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.