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TO: Office of Water Programs Staff

THROUGH: Allen R. Hammer, P.E., Director
Division of Water Supply Engineering

Eric H. Bartsch, P.E., Director
Office of Water Programs

FROM: Robert B. Taylor, P.E., Technical Services Administrator
Division of Water Supply Engineering

DRAFTED BY: R. M. Puckett, P.E., Deputy Field Director
Abingdon Field Office

SUBJECT: Water - Design - Distribution System - Air Release Valves

Purpose

This working memo will provide guidance in reviewing water distribution system plans and specifications relative to air release valves and provide guidance in air release valve surveillance.

Sources of Air in Pipelines

Air can enter a pipeline by being:

- entrapped at a pump or gravity inlet
- entrapped when a new line is filled or an existing line is refilled
- released from the water due to changes in temperature or changes in pressure (water is typically 2% air by volume)
- drawn into the line through air release valves or cross connection control devices
- drawn into the system under reduced pressures
- entrapped when flushing through a hydrant

Effects of Air in Pipelines

Air in pipelines can reduce hydraulic efficiency and cause serious damage due to pressure surges. The effects of air in pipelines are:

- **corrosion** - due to the increased dissolved oxygen
- **water hammer -** as air pockets move from one high point to the next and stop
- **line restrictions -** due to air pockets and the associated increased head loss which reduces flow rates and increases pumping costs; 10 to 15% loss in efficiency may occur
- **line blockage -** occurs if air pockets do not move or are not reduced in size by the increased fluid velocity that occurs as the pockets are first forming

Removal Methods

The simplest device to remove air is by tapping the waterline at high points and installing a valve vault and a manual air release valve, either a gate or ball valve. Predicting when to bleed off the air is difficult at best. With manual air release valves, protection of the system from vacuum damage in the event of a line break is not provided. Air removal through fire hydrants will reduce the size of an air pocket but, if connected in the usual manner, will not eliminate all air from the main. *Waterworks Regulations* §3.53A states that air and sediment may be removed through a standard fire hydrant. Hydrants are usually connected to the side of the distribution main via a "tee," usually a reducing "tee." This arrangement can leave a substantial pocket of air trapped at the top of the distribution main.

Automatic air valves are the industry standard for today's waterworks distribution systems. These valves will automatically release and/or admit air without operator assistance. There are three types of automatic air valves providing either a single function or a dual function with various orifice sizes designed to pass either large volumes or small volumes of air.

Automatic Air Valves

Air/vacuum valves. These valves are used to exhaust large quantities of air during system startup and to admit air into the line during system shutdown. The valve contains a single, large orifice (usually 1-inch diameter or larger) which passes air at a high rate (typically in cubic feet per second). As water enters the valve, its float rises, closing the discharge port. The port remains closed until system pressure drops to near 0 psi; it will not open and release air while the system is under pressure. This is a disadvantage of this type of valve.

The air/vacuum valve also provides pipeline vacuum protection. If a negative pressure develops, the valve opens, which admits air into the line, preventing a possible pipeline or joint collapse or intensified surges.

The air inlet/outlet port is NPT threaded on 3 or 4-inch and smaller valves. Larger valves may have a smooth, hooded port or a flanged port.

Air release valves. Unlike an air/vacuum valve, an air release valve continuously releases accumulated air during system operation. As air enters the valve, it displaces the water, allowing the float to drop. The air is then released to the atmosphere through the small orifice. As the air is vented, it is replaced by water, raising the float and closing the orifice. As air accumulates, the valve cycles in this manner to remove the collected air.

The air release valve contains a single, small orifice usually l/2 inch in diameter or less and releases air at a low rate, usually expressed in cubic feet per minute. The air outlet port is NPT threaded.

Combination valves. A combination valve combines the functions of an air/ vacuum valve and an air release valve, that is, it exhausts large quantities of air on startup, admits air on shutdown, and releases air continuously during operation. Combination valves are typically available in single-body and dual-body (an air/vacuum valve and air release valve piped together) configurations.

Combination valves contain one small and one large orifice and are sometimes referred to as double orifice valves. Valves may contain only one air inlet/outlet port with both orifices positioned below the port or may contain two ports on single-body models or one port each on dual-body models.

Selecting, Locating and Spacing Air Valves

Air release valves are intended to release air as it accumulates at high points during system operation. They are not normally recommended for vacuum protection, although they will permit air to re-enter. Furthermore, they are not intended to vent large volumes of air because of their small orifice. Air release valves are normally used in combination with other types of air valves along the distribution main. For example, a minimal high point could be protected with an air release valve if combination air valves are at the grade changes within a 1/2 mile or so and on each side of the air release valve.

Air release valves on long stretches at l/4 to l/2 mile intervals are acceptable at the following locations where combination valves (see below) are also provided on the system:

long horizontal stretches
long ascending stretches
long descending stretches

Air/vacuum valves only provide protection during refilling and draining. They also prevent damage in the event of a line break.

Combination valves are the preferred air valve for maximum protection and efficiency. Combination valves should be considered at the following locations:

points of increasing or changing downward grade
points of decreasing or changing upward grade
peaks or high points on pipeline gradient
pipeline elevation approaches the hydraulic gradeline at l/4 to l/2 mile intervals on long horizontal ascending or descending stretches
up gradient, in each direction from blowoffs and drains

Sizing Orifices

The linear velocity of air discharged through an orifice increases as pressure differential across the orifice increases, until reaching a maximum velocity of approximately 300 feet per second. This maximum air velocity occurs at about 7 p.s.i. and remains a constant thereafter, regardless of further increase in the pressure.

The amount of air actually expelled through the orifice, however, continues to increase indefinitely as the pressure increases, because, while there is no further increase in the escape velocity beyond 7 p.s.i. approximately, the air escaping at this velocity itself becomes progressively denser and hence, represents a greater amount when expressed in cubic feet of free air at atmosphere per minute. To accommodate this condition, flow of air is always referred to in cubic feet of free air per minute (C.F.F.A.M.) even though the air under consideration is usually at some other pressure than atmosphere.

Small Orifices Used in Air Release Valves and Combination Valves

Valve and Primer Corporation's catalog, APCO Valves, recommends the venting capacity of small orifices be 2% of the flow rate of the water such that:

$$\text{CFFAM} = (\text{Qgpm} \times 2\%)/7.48\ \text{gal/ft}^3$$

The orifice size is based on this needed venting capacity and the system pressure at the air valve. Manufacturers' graphs and charts are used to select the appropriate model.

Large Orifices Used in Air/Vacuum Valves and Combination Valves

APCO's criteria for sizing large orifices is based on a maximum pressure differential (psid) across the orifice with air flow rate equal to the maximum water flow rate, in CFS. The maximum water flow rate will be the larger of the pumped flow rate (pipeline filling, air flowing out) or the gravity draining flow rate (pipeline draining, air flowing in).
The orifice size is first calculated using pumped flow rate in CFS equal to the air outflow rate through the orifice while the pipeline is being filled with a maximum 2 psid pressure differential across the orifice. Above 2 psid the air flow rate becomes so great it may cause the float controlled valve mechanism to close prematurely due to air turbulence within the valve thus trapping an air pocket. The abrupt closure may cause pressure waves damaging the valve and pipeline.

$$\text{Qcfs} = (\text{gpm})(1\text{cfs}/449\ \text{gpm})$$

The orifice size is again calculated using the greatest pipeline slope on either side of the high point and the diameter to determine the gravity flow rate in CFS. This air inflow rate through the orifice while the pipeline is being drained must not cause a pressure drop across the orifice greater than 5 psid. The 5 psid for air flowing in represents a safe average for protecting the pipeline and gasket joints from damage due to vacuum, unless thin-walled pipes are used. The psid across the orifice must be less than the pressure to collapse the pipeline or damage joints but not greater than 5 psid. This results in the vacuum within the pipeline being held to 5 psi or less which most AWWA piping systems should withstand.

$$\text{Qcfs} = 0.285\ Cd^{2.63}\ S^{0.54}(1\text{cfs}/449\ \text{gpm})$$
d = diameter inches
s = slope ft/ft
C = Hazen-Williams friction coefficient

Selecting Valve Model

Manufacturers' graphs and charts are used to select the appropriate valve model. One graph is used for outflow of air and another graph for inflow of air. The larger of the two orifices should be used. The orifice size and valve size are generally the same for air/vacuum valves.

Combination valves are available in single body with large and small orifices within the same body or in a duplex body with two air valves fitted together. The combination valves are available in a limited selection of large and small orifice size combinations within a single body.

Surveillance

Air valves affect the distribution system reliability. In addition, inadequately maintained or improperly installed air valves may pose a cross connection hazard. Therefore, air valves should be inspected for proper operation as well as potential sources of contamination.

Air valves should be removed for inspection every three to five years. Replacement is generally cheaper than repair costs.

Design Review

Distribution system review should include evaluation of the type, size and spacing of air valves. Combination valves are the preferred valves.

Manufacturers' sizing and spacing criteria should be followed. Generally, where combination valves are used:

one inch combination valve on 6-inch or smaller diameter waterline
two inch combination valve on 8-inch or larger diameter waterline

Air valve specifications should be reviewed for:

1. Type of inlet/outlet port connection - either NPT threaded, smooth with screened hood or flanged.

2. Insolation valves between the waterline and the air valve and between the air release valve and the air/vacuum valve on duplex body, combination valves.

Valve vaults should be reviewed for:

1. Chambers or pits containing valves, blowoffs, meters, or other such appurtenances to a distribution system shall not be connected directly to any storm drain or sanitary sewer, nor shall blowoffs or air release valves be connected directly to any sewer. Such chambers or pits shall be of sufficient depth to prevent freezing.

2. Such chambers or pits shall be drained to the surface of the ground where they are not subject to flooding by surface water, or to absorption pits located above the seasonal groundwater table elevations. The backfill material for the waterline may serve as an absorption pit if granular embedment material is laid from the pipe bedding up through the final backfill layer for the entire length of pipe in the chamber. Sump pumps may be used where other means are not practicable.

3. The open end of an air release pipe where provided shall be extended from the manhole or enclosing chamber to a point at least one foot above ground and provided with a screened, downward facing elbow. When an above ground extension is not practical or desired, the open end of an air release pipe shall be extended at least one foot above the valve body and provided with a screened, downward facing elbow. Where the open end of the air release pipe terminates within the valve chamber or pit or where the air valve is fitted with a smooth vent port and screened hood, the chamber or pit shall be vented to provide sufficient air flow to allow proper

operation of the air valve. Minimum chamber or pit vent diameter should be equal to or greater than the air valve inlet diameter.

4. The chamber or pit shall be designed to facilitate air valve inspection and serving.

Sources

Available text books, journals and pipe manufacturer handbooks revealed little or no detailed information on this subject. Much of the information was taken from the *Opflow* article, *"Air in Pipe? Time to Review Air Valve Basics,"* which appeared in the March 1994 issue. This article was written by Phil Laden, a member of an AWWA committee that is currently developing an air release valve manual. Manufacturer information and criteria were taken from "APCO Valves Catalog 726" with a revised and reprinted date of 1995 and the Bermad Control Valves Company literature. The Valve and Primer Corporation, 1420 S. Wright Blvd., Schaumburg, Illinois 60193-4599, can be contacted by phone at (847) 529-9000 or (800) 323-6969 for a copy of their catalog. Bermad can be contacted at 1-800-821-6825. Their local representative, Virginia Water and Waste, provided the servicing and replacement recommendations. They can be reached at 1-800-552-6161.

Any mention of manufacturer or sales representative is not to be construed as product endorsement or preference for a supplier.

RMP/jm