Air in Pipelines

Dissolved air (or other gas) is a serious problem in pipelines that have intermediate high points or are nearly flat. If air comes out of solution, it forms bubbles that accumulate, reduce the water cross-sectional area, and increase resistance to flow—sometimes greatly—and the air-moisture environment is conducive to corrosion. In sewer force mains, air and consequent corrosion is disastrous. Various ways to deal with air in pipelines include (1) designing the pipeline profile to rise all the way to the exit; (2) installing air release valves at high points in the pipeline (or at frequent intervals for flat profiles); or (3) designing for velocities high enough to scour air bubbles to the exit. Obviously, the first is preferred if possible. Air release valves are risky because of uncertain maintenance. They should not be used at all on wastewater force mains because maintenance must be done so frequently (for example, monthly) and without fail. (See Sections 5-7 and 7-1 for an exception.) If the valves are not maintained properly, they are worse than useless because they then engender a false sense of security. Designing for scouring velocities in large pipes may result in excessive headlosses and energy needs. The required scouring velocities are given in Table B-9.

Some consultants customarily install manways at 450-m (1500-ft) intervals in water pipelines equal to or larger than 900 mm (36 in.) in diameter to permit worker entry and inspection of, and repairs to, the lining and to fix leaks. Air release valves are required in the manway covers to prevent the accumulation of air under them.

3-4. Headlosses in Pipe Fittings

Pumping stations contain so many pipe transitions (bends, contractions) and appurtenances (valves, meters) that headlosses due to form resistance (turbulence at discontinuities) are usually greater than the frictional resistance of the pipe. The simplest approach to design is to express the headlosses in terms of the velocity head, $v^2/2g$, usually immediately upstream of the transition or appurtenance. The equation for these losses is

$$h = K\frac{v^2}{2g} \tag{3-16}$$

in which K is a headloss coefficient (see Appendix B, Tables B-6 and B-7). The few exceptions to Equation 3-16 are noted in the tables.

The headloss coefficient, K, is only an approximation, and various publications are not always in agreement and may differ by 25% or more. The values in Tables B-6 and B-7 have been carefully selected from many sources and are deemed to be reliable.

In Equation 3-16, K varies with pipe size as noted in Table B-6. Furthermore, published values are for isolated fittings with a long run (for example, 20 pipe diameters) of straight pipe both upstream and downstream from the fitting. The headloss is measured between one point a short distance upstream from the fitting and another point at the downstream end of the piping system. This piping ensures symmetrical flow patterns. The difference in headloss with and without the fitting is used to compute K. Headlosses for a series of widely separated fittings are therefore directly additive.

Part of the headloss is due to the turbulence within the fitting, but probably about 30% (less for partially closed valves) is due to eddying and turbulence in the downstream pipe. So if one fitting closely follows another (as in a pumping station), the apparent K value for the first fitting is, probably, reduced to about 70%. For example, because K for a 90-degree bend is 0.25 (see Table B-6), K for two 90-degree bends would be 0.50 if the bends were separated by, say, a dozen pipe diameters. But if the bends were bolted together to make a 180-degree bend, K for the entire bend could be figured as $0.70 \times 0.25 + 0.25 = 0.43$, which is within 8% of the K value for a 180-degree bend in Table B-6. As another example, K for a 90-degree bend consisting of three 30-degree miters can be determined directly from Table B-6 as 0.30 or indirectly by adding reduced K values for each miter except the last. Thus, $0.70\ (0.10 + 0.10) + 0.10 = 0.24$—an error of 20% (one publication lists the K for the mitered fitting as 0.20).

Pumps, especially when operating on either side of their best efficiency point, usually cause swirling (rotation) in the discharge pipe. Swirling sometimes also occurs in inlets and suction pipes. The effect of such swirling is to increase eddy formation and turbulence; consequently, the headloss in fittings can be doubled or even tripled. If swirling is likely to occur and if headloss within the pumping station is critical (which is often true in suction piping), the safe and conservative practice would be to design for headloss without swirling and again for headloss using, say, 200% of the fitting losses. Because there is no definitive body of literature about this complex subject, designers must either rely on experience or guess at headlosses.

Another method for computing headlosses is to use an "equivalent length" of straight pipe. This

- Use rubber-cushioned flapper seats to prevent metal-to-metal contact and to cushion the closure.
- Install a pressure-actuated relief valve (see Figure 7-8).

For a more extensive discussion, refer to "Slam" in Section 5-4.

Choosing Check Valves

Choosing the right check valve is vital. Often there are profound differences in the same kind and style of valve offered by different manufacturers. Headlosses in some makes of swing check valves are twice as great as in others, and the massiveness of stressed parts varies widely.

Swing check valves should always be equipped with external levers, which are useful in several ways. The position of the lever indicates whether flow is occurring, and the lever can be equipped with an inexpensive switch that shuts off power to the motor (after a timed delay) if flow does not occur. The lever can be equipped with either springs or counterweights, which can be adjusted to mitigate slam or disc flutter. Dashpots can also be added to control slam. But whether counterweights, springs, dashpots, or pump-control valves are used, it is mandatory that the valves be properly adjusted in the start-up procedure; it is equally important that operators understand the valve operation and practice the necessary preventive maintenance.

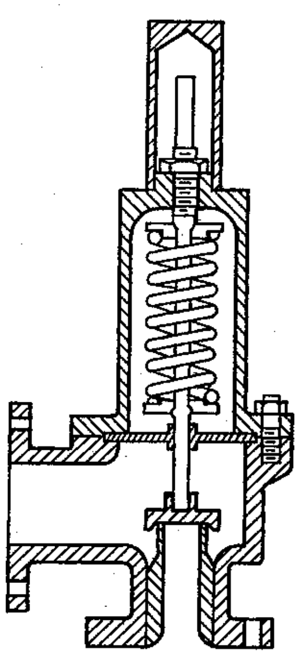

Figure 7-8. Pressure-actuated surge relief valve.

Because many contrary opinions prevail, designers should be extremely careful in specifying check valves. Investigate them thoroughly by obtaining and analyzing advice from several sources.

Filling Empty Pipelines

Small air bubbles, which collect at summits of pipelines, can be bled off with air release valves without creating hydraulic transients. However, the initial filling of pipelines must be done cautiously with velocities kept below 0.3 m/s (1 ft/s) and with air release valves open to exhaust the air slowly. Avoid full-capacity start-ups until all of the large air bubbles are exhausted. Provide properly sized air and vacuum valves or slow-acting pump-control valves for pumps with long discharge columns. These measures complete air evacuation without sudden slamming of valves, which creates high transient pressures. Always include the start-up procedure for empty pipelines in the O&M manual.

Pipelines that are nearly flat may require air release valves spaced at intervals of approximately 400 to 800 m ($\frac{1}{4}$ to $\frac{1}{2}$ mi) to vent air properly during filling. Knees and high points require both air and vacuum valves. At best, air pockets in pipelines increase flow resistance by as much as 10% or even more. At worst, air pockets can generate pressures as high as 10 times normal operating pressures, and air trapped at high points reduces the water cross-sectional area and, thus, acts like a restriction in the pipe.

Air release cocks or valves must be installed in pump casings (or at high points of pump manifolds) to prevent air binding. If the HGL can fall much below any part of the system on a downsurge, an air and vacuum valve is needed to prevent vapor cavities. Limit the vacuum to about half of an atmosphere, and exhaust the air slowly so that it acts as a cushion. Alternatively, especially for raw wastewater, reroute the pipeline to produce a uniform or, better, an increasing gradient with no knees.

7-2. Control of Pumps

None of the methods for controlling water hammer is universally applicable. Some methods might control one cause of water hammer but leave the system unprotected from other causes. Some methods may be unacceptable for a variety of reasons, such as excessive maintenance or unreliability. Because a

single device is often
to provide full prot
trolling pumps can
start-up and shut-d
control of surges du

Pump Sequencing

By controlling the
shut-down so that th
pumps are staggered
at any one time is re
for normal operatic
able, and inexpensiv

Pump-Control Va

By interlocking the
discharge piping, tra
start-up and shut-d
control valves are se
times t_c). Upon star
closed valve. As th
pipeline gradually ir
Upon shut-down, t
decelerate the flow,
shut off (but not un

To circumvent p
operated by a store
such as trickle-char
or a compressed ai
operate every valve
water or an oil valv
lent for either water
service, butterfly va
poor throttling cha
required to control
ure. Diaphragm-act
pipeline pressure wi
be used. For wastew
can be used. Pump
prevent downsurge

Increasing the Ro

The moment of iner
important effect up
ing downstream fro
power failure, the p
crease and a negativ
propagated down t

vulnerable than others. Cavitation occurs at regions of large pressure drops.

Pump-Control Valves

Pump-control valves can be any type—angle, ball, butterfly, cone, globe, or plug—suitable for the liquid being pumped. Use angle and globe valves where high headloss can be tolerated or is desirable (as in bypass pipelines); and use ball, butterfly, cone, or plug valves where energy costs are important (see Example 5-1). Controls and electrical interlocks are provided so that the valve is closed when the pump starts. After the pump starts, the main valve opens slowly at an adjustable rate. When the pump is signaled to shut off, the valve slowly closes at an adjustable rate. When the valve is 95 to 98% closed, a limit switch assembly shuts off the pump.

Surges induced by start-up and shut-down of constant-speed water pumps can be effectively controlled by diaphragm- or piston-operated globe-type valves utilizing differential pressure to open and close the valve. Operation is usually initiated by activating solenoid valves that act on the trim piping controlling pressure on the diaphragm. The initiation of solenoid operation is usually linked electrically to the pump motor control circuit, and the speed of operation is controlled by adjusting needle valves in the trim piping. Variations of this basic type of valve include straight-through or angle bodies, surge relief valves, and head sustaining valves. To provide some assurance of reliability, the trim piping to the power side of the diaphragm must be fitted with a fine strainer to remove particulate material that might otherwise interfere with valve operation.

Piston-operated globe valves have an advantage over diaphragm-operated valves in that leakage from the valve occurs long before failure. Diaphragm-operated valves are completely sealed and do not leak, but, on the other hand, they give no warning of impending diaphragm rupture, which puts the valve out of service. Both valves are very effective in reducing surges due to pump start-up and normal pump shutdown, but they cannot prevent surges caused by power failure.

Power-actuated ball, butterfly, cone, and plug valves are more expensive to install but, when fully open, cause less headloss than other valves.

Control Valves for Water Service

The control valves likely to be used for water service include angle, ball, butterfly, cone, globe, needle (for fine flow regulation in control piping), and eccentric, lubricated, or nonlubricated plug valves. See Figure 5-14.

Control Valves for Wastewater

The only valves suitable for control of wastewater are ball, cone, long radius elbow, and eccentric, lubricated or nonlubricated plug valves.

Description of Control Valves

Except for globe and needle valves, all of the valves that can be used for control are described in Section 5-2. Recommendations for their use are given in Table 5-4.

Angle Valves

Angle valves and globe valves are similar in construction and operation except that in an angle valve, the outlet is at 90 degrees to the inlet and the headloss is half as great as it is in the straight-through globe valve. An angle valve is useful if it can serve the dual purpose of a 90-degree elbow and a valve. Conversely, an angle valve should not be used in a straight piping run;

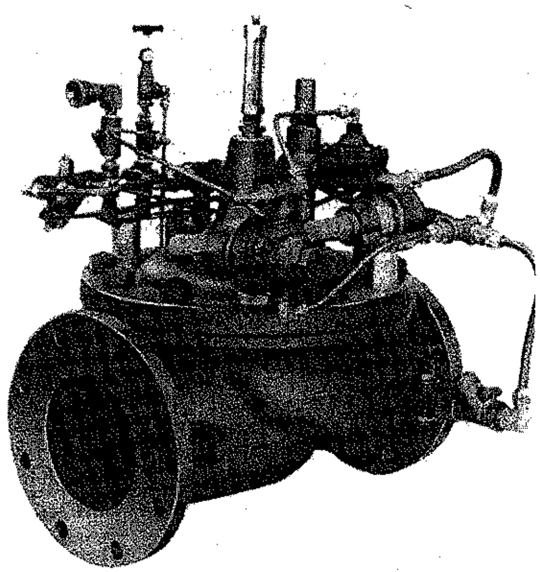

Figure 5-14. Control valve for water service with external piping arranged for surge anticipation. Courtesy of Cla-Val Co.

Table 5-4. Recommend

Type of valve
Angle
Ball
Butterfly
Cone
Globe
Diaphragm
Differential piston
Surge relief
Diaphragm or piston
Angle valve (for water
Long radius elbow val
Surge anticipation
Diaphragm or piston
Angle valve (for wate
Long radius elbow valve

[a]E, excellent; G, good; F, f

instead, use a globe v valves are best used fluids containing gri erosion. Globe valve raw wastewater servi coming plugged with

Globe Valves

As in the angle valv that moves vertic through a globe v degree turns—upw controlled or restri sure drop or headl butterfly, or ball v

Because of this wide-open positio used as isolation v fuel oil pipelines. quiring throttling, Globe valves are s not for fluids co cause severe seat wastewater or slu to becoming plug

Globe or Pistor

Globe or piston to eliminate seat