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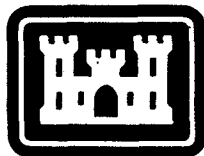
ENGINEERING AND DESIGN

SANITARY AND INDUSTRIAL WASTEWATER PUMPING

MOBILIZATION CONSTRUCTION

**DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS**

Engineering and Design
SANITARY AND INDUSTRIAL WASTEWATER PUMPING
Mobilization Construction

1. **Purpose.** This manual provides guidance for the design and construction of sanitary and industrial wastewater pumping facilities at U.S. Army mobilization installations.

2. **Applicability.** This manual is applicable to all field operating activities having mobilization construction responsibilities.

3. **Discussion.** Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:

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CHAPTER 1

GENERAL

1-1. Purpose and scope. This manual presents mobilization procedures for the design of sanitary and industrial wastewater pumping facilities for mobilization construction of Army installations.

1-2. Special wastes. Pump systems receiving hazardous and explosive wastes, corrosive acids or alkalis, or other special industrial wastes, will generally require the selection of highly resistant materials for pumps, valves, and piping. Design of these systems will be in accordance with special criteria developed for the particular situation. Selection of materials for pumps, piping, valves, and controls, etc., will be based on manufacturer's recommendations, product specifications and other appropriate design guidance.

1-3. Pumping station alternatives. Pumping stations and pneumatic ejectors will normally be required to remove wastes from areas which cannot be served hydraulically by gravity sewers. In certain situations, however, a gravity sewer system can be utilized but only at the expense of deep trench excavation, jacking, boring, tunnelling, or construction of long sewer runs to avoid high terrain. Depths of gravity sewers greater than 15 feet are usually uneconomical, however, a gravity sewer system will generally be justified until its cost exceeds the cost of a pumped system by 10 percent.

1-4. Grinder pumps. There may be remote areas so limited by high ground water, subsurface rock, unstable soil, or steep topography, that neither gravity sewers nor centralized pumping stations will be feasible. In these cases, the use of grinder pumps may be investigated. Grinder pump consideration should be limited to the remote locations and where small force mains are required or where the use of manually cleaned bar screens could present a serious maintenance problem.

CHAPTER 2

LOCATION OF PUMPING STATIONS

2-1. Service areas. Service areas are determined by topographic considerations, natural boundaries, private property lines, and political jurisdictions. The requirement that an area be served by a wastewater pumping facility will in most cases be determined by building and grade elevations which are too low for proper gravity drainage.

2-2. Site selection. The location of pumping facilities within a service area will be based primarily on topographic considerations. Pumping stations will be located so that all points within the intended service area can be drained adequately by gravity sewers. Any planned development within the service area for the project 5 year life expectancy such as construction of new buildings or projected shifts in population and/or work force will be considered. The following general guidelines for site selection and location of pumping stations will be followed.

   a. Pumping facilities will not, to the maximum extent practical, be constructed beneath buildings, streets, roadways, railroads, aircraft aprons or runways, or other major surface structures.

   b. Pumping stations will not be located closer than 500 feet to buildings, or other facilities to be occupied by humans, unless adequate measures are provided for odor and gas control.

   c. Pumping stations at wastewater treatment facilities will normally be located adjacent to, or in connection with, other plant elements as required for proper functioning of the treatment systems. Domestic wastewater treatment facilities are covered in detail in EM 1110-3-172.

   d. The location of pumping stations will be made with proper consideration given to the availability of required utilities such as electric power, potable water, fire protection, gas, steam, and telephone service.

2-3. Building and site requirements.

   a. Floor and building elevations. The invert elevations of incoming sewers will determine the depths of underground portions of the pumping station. It is common practice to set the maximum liquid level in the wet well at an elevation which allows 80 to 90 percent submergence of the diameter of the lowest incoming sewer. Subsurface and soil conditions at the site will dictate the structural design. The elevation of the ground floor will be set above the maximum expected flood level.

b. Architectural and landscaping. Pumping stations and facilities will be provided with fencing where necessary to prevent vandalism and to protect people from hazardous contact with electrical transformers and switching equipment.

c. Access. All pumping stations will be readily accessible from an improved road. For stations that are not enclosed, access will be provided for direct maintenance from a truck equipped with hoist attachments. For enclosed stations, provisions will be included in the structure to facilitate access for repair and to provide a means for the removal and loading of equipment onto a truck.

CHAPTER 3

TYPE AND CAPACITY OF PUMPING STATIONS

3-1. Required pumping capacity. Proper selection of the number and capacity of pumping units is dependent upon the quantity and variation of wastewater flows to be handled. Except as indicated below for small stations, pumping units will be selected to handle the normal daily range of wastewater flows generated in the service area. The number and capacity of pumps provided will be sufficient to discharge the minimum, average, peak daily, and extreme peak flowrates as calculated in EM 1110-3-174. Pumping capacity will be adequate to discharge the peak flowrates with the largest pump out of service.

a. Small stations. Pumping stations required for small remote areas will be provided with two identical pumping units. Each pumping unit will be capable of discharging the extreme peak wastewater flowrate. The station will be designed to alternate between zero discharge and peak discharge. This arrangement will provide 100 percent standby capacity to allow for necessary maintenance and repairs. Pneumatic ejector stations will be provided with duplex ejectors, each sized for the extreme peak flowrate.

b. Large stations. Pumping stations serving large areas of the installation, and especially stations where the entire wastewater flow or major portions thereof must be pumped to the treatment facility, will be designed so far as practicable to operate on a continuous basis. The rate of pumpage must change in increments as the inflow to the station varies. This mode of operation will normally require two or more wastewater pumps of the constant or variable speed type, operating in single or multiple pump combinations, as required to match the incoming flowrates.

3-2. Type of construction. A classification of pumping stations by capacity and the method of construction normally utilized for that capacity is provided in table 3-1. Factory assembled pumping stations, commonly referred to as package type stations, are manufactured in standard sizes and are shipped from the factory in modules with all equipment and components mounted, installed, and ready for connection. These types of stations will be suitable for low flows and where the need to protect pumps from clogging is minimal. Conventional field erected pumping stations are designed for a particular location and to meet specific requirements. Field constructed stations will be used where the quantity of flow or its variation, or both, exceeds the capacity of available factory assembled stations or where site conditions require the use of special designs or construction methods.

Table 3-1. Classification of Pumping Stations

Class/Type	Recommended Capacity Range gpm
Factory Assembled (Package Type)	
Pneumatic Ejectors	30–200
Wet Pit Submersible Pumps	100–500
Dry Pit Pumps	100–2,000
Conventional Field Erected	
Small	300–1,500
Intermediate	1,500–10,000
Large	over 10,000

Note: Package type, dry pit pumping stations in the capacities shown are generally available off-the-shelf. However, station capacities up to 5,000 gpm can be obtained by special order.

CHAPTER 4

WASTEWATER PUMPING EQUIPMENT

4-1. Wastewater pumps.

a. Centrifugal pumps. The centrifugal pump is the predominant type of wastewater pump used. These pumps are available in three variations: radial flow, mixed flow, and axial flow. Centrifugal pumps will not be used in capacities of less than 100 gpm. Submersible type centrifugal pumps may be used when suitable. Centrifugal pumps are also available with self-priming features when conditions dictate their use.

(1) Radial flow pumps. The radial flow centrifugal pump is the major type used for pumping raw wastes. In a radial flow pump, the fluid enters the impeller axially and is discharged at right angles to the shaft. Two types of radial flow pumps are available: single suction and double suction. In a single-end suction pump, fluid enters the impeller from one side. The shaft does not extend into the suction passage, and because of this, rags and trash do not clog the pump. The single-end suction pump will be suitable for handling untreated wastewater. For a double suction pump, fluid enters the impeller from both sides; however, the shaft extends into the suction passage, thereby limiting its use to handling only clear water. Radial flow centrifugal pumps are available in discharge sizes of 2 to 20 inches. However, pumps with a capacity to pass 2-1/2 inch minimum solids will be required. The recommended capacity range for these pumps is 100 to 20,000 gpm. Pumps are available in discharge heads of 25 to 200 feet total dynamic head (TDH). Peak design efficiency ranges from 60 percent for smaller pumps to 85 percent for larger pumps. Radial flow pumps are suitable for either wet well or dry well applications. They can be installed with horizontal or vertical shafting; however, vertical shaft pumps require considerably less space.

(2) Mixed flow pumps. The mixed flow centrifugal pump is an intermediate design between the radial flow type and the axial flow type and has operating characteristics of both. The mixed flow pump is designed with wide unobstructed passages and is therefore suitable for handling wastewater or clear water. Mixed flow centrifugal pumps are available in 8- through 84-inch discharge sizes. The recommended capacity range for these pumps is 1,000 to 80,000 gpm. Pumps are available to operate at 10 to 60 feet TDH. Peak design efficiency depends on the size and characteristics of the individual pump but generally ranges from 80 to 88 percent. The mixed flow centrifugal pump is normally used only in dry well applications, with either horizontal or vertical shafting configuration.

(3) Axial flow pumps. Axial flow centrifugal pumps will not be used to pump raw untreated wastewater. This pump is designed primarily

for clear water service and for wet well installations. The pump is furnished with vertical shaft having a bottom suction, with the propeller mounted near the bottom of the shaft and enclosed in a bowl. The propeller is totally submerged and can be clogged by large solids, rags, or trash. Therefore, this pump will only be used for clear well applications. Axial flow centrifugal pumps are available in 8-inch through 72-inch discharge sizes. The recommended capacity range for these pumps is 500 to 100,000 gpm. Pumps are available to operate from 1 to 40 feet TDH.

(4) Pump construction. The proper selection of materials used in the construction of pumps for handling sanitary and industrial wastewater is largely dependent on the expected characteristics of the liquid to be pumped, the size of the units, the difficulty of maintenance, and on whether the duty is continuous or intermittent. When operating in wastewater containing substantial quantities of grit, impellers made of bronze, cast steel, or stainless steel will be required. Enclosed impellers will be specified for wastewater pumps required to pass solids. Pump casings of the volute type will be used for pumping raw untreated wastes and wastewaters containing solids. Diffusion or turbine type casings may be utilized for effluent or clear water service at waste treatment facilities.

(5) Pump seals. Most sewage pumps can be obtained with either packing glands or mechanical seals.

(a) Packing glands. Packing glands will be lubricated and sealed against leakage of wastewater (into the stuffing box) by grease, potable water, or another clear fluid. The lubricating and sealing medium will be supplied to the stuffing box at a pressure of 5 to 10 psi greater than the pump shutoff head. Grease seals are usually provided by cartridges which are either spring loaded or pressurized by connections off the pump discharge. These arrangements generally do not maintain sufficient seal pressure on the stuffing box. However, they will be acceptable for low head pumps and where the wastewater contains little grit, as when pumping treated effluent. When pumping raw untreated wastes containing the usual quantities of grit, a potable water seal system with seal pump will be required if a potable water line is accessible within a reasonable distance. The water seal system will be capable of supplying 3 gpm per pump minimum. Water serves multiple purposes as a sealing medium; it seals, lubricates, and flushes. Flushing is particularly important where abrasive material is involved in that it helps prevent this material from entering the seal. Grit and ash are very abrasive and either will cut the shaft sleeves in a relatively short time. Where pumps are controlled automatically, a solenoid valve interlock with the pump starting circuit should be provided in the seal water connection to each pump. A manual shutoff valve and strainer should be provided on each side of each solenoid valve, and a bypass line should be provided around it. When freezing of seal water is likely to occur, protective measures will be taken.

There must not be, under any circumstances, a direct connection between the pumps and a potable water system, nor any possibility of backflow of wastes into a potable water system.

(b) Mechanical seal. Mechanical seals have the disadvantage of requiring the pump to be dismantled so that the seal can be repaired. Often it is easier to replace the seal rather than repair it, and it is desirable to keep a spare on hand for this purpose. Mechanical seals can be lubricated by the sewage being pumped providing it is filtered. When mechanical seals are used, a connection is normally provided between the pump discharge and the seal with a 20 to 40 micron in-line strainer to prevent foreign material from entering the seal.

b. Screw pumps. The screw pump is classified as a positive displacement pump, and as such, maintains two distinct advantages over centrifugal pumps. It can pass large solids without clogging and can operate over a wide range of flows with relatively good efficiencies. Screw pumps are normally available in capacities ranging from 150 to 50,000 gpm with a maximum lift of 30 feet. Because of its nonclog capabilities and wide pumping range, the screw pump is best suited for lifting raw untreated wastewater into the treatment facility and for the pumping of treated effluent. Screw pumps are usually driven by a constant speed motor with gear reducer and are inclined at angles at 30 to 38 degrees from the horizontal. In most instances, screw pumps will be installed outdoors with only the drive unit enclosed.

c. Pneumatic ejectors. Pneumatic ejector stations will generally be used only in remote areas where quantities of wastes are small and where future increases in waste flows are projected to be minimal. A pneumatic ejector consists of a receiving tank, inlet and outlet check valves, air supply, and liquid level sensors. When the wastewater reaches a preset level in the receiver, air is forced in ejecting the wastewater. When the discharge cycle is complete, the air is shut off and wastewater flows through the inlet into the receiver. Generally, duplex ejectors operate on a 1-minute cycle, filling for 30 seconds and discharging for 30 seconds. Thus, each receiver tank will be equal in volume to 30 seconds at the extreme peak flow rate. Pneumatic ejector stations are available in capacities ranging from 30 to 200 gpm with recommended operating heads up to 60 feet TDH. A typical ejector installation will include duplex units with two compressors, receivers, level sensors, etc.

4.2. Pump drives.

a. Electric motors. As a general rule, electric motors will be provided as the primary drive unit in sanitary and industrial wastewater pumping stations. Small pumping stations serving remote areas where electric power is not available, will usually require engine drives. The three types of electric motors most commonly used in wastewater pumping are squirrel-cage induction, wound-rotor

induction, and synchronous. Squirrel-cage induction motors will
normally be selected for constant speed pump applications because of
their simplicity, reliability, and economy. They can also be used for
variable speed operation when provided with the proper speed control.
Synchronous motors may be more economical for large capacity, low rpm,
and constant speed pumps. Wound-rotor induction motors are most
commonly used for pumps requiring variable speed operation. Variable
speed drives are used extensively in sewage related applications.
These units generally consist of constant speed motors with adjustable
speed drives. Selection of the type of variable speed drive to be used
is usually based on initial cost and space considerations and
differences in operating efficiency. Variable speed drives are
particularly appropriate for raw sewage installations which discharge
to a treatment plant. Use of this equipment allows the treatment
facilities to operate continuously rather than intermittently surging
the plant at incremental pumping rates. Variable speed drives are used
to pump settled sewage and biological sludge where intermittent surging
would adversely affect the treatment process. For a 60 cycle, a.c.
power supply, the maximum synchronous motor speed allowed for
wastewater pumps will be 1,800 rpm (approximately), 1,770 rpm induction
speed). The normal range of speeds is from 600 to 1,200 rpm, with
speeds below 450 rpm unusual at Army installations. Lower speed pumps
and motors are larger and more expensive but generally are more
reliable. The selection of electric motors will depend upon the type,
size, and location of the pumps, type of speed control used, and the
power available at the site. Pumping location will determine the type
of motor enclosure. For dry pit pumping installations, motor
enclosures will normally be the open, drip proof type. Pumps installed
outdoors, or in dirty or corrosive environments, will require totally
enclosed motors. Submersible pumps will have motor enclosures which
are watertight. Motors installed outdoors will have temperature
ratings adjusted to suit ambient operating conditions. For pumps
designed to operate on an intermittent basis, space heaters will be
provided in motor housings to prevent condensation. Motors installed
in wet wells will be explosion proof. Motor starting equipment will be
selected in accordance with paragraph 7-3 and will be suitable for the
type of motor and the required voltage. Motor starters will be
designed for limiting the inrush current where shocks or disruptions to
the electrical supply are likely to occur as a result of pump startup.
Where low starting inrush current is required for constant speed pumps,
such as when using engine driven generator sets, wound-rotor motors
will be considered as an alternative to squirrel-cage motors. The
voltage required for operation of motors and other equipment will be
determined in accordance with paragraph 7-3.

    b. Internal combustion engines. Internal combustion engines will
be used primarily at large pumping stations where electric motors are
the primary drive units and where emergency standby facilities are
required. Conditions which dictate the use of fixed, standby power at
wastewater pumping stations are outlined in paragraph 7-4. Internal

combustion engines will be required for small pumping stations in remote locations where no electric power source exists. At large wastewater treatment plants where abundant digester gas is produced, consideration is to be given to utilization of waste gas as fuel. Internal combustion engines may be arranged to drive horizontal pumps by direct or bolt connections, or they may drive vertical pumps through a right angle gear drive with an electric motor as the primary drive unit (dual drive). It is more common, however, and will be the general rule at large pumping stations, to provide fixed emergency generator sets powered by internal combustion engines. Generators produce electric power not only for pumps but also for auxiliary equipment such as heaters, lights, alarms, etc., and for critical pumping control systems. The types of internal combustion engines normally used include: diesel; gasoline; natural gas, primarily digester gas; and dual-fuel diesel. The use of gasoline engines for anything except small, remotely located pumping stations is not recommended due to the hazards associated with fuel handling and storage. Dual-fuel diesel engines fire a mixture of diesel oil and natural gas, with a minimum of 10 percent diesel fuel required to ignite the mixture. Propane is usually provided as a backup fuel for gas and dual-fuel diesel units. The selection of internal combustion engines will be coordinated with the installation's facility engineer to insure that adequate operation and maintenance can be made available.

4-3. Drive mechanisms.

a. Direct drive. Direct drive, with the shaft of the drive unit directly connected to the pump shaft, is the most common configuration. This connection can be either close coupled or flexible coupled. When using a close coupled connection, the pump is mounted directly on the drive shaft. This is the normal arrangement for a vertical pump driven by an electric motor. A horizontal pump will usually have a flexible connection, with the engine mounted adjacent to the pump. A vertical motor mounted above, and at a distance from a vertical pump, will be connected to the pump with one or more lengths of flexible shafting. Direct drive is the most efficient operation because no power is lost between the drive unit and the pump.

b. Belt drive. Belt drives may be utilized if the pump speed is different from those available with standard drive units or if speed adjustment is required. Speed adjustment is accomplished by changing pulley or sheave ratios. Belt drives used with horizontal pumps require more floor space than a direct drive unit, and belt wear increases maintenance requirements. Belt drives will be used only when it is not possible to choose single speed equipment to cover service conditions, or where pump speed adjustments may be required, but variable speed operation is not.

c. Right angle drive. Right angle drives will be used on vertical pumps being driven by horizontal engines. If the engine serves as

emergency standby, a combination gear box will be installed on the angle drive to allow operation of the pump by the primary drive unit, which is normally an electric motor. A clutch or disconnect coupling disengages the right angle gear when the motor drives the pump. When the engine drives the pump, the clutch is engaged and the motor rotates freely. In case of a power failure, the engine is automatically started, and after reaching partial operating speed, is engaged to drive the pump.

4-4. Pump speed controls.

   a. Mode of operation. Wastewater pumps will be designed to operate in one of the following modes: constant speed, adjustable speed, or variable speed. The type of speed control system will be selected accordingly.

   (1) Constant speed. Constant speed drive will be suitable for the majority of wastewater pumping applications at Army installations.

   (2) Adjustable speed. By changing pulley or sprocket ratios on a belt driven pump, the speeds can be adjusted to accommodate several constant speed pumping rates. Where automatic operation is needed, pulleys or sheaves can be positioned through the use of pneumatic, hydraulic, or electric devices. This type of system is used mainly in sludge pumping, but can be a good alternative to variable speed control when speed adjustment is not required too often.

   (3) Variable speed. Variable speed operation will usually be required at large pumping stations where the entire wastewater flow, or major portions thereof, must be pumped to the treatment facility and where it is desired to match the incoming flowrates in order to maintain a smooth, continuous flow into the plant.

   b. Speed control systems. The simplest system which allows pumps to accomplish the required hydraulic effects will be chosen for design. A minimum control range of 3 feet between maximum and minimum water levels is desirable. Pumping stations will normally be designed for automatic on/off operation of the pumping units, with manual override by push button or selector switch.

   (1) Constant and adjustable speed. Most automatic constant speed and adjustable speed systems will operate from level signals. Pumps are turned on as the liquid level in the wet well rises and are turned off when it falls. Float switches and bubbler tubes are more common and reliable. Electric and ultrasonic sensor devices can also be used.

   (2) Variable speed. A bubbler system will in most cases be employed to control the operation of automatic variable speed pumps. In these systems, the backpressure from the bubbler tube is transduced

to a pneumatic or electronic signal for use in on/off and variable speed control of the pumps. On/off controls are usually provided by pressure or electronic switches. Variable speed control devices consist of magnetic (eddy current) clutches, liquid clutches, variable voltage controls, variable frequency controls, and wound-rotor motor controls. Magnetic and liquid clutches have been available for many years as controllers for variable speed pumps. These older methods are inefficient in that the slip losses which develop are lost as heat. The recent development of solid state electronics has led to the introduction of newer methods of variable speed control suitable for both squirrel-cage and wound-rotor induction motors. The variable voltage and variable frequency controls are suitable for use with squirrel-cage motors. Variable frequency drives are possible in efficiencies up to 95 percent and are available in sizes up to 250 hp. However, the variable voltage units are inefficient and are not recommended for use. Wound-rotor motor controls come in five categories, (1) fixed step resistors, (2) liquid rheostats, (3) reactance/resistance controllers, (4) electronic rheostats, and (5) regenerative secondary controls. Of these, the regenerative secondary control offers the best efficiency, while the other units are considerably less efficient and require more maintenance. In general, variable speed control devices are more responsive, less efficient, and require a higher degree of maintenance than constant speed controls.

CHAPTER 5

PUMPING SYSTEM DESIGN

5-1. Force main hydraulics.

a. General. The pipeline which receives wastewater from a pumping station and conveys it to the point of discharge is called a force main. Force mains will be designed as pressure pipe and must be adequate in strength to withstand an internal operating pressure equal to the pump discharge head, plus an allowance for transient pressures caused by water hammer. The internal operating pressure is maximum at the pumping station and is reduced by friction to atmospheric, or near atmospheric, at the point of force main discharge. The primary consideration in the hydraulic design of force mains is to select a pipe size which will provide the required minimum velocities without creating excessive energy losses due to pipe friction. The size is usually governed by the need to maintain minimum velocities at low flows to prevent deposition of solids and to develop sufficient velocity at least once a day to resuspend any solids which may have settled in the line. The minimum diameters to be used are 1-1/4-inch for pressure sewers at grinder pumping installations, 4-inch for force mains serving small pumping stations and pneumatic ejectors, and 6-inch for all other force mains.

b. Design formula and chart. Force mains will be designed hydraulically with the use of Hazen-Williams formula as follows:

$$V = 1.32CR^{0.63}S^{0.54}$$

where:

V = velocity in fps
C = coefficient of pipe roughness
R = hydraulic radius in feet, and
S = slope of energy grade line in foot per foot

A solution to the Hazen-Williams formula is given in figure 5-1.

(1) Velocity. Velocity criteria for force mains are based on the fact that suspended organic solids do not settle out at a velocity of 2.0 fps or greater, and that a velocity of 2.5 to 3.5 fps is generally adequate to resuspend and flush any solids from the line. Force mains serving small pumping stations, which are designed to operate on an intermittent basis, will be sized to provide a minimum velocity of 3.5 fps at the peak discharge rate. Where small stations have very low and intermittent flows, both pumps can be operated manually once a week to accomplish line flushing. Larger stations having three or more pumping units, which operate a major portion of
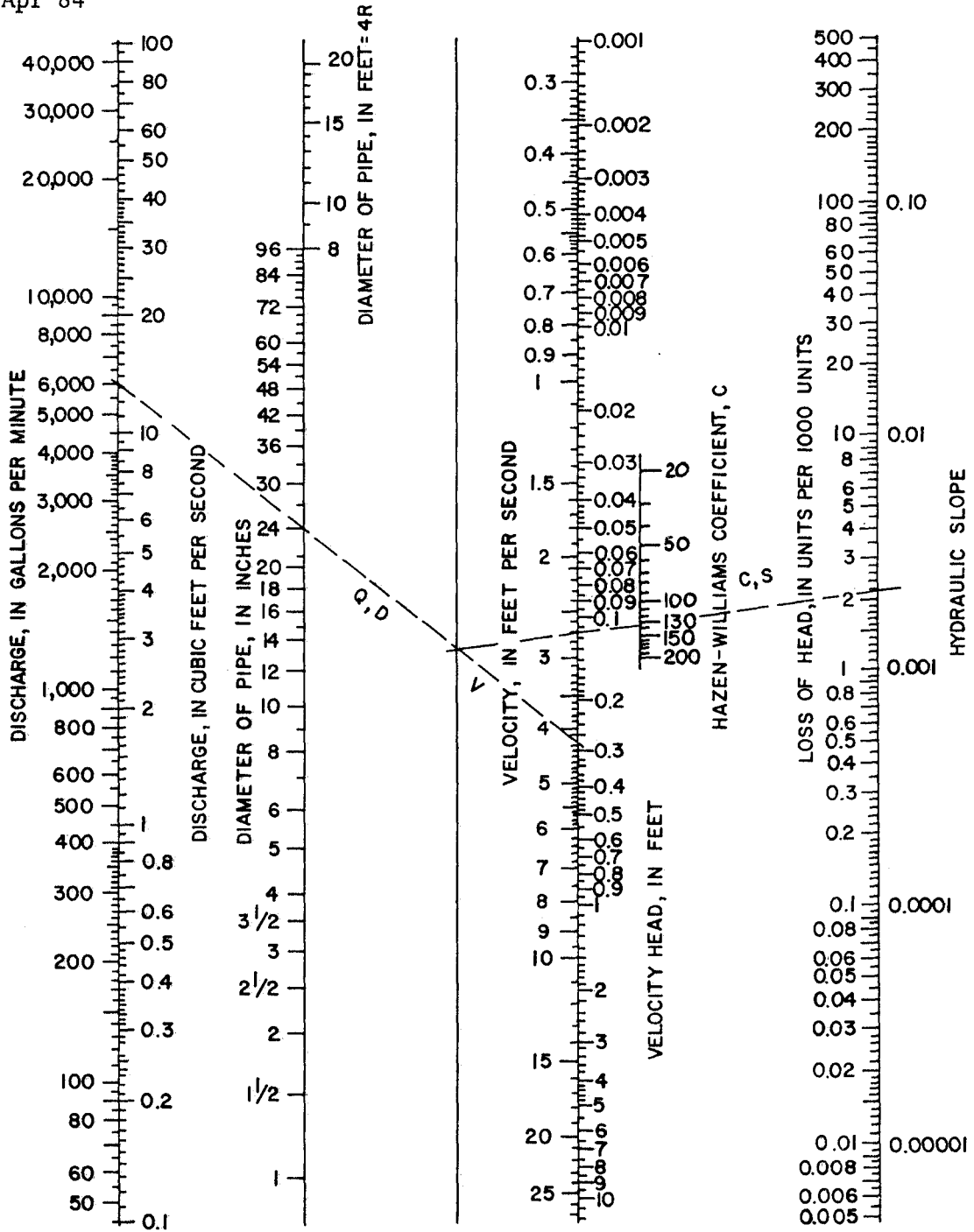
DESIGN AND CONSTRUCTION OF SANITARY AND STORM SEWERS, WPCF MANUAL OF PRACTICE NO. 9 BY WATER POLLUTION CONTROL FEDERATION, 1970, P. 83.

FIGURE 5-1. NOMOGRAPH FOR HAZEN-WILLIAMS FORMULA

the time, will require minimum force main velocities ranging from 2.0
fps with one pump operating to 5.0 fps with several pumps operating.
Maximum operating velocity for force mains should be limited to 10
fps.

- (2) Slope. The value of S in the formula is equivalent to the
kinetic energy loss due to pipe friction divided by the length of
conduit, or $S = H_f/L$. Minor energy losses from fittings and valves
will be converted to equivalent lengths of conduit for use in the
formula. Conversion tables for fittings and valves can be found in
standard hydraulics textbooks. The total kinetic energy loss in a
force main will be computed by multiplying the slope of the energy
grade line by the total length of conduit including equivalent lengths
or the following equation:

$$H_f = S \times L$$

(3) Roughness coefficient. Values of C in the formula range
from 100 for older force mains to 140 for new force mains.

5-2. Pump analysis and selection.

a. Total dynamic head. The head in feet against which a pump must
work when wastewater is being discharged is termed the total dynamic
head (TDH). The two primary components of TDH in wastewater
applications are the static discharge head and the kinetic losses due
to pipe friction. Velocity and pressure heads are also present but are
usually insignificant. The TDH will be calculated with the use of the
Bernoulli energy equation, which can be written as follows:

$$TDH = (P_d/w + V_d{}^2/2g + Z_d) - (P_s/w + V_s{}^2/2g + Z_s) + H_f$$

where:

P_d, P_s = gage pressures in psf
V_d, V_s = velocities in fps
Z_d, Z_s = static elevations in feet
H_f = kinetic energy loss from pipe friction, fittings
             and valves, as calculated in paragraph 5-1.b.(2)
w   = specific weight of fluid in pcf
           and
g   = acceleration due to gravity (32.2 feet/sec^2)

All head terms are in feet. Subscripts d and s represent force main
discharge and pump suction, respectively. In order to determine
hydraulic conditions at the pump suction, it will be necessary to write
an energy equation from the liquid level in the wet well to the pump
suction nozzle.

b. System head-capacity curve. To determine the head required of a pump, or group of pumps, that would discharge at various flowrates into a force main system, a head-capacity curve must be prepared. This curve is a graphic representation of the total dynamic head and will be constructed by plotting the TDH over a range of flowrates from zero to the maximum expected value. Friction losses for the first 5 years (which is the design life for the system) are not expected to vary significantly from new pipe condition. For basic system design, a C value equal to 130 is acceptable for the various pipe materials considered to be smooth lined pipe. The evaluation of capacity for the pumping units and their operation should however consider a range of possible friction losses as well as high and low wet well levels. The typical set of system curves will generally consist of two curves using a Hazen-Williams coefficient of C=100 (one for maximum and one for minimum static head) and two curves using a Hazen-Williams coefficient of C=140 (for maximum and minimum static head). These coefficients represent the extremes normally found in wastewater applications.

c. Pump head-capacity curve. The head that a particular pump can produce at various flowrates is established in pump tests conducted by the pump manufacturer. The results of these tests are plotted on a graph to form the pump chracteristic curve. Along with the discharge head developed, the pump operating efficiency, required power input, and net positive suction head are generally included on the same diagram.

(1) Efficiency and power input. Pump efficiency is the ratio of the useful power output to the power input, or brake horsepower, and can be computed using the following equation:

$$E = \frac{wQ \; TDH}{bhp \times 550}$$

where:

E = pump efficiency (100 X E = percent efficiency)
w = specific weight of fluid in pcf
Q = pump capacity in cfs
TDH = total dynamic head, and
bhp = brake horsepower

Pump efficiencies usually range from 60 to 85 percent. Most characteristic curves will indicate a best efficiency point at which pump operation is most efficient. Where possible, pumps will be selected to operate within a range of 60 to 120 percent of the best efficiency point.

(2) Net positive suction head. When pumps operate at high speeds and at capacities greater than the best efficiency point, the potential exists for pump cavitation. Cavitation can reduce pumping

capacity and may in time damage the pump impeller. Cavitation occurs
when the absolute pressure at the pump inlet drops below the vapor
pressure of the fluid being pumped. To determine if cavitation will be
a problem, the net positive suction head (NPSH) available will be
computed and compared with the NPSH required by the pump. The NPSH is
not normally a problem when discharge heads are less than 60 feet.
However, when heads are greater than 60 feet, or when the pump operates
under a suction lift, or far out on its curve, the NPSH will be
checked. The NPSH available at the eye of the impeller in feet will be
calculated using the following equation:

$$NPSH_A = H_s + P_a/w - P_v/w$$

where:

H_s = total energy head at pump suction nozzle
   = $P_s/w + V_s^2/2g + Z_s$
P_a = atmospheric pressure in psf absolute
P_v = vapor pressure of fluid being pumped in psf absolute,
   and
w = specific weight of fluid in pounds pcf

All head terms are in feet.

   (3) Affinity laws. A set of relationships derived from flow,
head and power coefficients for centrifugal pumps, can be used to
determine the effect of speed changes on a particular pump. The
relationships, known as affinity laws, are as follows:

$$Q_1/Q_2 = N_1/N_2$$

$$H_1/H_2 = N_1^2/N_2^2$$

$$P_1/P_2 = N_1^3/N_2^3$$

These relationships will be used in analyzing variable speed pump
operation in the absence of manufacturer's characteristic curves, or
where characteristic curves do not show performance at the desired
speeds.

   d. Pump selection. System analysis for a pumping station will be
conducted to select the most suitable pumping units which will meet
service requirements and to determine their operating points,
efficiencies, and required horsepower.

   (1) Single pump operation. A system head-capacity curve will
be prepared showing all conditions under which the pump is required to
operate. The system curve will then be superimposed onto a pump
head-capacity curve, or characteristic curve, to define the pump
operating point. The point where the two curves intersect represents

the head and capacity at which the pump will operate in the given piping system.

(2) Multiple pump operation. Where two or more pumps discharge into a common header, the head losses in individual suction and discharge lines will be omitted from the system head-capacity curve. This is because the pumping capacity of each unit will vary depending upon which units are in operation. In order to obtain a true picture of the output from a multiple pumping installation, the individual suction and discharge losses are deducted from the pump characteristic curves. This provides a modified curve which represents pump performance at the point of connection to the discharge header. Multiple pump performance will be determined by adding the capacity for points of equal head from the modified curve. The intersection of the modified individual and combined pump curves with the system curves shows total discharge capacity for each of the several possible combinations. Pumps will be selected so that the total required capacity of the pumping installation can be delivered with the minimum level in the wet well and maximum friction in the discharge line. Pump efficiency will be a maximum at average operating conditions. A typical set of system curves with pump characteristic curves is shown in figure 5-2.

5-3. Wet well volume.

a. General. Wet wells will be constructed at pumping stations for the purpose of storing wastewater flows prior to pump operation, allowing for proper pump and level controls, maintaining sufficient submergence of the pump suction inlet, preventing excessive deposition of solids, and providing ventilation of incoming sewer gases. The installation of bar racks or screens is generally required to protect pumps from clogging. Overflows from wet wells are prohibited.

b. Storage volume. If pumps are the constant or adjustable speed type, the wet well volume must be large enough to prevent short cycling of pump motors. For pumps driven by variable speed drives, the storage volume may be small provided pumping rates closely match the incoming flowrates. The volume required for the wet well will be computed with the following equation:

$$V = tq/4$$

where:

V = required volume in gallons between start and stop elevations for a single pump, or a single speed step increase for adjustable or variable speed operation

t = minimum time in minutes of one pumping cycle (time between successive pump starts), or time required for a speed or capacity change, and
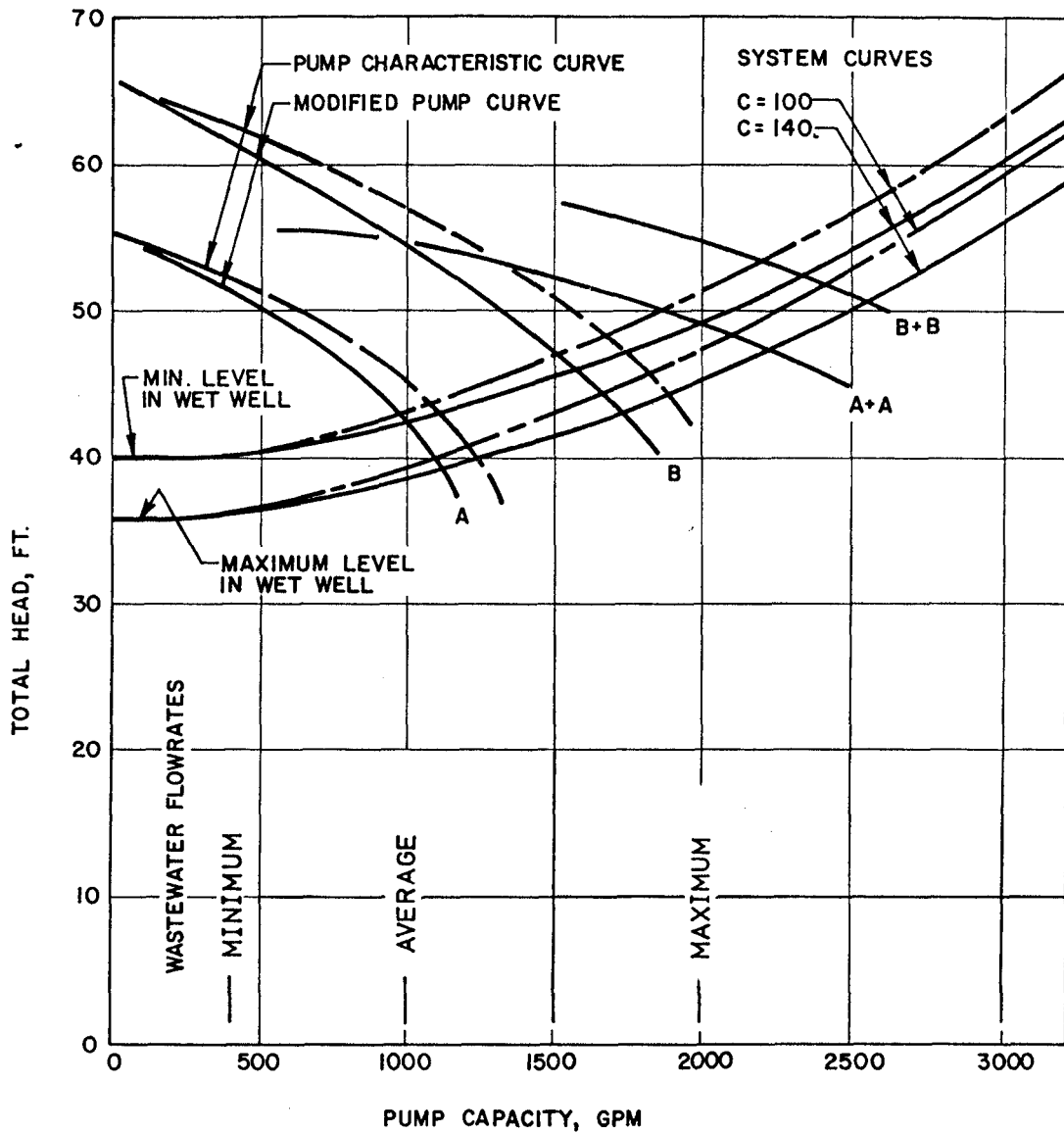
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FIGURE 5-2. TYPICAL PUMP-SYSTEM CURVES

q = pump capacity, or increment in capacity where one or more pumps are operating and an additional pump is started, or where pump speed is increased, in gpm

Constant or adjustable speed pumps driven by squirrel-cage induction motors will be designed for minimum cycle times as shown in table 5-1.

Table 5-1. Minimum Pump Cycle Times

Motor size (bhp)	t (minutes)
Less than 20	10 to 15
20 to 100	15 to 20
100 to 250	20 to 30
Over 250	as recommended by manufacturer

The storage volume calculated for small stations (with capacities less than 700 gpm) which utilize two identical constant speed pumps may be reduced one half by providing a control circuit to automatically alternate the pumps. The storage volume required for variable speed pumps will be based on providing sufficient time for a change in capacity when a pump is started or stopped. The maximum retention time in the wet well will not exceed 30 minutes to prevent septicity.
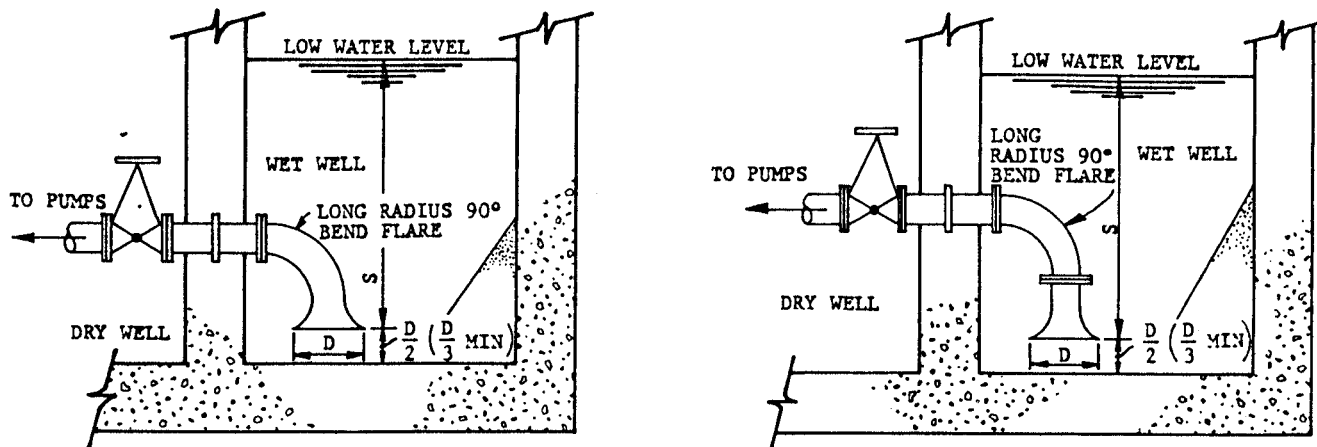
c. Suction pipe connections. Pump suction piping will be selected to provide a velocity of 4 to 6 fps. Pipe should be one or two sizes larger than the pump suction nozzle. Typical piping arrangements for vertical pumps installed in a dry well adjacent to a wet well are illustrated in figure 5-3.

d. Submergence of the suction inlet. Adequate submergence of the suction inlet is critical to prevent air from being drawn in by vortexing. Minimum required submergence depths(s) are given in table 5-2 as a function of suction inlet velocity. The net positive suction head (NPSH) will also be considered when determining S. See paragraph 5-2c(2).

Table 5-2. Required Minimum Submergence Depth to Prevent Vortexing

Velocity at Suction Inlet Diameter D, (fps)	S, (feet)
2	1.0
4	2.6
5	3.4
6	4.5
7	5.7
8	7.1

TYPICAL SUCTION PIPING
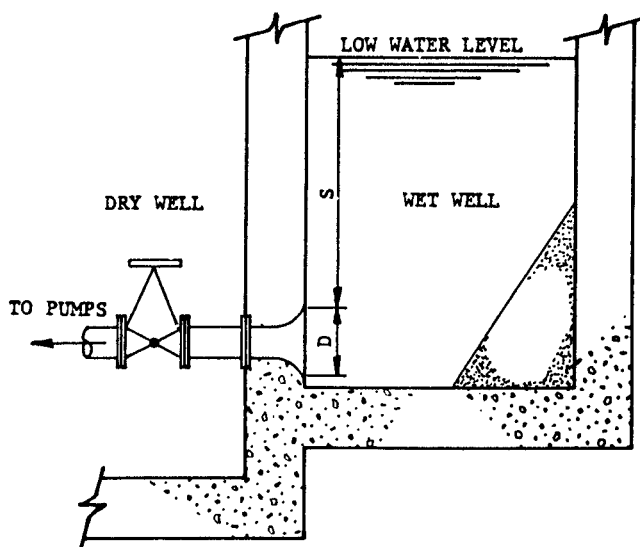
ALTERNATE SUCTION PIPING

D = DIAMETER OF FLARE
S = SUBMERGENCE DEPTH (SEE TABLE
    5-2 FOR MINIMUMS AS A FUNCTION
    OF VELOCITY OF LIQUID AT MOUTH
    OF FLARE)

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FIGURE 5-3. PUMP SUCTION CONNECTIONS TO WET WELL

e. Wet wells with two or more sections. Larger, conventional type pumping stations will normally be constructed with wet wells divided into two or more sections, or compartments, so that a portion of the station can be taken out of service for inspection or maintenance. Each compartment will have individual suction pipes and will be interconnected with slide or sluice gates. The floor of the wet well will be level from the wall adjacent to the pump to a point 12 to 18 inches beyond the outer edge of the suction bell and then will be sloped upward at a minimum 1:1 slope.

f. Screening devices. Centrifugal pumps are susceptible to clogging by rags, trash, and other debris normally found in wastewater. To protect pumps from clogging, equipment will be installed to screen these materials prior to pumping. Small pumping stations with capacities of less than 200 gpm, including grinder pumps and pneumatic ejectors, are exempt from this requirement. The types of equipment to be used include manually cleaned bar racks and screens which are installed in the wet well or in a separate influent channel.

5-4. Pump controls and instrumentation.

a. General. Instrumentation at a pumping station includes automatic and manual controls used to sequence the operation of pumps and alarms for indicating malfunctions in the pump system. Automatic control of pumps will usually be based on the liquid level in the wet well. Manual control of pumps is always required. Manual override will be set to bypass the low level cut-off but not the low level alarm.

b. Selection of control points. A control range of at least 3.0 feet is required between maximum and minimum liquid levels in the wet well. A minimum of 6 inches will be used between pump control points such as starting and stopping successive pumps or pump speed changes. For small stations, the control range may be less, however, control points will not be set closer than 3 inches.

(1) Constant or adjustable speed pumps require simple on-off switches to start or stop pumps or to change from one speed step to the next.

(2) Variable speed pumps require a more complex control arrangement. The two basic types of level control for variable speed operation are variable level and constant level. For variable level control, a narrow band of control points is established in the wet well. Pump speed is then adjusted in steps by the level detection system (usually a bubbler tube) as the level varies. Pumps operate at maximum speeds near the HWL and at minimum speeds near the LWL. However, pumps are started and stopped by level switches. Constant level control will only be required where a very narrow band of operation is necessary.

c. Alarms. Alarms will be provided to signal high and low liquid levels in the wet well, pump failure, or a malfunctioning speed control system. The high level alarm will be set above the start point of the last pump in the operational sequence but below the start point of the standby pump, if used. The low level alarm will be set below the shutoff point of the lead pump. A low level pump cutoff will be set below the low level alarm for emergency conditions.

5-5. Surge phenomena.

a. Water hammer. Sudden changes in flow and velocity in force mains can occur as a result of pump startup, pump shutdown, power failure, or the rapid closing of a valve. These velocity changes can produce large pressure increases or surge phenomena known as water hammer. The most severe water hammer conditions are usually caused by a pump shutdown or power failure. An analysis of water hammer will include calculating the critical time, determining the maximum pressure increase, and selecting a method of control.

b. Critical time. When flow is suddenly changed in a force main, a pressure wave is generated which rapidly travels the entire length of conduit and back to the point of change. The time required for this round trip can be calculated by using the following equation:

$$T_c = 2L/a$$

where:

T_c = critical time in seconds
L = length of force main between point of flow change and
    point of discharge in feet, and
a = velocity of pressure wave in fps

When the flow is completely stopped ($Q=0$) in a time interval greater than T_c, the maximum theoretical pressure increase is not fully developed. However, when flow is stopped in a time interval less than or equal to T_c, the change is said to be instantaneous, and the maximum pressure increase is developed as given below.

c. Maximum pressure increase. The maximum theoretical pressure increase or surge caused by water hammer is calculated from the following equation:

$$h_w = aV/g$$

where:

h_w = pressure increase in feet

V = velocity of fluid in the pipeline prior to flow change in fps

g = acceleration due to gravity or 32.2 feet/sec^2 at sea level, and

a = velocity of pressure wave in fps

Some typical values of "a" are given in table 5-3.

Table 5-3. Water Hammer Wave Velocities

Pipe Material	a, (fps)
Asbestos-Cement	2,700-3,400
Ductile Iron	3,100-4,200
Steel	2,700-3,900
Concrete	3,300-3,800
Plastic	1,100-1,500
Fiberglass	1,200-1,600

d. Methods of control. Whenever a pump is shut down or power to the station fails, the pump motor is suddenly cut off. Pump speed along with flow and velocity in the force main are quickly decelerated by pressure waves which travel up the pipeline and back. When the velocity is reduced to zero, reverse flow through the pump would occur if a gravity operated check valve or an automatic control valve were not installed on the pump discharge line and did not close properly. Reverse flow fully accelerated through the pump could cause transient flows and pressures well above maximum design conditions. A swing check valve which stuck open temporarily and then slammed shut under these conditions would result in a large pressure surge as given by paragraph 5-5c above. In order to control and limit these surge phenomena, the following practices will be followed.

(1) Gravity check valves. For simple cases involving small to medium sized pumping stations with gradually rising force mains (no intermediate high points) of less than 1,000 feet in length and with static discharge heads of less than 50 feet, a gravity operated check valve will usually be sufficient. Gravity type check valves may be either swing checks utilizing outside lever and weight (or spring) set to assist closure, or they may be ball checks. Swing check valves are usually installed horizontally, while ball check valves may be either vertical or horizontal. For additional protection, a pressure relief valve may be installed in conjunction with a check valve, to allow reversing flow to re-enter the wet well. Pressure relief valves must be specially designed for sewage applications. As an alternative to relief valves, a hydro-pneumatic tank may be utilized.

(2) Automatic control valves. In situations where long force mains are required, pipe profiles must conform to existing ground elevations for economic reasons. This normally will result in high points in the force main with the possiblity of water column separation at the high points during pump shutdown or power failure. The pressures generated when these separated columns come to rest against closed valves or against stagnant columns may be large and are again determined by paragraph 5-5c above. In general, where force mains are greater than 1,000 feet in length or contain intermediate high points, and where pumping stations are large in capacity or static discharge heads are greater than 50 feet, control valves will be automatically operated ball, plug, or butterfly valves. Pinch valves, although normally used in sludge handling, may be used as automatic control valve for this service. When butterfly valves are used, caution should be taken to maintain sufficient flows through the valve to avoid sediment collection which could interfere with valve action. Normal operation of these valves upon pump shutdown is to slowly close the valve while the pump continues to run. When the valve is closed, a limit switch then stops the pump motor. On power failure, an emergency hydraulic or other type operator closes the valve slowly. The time of valve closure is of utmost importance. Valves should be half closed when the velocity in the force main has dropped to zero. The time required to reach zero velocity can be calculated with the following equation:

$$t = LV/gH_{av}$$

where:

t = time in seconds
L = length of force main in feet
V = velocity of fluid in pipeline in fps
H_{av} = average decelerating head including pipe friction in feet, and
g = acceleration due to gravity = 32.2 feet/sec^2

The types of valve operators most often utilized are hydraulic, electric, and pneumatic. Valves and operators specified for use will be fully adjustable for closure times ranging from t to 4t minimum. In some large pumping stations, the use of automatically controlled valves alone will not be sufficient. Extremely long force mains (over 1 mile) may require very long valve closing times and thus result in excessive backflow to the wet well and reverse rotation of the pump and motor. To solve these problems, a pump bypass with surge relief valve will generally be required. Valves used for surge relief will be automatically controlled cone or butterfly valves, similar to the pump discharge valves. Normal operation upon pump shutdown where excessive backflow conditions exist will require the pump discharge valve to be fully closed when the velocity has dropped to zero. The surge relief valve will be fully open allowing backflow to enter the wet well at a

reduced rate. As before, the relief valve must close slowly to avoid
water hammer. Most cases involving large pumping stations with long
force mains, which contain several intermediate high points, will be
too complex to solve by hand using conventional methods such as
graphical solutions, arithmetic integration, or water hammer charts.
Many computer programs are now available for water hammer analysis and
are recommended for use in those instances.

CHAPTER 6

PIPING, VALVES, AND APPURTENANCES

6-1. Pipe materials, fittings, and joints.

a. General. The major factors to be considered in the selection of
pipe materials and piping systems for mobilization:

- Availability of pipe in required sizes, strengths, etc.

- Availability of fittings, connections, and adapters.

- Ease of handling and installation.

- Physical strength and pressure ratings.

- Flow characteristics or friction coefficient.

- Joint watertightness.

- Resistance to acids, alkalis, high temperature or corrosive
  wastes and corrosive soils.

b. Ductile iron. Ductile iron (D.I.) pipe is suitable for force
mains used at pumping stations and wastewater treatment facilities.
Special uses include river crossings, pipe located in unstable soils,
highway and rail crossings, and pipe installed above ground. D.I. pipe
is susceptible to corrosion from acid wastes and aggressive soils.
Cement linings, bituminous coatings, or polyethylene linings are
usually provided for interior protection. Exterior bituminous coatings
are standard, and for extremely corrosive soils, a polyethylene
encasement may be required. Pipe is available in 3-inch through
54-inch diameter and with mechanical, push-on, or flanged joints.
Flanged joints are restricted to interior piping.

c. Steel. Steel pipe may be used for force mains when lined with
cement mortar or bituminous materials to provide internal protection.
A bituminous coating must be applied for external protection also.
Lined and coated steel pipe is available in diameters 6-inch through
144-inch. Galvanized steel pipe will be used for small diameter force
mains and pressure sewers from 1-1/4 inch to 4-inch in size. Joints
for steel pipe less than 6-inch will be threaded. Pipe 6-inch in
diameter and larger will have mechanical, push-on, or flanged joints.
Threaded and flanged joints will be used only for interior piping where
6-inch and larger diameter pipe is required.

d. Concrete. Concrete pressure pipe will generally be used where
high strength or large diameter force mains are required. Pretensioned
reinforced concrete pressure pipe is available in diameters 10-inch

through 42-inch, prestressed concrete pressure pipe in diameters
16-inch through 144-inch, and reinforced concrete pressure pipe in
diameters 24-inch through 144-inch. Each type utilizes bell and spigot
joints with rubber gaskets.

    e. Asbestos-cement. Force mains constructed of asbestos-cement
(A.C.) pressure pipe are durable and light in weight. However, A.C.
pipe is affected by corrosive wastes and aggressive soils and must be
provided with plastic linings for protection. Pipe is available in
diameters 4-inch through 42-inch and will be joined by means of
couplings utilizing rubber gaskets.

    f. Plastic. Characteristics which make plastic pipe highly
desirable for force main use include high corrosion resistance, light
weight, and low coefficient of friction. Disadvantages include
possible pipe wall deflections when installed improperly or subjected
to high temperature wastes. Chemical breakdown caused by prolonged
exposure to sunlight is also a disadvantage with plastic pipe. The
following types of plastic pipe are suitable for use.

    (1) Polyvinyl chloride (PVC). PVC pipe is available in
diameters 4-inch through 12-inch and with push-on or solvent weld
joints.

    (2) Polyethylene (PE). PE pipe may be used in diameters 1-1/2
inch through 48-inch. Pipe joints consist of mechanical, flanged, or
heat fusion types.

    (3) Polypropylene (PP). Pipe diameters available with
polypropylene pipe are 1-1/2 inch through 4-inch. All pipe will be
joined by heat fusion methods.

    g. Fiberglass. Fiberglass pipe provides a good alternative for use
in large diameter force mains. High structural integrity, low pipe
friction coefficient, and a high resistance to internal/external
corrosion in addition to high temperature wastes, are important
properties of fiberglass pipe. The following types of fiberglass pipe
may be used.

    (1) Reinforced thermosetting resin pipe (RTRP). RTRP pipe may
be installed in diameters of 6-inch through 144-inch. Jointing systems
for RTRP pipe include ball and spigot, flanged, or special mechanical
type couplings. Elastomeric gaskets are used to provide flexible
joints.

    (2) Reinforced plastic mortar pipe (RPMP). Pipe diameters
available for RPMP pipe range from 8-inch to 144-inch. Pipe joints are
made with grooved couplings or ball and spigot joints utilizing rubber
gaskets.

h. Interior piping. Pump suction and discharge piping inside the station will normally be ductile iron or steel. However, other pipe materials covered in this paragraph are not precluded from use. Pipe, fittings, and joints serving as force mains will be selected to withstand the maximum internal operating pressures including transient surges. The project specifications will indicate the appropriate pressure class and rating for each pipe application.

6-2. Valves and appurtenances. The use of valves in wastewater pumping applications can be divided into the following categories.

a. Isolation or shutoff valves. Where there is the need to isolate parts of the piping system, manual shutoff valves will be used. Gate valves or butterfly valves generally serve as shutoff valves, however, ball valves or plug valves may also be used. Shutoff valves are required on the suction and discharge sides of all pumps.

b. Surge control valves. To protect pumps and piping from surges, gravity operated swing check or ball check valves, or automatically operated ball, plug, butterfly, or pinch valves will be installed in the pump discharge line.

c. Blowoff valves. A valved outlet installed at the low point in a force main and arranged to drain or flush the pipeline is termed a blowoff. Normally, blowoffs will be required only on long depressed sections of force main, or where an accumulation of solids is likely to occur. Blowoff connections will be installed in manholes or valve structures and will be protected against freezing.

d. Air valves. Air valves will be installed at high points in force mains for the purpose of admitting and releasing air. When the pipeline is taken out of service for draining, flushing, and filling operations, a manually operated valve will be adequate. However, where air pockets or pressures less than atmospheric are likely to occur with the pipeline in service and under pressure, automatic air release and/or air vacuum valves will be used. All valves will be installed in a manhole or valve structure with adequate drainage and protection against freezing.

6-3. Installation.

a. Structural design. Structural design of force mains will be in accordance with the requirements for sewers set forth in chapter 5 of EM 1110-3-174.

b. Anchorage. Force mains will be anchored to resist thrusts that develop at bends or branch connections, and plugs in the pipe. The magnitude of such forces can be calculated with the use of formulas found in the detailed discussion of thrust block design given in

EM 1110-3-164. Required anchorage will consist of tie rods and clamps or concrete thrust blocks.

    c. Depth of cover. Force mains will be installed with sufficient depth to prevent freezing and to protect the pipe from structural damage. A minimum cover depth of 3 feet will ordinarily be required for freeze protection. However, in unusually cold climates, a greater depth may be required.

    d. Protection of water supplies. Force mains and pressure sewers will not be installed closer than 10 feet horizontally to potable water lines. If conditions prevent a 10 foot clearance, a minimum distance of 6 feet will be allowed, provided the bottom of the water pipe is at least 12 inches above the top of the pressure pipe. Where a pressure pipe must cross a potable water line, the pressure line will always be installed below the water line with a minimum vertical clearance of 2 feet.

CHAPTER 7

PUMPING STATION COMPONENTS

7-1. Construction requirements.

a. Station configuration. The space requirements of pumps, piping, and equipment, along with the storage volume required in the wet well, will be carefully determined so that the proper size, shape, and configuration of the pumping station can be selected. The size and shape of the station will often be dictated by equipment other than pumps, such as bar racks or screens. Rectangular or square structures normally have more usable interior space than circular ones and will be employed wherever possible in the design of medium to large sized pumping facilities. The below ground portion of the station must sometimes be made deep to accommodate incoming sewers. Where deep stations are required and where foundation conditions are poor, circular caisson type structures will be required if lateral earth pressures are excessively high. Factory assembled or package type stations will generally be circular in design and will be anchored to base slabs where warranted by subsurface conditions. All stations will be designed to avoid flotation when empty.

b. Designing for operation and maintenance. The design of medium to large sized, conventional type pumping facilities will include adequate floor openings, doorways, or access hatches for the installation, removal, and replacement of the largest items of equipment. Interior dimensions in the dry well will provide a minimum clearance of 4 feet between adjacent pump casings and a minimum of 3 feet from each outboard pump to the closest wall. Other major items of equipment will be provided similar spacing. Smaller package type stations will be furnished with necessary access openings for removal of pumps and equipment; however, interior dimensions and clearances will generally be less than for field erected stations. Wet wells for medium to large sized stations will be divided into two or more compartments to facilitate cleaning and repairs. Wet wells for all stations will have no length, width, or diameter smaller than 4 feet. Eye bolts or trolley beams will be provided in smaller stations and overhead bridge cranes in large stations, for hoisting and removing equipment from mountings. Stairs will be provided in medium to large sized stations so that personnel may inspect and maintain equipment. Smaller stations, except those utilizing submersible pumps, will require the use of vertical safety ladders. A suitable means will be provided to service and maintain all equipment. A floor drainage system will be provided in the dry well, and throughout the superstructure, for collection of wash down, seepage, and stuffing box leakage. These wastes will be piped or conveyed to the wet well, either by gravity or by sump pump. Openings to the wet well and dry well through the main floor of the station will be above the maximum flood level, or will otherwise be protected from flooding.

c. Personnel safety. Metal protective guards will be placed on and around all equipment where operators may come in contact with moving parts. Railings will be required around all floor openings and along platforms or walkways, where there is a danger that personnel may fall. Warning signs will be placed at all hazardous locations. Rubber mats will be provided in front of all electrical equipment where the potential exists for electrical shock. Adequate lighting and ventilation will be provided as required in paragraphs 7-2 and 7-3.

7-2. Heating and ventilation.

a. Heating. All pumping stations subject to possible freezing will be supplied with automatically controlled heaters in the equipment areas. For unattended stations, temperatures will be maintained at 40 degrees F. Attended stations will be heated at 65 degrees F. Although wet wells are generally unheated, thermostatically controlled heaters may be used to prevent condensation on walls and floors during cool weather providing that the ventilation system is shut off.

b. Ventilation.

(1) Wet wells will be provided with a positive ventilation capacity of 30 air changes per hour during occupancy, based on the wet well volume below grade and above the minimum waste level.

(2) Unattended dry wells will be provided with positive ventilation capacity of 30 air changes per hour. Attended dry wells will be provided with continuously-operated ventilation consisting of 6 air changes per hour, supplemented with additional ventilation in warm climates to remove pump motor heat to within 5 degrees F. of the outside air temperature. Supply intakes and exhaust outlets must be located properly to introduce fresh air and remove hazardous gases or fumes. The wet and dry well sides of the station will be provided with separate ventilation systems.

7-3. Electrical equipment and lighting. Pumping station equipment will be suitable for operation at 208 volt, 230 volt, or 480 volt, 60 Hz, three-phase power supplies. However, equipment with motors smaller than 0.5 hp including meters, switches, timers, clocks, and similar equipment will be suitable for operation at a 125 volt, 60 Hz, single-phase power source.

a. Service transformers. Service transformer installations will conform to requirements of EM 1110-3-190.

b. Motor starters and controls. Motor starters and controls will be provided and housed in a factory assembled free-standing control center located on the ground floor. The center will include motor starters, switches or circuit breakers, instrumentation, and controls.

A pumping station requiring a few small size starters is an exception and will employ wall mounted or angle iron stand mounted equipment.

   c. Control for submersible pumps. Enclosures for submersible pump controls will be installed above grade.

   d. Trouble alarms. Local trouble alarms will be provided at all pumping stations. Alarms will be annunciated remotely from unattended locations. Alarm systems will be provided with manual silencing.

7-4. Standby power. The requirement for standby power at wastewater pumping stations will depend upon the type, location, and critical nature of each facility. For stations situated in low-lying areas or in areas remote from a treatment plant, standby capability will be provided if a power outage would result in flooding of the station, overflows at sewer manholes, or backup of wastes into buildings. Pumping stations located at, or in conjunction with, treatment facilities will require standby power if the pumping is essential to critical treatment processes or plant flow control. Paragraph 4-2 contains design criteria for selecting pump drive units and describes various arrangements to be used in providing standby power capability at wastewater pumping stations.

7-5. Paints and protective coatings. The use of paints and protective coatings at wastewater pumping stations will be directed at providing protection of surfaces for periods compatible with the 5-year life expectancy of mobilization construction. Paint materials selected will be appropriate for the types of surfaces being protected, both submerged and nonsubmerged. Coating systems will be designed to resist corrosion from the wastes being handled and from gases and vapors present. Coating systems will consist of adequate surface preparation, prime coats, and finish coats using compatible materials as recommended by the coatings manufacturer. Particular care will be taken to protect welds and threads at connections. All pumps and equipment will receive protective coatings in conformance with the manufacturer's recommendations. Package type stations will be shipped to the construction site with factory applied paints and coatings sufficient for the required use and duration of service.

APPENDIX A

REFERENCES

Government Publications.

Department of the Army.

EM 1110-3-164	Water Supply, Water Distribution.
EM 1110-3-172	Domestic Wastewater Treatment.
EM 1110-3-174	Sanitary and Industrial Wastewater Collection.
EM 1110-3-190	Electric Power Supply and Distribution.

Nongovernment Publications.

Water Pollution Control Federation (WPCF), 2626 Pennsylvania Ave. NW, Washington, DC 20037.

Manual of Practice No. 9   Design and Construction of Sanitary and Storm Sewers.