Over pressure protection for pressure sewer systems

By ***David Fletcher & Stephen Wallace***

Pressure sewer systems have been around on a global basis for more than 30 years and have proven robust, reliable and the most cost effective solution (on a whole-of-life cost basis) in many applications.

In the context of Australia, the first true pressure sewer system was installed at Tooradin in South East Water's region. Tooradin is very flat and had a major issue with grey water retention at the street level, hence South East Water's requirement to upgrade the system.

The pressure sewer system installed was supplied by Environment One and has operated for more than four years with a mean time between service calls (MTBSCs) of greater than 15 years (data supplied by SE Water), well above what was expected by the client or in fact estimated by the supplier (MTBSCs typically run at greater than 10 years).

Thousands of installations later, in a very challenging project, it became apparent that although the water being discharged was very similar to that in the United States, the polyethylene piping supplied in Australia was rated very differently from that available in the Untied States, in fact so different that any of the off-the-shelf grinder pumps available in Australia could have pushed the piping to failure in the unlikely event that service personnel inadvertently left specific isolation valves shut for an extended period of time. The issue here was not the ability of the pump to produce enough pressure to cause deformation or even failure of the pipe, rather the potential for extreme static system pressures coupled with the pump discharge pressure becoming greater than the working pressure of the polyethylene pipe.

Following is a brief discussion of over pressure in pressure sewer systems, when you should consider it, how to deal with it and various methods of preventing it along with specific issues that must be evaluated to ensure that the solution provided is the correct solution for your application. It should be noted that this is not considered to be a definitive work; however, the issues identified will provide a good start point for anyone designing pressure sewer systems.

Pressure sewer systems have been used around the globe for more than 30 years and have proven robust, reliable and a cost effective solution in many situations.

What is over pressure?

Over pressure is a condition where the sum of the static head and the pump discharge pressure approaches the working rating of the pipe network. This can be made from high pressure pumps, high static head or most likely a combination of the two. In addition the over pressure condition can be exacerbated by the selection of an inadequately rated piping material.

When should over pressure be considered?

Over pressure is not limited to any specific applications and, as noted above, it can be the result of a combination of factors. As such, over pressure should be considered when designing any system. Environment

One recommends that the conditions be analysed by a professional in all cases, especially in areas of significant relief (> 40 m), when pumping downhill and when piping is only available in specific classes (for example PN 12.5 pipe may not be suitable for a specific application and may create an over pressure condition, this could be eliminated by using a high rated product, for example PN 16).

How to deal with over pressure conditions

Ultimately, the best means of dealing with over pressure conditions is to design them out, a little thought and some good ol' fashion Aussie ingenuity can go a long way. Where this is not possible, an electrical/mechanical solution may be sought.

There are many of these available and each has its place, the key is knowing when to use what. Environment One currently offers three electrical/mechanical solutions to over pressure conditions. These include:

- a pressure transducer mounted on the pump discharge line of the pump;
- a proprietary current measuring device;
- the 'M3' rotor stator combination.

Pressure transducers are commonly available and have the benefit of being adjustable to cut the pump at a variety of different discharge pressures. The down-side of the pressure transducer is that these devices were never designed to operate in a tank full of sewage and as such have proven unreliable. Should pressure transducer's be used, it is important that the impact of such a device on the system be considered. Some specific considerations that should be addressed include:

- system recovery after a power outage;
- flushing capabilities;
- airlocking.

These issues will be discussed in further detail below.

Current measurement relies on the motor drawing a specific current at a specific discharge pressure. These units have proven very successful and have an excellent track record in the Australian

Table 1. System pipe sizes and the required flow rates to move solids through the system

Pipe Size (mm)	Required flow rate to flush pipe (l/S)	Number of stations required to provide flowrate	Litres per metre of pipe	Approx metres of pipe to be flushed using number of stations in column 3
40	0.58	1	0.8	750
50	0.58	1	1.25	480
63	1.16	2	2.04	588
75	1.74	3	2.92	616
90	3.47	6	4.18	861
110	5.21	9	6.22	868
125	6.94	12	8.01	900

Based on
1. a flushing velocity of 0.6m/s (minimum)
2. a nominal 600L station capacity, will vary with different models
3. Polyethylene PN 16 PE 100 pipe to AS 4130

market. The major downfall of the current measuring device is that its accuracy is determined by the nature of the current drawn by the motor. Many motors have a relatively flat current draw in the operating range of the pump and this can reduce the accuracy of the cut out pressure.

The M3 rotor, stator combination is the most elegant solution available and comes at no additional cost. The design of the rotor stator combination is such that the pump can not physically deliver more than a specific discharge pressure. The M3 combination also has a drawback in that the maximum pressure delivered is not adjustable.

Elevated pressure versus over pressure

Whilst over pressure conditions as defined above can be a concern and should be addressed when designing pressure sewer systems, the means used to address or prevent these over pressure conditions should also be a concern to the designer. Pressure sewer systems are unique in sewerage reticulation systems in that the system must be considered on a whole rather than on a pump-by-pump basis (as is the case with the many thousands of 'pump up' solutions installed around the country. The 'pump up' solution is purely one of liquid elevation, and there is virtually zero interaction within a system where the pump up discharges into a gravity main or manhole).

Pressure sewer systems are termed 'systems' as each and every pump within the 'system' has the ability to interact with the others. This interaction requires that a designer must address the impact on the system of specific circumstances, not just on the pump or even street of pumps that are immediately affected.

The operating profile of a pressure sewer system is not consistent with a traditional sewer rising main from a pump station. A pressure sewer system has a variation of flow regimes from zero flow at periods overnight to peak instantaneous flow which lasts for a short duration at infrequent periods. As such the velocities of the sewage flow in the pipe will vary accordingly. A pressure sewer pipe section which has a high point may entrap air causing the following scenario; the flow increases from a low-flow period to an absolute peak instantaneous flow period; subsequently the air will create an additional pressure within the system, increasing up to the point of air sweeping velocity crossover and purging the air along the downstream grading pressure sewer section. Therefore the highest pressure the air lock will impose on the pressure sewer system may be at the flow point just prior to this air sweeping velocity crossover. A number of issues exist with this situation as follows:

- The crossover point may be at a high-flow rate, which the average daily peak may not reach.
- The peak flow rates required to reach the required air sweeping velocity crossover may only be for a short period of time - for example, less than a minute. This time may not be sufficient to purge the system.
- The semi-positive displacement grinder pumps may be exposed to an additional head at every operation.

This may be overcome in following ways:

- Vent air to atmosphere – where air cannot be scoured to the outlet, an alternative is to vent the air to atmosphere at an air release point. The pressure sewer system design accommodates the use of air valves to release air from the system and therefore eliminate the additional pressure ('air head') the pump would otherwise experience.
- Designing for air entrapment – where venting to atmosphere is not practical, it may become necessary to design the systems to allow the grinder pumps and other system components to overcome the additional head loss caused by the entrapped air.

If we look at a system that under extreme conditions or due to human error, could result in an over pressure event, it may be considered appropriate to simply limit the discharge pressure of the pumps to ensure that the over pressure condition can never occur. Systems have been installed with maximum discharge pressure as low as 45m and whilst this ensures an over pressure event cannot occur, it can result in other more significant issues including air locking (or binding) and pipe blockages.

In the 1970s at Grandview Lake in Indiana, it was demonstrated that air locking in pressure sewer lines can regularly require at least 40+ metres line pressure to clear the lines and in this case, the centrifugal pumps installed in the application were unable to clear the lines and, without intervention, would have resulted in mass overflows of the system. Grandview Lake is but one example of the air locking that can and will occur in pressure sewer systems. As designers, it is our role to ensure that the potential for air locking is addressed and that we ensure the system is able to achieve the pressures required to move the air through the system or that other means of relieving this condition are designed into the system such as air release valves, along with the appropriate air scrubbing systems and a rigorous maintenance schedule.

Blocking of piping systems is a far less common event and can be a result of many abnormal factors, most of which are related to poor construction techniques or unique combinations of contaminants entering the system. Trade waste discharges of grease and other solid materials will increase the likelihood of blockages and hence applications with these discharges increase the necessity for high pressures to assist in clearing these situations. In most instances a semi-positive displacement-style pump will work to clear the line as has been demonstrated in various systems throughout the country. As a blockage builds up over time the system pressure is increased with the pumps working harder and harder, usually a fluid velocity is reached at which the build-up will be removed and moved along the line to the discharge point. These elevated velocities create higher friction losses and hence higher system pressures. A system with a pump that is unable to operate at elevated pressures is more likely to require operator intervention to maintain satisfactory long term performance.

System recovery after extended power outages

In the rare event of an extended power outage, pressure sewer units will generally fill to a level that exceeds the point at which the alarm is activated. When the power is restored, all of the units will attempt to start and immediately the units that are seeing the highest pressures will thermal out and restart when the thermal device resets. This arrangement requires the unit to be designed with a robust thermal device to ensure a suitable recovery, EOne's design has proven extremely successful. If the system is designed with an overpressure device, it will struggle to recover after a power outage as each station will be 'over pressure' and will shut out. If and when the pressure is reduced, all units will restart and will immediately trip out on 'over pressure' again. This condition could continue indefinitely.

System flushing

System flushing can also be achieved (without external intervention) when a system utilises pumps that can operate at elevated pressures.

The nature of the semi-positive displacement grinder pump allows the operator to use a series of pressure sewer units operating simultaneously as a flushing facility for the system. This method of operation is particularly easy to accomplish with the small diameter pipes commonly seen in pressure sewer systems.

Table 1 demonstrates system pipe sizes and the required flow rates to move solids through the system. Columns 4 and 5 outline pipe volume and the length of pipe the combination of pressure sewer units discharging simultaneously will flush.

Overcoming high pressure/over pressure situations

- Design it out by changing the discharge location.
- Separate the system between low and high pressure systems with check valves between the two systems.
- Limit the locations (high and low) of pressure sewer unit in a development. This limits the maximum and minimum pressures a system may experience.
- Provide an intermediate sewer pump station or break tank.
- Install high pressure rated components.
- Implement management practices.
- Limit the shut-off head of the pump, utilising one of the methods described above.

It should be noted that limiting the maximum discharge pressure of the pumps in the system can have disastrous consequences in a pressure sewer system and the impacts of this course of action should be well understood before such a decision is implemented. Limiting the maximum pressure available in a system can lead to significant increases in system operating costs along with lower reliability and reduced customer satisfaction and, as we all know, that is what it is all about!

References

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EPA-R2-72-091, *A Pressure Sewer System Demonstration*

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