MUNICIPAL WASTEWATER PUMP STATION DESIGN PROBLEMS AND SOLUTIONS

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ABSTRACT

The growth of the Northern Virginia Area around Washington D.C. has resulted in the requirement for numerous new wastewater pumping stations and the upgrade and expansion of existing pump stations. This paper presents practical problems and solutions associated with the following pump station design issues: 1.) Concrete Corrosion Protection, 2.) Corrosion Resistant Materials, 3.) Pump Protection from Influent Sewage Debris, 4.) Pump Selection Based on Total Dynamic Head Calculations, 5.) Energy Efficient Operation, 6.) Pump Station Appearance, 7.) Surge Protection, 8.) Rehabilitation of Existing Pump Stations, 9.) Odor Control, 10.) Prevention of Leakage into the Pump Station Structures, 11.) Provisions for Future Expansion and 12.) Grit Deposition in Wet Wells Sized for Future Flow Rates.

KEYWORDS

Wastewater, Pump, Station, Design, Corrosion, Energy, Appearance, Surge, Rehabilitation

INTRODUCTION

In the Northern Virginia suburbs of Washington DC rapid residential growth has resulted in the need for construction of numerous municipal wastewater pumping stations. Municipal pump stations in Northern Virginia typically are submersible type pump stations with a design capacity between from 100 gpm to 1 MGD. The design requirements for submersible type pump stations continue to evolve to address construction and operation problems. This paper identifies several of these problems and the solutions that have been implemented in the design of several recently constructed wastewater pump stations in Northern Virginia. The author has prepared this paper based on his 32 years of experience in wastewater pump station design in the Northern Virginia Area.

METHODOLOGY

Each of the identified pump station design problems is listed below by number with the corresponding design solution indicated under the problem.

PROBLEMS AND SOLUTIONS

1. Concrete Corrosion Protection

Problem: Until recently, most pump stations in Northern Virginia were constructed of concrete. Typically the wet well interior and exterior concrete surfaces received two coats of a coal tar epoxy coating to protect the concrete from the corrosion due to hydrogen sulfide in the influent sewage. Experience has indicated that concrete corrosion will result if either the coal tar epoxy is not properly applied, or is not reapplied when it deteriorates over time. It is very difficult to reapply coal tar epoxy, because usually the pump station wet well can not be taken out of service.

Solution: New pump stations include a high density polyethylene (HDPE) liner on the interior of the concrete surfaces exposed to wastewater for corrosion protection. This liner is provided as an option by the precast concrete suppliers and the concrete is formed around the outside of the liner. Following installation of the lined precast concrete structure a certified welder field welds the seams and welds around pipe penetrations to assure that the HDPE liner prevents sewer gas from attacking the concrete. Another alternative is to utilize precast polymer concrete structures. Polymer concrete utilizes epoxy to bind the aggregate instead of cement. Thus the polymer concrete is not susceptible to corrosion due to sewer gas.

2. Corrosion Resistant Materials:

Problem: Previous pump station designs included the use of galvanized steel and coated metal components in areas susceptible to hydrogen sulfide in influent sewage. After several years the metal components corroded and had to be replaced. These items included piping, pump guide rails, supports, grating, hand rails, stairs, bar screens, bolts, weirs, ladders, slide gates and other items.

Solution: Type 316 stainless steel is specified for guide rails, brackets, bolts, nuts, structural steel, supports, and stairs. Fiberglass grating and ladders are specified. Aluminum hatch covers and slide gates are still specified because they are light way and durable, but they are susceptible to corrosion over time. The exterior of ductile iron piping is epoxy coated. Corrosion resistant materials should also be specified for electrical components.

3. Pump Protection from Influent Sewage Debris

Problem: Most of the older pump stations had the influent sewer entering directly into the wet well and relied on the ability of the submersible pumps to pump a 3 inch diameter solid. Some pump stations had a basket screen attached to the influent sewer inside the wet well to try to protect the pumps from damage. However, the screens have to be manually lifted out of the wet well and cleaned by hand often to be effective.

Solution: In order to assure that the pumps are adequately protected, new submersible pump stations in Northern Virginia often include a comminutor vault preceding the wet well. Raw wastewater entering the pump station flows through the comminutor vault influent channel which is equipped with a grinder. The grinder is a hydraulically driven horizontal screen and cutter assembly. The rotating screen directs solids toward and into the cutters where the influent solids are ground into fine particles to protect the downstream pumps. The grinder 5hp hydraulic power pack is located in a fiberglass enclosure mounted on top of the comminutor vault. In the event the grinder must be taken out of service, slide gates are provided to direct comminutor vault influent flow to a bypass bar screen. Also, in the event flow backs up upstream of the grinder the influent channel wall has an overflow notch just upstream of the bar screen. The bar screen is constructed of stainless steel bars and must be manually cleaned with a rake. The comminutor vault is a 12 ft. diameter precast concrete manhole with an HDPE liner. Stainless steel alternating tread stairs are used for access to the bottom of the vault. All lighting and electrical equipment is explosion proof inside the vault. A ventilation fan is provided on top of the comminutor vault.

4. Pump Selection Based on Total Dynamic Head Calculations

Pumps are selected based on total dynamic head (TDH) calculations which can lead to improper sizing unless the Engineer carefully considers the exact pipe inside diameter, the Williams Hazen flow coefficient (C), and the location of high points in the force main. Each of these factors is discussed as follows:

Inside Pipe Diameter: Typically in Northern Virginia force main piping is either double cement lined ductile iron pipe or PWC pipe per AWWA C-900. The inside pipe diameter may vary considerably depending on the type of pipe selected. For long force mains extending two or more miles in length this can result in a significant difference in friction head component of the TDH.

Solution: Determine the type of force main to be constructed and the exact inside pipe diameter in preparing TDH calculations. If the force main could be either ductile iron pipe, PVC or some other material, the TDH calculations should be prepared for each possible pipe material to make sure that the selected pump is adequate for all pipe materials.

Williams Hazen flow coefficient (C): For new ductile iron pipe a C factor of 140 is often used in TDH calculations to estimate friction head in the force main when it is first placed in service. A C factor of 120 is often used to estimate the friction head in the force main after several years of operation. Pump selection based on a C factor of 140 alone will result in a pump that may be undersized when the force main pipe C factor decreases due to increased roughness of pipe internal surfaces over time. If the pump selection is based on a C factor of 120, the pump may pump too high a flow rate at startup because the new smooth pipe C factor is actually 140. This can result in overloading the pump motor. Also, it is important to note that field measurements of the actual C factors for old force mains which have been in continuous service for over 25 years has indicated that the C factor has decreased to approximately 100.

Solution: For new pump stations, prepare TDH calculations based on the initial new pipe C factor and the anticipated C factor after the force main has been in service for several years. When expanding the capacity of existing pump stations which have been in service for many years, the actual C factor of the force main should be determined by field measurements.

Problem involves a *Force Main High Point near the pump station:* Typically the TDH calculations are based on the entire length of force main pipe from the pump station to the discharge point. However, when pumping from one valley over a hill to a gravity sewer on the other side of the hill it is important to consider whether or not there is free fall in the down hill segment of the force main such that the downhill length of pipe does not need to be considered in the TDH calculations. If the static head from the high point to the discharge point exceeds the full flow headloss in the downhill segment of force main, sewage should flow by gravity through the force main similar to a gravity sewer instead of as a full pipe under pressure. Failure to recognize this condition in long force mains with a high point near the pump station can result in the selection of much higher capacity pumping equipment than actually required, and in significantly higher pumping rates than anticipated.

5. Energy Efficient Operation

Problem: Common pump station design practice over the past 50 years has been to provide two pumps sized for the peak design flow rate, one of which is a standby pump. For pump stations with long force mains, the friction loss when operating at the design peak flow rate is excessive, resulting in high energy costs. Energy efficiency is becoming a very important consideration in pump station design. The Town of Purcellville East End Pump Station in Loudoun County, VA was equipped with two 75 hp submersible pumps which cycled on and off at the peak design flow rate of 600 gpm at 127 feet TDH. Sewage is pumped through an 8-inch force main, 4,572 feet long with friction headloss of 39 feet and excessive energy costs from frequent pump cycling on and off due to sewer infiltration/inflow.

Solution: A small 10 hp submersible jockey pump was installed in the wet well to operate almost continuously through the day at a flow rate of approximately 100 gpm. This lower flow rate significantly reduced the friction loss and energy requirements while providing reliable service. The friction headloss was reduced from 39 feet to 2 feet. The larger pumps only operate a few times a day during peak flow periods in the morning and evening which is sufficient to flush out solids in the force main. Power costs were significantly reduced based on three years of operation.

6. Pump Station Appearance

Problem: For many years pump stations were designed to be functional with little attention given to the exterior appearance and the impact on the surrounding community. Many of the new pump stations in Northern Virginia are located next to new homes costing over $700,000 or next to attractive commercial development. Standard utility buildings with barbed wire exterior fencing are often unacceptable to the developers in Northern Virginia.

Solution: The pump station control building exteriors include stone faced block walls or other features to match the surrounding development architecture. Ten foot high black galvanized steel picket fence is used with an extended top slanted for security.

7. Surge Protection

Problem: When the pumps cycle off or there is a power failure, high surge pressures can damage piping.

Solution: Soft start/stop electrical control equipment significantly reduces surge pressures. As backup protection a surge relief valve is often installed at each pump station in the event of a power failure or a failure of the soft start/stop equipment.

8. Rehabilitation of Existing Pump Stations

Problem: Fairfax County has a program to rehabilitate four to eight pump stations every few years under one construction contract as necessary. After approximately 20 years of service they have found that parts are no longer available for electrical controls, and pumps and valves need to be replaced. Also, the building structures, roads and electrical service are often in need of replacement. The pump station must be maintained in continuous service through construction and thus constructability issues must be identified in the design process.

Solution: Based on over 15 recent pump station rehabilitation projects, a typical scope of work can be identified for construction rehabilitation. Each pump station needs to be examined separately to determine what rehabilitation measures are needed. Pumps and valves and other mechanical equipment items are replaced. Typically, dry pit submersible pumps are used to replaced shaft pumps. New electrical controls are installed. Corrosion resistant materials are installed to replace corroded materials or epoxy coatings are applied to existing surfaces. Structural and architectural improvements are identified. The construction phasing and temporary pumping requirements are identified in the contract documents for construction. An existing 20 MGD wet well/dry well pump station with vertical shaft pumps was expanded to 40 MGD capacity with dry pit submersible pumps while maintaining continuous operation. This was achieved by first installing two of the submersible pumps in the wet well and providing a temporary force main. Once this temporary pumping system was operations, all of the equipment in the dry well was replaced with new equipment. Once two of the four dry pit submersibles were installed in the dry well, the two pumps in the wet well were removed and also installed in the dry well to complete the project.

9. Prevention of Leakage into the Pump Station Structures

Problem: Cracks or joints in precast concrete manhole structures used to construct new pump stations can result in groundwater leakage into the pump station which must be pumped to the treatment facility resulting in unnecessary costs and reduced capacity. It is often difficult to permanently seal such cracks or joints after construction is completed and the pump station is in service creating a confined space. This is especially true for deep pump stations.

Solution: All weather butyl joint sealant materials are available for effective sealing precast concrete joints exposed to high groundwater pressures. Butyl sealants are rubber based and exhibit physical properties such as rebound, compression, low temperature and high temperature flows that are all required for long term sealing performance. This joint material was effectively used at the 50 foot deep Morris Farm Pump Station in Prince William County to prevent leakage. Other methods of sealing the joints and concrete surfaces are also available including bentonite.

10. Odor Control

Problem: Sewage piping designed for future ultimate design flows is often way oversized for initial flows resulting in long pipe retention times and septic odors.

Solution: Chemical feed addition at pump stations can help minimize odor problems throughout the downstream sewer system. Bioxide® chemical solution has been utilized at several new pump stations to minimize odors. The Bioxide® material utilizes the inherent ability of the facultative bacteria normally present in wastewater to metabolize hydrogen sulfide and other odor-causing, reduced sulfur containing compounds. The material provides nitrate-oxygen to the wastewater to support this biochemical mechanism. This nitrate-oxygen is applied via nitrate salts. The material shall be chemically stable, allowing continuous removal of sulfide contributed by side streams downstream of the application point. The pump station design includes a pad mounted Bioxide chemical storage tank and automatic chemical feed equipment.

11. Provisions for Future Expansion

Problem: The rapid growth experienced in Northern Virginia over the past few years can result in pump stations being undersized to convey projected flow rates. If provisions for future expansion are not included in the design, the entire pump station or major components of the pump station may have to be replaced.

Solution: Provisions for future expansion include the selection of pumps with higher than required motor horsepower to allow the future installation of larger diameter impellers capable of pumping increased flows. The Morris Farm Pump Station in Prince William County was almost over capacity at start up because of the addition of unanticipated sewage flows from a new elementary school which was supposed to be served by an adjacent gravity sewer system. Fortunately, by adding a larger impeller the additional flow could be accommodated without any other changes. Other considerations include sizing the force main, generator set, wet well, electrical service and other components to allow some increase in capacity without causing problems during initial operation.

12. Grit Deposition in Wet Wells Sized for Future Flow Rates

Problem: The design criteria for submersible pump wet well sizing can lead to excessive grit deposition in the wet well due to initial low flow conditions. The grit can result in serious odor problems and is difficult to remove.

Solution: Provide temporary solid concrete block filler in the wet well areas subject to grit deposition or provide baffle walls to reduce the wet well area during initial low flow conditions. In the future when the flows approach the design flow rate, the blocks or baffle walls can be removed.

CONCLUSION

The planning and design of new municipal wastewater pump stations or rehabilitation/expansion of existing pump stations requires careful consideration of potential problems and possible solutions presented above.