### 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