PUMPING STATIONS FOR SEWAGE, SLUDGE, AND AIR

Robert L. Sanks
Montana State University, Bozeman, MT, USA (Sewage Pumping)

David G. Hanna
Ferris State University, Big Rapids, MI, USA (Sludge Pumping)

Garr M. Jones
Brown and Caldwell, Walnut Creek, CA, USA (Air and Sludge Pumping)

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Summary

Because of the similarities between the pumping of water and sewage, readers should first read *Water Pumping Stations.* There are, however, significant differences between water and sewage pumping as well, and these become apparent in this article. Pumps, wet wells, piping systems, water hammer control, and ventilation are described.

Sludge pumping is a difficult pumping service due to the solids content and variability. Special pumps and piping are often needed. Piping must be well arranged for maintenance, for preventing blockages, and for cleaning.

Pumping is not a term commonly applied to air. Instead, air is compressed or blown. Air lift pumps and air systems for instruments and tools are discussed.

1. Sewage Pumping

The presence of grease and other floating material, settleable solids including grit, stringy materials, and biodegradable organic substances in wastewater makes many types of pumps, valves, devices, and systems that are adequate for water unsuitable for sewage. Sewage pumps are customarily required to pass 75-mm spheres. Pumps and valves must not entrap stringy materials. Grease clogs small orifices and makes many water control devices unreliable. Biodegradable organic substances putrefy and produce hydrogen sulfide (H_2S), a noxious gas deadly to humans and corrosive even in minute concentrations to electronic and electrical devices. Wet wells should be either (1) frequently or continuously cleaned to reduce the production of hydrogen sulfide or (2) completely sealed except for a small vent. Concrete exposed to hydrogen sulfide in air (even in small concentrations) requires protection by coatings or linings of inert material for permanence. Minute concentrations of hydrogen sulfide corrode electronic and electrical equipment.

1.1 Pumps

To ensure a pumping station is always capable of pumping the maximum hourly flow rate anticipated, a standby pump (equal in capacity to the largest pump) is always installed. Three pumps are usually the optimum number although circumstances sometimes require more, and small stations are usually equipped with two pumps.

Sewage pumps are often externally similar to water pumps, but they must have large openings to pass solid objects with impellers, cutwaters, and diffuser vanes having rounded leading edges to pass stringy material. (Water pumps are designed for high efficiency with no need for large passages or rounded noses.) Although sewage pumps are called “nonclog”, they occasionally do clog and are fitted with removable hand hole plates for removing trapped material. The most common pumps are (1) overhung-impeller, end-suction, (2) submersible, (3) vertical turbine, (4) self-priming, and (5) screw (sometimes called Archimedes screw).

End suction pumps are often placed in a “dry pit” alongside the wet well and connected to the wet well with a horizontal suction pipe. To conserve floor space and protect motors from possible flooding, the pumps are sometimes mounted vertically with long drive shafts to motors on the ground floor. Occasionally, motors are placed in the dry pit, but usually neither motors nor pumps can be operated if the dry pit is flooded. After dewatering the dry pit, most motors must be cleaned and dried before use although motors constructed with Class F insulation but designed for a Class B temperature rise can be returned to service immediately after the dry pit is dewatered. Some immersible motors can be operated for a few hours under water. End suction pumps may be close-coupled with the impeller mounted on the motor shaft and the motor bolted directly to the pump casing. Or they can be frame-mounted with the impeller fastened to a pump shaft held by the frame bearings with a coupling to the motor shaft as in Figure 1 in Water Pumping Stations. The latter is more rugged and easier to maintain but more expensive and subject to greater forces in earthquakes. Horizontal pumps are usually skid-mounted by the manufacturer, an advantage in ensuring proper alignment of motor and pump shafts but a disadvantage in the larger floor space required.

Submersible pumps, introduced to sewage pumping in the 1950s, have become very popular in all sizes. As shown in Figure 1, a submersible pump is a close-coupled, end suction unit with the motor enclosed in a casing with watertight connections for electric cables and watertight mechanical seals on the motor shaft. The entire unit can be submerged in sewage. When installed in the wet well, a discharge coupling that allows the pump to be lifted out by a crane or hoist and reinserted on guide rails supports them. Some inundated submersible pumps have operated continuously without problems for five years or more. With air-cooling fins on the motor jackets or with a second enclosing casing filled with the pumped fluid, submersible pumps can be placed in dry wells thereby (1) eliminating the need for long motor shafts and for seal water supply and (2) making it possible to continue pumping if the dry pit is flooded. With water cooling, the motors can be started and stopped more frequently than the usual air-cooled motor.

Figure 1: Submersible sewage pump. Liquid enters from the bottom and is discharged through the expander at left. *Courtesy of ITT Flygt Corp., Trumbull, CT, USA*

Self-priming pumps are horizontal machines with a large chamber (colored orange in Figure 2) partly filled with the pumped fluid connected by an airtight suction pipe to the wet well. When the pump is started, the circulation of water from the chamber to the pump volute creates a partial vacuum that sucks water up the suction pipe. Pumping refills the chamber so the pump can reprime itself on the next start. These pumps are limited to shallow (about 7.6 m) wet wells and small flows (up to about 40 L s^{-1}). The advantage is that the machinery is above grade for easy access. Disadvantages include (1) long priming times and (2) the limited suction heights made somewhat more limited by gas generated in sewage and the remote possibility that a machine idle for a long time might (because of gas generation) be unable to prime itself. Another system for priming consists of a motor-driven vacuum pump to prime the main pump. That system can be applied to large units.

Vertical column type wastewater pumps that can pump water laden with trash and other solids were introduced in the 1970s and are now becoming common. See Figure 3. They are rugged, efficient, non-clog units with the advantages that only the pump is submerged in sewage and standard motors can be used. Names given to them by different manufacturers include VTSH (for vertical turbine, solids-handling), MPVT (for multi-purpose vertical turbine), and QMN.

Figure 2: Self-priming pump.
Courtesy of The Gorman-Rupp Company, Mansfield, OH, USA

Screw pumps, sometimes called Archimedes screws, are water lifters (and not really pumps) because they drag water up an inclined trough, as shown in Figure 4, open to the atmosphere and do not pressurize the fluid. They have been used for irrigation for many centuries and are sometimes used in sewage treatment plants where the lift is less than 10 m. Their principle advantage is that they operate as variable flow machines even though they rotate at constant speed. The disadvantages include high cost, large space requirement, problems of freezing, sweeping of volatile, noxious gasses into the atmosphere, inaccessibility of the lower bearing, and poor efficiency for high lifts and low flows. At a higher cost, the last two disadvantages are overcome in a modified design in which the screw is enclosed in a rotating drum.

Figure 3: Vertical column pump for solids handling (VTSH®).
Courtesy of Fairbanks Morse Pump—Pentair Pump Group, Kansas City, KS, USA

Figure 4: Spiralift^{TM} screw pump.
Courtesy of USFilter's Zimpro Products, Rothschild, WI, USA

1.2 Drivers

Most pumps are driven by electric motors, but electric power is prone to interruption. Even a few minutes of down time may be disastrous, so it is common to have a standby engine-generator that starts automatically when electric power fails. An alternative is an engine directly coupled to the pump shaft through a clutch and a right angle gear. See also *Drivers* in *Water Pumping Stations.*

Pumps can be driven at constant speed (C/S) or at variable speed (V/S). The advantages of C/S pumping are (1) lower first cost, (2) simplicity, and (3) reliability. The disadvantages include (1) the large size of the wet well needed to store water between pump starts, and (2) the degradation of downstream treatment due to sudden bursts of flow. The sudden drop in electric power line voltage for across-the-line starting for large motors may require somewhat expensive soft-starting equipment.

The advantages of V/S pumping are (1) gradually varying the flow at the treatment plant, (2) probably reduced energy cost (because friction in force mains is substantially reduced at the low flow rates that occur most of the time), (3) smaller wet wells (because little storage is required), (4) less transit time for the sewage (which stays fresher and is easier to treat), and (5) no surges in the electric utility power lines due to the oft-repeated starts of C/S motors. The disadvantages are (1) the high cost of V/S equipment, (2) potential for early obsolescence of V/S drive components, (3) increased maintenance, and (4) reduced reliability. Some of these drawbacks can be mitigated by a careful selection and application of equipment in a well-designed friendly environment.

Motors for C/S pumping in small to medium power are started across the line simply by closing a switch. The sudden surge of power heats the motor and limits the number of starts per hour that can be tolerated. The time between starts governs the size of the wet well. Soft starting reduces the high surge of power and starts the motor more slowly, but does not reduce motor heating.

The speed of electric drives in variable speed systems is now almost exclusively controlled by means of adjustable frequency converters (AFDs). There are a number of kinds but the net result of all of them is to change the cyclic frequency of power reaching the electric motor. Motors and AFDs must be matched (and sometimes filters added) to reduce the electrical spikes both to the motor and back into the utility's power line. The AFDs are expensive—often more so than pump and motor combined. Direct engine drives are ideal for V/S, because the engine can be easily throttled.

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Biographical Sketches

Robert L. Sanks, Ph.D., P.E, is Professor Emeritus, Montana State University at Bozeman and a consulting engineer. He has B.S. and Ph.D. degrees from the University of California at Berkeley and the M.S. degree from Iowa State University. He established the graduate environmental engineering program at Montana State University, directed it, and taught the subject for many years. He conceived and directed the Conference on Pumping Station Design for the Practicing Engineer and was Editor-in-Chief for the first (Award of Excellence, Association of American Publishers) and second editions of Pumping Station Design published by Butterworth-Heinemann. He has studied hydraulic models of pump intake basins for many years and has consulted on the design of several medium to large pumping stations. He has written five books and many papers and monographs. He is a Life member in American Society of Civil Engineers and a member of American Water Works Association and Water Environment Federation.

David Hanna, P.E., is a Professor of Construction Management at Ferris State University in Michigan, USA where he teaches construction and hydraulic engineering. He has designed and evaluated numerous water, wastewater, and sludge pumping systems while employed as a hydraulic engineer for 19 years prior to joining the faculty at Ferris State University. He has experience in training professional engineers, design engineers, and system operators of pumping systems design and operations at location throughout the United States from 1999 to 2002. Professor Hanna is a chapter author of the engineering reference “Pumping Station Design,” 2cd Ed, R. L. Sanks, Chief Editor, Butterworth-Heinemann publishers.

Garr M. Jones, P.E, is Senior Vice President, Design for Brown and Caldwell, Consulting Engineers, San Diego, California, USA. He has been involved in virtually all aspects of design of water and wastewater collection, distribution, treatment and disposal. Mr. Jones has Bachelor of Science degrees in Civil Engineering and Industrial Engineering from the University of Washington and holds Life Memberships in the Water Environment Federation, the American Society of Civil Engineers and the American Water Works Association. He is currently serving as chair for Committee 820 (Wastewater Facilities) for the National Fire Protection Association. Mr. Jones participated in the development of ANSI/HI 9.8 (Pump Intakes) and the AWWA standards for Weirs and Scum Baffles and Wash Water Troughs. Mr. Jones is licensed to practice engineering in 30 states in the United States of America and the Province of British Columbia. Mr. Jones served as a co-editor for the publication *Pumping Station Design*, First and Second editions, Butterworth Heinemann, and has authored 12 papers on various subjects dealing with water and wastewater applications.