DESIGN, CONDITION AND OPERATIONAL CONSIDERATIONS FOR SEWAGE PUMPING STATIONS

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ABSTRACT

This paper is aimed at providing a broad understanding of the design principles behind conventional gravity sewage pumping stations, the operating and maintenance requirements and aspects of condition assessment.

Much of what I want to talk about is common sense but often people don't always apply it or have forgotten. A good reason to talk about pumping stations at this conference is that many treatment plant operators also operate and maintain pumping stations. The following comments should be part of an ongoing education process to familiarize those operators with some of the associated issues they face.

1.0 General Guidelines to Station Operation and Maintenance

Submersible sewage pumping stations are part of the transportation process which moves raw sewage from the source to the treatment process. They come in all shapes and sizes but in Australia tend to follow a consistent theme. Size is related to the volume of sewage to be handled and the size and number of pumps required to fit in the station.

Most of the smaller capacity stations tend to be submersible type and generally have two submersible motor pumps installed. Submersible stations are less expensive to construct than an equivalent dry well station and the pumps are easier to repair as they can be removed from the well whereas for a dry well station pump removal and re-installation must be done down the bottom of the well.

Whilst many of the same comments apply, today I will be talking about submersible stations.

2.0 Design

The pumping rate of a sewage station is based on the expected inflow rate. That is, how many litres per second enters the station at any time and needs to be pumped out. The inflow volume relates to the number and type of properties to be serviced and takes into account the total number of persons residing or working in those premises that will contribute to the inflow. For each person there is a daily volume to be allowed. From this, the total dry weather flow assumed to enter the station can be calculated.

Whilst the end figure may be an average over 24 hours, inflow will vary throughout the day, with morning and evening peaks.

Added to this figure is a storm allowance. This allowance recognises the likelihood that wet weather will result in rainwater infiltrating the ground and entering the gravity sewer pipes which lead to the station and in turn increase the inflow to the station. For example, in some systems where the pipes may be old or ground movement has caused the pipes to break or loosen at the joints, wet weather inflow may be as much as 10 times dry weather flow. In some cases houses have their roof water directed to the sewer.

The maximum rate of inflow determines the holding volume required based on a maximum number of pump starts per hour. For example, if the well was huge, the pump may only operate once a day. The cost of the station would be enormous and the sewer in the well would soon turn septic.

Conversely, if the well was very small, the pump would be cutting in and out all the time. This would soon destroy the pump and switchgear. Therefore a balance is generally reached where the well is sized for between 8 and 12 pump starts per hour maximum.

The physical size of the well is also influenced by the size of the pumps and the number of pumps required so that they will fit in the well. For example, whilst most stations may have two pumps, being duty/standby, sometimes it may be less expensive in the longer term to have three pumps (2 duty/1 standby). This could be because the dry weather flow is low compared to the wet weather flow and if the rising main is long, energy will be saved by using a smaller pump to pump the dry weather flow. This flow is at a lower velocity compared to using one large pump designed for wet weather conditions and which would operate more in a start/stop manner and use more energy during dry weather.

The volume of dry weather flow can be some 85% to 90% of the total. So the potential energy savings can be considerable but it totally depends upon the particular system as to whether this approach is viable.

Another important aspect of station design is to ensure that inflow does not drop onto the pump and allow air entrained fluid to be drawn into the pump which leads to air getting into the rising main and causing restrictions, similar to having a partially shut valve in the line. Turbulent inflow will certainly reduce pumping performance and pump life.

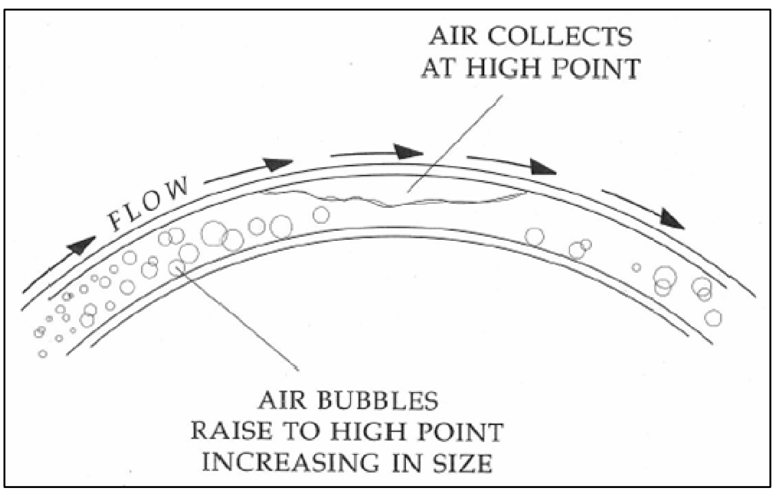

Figure 1: ***Air entrapment in pipelines***

So the correct positioning of the pumps in relation to the inlet is important. For example, some package type stations, which may be designed primarily with cost in mind, may not have sufficient hydraulic setback. Inflow needs to enter the pump at a uniform velocity from all around the pump and not be turbulent.

Velocity in the pump discharge pipework is also important. Care must be taken not to oversize or undersize the pipes. This is for a number of reasons. One is to make sure the solids contained in the sewage are transferred up into the rising main rather than sit at the bottom of the riser pipe if the pipe was oversized. Another reason is to ensure that the hinged flap in the non-return valve does not "flutter" and wear out the shaft bushes as could happen if the velocity was too low

If the pipe is too small, blockages may occur, particularly at bends, and scouring of the cement lining could occur plus it increases the pumping headloss and uses more power than it should.

3.0 Materials

Materials selection is a key factor in station life expectancy, and there is a need to provide a longer life and eliminate the need for rehabilitation works due to corrosion. Such corrosion can be caused by sewer gases such as hydrogen sulphide (H_2S) because in a damp environment it will form sulphuric acid and will attack cement and metal components. Products used to control septicity and odours in sewer lines can also attack metal components.

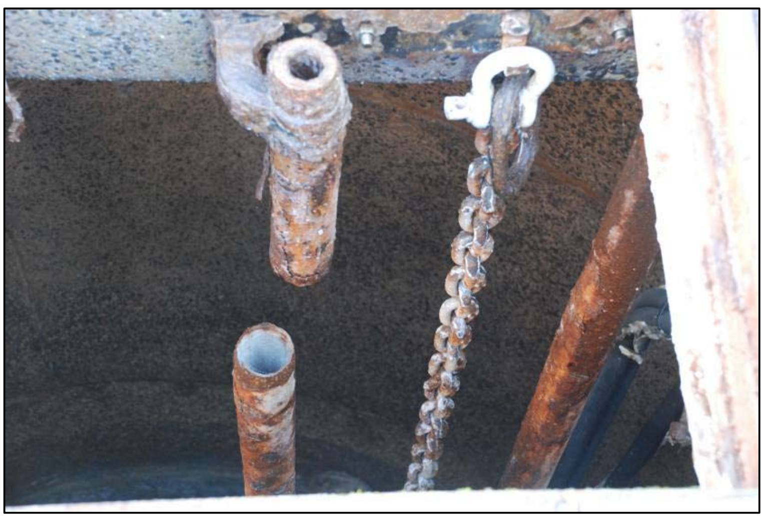

Figure 2: ***Badly corroded pump guiderails***

Poor initial materials selection will lead to shortened asset life and the need to replace components at an early stage. Isolating the station to do this can be costly. Better materials will cost more to start with but will pay for themselves in the long run.

The use of grade 316 stainless steel is an excellent way of fighting corrosion. This can particularly apply to nuts and bolts, lifting chain and pump guiderails.

Good ventilation within the well can play a part in reducing above surface corrosion.

4.0 Safety

Operator Safety
Operator safety is an important aspect not always considered, given that many hazards are so often needlessly placed at or around pumping stations.

Tripping obstacles placed too close to the station are a definite safety hazard, as are open wells.

<u>Figure 3:</u> ***Serious accident potential***

Gatic covers, for example, may provide good public safety and allow vehicle access over, but are very hazardous for operators, not only in removing them but in placing them back in position.

A safety grille of some type offers protection from a fall if the screen is in position. However, to remove a pump the screen has to be firstly removed and this is when danger is most evident.

Public Risk
Public risk exposure is another element, where hatch covers or lightweight covers over access chambers or pump wells are not locked or adequately secured.

Housekeeping
Housekeeping is important in reducing the build up of material in the well which could cause pump blockages and odours.

Regular hosing down and cleaning to prevent build up of fat and other debris is important otherwise it can break away from the walls and clog pumps.

5.0 Effects of Insufficient Maintenance

Where you have rotating machinery, maintenance will generally be necessary to keep that item functioning without excessive wear. This maintenance cannot be done on site and pumps must be removed from the well at regular intervals and taken to a workshop facility. The maintenance intervals can be based on running hours, elapsed time, wear ring wear as measured when the pump is lifted from the well, or when alerted by the seal chamber moisture alarm etc.

With submersible sewage pumps the key items that wear and need to be replaced are:

- Motor shaft bearings
- Mechanical seals
- Impeller wear rings
- Casing wear rings
- Impeller
- Casing

If pumps are not maintained in a regular manner then components will fail, generally with little warning and the pump could be out of service for some time. Moreover, because other damage could have also been done, the repair cost is likely to be far greater than for regular maintenance replacements.

6.0 Condition Assessment

A condition audit on pumping stations can be undertaken to document their condition and to highlight items that require attention. This will allow the preparation of a program of works and the allocation of funding according to priorities.

The inspection can be a visual examination of individual components which make up the station. This would include the physical condition of the concrete, metalwork, pipework and other items. The condition of the components for each station is recorded on an audit log sheet (pro-forma) and photographs of the items taken.

Condition is ranked on a scale of 1 to 5, with 5 being the worst condition. Criticality to basic station operation for the components is also identified, ranging from Low; Medium; and High.

7.0 Assessing Pump Performance

Pump wear can often occur over a relatively short period after commissioning. Pumping performance compared to new can be checked by carrying out simple tests.

Impeller/ volute casing wear

Pump performance can be checked by carrying out a "drop test" or by taking a pressure gauge reading. Such tests can provide an indication of how the pump is performing compared to the originally specified flow rate and head. Wear will lead to longer running hours and increased power cost. This must be weighed against the cost of overhauling the pump if there is nothing else wrong with it. Only the results of testing will assist in determining whether the pump should be overhauled or left until other more vital work is needed.

Wear occurring on the impeller wear ring allows water from the impeller to leak back into the pump inlet and get re-circulated.

A drop test is done by having the pump running and then measuring the time it takes to drop the level in the well by say 300mm as measured with a linen tape attached to a wooden float. By knowing the well diameter, the volume occupied by the 300mm can be determined and the pump out rate calculated.

If the test is done without first shutting the inlet valve (if there is one), a further measurement is taken of the rise time for the well. This gives the inflow rate. The inflow rate is then subtracted from the outflow rate to arrive at the true pumping rate figure.

A pressure gauge to measure shut head pressure is another means of assessing pump performance, but this test may be less informative unless more is known about the pump and system.

Discharge Stand (Connection) Wear

Wear between the pump outlet face and mating discharge stand face is an area which can lead to pumping inefficiency. Such wear can be identified by visual examination during pump down to see if water sprays out.

The wear starts with perhaps a bit of vibration shaking the pump about and some sewage leaks out under pressure, carrying grit and other abrasive material. Progressively the metal faces will become scored, thereby allowing more leakage and so on.

If there is a sign of leakage, the wear could be on the pump face or discharge stand face or both. It is more difficult to remedy if the discharge stand face itself is worn because it is bolted to the floor of the well. Such wear can be identified by visual examination during pump down.

8.0 Summary

In summary, to ensure that a pumping station operates efficiently and has a long life, there is quite a deal to consider. Moreover, pumping stations are hazardous environments and we should try to make them as safe as possible. Too often little thought is given to this.

The lack of regular maintenance will end up costing more in the long run and lead to unplanned downtime. Regular condition assessment followed by remedial work will help maintain a station in good repair.

Finally, maintenance of the pumping units themselves before they deteriorate too far is a good investment in terms of pumping efficiency and reliability.