CONTROLLING AND UNDERSTANDING THE EFFECTS OF AIR IN PIPELINES

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ABSTRACT

The paper covers some of the experiences encountered in visiting and discussing many of the problems associated with the controlled release and intake of air into pipelines to maximise their performance. It appeared that there was generally a poor understanding of how critical the product was to the safety and reliability of the pipeline.

Today in all industries involved within water transfer, the issue of reduced pipeline failure and increasing performance is high on all agendas. This paper will best describe some of the roles that the air release valve plays in various pipelines, and how it can be safely and effectively used in order to achieve greater results.

1.0 INTRODUCTION

The controlled intake and release of air from pressurised pipelines, is controlled by the installation of several different types of air release valves, located generally at the high spots along the pipeline length. The valves have generally ranged from 20 to 200mm in size, and have been manufactured in a wide variety of designs in order to provide various functions relating the control of air in liquid pipelines. After consultation with many different pipeline operators and engineers, there were many problems found with existing installations.

Some of the following were typical comments of existing pipelines:

- Valves were incorrectly specified to perform their required function in the pipeline.
- The valves were undersized for the pipeline profile and diameter.
- The valves were generally corroded and several leaks apparent from different areas.
- As many of the valves leaked, snakes were attracted to the pits much to the danger of the operators.
- The inability to stop the valves leaking either due to failure of one of the floats, or low-pressure conditions, caused the valves to be isolated by the gate/sluice valve under the air valve.
- Many of the valves located in below ground pits did not have the area vented sufficiently in order to have the valve operate within its design. The valves would then fail to operate correctly.
- Many of the operators and engineers had a poor understanding of the operation of the valves, and an ability to safely select a correct product to suit a pipeline profile.

2.0 PROBLEMS ASSOCIATED WITH INEFFECTIVE AIR VALVES.

The problems associated with ineffective air release valves impact on the performance of the pipeline. The introduction of the correct product can rectify many inherent problems that have existed since pipeline inception.

- **Reduced flow.** As many pipelines use a kinetic (large orifice) air valve only, there is no automatic manor in which dissolved air is released from the pipeline when it is the charged. In this instance, dissolved air will rest at the high spots in the pipeline, which in effect reduces the pipeline diameter at this point. The air will only continue along the pipeline when the velocities are increased beyond 2m/sec.

If the velocities remain low, then the high point will generate a head loss across that location, and thus reduce the flow. In some instances, fitting a hydrant valve, and trying to scour the air out under high water velocity will release most of the air as long as the hydrant is at a high point and the velocity.

- **Increased pump-running costs.** As the dissolved air is not released automatically (when using kinetic valves), the head loss generated at the peaks of the main in effect reduce the pipe diameters at these points. As we are generating a head loss at these points, the pump has to work harder in order to achieve the required performance.

- **Water hammer.** When the pipeline has the pockets of air at the high points, these can compress on pump start up and shut down, which can exaggerate the water hammer conditions. In addition if sections of the pipeline drain and refill on pump start up, undersized air valves can prematurely close when the velocity is too great at the kinetic valve. When this function occurs, the air is compressed and can generate excessive water hammer problems.

- **Corrosion.** When dissolved air sits at the high spots on the pipeline, the valves and metallic pipeline is subject to oxygen, which in effect will start corrosion at these points. Corrosion will weaken the steel and shorten life expectancy.

- **Collapsed pipelines.** In pipe diameters where the relationship to from the pipe thickness to the diameter is below a specific ratio, then the pipe is at risk during vacuum conditions of collapsing. Insufficient size and spacing of air valves during either scouring or draining can cause excessive vacuum, which theoretically can collapse pipeline lengths. It is more apparent in government owned effluent irrigation pipelines where pipe selection is not anywhere as critical as in water distribution systems.

3.0 PRINCIPALS OF AIR VALVE OPERATION

One of the major problems associated with incorrect installation is the poor understanding of the air valves operation. The operation of the three different types of valves are detailed as shown below:

- **Kinetic valve.** This product is sometimes called the *large orifice* valve. Its prime purpose is to release large amounts of air during the filling of the pipeline. As the pipe is filling the valve should be sized to ensure that the air volumes leaving the orifice do not exceed a specific velocity which will prematurely close the valve before all the air is adequately released. During drainage the valve must allow air to re-enter the pipeline to prevent vacuum conditions. Admitting air into the pipeline is critical for pipes which may collapse due to negative pressure in the line. It also has an effect on the flow rate of drainage. This is particularly important when emptying pipelines for maintenance purposes. When the pipe is charged and under pressure, the *kinetic valve* will not let dissolved air release from the pipeline. The system pressure on the surface of the upper orifice of the valve will create a force exceeding the weight of the float. When there is no pressure in the system, the float will fall allowing air to re-enter the pipeline. Typically the kinetic valve will seal from pressures as low as 2 metres, and have maximum pressure ratings up to a maximum of 100 bar. The valves are manufactured in either engineered plastics, or cast metals dependant on the pressure ratings of the valves. Valve sizes range from 25 to 200mm in diameter.

- **Automatic valve.** The typical terminology for this type of valve is *small orifice*. Its primary purpose is to allow small quantities of dissolved air to release from the valve when the pipeline is under pressure. This ensures that the pipeline remains fully charged, and avoids many of the problems associated with entrapped air. The valve can also be used as a *kinetic* in smaller diameter pipelines to fill and drain the pipe. This needs to be accurately selected due to limited orifice size of such valves. The materials of construction vary from engineered plastics to cast metals in sizes from 12 to 25mm.

- **Combined valve.** The combination valve is commonly referred to the *double orifice* or *double acting* valves, as it incorporates both the kinetic and automatic function in the same valve. The two functions are generally cast or moulded into the same housing, and in some instances can incorporate an isolation valve. The materials of construction and valve sizes are similar to the *kinetic* valves.

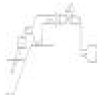
4.0 DISSOLVED AIR

When discussing with many water authority personnel, problems associated with entrapped air in larger trunk mains, a frequent response has been *"our main is always charged, and we do not have any entrapped air"*. Due to this misunderstanding, many larger pipelines only utilise *kinetic* air release valves as their primary method of air release and intake. As previously discussed the kinetic valve will never release dissolved air from the pipeline. It there fore is critical to understand *"how does dissolved air release from the water in the pipeline"*. The usual way in which high volumes of dissolved air becomes apparent, is when water appears milky or white in colour. When left to settle in a glass, it returns to translucent. In bore pump installations where the water temperature can be up to 40 degrees C, it is easily seen in the water exiting the bore. If this water is travelling along long pipelines, dissolved air can be a major problem. The following points are examples where dissolved air conditions are situations where the air is dissolved from the water:

- **Pump station.** On the inlet to transfer pumps, if the fittings are not tight enough, air can be drawn into the pump suction, which can cause the pump to cavitiate and run rough.

  This is more apparent when the pump suction is working in a vacuum condition, rather than a flooded suction. The end result is that the air is discharged into the pipeline when the main is under pressure. Typical fittings can include strainer seals, foot valves or pump gland seals. When the pumps are drawing from rivers and the depth of water is low in summer conditions, it is possible to draw a vortex in the suction line, which in some instances can release up to 15% of the water capacity in dissolved air.

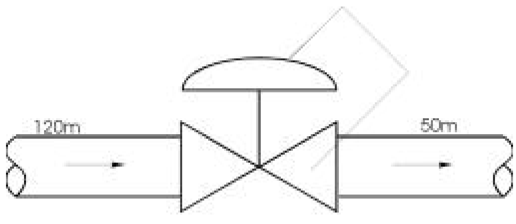
Should multistage pumps be used with several impellors, this generates a very high turbulent zone, which can release dissolved air into the pipeline as the pipe diameter increases after the pump shed.



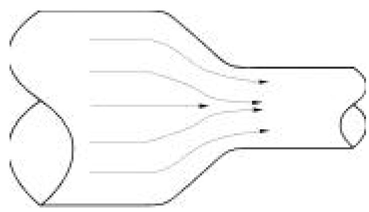
- **Friction along the pipe length.** As water travels along the pipe length, friction is generated between the water and the inner wall of the pipe. The greater the velocity in the pipe, the greater the amount of air is released from the water. Typically when trunk main velocities remain around 1m/sec, it usually takes long sections of pipe to have substantial amounts collect at the high spots in the pipe. When the velocities are greater than 1m/sec, the rate of air release is increased. It is very apparent in fire control conditions where several hydrants are used. These high velocities release great amounts of air and accentuate water hammer conditions, which are frequent at this time.

- **Turbulent zones.** At many points along the pipeline where there is high turbulence, air can be released at these points. As previously mentioned, at pump outlets the water has changed direction frequently. Air will be released immediately into the main. Where the pipe changes direction quickly (ie. 90-degree bends), the turbulence created here will over time leave a pocket of air at this point.

- **Changes in velocity.** Where pressure reducing valves or globe valves are installed along trunk mains, the water velocity is reduced in accordance with the pressure. At this point the water is trying to expand down stream of the PRV and thus releasing small pockets of dissolved air. This is accentuated in larger diameter pressure reducing valves with reduction ratios greater than 2:1. Where pipe reducers are used, this can have a similar effect to a pressure-reducing valve. In the application where the gradient of the pipe changes dramatically to a long descending pipe outlet, the velocity increases dramatically. A sufficient air valve is required to release high quantities of air to allow correct drainage without any possibility of excessive vacuum.



Pressure Reducing Valves


Pipe Diameter Reduction

5.0 AIR RELEASE

In the majority of water industry pipelines, typical water velocities would be between 0.5 to 1.5 m/sec. In conditions where the velocities are as great as 2 m/sec, the dissolved air released from the water, has a high possibility of travelling along the pipeline as long as there is not a great fall in gradient. In conditions where the pipe is running vertically downwards (ie road crossing bends), a velocity as great as 5m/sec is required in order to push the air vertically downwards. This highlights the importance in having an automatic orifice air release valve installed prior to the bend running downwards to avoid the energy loss required keeping the air moving. It is obvious that an automatic orifice air release valve is required in order to release the dissolved air from the high spots. Typically an automatic air release valve, if being used on its own, will have an inlet thread around 1" BSP in size. When this is attached to larger pipe diameters (ie >300mm diameter), this is a very small opening for the air to collate at.

By installing a tee with an 80mm to 100mm upper flange, allows the air to accumulate in this area. With the 1" air valve located on a blank flange on top of the tee gives a good possibility of the valve being effective. In many instances, it is more cost effective to install a tapping saddle with the 1" valve located on top of the saddle.

This gives a very small opening for the air to accumulate, and reduces its effectiveness. The key point is ensuring that the air is able to collect at the air valve location in order for it to be released effectively. In applications where there is a high percentage of dissolved air release (ie bore pump installations, long pipe lengths), by reducing the water velocity and installing a tee, this will further enhance the ability of the air to release effectively.

The valves must always be installed on top of the valve, and where possible used in the vertical plain. It is often found in below ground installations used in treatment plants where the pipe is situated close to the roof, that the air valve is located off the side of the pipe. This ineffective when dissolved air has to be released during pump running.

6.0 WATER HAMMER

In many instances where air release valves are used in long pipelines with varying peaks, problems can sometimes occur when pumps ramp down quickly. Typically this is more apparent when power failure occurs at the pump station, and a return wave creates large pressure peaks at the pump station. During this condition, the air valves along the main open very quickly, during the vacuum condition. When the return wave allows the positive pressure vent the air from the air valve, the water columns meeting can cause severe water hammer along the pipeline length. This effect of water column separation can be controlled in two different methods. Specific air release valves can be installed which allow air to enter the pipe quickly, but release in a controlled closure speed. In effect the air valve tends to act as a shock absorber during the exiting of the air. A considerably safer and more effective method is introducing a surge anticipation control valve at the pump station. This valve will anticipate the return wave travelling to the pump station check valve, and will allow the momentum of the water to continue in the one direction and close under a slow controlled speed. This in effect reduces the effect of the water column return at the air release valve, which reduces air valve water hammer.

More commonly air release valves have a considerable effect on reducing the water hammer conditions along the profile of the pipeline, which is highlighted in the majority of the water hammer computer modelling programs. The air release valves effect on ensuring the pipeline is not subjected to excess vacuum conditions, ensures the pipelines do not collapse during drainage, scouring or pipeline rupture.

Another little known problem that can occur with traditional valves is the situation caused by the *kinetic* valve prematurely closing prior to the pipeline filling with water completely. In this condition, the kinetic valve being closed, air will only vent from the automatic orifice, which usually is only 1mm diameter. This condition will compress the air trying to leave the valve creating high-pressure spikes, and effectively reducing the velocity of the filling water substantially over a split second. It is there fore critical to understand the closure point of the valve selected for the pipeline application. A method over partially overcoming this problem is to select a suitable automatic air valve that incorporates the *rolling seal* principle. This type of valve has air discharge rates many times greater than the traditional round ball float mechanism. The greater orifice diameter reduces the effects of the kinetic valve slamming shut.

7.0 AIR VALVE SELECTION

If all of the conditions are understood how air is accumulated in the pipe and conditions where this is accentuated, it makes the task of selection considerably easier. For some time now engineers have used the thumb rule condition *"the valve will be 10% of the pipe diameter"*. Using this percentage rule today is not satisfactory, understanding the ramifications of incorrect selection. With many manufacturers today developing new and non-traditional methods of valves with greatly varying degrees of performance, many points should be taken into consideration. The following points are some of the key areas to be considered when selecting the best valve for the location.

- **Pump station.** This is a high turbulent zone, and there is a great possibility of air being dissolved from the water, it is critical to effectively release the air prior to its entering the pipeline. Where possible locate a minium of an automatic orifice valve at the high collection point where the water velocity is at is lowest. If the pipeline is travelling downward use a combination air valve. The diameter of the kinetic valve should be sized to match the pipe diameter and next available air valve location along the pipe length.

- **High peaks along the pipeline.** All of the peaks in the pipeline should be mapped out in a tabulated form indicating the distance between valve locations and variance in height. Scour points, pipe diameters and classes of pipes are essential for *kinetic* valve selection. The relationship between the pipe diameter and wall thickness of the pipe indicates the differential air pressure acceptable at the air valve. This in turn ensures the pipe does not exceed the safe working vacuum conditions. As for the filling rate for the *kinetic* orifice, both the filling rate of the liquid in the pipeline and the topography of the pipeline are needed to calculate the correct orifice size. It is not always safe to assume that if the pipeline is filling at a velocity of 0.1 m/sec (eg 100 l/sec), you should not assume that the air would constantly release air at the same rate. Being an easily compressible medium the velocity will increase as the pipeline extends.

- **Locations of changing direction and varying water velocity.** As discussed, it is important to locate *automatic* orifice air valves at points where dissolved air will accumulate.

The following table is a thumb rule combined air release valve selection chart indicating valve size to pipe diameter. This data is specifically based on the *ARI* air release valves, and may not suit other manufacturer specifications. The selection is based on having an air valves located along a pipeline with a spacing every 500 metres. As a thumb rule only, this will ensure vacuum conditions will not stress the pipe during drainage or pipeline failure conditions. A correct analysis should be made to confirm valve selection.

Pipeline Inside Diameter	Combined Air Release Valve Diameter

50 to 250mm	50mm
300 to 400mm	80mm
450 to 550mm	100mm
600 to 900mm	150mm
1000mm upwards	200mm

8.0 CONCLUSIONS

It is my belief that with further industry education, and continued development on the correct usage of such valves, that they will be part of a complex solution to improve the efficiency of pipelines in municipal water authorities.

9.0 REFRENCES

1997 *Recommendations for air release valves* ARI. Israel