Manual of Water Supply Practices

M51

Air-Valves:

Air-Release, Air/Vacuum and Combination

Second Edition

American Water Works Association

Contents

Chapter 1

Introduction

Air valves are hydromechanical devices designed to automatically release air and wastewater gases or admit air during the filling, draining, or operation of liquid piping systems for water and wastewater services. The safe and efficient operation of a liquid piping system is dependent on the continual removal of air and wastewater gases from the liquid piping system. This chapter includes an explanation of the effects of air and wastewater gases and their sources in liquid piping systems.

OCCURRENCE AND EFFECT OF AIR AND WASTEWATER GASES IN LIQUID PIPING SYSTEMS

Water contains approximately 2 percent dissolved air or gas by volume at standard conditions (14.7 psia [101 kPa absolute] and 60°F [16°C]) (Dean 1992) but can contain more, depending on the liquid pressure and temperature within the liquid piping system.

Wastewater systems can also contain more undissolved air and wastewater gases due to the decomposition of materials in the wastewater. Dissolved air and wastewater gases can come out of solution in pumps and in different locations along the liquid piping system where turbulence, hydraulic jumps, and other pressure variation phenomena occur. Once out of solution, air and wastewater gases will not readily dissolve and will collect in pockets at high points along the liquid piping system.

Air and wastewater gases come out of solution in a liquid piping system due to low-pressure zones created by partially open valves, cascading flow in a partially filled pipe, variations in flow velocity caused by changing pipe diameters or slopes, and changes in pipe elevation. Entrained air that reaches water service connections may be detrimental to the customer's water systems.

An air and wastewater gas pocket may reduce the flow of liquid in a liquid piping system by reducing the cross-sectional flow area of the pipe, and if the volume of the air and wastewater gas pocket is sufficient, complete binding of the liquid piping system is possible, stopping the flow of liquid (Karassik et al. 2007).

The velocity of the flow of liquid past an enlarging pocket of air and wastewater gases may only be sufficient to carry part of the pocket of air and wastewater gases downstream unless the liquid velocity is greater than the critical velocity for transporting air and wastewater gases in that particular pipe diameter (Escarameia et al. 2005). The velocity needed to scour a pocket of air and wastewater gases in larger piping systems (e.g., 24 in. [610 mm]) may be as high as 7.1 ft/sec [2.2 m/sec] at a 5 percent slope as shown in Table 1-1 (Jones et al. 2008). Although the flow velocity of the liquid may prevent the liquid piping system from complete air and wastewater gas binding, the pockets of air and wastewater gases will increase head loss in the liquid piping system (Edmunds 1979). As shown in Figure 1-1, a pocket of air and wastewater gas can reduce the flow in the pipe to *d* and create head loss equal to H_L due to the restricted cross section. Additional head loss in a liquid piping system decreases the flow of liquid and increases power consumption required to pump the liquid. Pockets of air and wastewater gases in a liquid piping system are difficult to detect and will reduce the liquid piping system's overall efficiency.

Pockets or air and wastewater gases may also contribute to water hammer problems, pipe breaks, system noise, and pipe corrosion—especially hydrogen sulfide corrosion—and can cause erratic operation of control valves, meters, and equipment. Studies have shown that small pockets of air and wastewater gases in certain locations along the system can cause transients and surge and/or intensify transients and surges, including downsurges (Pozos-Estrada 2007). However, temporary pockets of air and wastewater gases may be needed in special circumstances to prevent vacuum conditions in a liquid piping system after pump outages or line breaks. Vacuum conditions should be avoided as they may result in collapse and/or deformation of thin-walled pipe. Finally, on system applications, in locations where liquid column separations and returns may occur, a vacuum breaker with air-release valve or an air valve with restricted outflow (slow-closing device or throttling device) should be considered.

Table 1-1 Velocities required to scour air and wastewater gases from pipelines

Scouring Velocities by Pipe Size and Slope					
Pipe Size	Velocity, ft/sec (*m/sec*)				
	Negative Slope				
in. (*mm*)	0° (0%)	2.9° (5%)	14° (25%)	45° (50%)	90° (vertical)
4 *(100)*	2.7 *(0.8)*	2.9 *(0.9)*	3.1 *(0.9)*	3.4 *(1.0)*	3.5 *(1.1)*
8 *(200)*	3.8 *(1.2)*	4.1 *(1.2)*	4.4 *(1.3)*	4.8 *(1.5)*	5.0 *(1.5)*
12 *(300)*	4.7 *(1.4)*	5.0 *(1.5)*	5.4 *(1.6)*	5.9 *(1.8)*	6.1 *(1.9)*
24 *(600)*	6.6 *(2.0)*	7.1 *(2.2)*	7.6 *(2.3)*	8.3 *(2.5)*	8.6 *(2.6)*
36 *(900)*	8.1 *(2.5)*	8.7 *(2.7)*	9.3 *(2.8)*	10.2 *(3.1)*	10.6 *(3.2)*

Source: Jones et al. 2008.

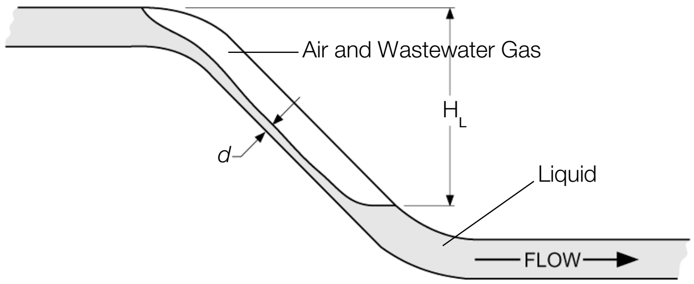

Figure 1-1 Air and wastewater gas pocket in a pipeline

SOURCES OF AIR AND WASTEWATER GASES IN LIQUID PIPING SYSTEMS

In addition to air and wastewater gases coming out of solution, air may enter liquid piping systems at leaky joints where the pressure within the liquid piping system falls below atmospheric pressure. These conditions exist in the vortex at the pump suction, at pump glands where negative pressure occurs, and at all locations where the pipe elevation is above the hydraulic grade line.

Air may enter liquid piping systems through air/vacuum and combination air valves following complete pump shutdown, through the orifices of air-release valves installed in locations where the pressure is less than atmospheric, and through pump suction pipes or inlet structures that are not properly designed to prevent vortexing. Finally, most vertical turbine and well pumps start with air and wastewater gases in the pump column as shown in Figure 1-2, which may pass by the check valve and flow into the liquid piping system with every pump start.

Air and wastewater gases entrainment is much greater in wastewater force main systems than in other pumped liquid transmission systems owing to their unique design and operational characteristics. Lift stations with wet wells or other sewage collection basins are a major source of entrained air and wastewater gases induced by plunging jets of sewage and by vortices of air and wastewater gases sucked into the pump. Because of the cyclic operation of force main systems, sections of the force mains empty out at the end of each pumping cycle, drawing air and wastewater gases into pipes. At the entrance to sewage lift stations, air and wastewater gases are entrained from plunging jets of sewage.

AIR AND WASTEWATER GAS POCKET BEHAVIOR IN PIPELINES

Four major factors influence entrained air and wastewater gas behavior in liquid piping systems: buoyancy, velocity, drag, and equilibrium in surface tension between the liquid, air and wastewater gases, and the pipe wall. These factors, together with air and wastewater gas pocket size and concentration, influence the tendency of bubbles to aggregate and increase in size and determine the direction of their movement either with or opposite to the direction of liquid flow. These factors also affect the entrained air and wastewater gases pockets' influence on liquid flow capacity, head loss, and energy consumption. In rising pipe sections and when there is no flow in the pipeline, buoyancy will force air and wastewater gas pockets of all sizes and shapes to travel to peaks or high points along the liquid pipeline. At downsloping and level pipe sections, when buoyancy exceeds drag, the pockets will travel upward in the opposite direction to the flow. When drag exceeds buoyancy, the pockets will travel in the direction of liquid flow. Large air and wastewater gas pockets traveling in opposite direction to the liquid flow often break up in flow due to buoyancy, resulting in smaller air and wastewater gas pockets, including bubbles, changing direction and being dragged in the direction of the liquid flow with the larger air and wastewater gas pockets or continuing to travel upstream against the flow. Pockets of air and wastewater gases traveling with the liquid stream also break up into smaller air and wastewater gas pockets and bubbles that disperse in the liquid stream, traveling in different velocities. In all these cases, the air and wastewater gas pocket's movement disturbs the flow where drag and turbulence increase head losses, resulting in decreased flow capacity and increased energy consumption (Lubbers and Clemens 2005).

Figure 1-2 An air valve installed on the outlet of a pump and upstream of the check valve

REFERENCES

Dean, J.A. 1992. *Lange's Handbook of Chemistry,* 14th ed. New York: McGraw-Hill.

Edmunds, R.C. 1979. Air Binding in Pipes. *Jour. AWWA,* 71(5): 272–277.

Escarameia, M., C. Dabrowski, C. Gahan, and C. Lauchlan. 2005. *Experimental and Numerical Studies on Movement of Air in Water Pipelines,* Report SR 661, Release 3.0. Wallingford, Oxfordshire, UK: HR Wallingford Ltd.

Jones, G.M., R.L. Sanks, G. Tchobanoglous, and B.E. Bosserman II, eds. 2008. *Pumping Station Design*, rev. 3rd ed. Boston: Butterworth-Heinemann.

Karassik, I.J., J.P. Messina, P. Cooper, and C.C. Heald. 2008. *Pump Handbook*, 4th ed. New York: McGraw-Hill.

Lubbers, C.L., and F.H.L.R. Clemens. 2005. Capacity Reduction Caused by Air Intake at Wastewater Pumping Stations. In *Proc. Water and Wastewater Pumping Stations Conference, April.* Cranfield, UK: University of Cranfield.

Pozos-Estrada, O. 2007. Investigation on the Effects of Entrained Air in Pipelines, Dissertation Volume 158. Stuttgart, Germany: Institute of Hydraulic Engineering Faculty of Civil and Environmental Engineering, Engineering and Allied Operations, Institut für Wasserbau der Universität Stuttgart.