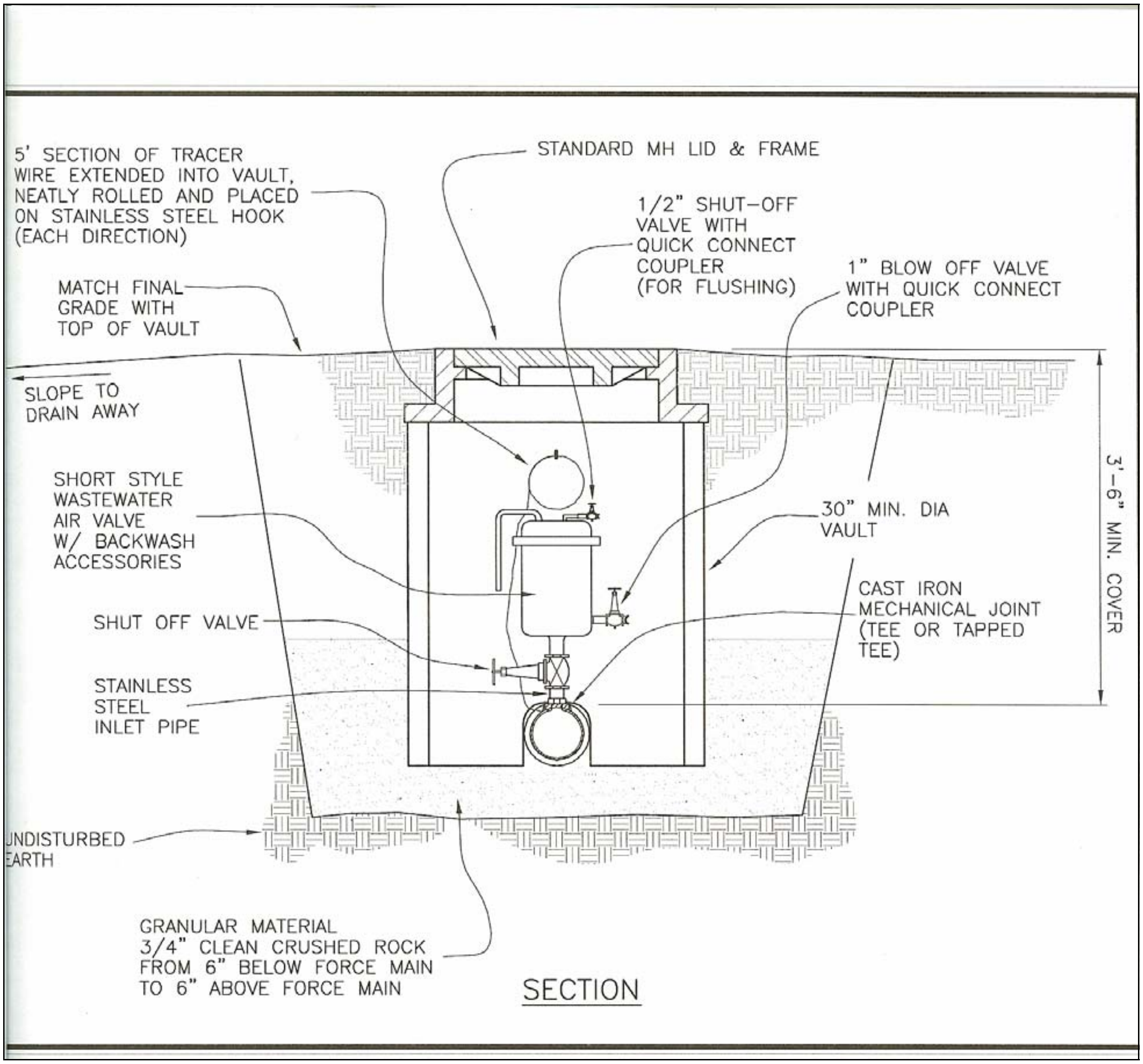


NOTES:

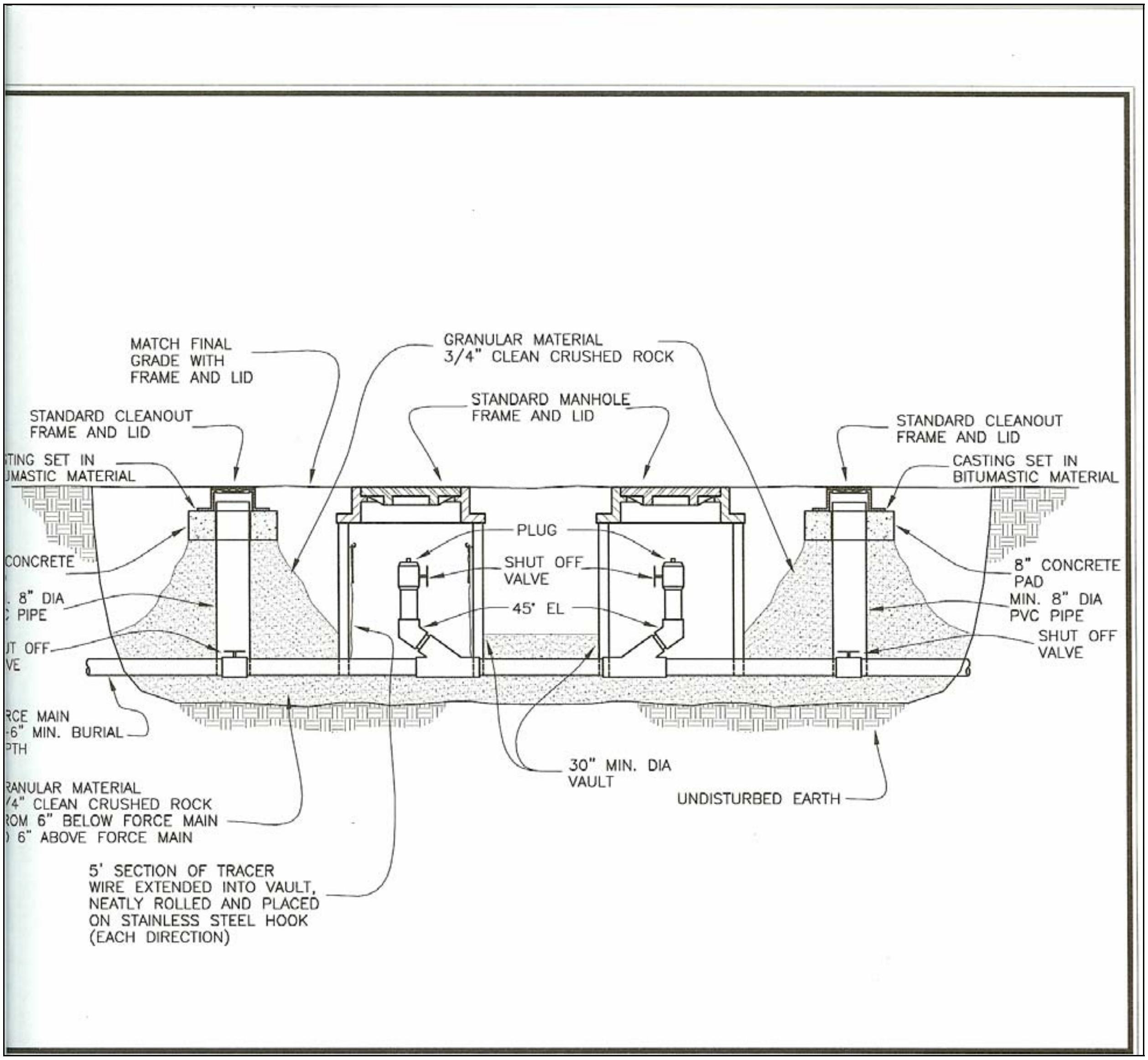
1. ALL POURED CONCRETE SHALL BE LAID ON UNDISTURBED EARTH AFTER EXCAVATION ACCORDING TO DIMENSIONS INDICATED ON THRUST BLOCK DIMENSION TABLE OR IT SHALL BE LAID THE FULL WIDTH OF TRENCH FROM UNDISTURBED WALL BUT NOT LESS THAN LISTED ON THRUST BLOCK TABLE.
2. ALL POURED CONCRETE SHALL BE IN ACCORDANCE WITH "CITY OF COLUMBIA STREET & STORM DRAINAGE SPECIFICATIONS & STANDARDS", SECTION 250 CONCRETE STRUCTURES.
3. ALL RODS TO BE 316 OR 304 STAINLESS STEEL.

FOR VERTICAL ALIGNMENT

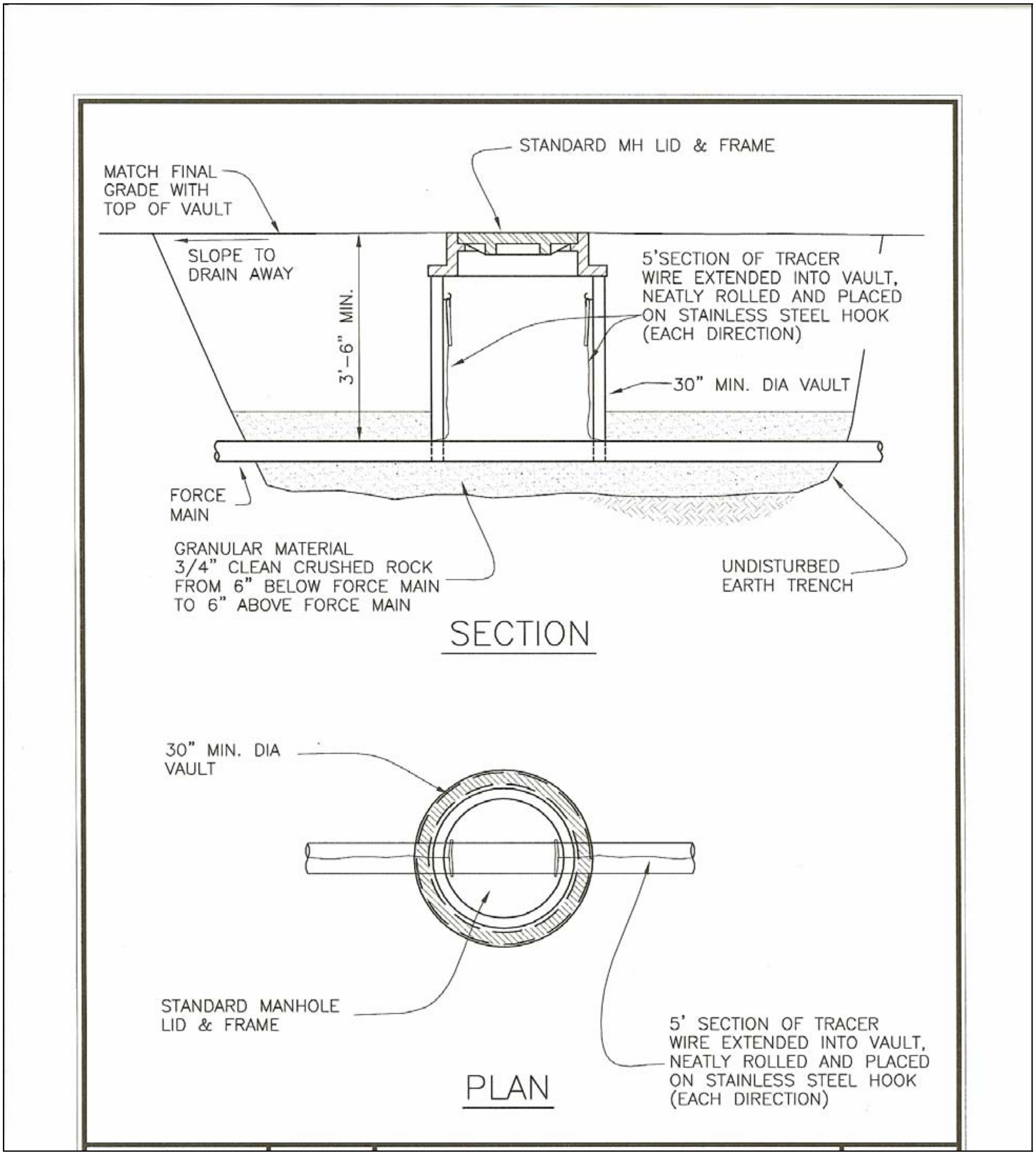
VERTICAL THRUST BLOCK



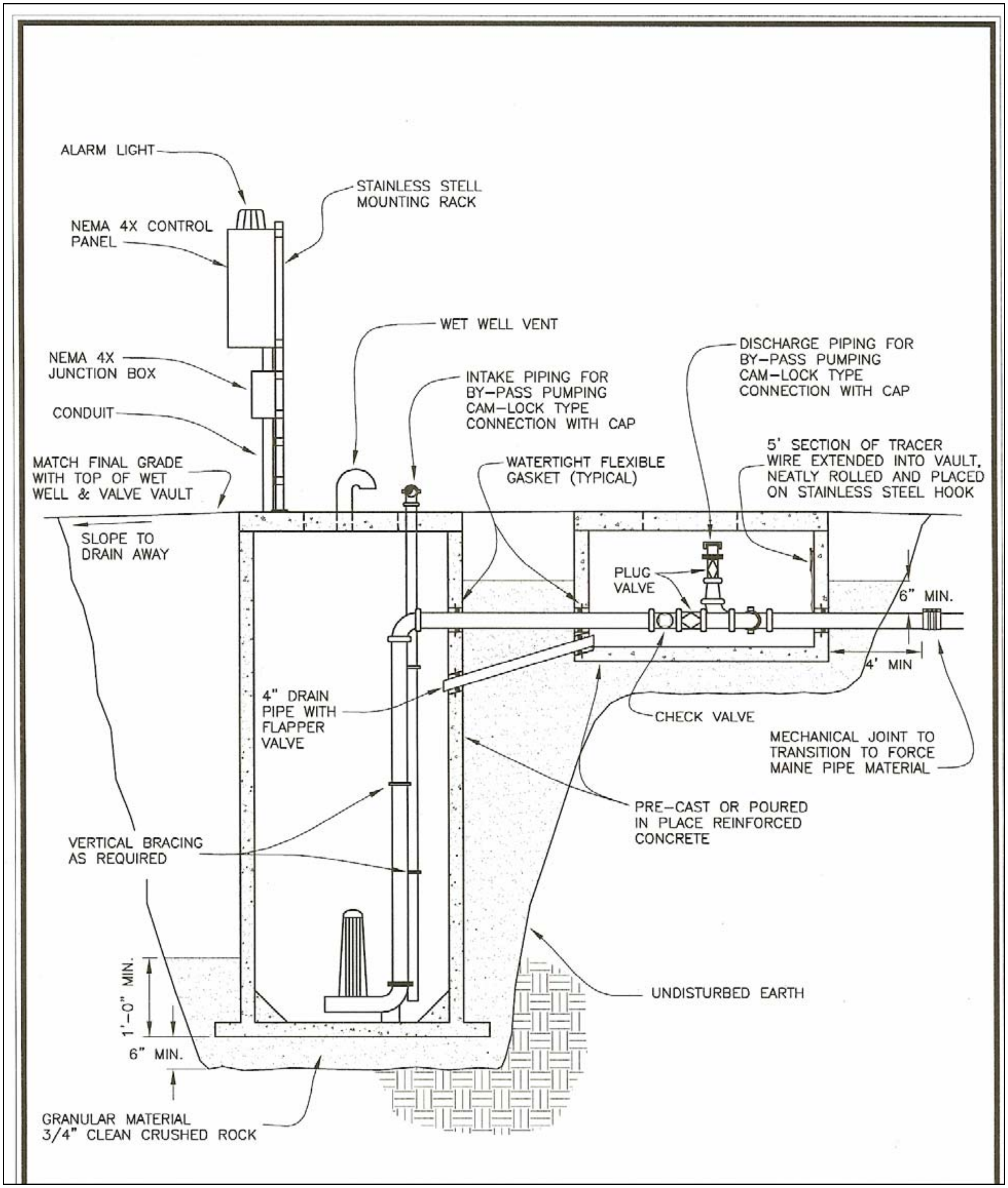
AIR RELEASE VALVE (SECTION VIEW)



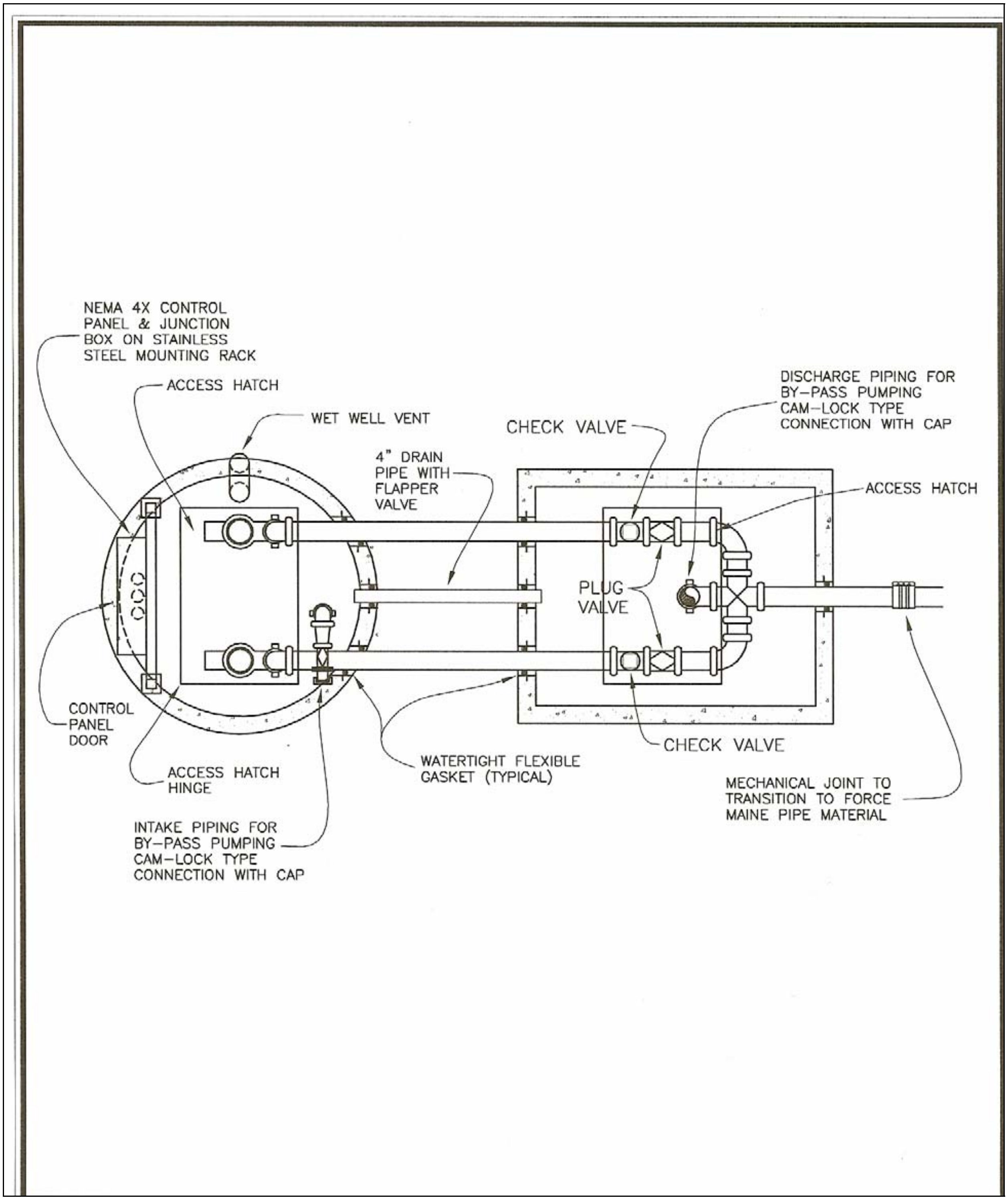
IN-LINE CLEAN OUT



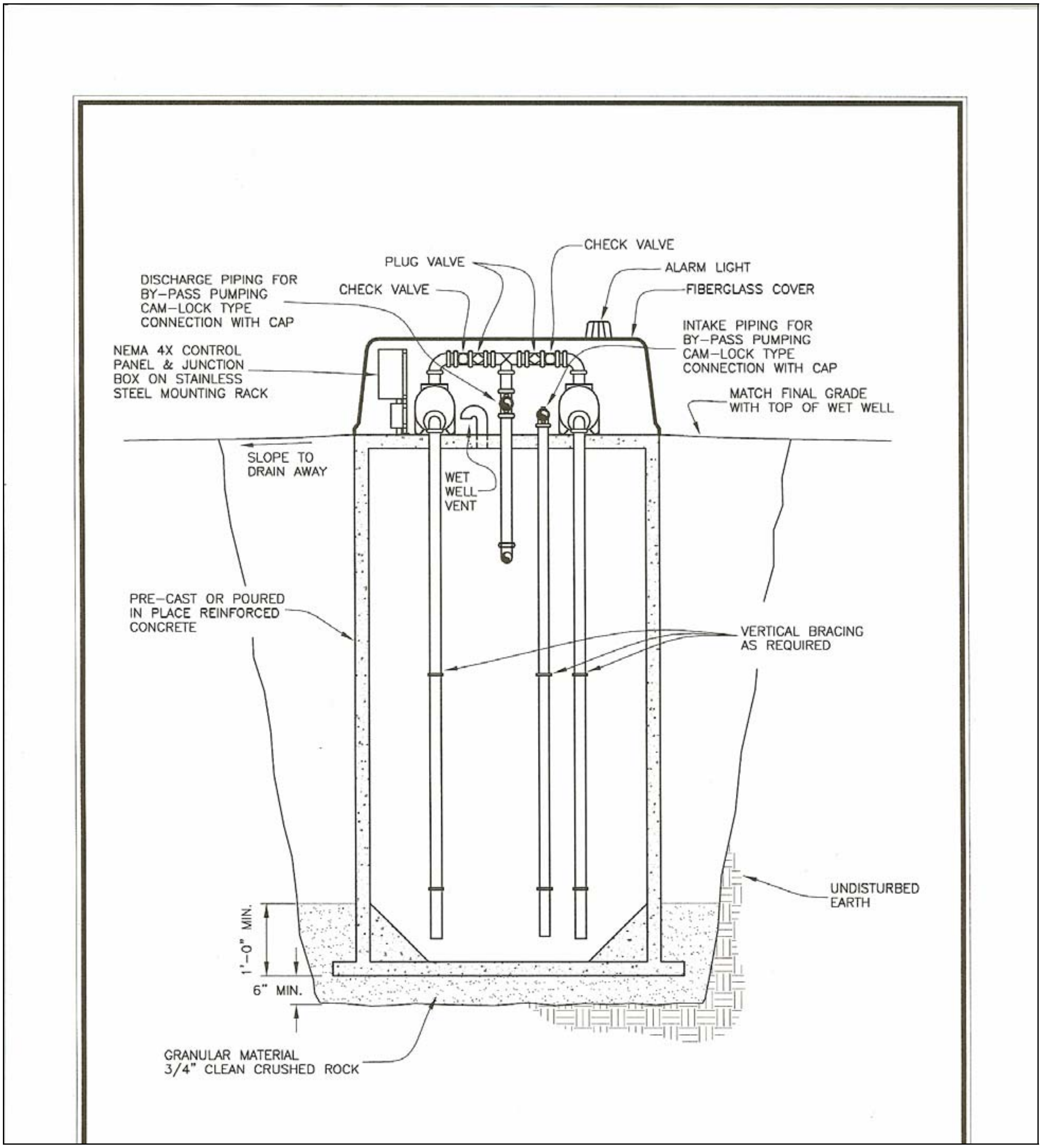
TRACER WIRE ACCESS VAULT



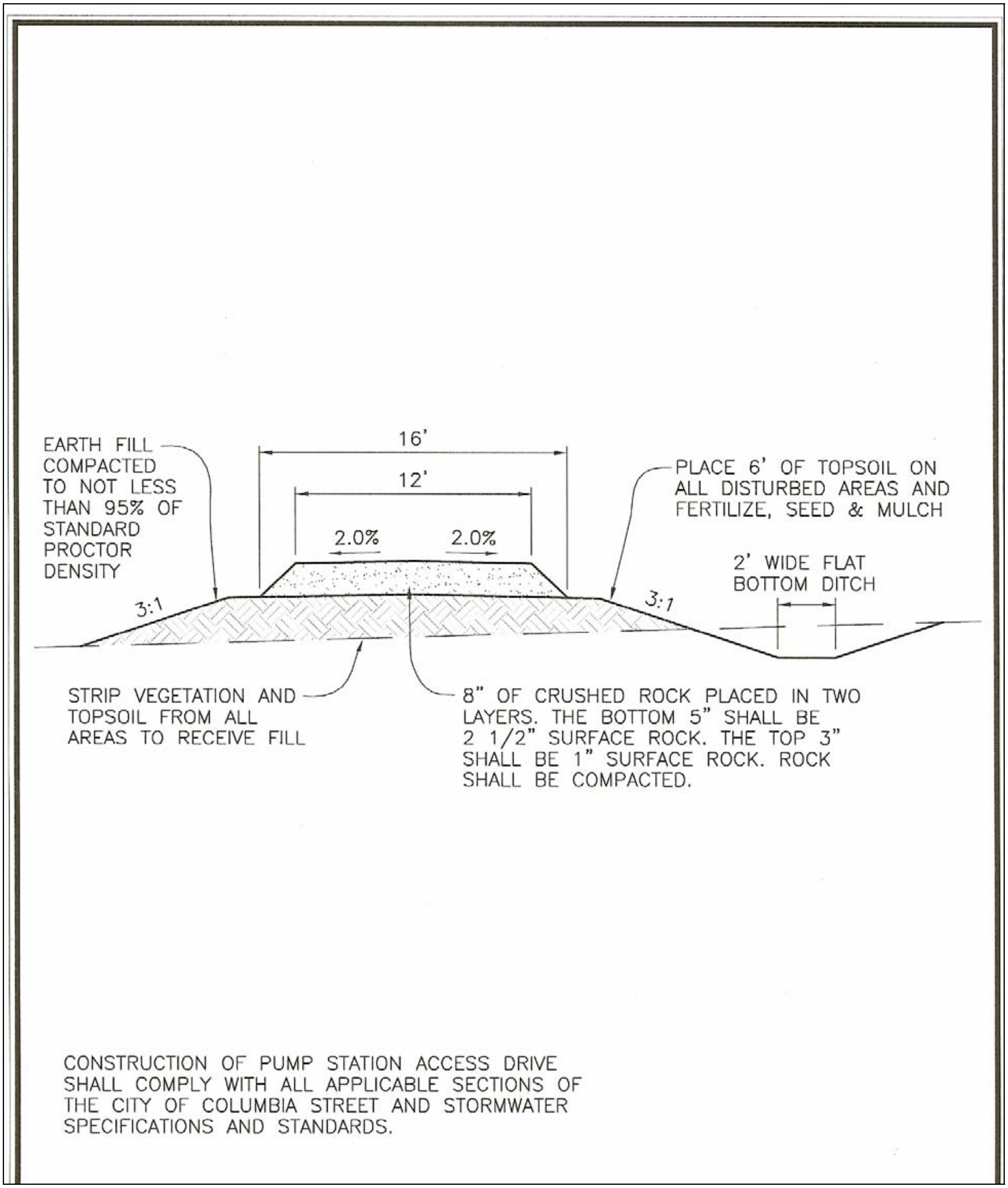
SUBMERSIBLE PUMP STATION, SECTION



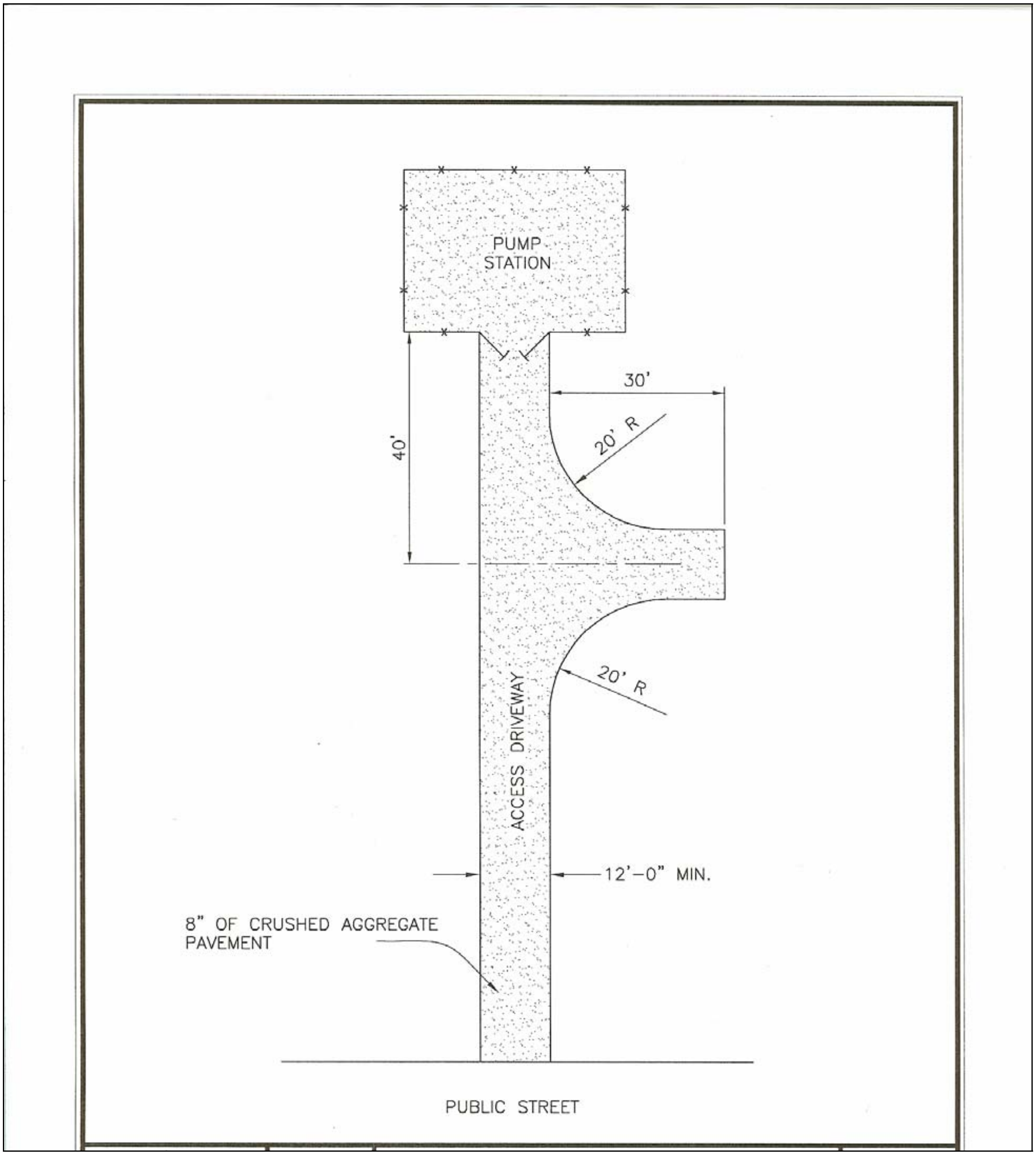
SUBMERSIBLE LIFT STATION



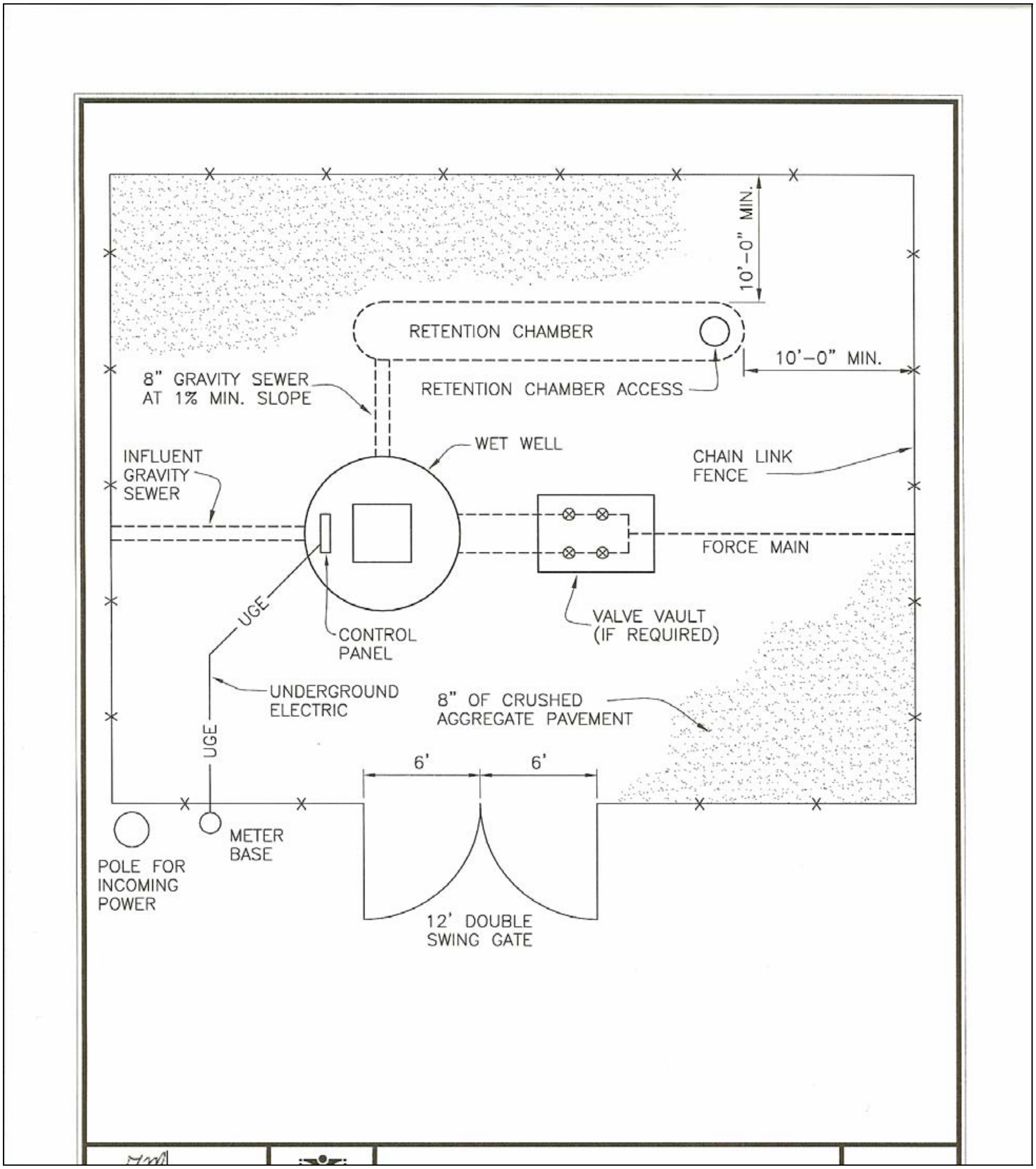
SUCTION LIFT LIFT-STATION – SECTION



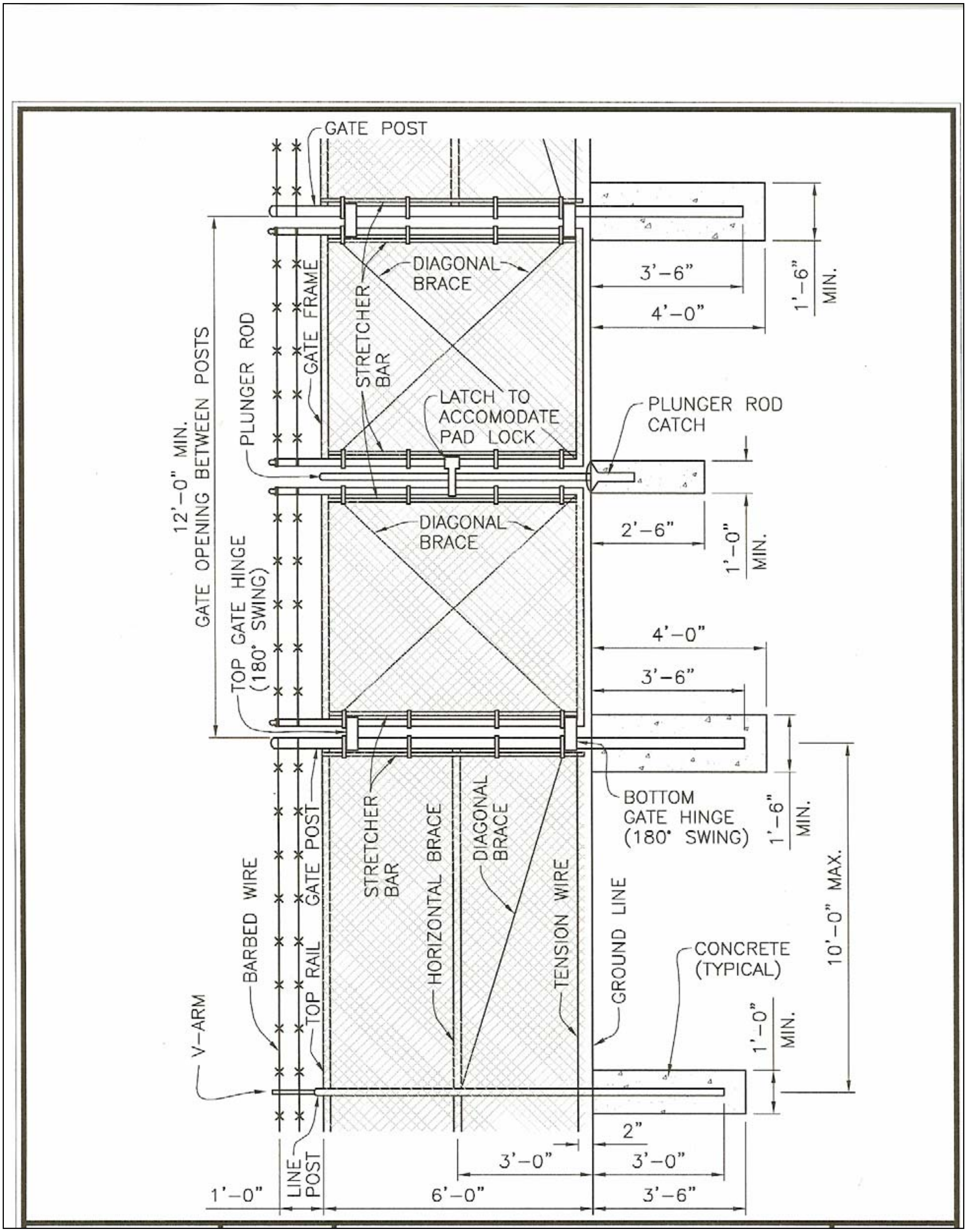
PUMP STATION ACCESS DRIVEWAY CROSS SECTION



ACCESS DRIVEWAY & TURN AROUND AREA



TYPICAL PUMP STATION SIE PLAN



STANDARD GATE

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1. ASCE-Manual and Reports On Engineering Practice
2. Weller, L. W., "That Attractive House May Be a Pumping Station." Pub. Works, 95, 4, 86 (1964).
3. "Standards of Hydraulic Institute." 10th Ed. Hydraulic Institute, New York (1959) .
4. Karassik, 1. J., "Vertical Pumps." Water and Sew. Works, 107, 56 (1960).
5. "Sewage Treatment Plant Design." .Manual of Practice No.8, Water Poll. Control Fed., Washington, D.C.; also known as Manual of Engineering Practice No. 36, Amer. Soc. Civil Engr., New York (1959).
6. City of Columbia, Missouri, Specifications for Pump Station Design.
7. Benjes, H. H., "Sewage Pumping." Sanitary Engineering Division, Proc. American Society Civil Engineering. 84, SA3, 1665-1 (1958).