TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE CASPER, WYOMING SOIL CONSERVATION SERVICE

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Waterhammer & Operation Considerations for PVC Pipelines 4 Inch in Diameter or Larger

Introduction

The term waterhammer is used to define the concussion of moving water against the sides of a pipe. Whenever the flow of water within a pipeline is changed, waterhammer will occur. Flow changes occur by operating valves, starting or stopping pumps, the sudden release of entrapped air, or the actuation of a pressure relief valve.

Whenever waterhammer does occur an increase in pressure will result. The intensity of the increase in pressure will depend on the elapsed time involved in the change of velocity within the system. Hence, when a riser valve is closed quickly and the velocity within a pipeline is reduced, additional pressures are developed within the system.

The intensity of waterhammer may be restrained by the selection of appurtenances, and the scrupulous operation of the system. We have little or no control over the operation of the system, therefore, it becomes necessary to design for operation under adverse conditions.

Design PVC Safety Factor

The pressure rating (i.e., 80 psi, 100 psi, 125 psi, etc.) of PVC plastic pipe is based on a 2:1 safety factor. This is based on a long term hydrostatic strength of 4,000 psi, for PVC 1120, 1220 and 2120. Other materials such as PVC 2116, have a lower strength. (Refer to ASTM Specification D-2241 for values.) To apply the 2:1 safety factor, the hydrostatic strength is divided by 2. The formula for computing the pressure rating of the pipe then becomes:

$$\text{Pressure Rating} = \frac{\frac{4000}{2}}{\frac{(SDR-1)}{2}} \text{ or } \frac{4000}{(SDR-1)}$$

$$\text{where SDR} = \text{Standard Dimension Ratio} = \frac{\text{outside diameter}}{\text{wall thickness}}$$

Computing the intensity of waterhammer pressures can be very complex, if not impossible, because of assumptions that must be made. PVC materials are subject to cyclic stress regression. By this we mean, whenever a PVC pipe is subjected to exceedingly high pressures, each cycle has a tendency to reduce the hydrostatic strength of the material. Which eventually will lead to failure.

Because of the many unknowns, major manufacturers recommend the use of a safety factor of 2.8:1. In doing so, the pressure rating of a pipe is determined by the following formula:

$$\text{Pressure Rating} = \frac{\frac{4000}{2.8}}{\frac{(SDR-1)}{2}} \quad \text{or} \quad \frac{4000}{1.4(SDR-1)}$$

The above formula will indicate that the design dydrostatic pressures should not exceed 72% (1 ÷ 1.4) of the pressure rating of the pipe.

On long, multilateral systems, where waterhammer pressures can occur in varying intensities, a safety factor of 2.8:1 shall be used in selecting the pressure rating of the pipe. The following tabulation lists the pressure rating of PVC 1120, 1220 and 2120 based on a safety factor of 2.8:1.

SDR	Max. Operating Pressure, psi
51	55
41	70
32.5	90
26	115
21	145

On the shorter, relatively simple lines, where we have confidence in the owner's ability to operate the system in accordance with a recommended procedure, the use of the 2.8:1 safety factor could result in a very conservative design. When to alter the safety factor becomes a matter of judgement based on the design and confidence in the operator's ability to operate the system.

On the shorter, relatively simple lines, where it is possible to predict the operating procedure, waterhammer intensities can be computed. To assist in this computation, refer to Figure 1 to determine the increase in pressure resulting from an instantaneous valve closure. The following examples will explain its use: (Use Technical Note #10(Revised) to obtain plastic pipe dimensions.)

Example 1. A 12" diameter SDR 51 (80 psi) PVC pipe is to transport 1700 gpm (3.78 cfs) at 70 psi maximum static pressure. Determine waterhammer pressure if one field lateral transporting 250 gpm (0.56 cfs) is instantly turned off.

Solution: Velocity @ 3.78 cfs = 3.78 ÷ 0.754 = 5.01 ft./sec.
Q after valve closure = 3.78 - 0.56 = 3.22 cfs.
Velocity after closure = 3.22 ÷ .754 = 4.27 ft./sec.
Velocity change = 5.01 - 4.27 = 0.74 ft./sec.
From Figure 1 - pressure increase = 8 psi.

This would indicate that the maximum operating pressure could be 78 psi. This is less than the 80 psi rating of the pipe so should be okay.

Example 2. A 6" diameter PVC line is being designed to transport 400 gpm (0.88 cfs) @ 65 psi maximum static pressure. The line is to serve two field laterals each requiring 200 gpm (0.45 cfs). Determine SDR required.

Solution: Assume one lateral could be instantly shut down.

$$\text{(SDR 51-PIP) velocity @ 0.89 cfs} = \frac{0.89}{0.19} = 4.68 \text{ ft./sec.}$$

$$\text{(SDR 41-PIP) velocity @ 0.89 cfs} = \frac{0.89}{0.186} = 4.78 \text{ ft./sec.}$$

If Q is reduced to one half, the velocity would be reduced to one half. From Figure 1, for a velocity change of 2.34 and 2.39 ft./sec. we could expect a pressure increase of about 26 psi. The maximum operating pressure will then be 65 + 26 = 91 psi, which would indicate that SDR 41 (100 psi) pipe would be specified.

Figure 1 is based on instantaneous valve closure. It is realized that it is improbable that a valve will be instantly closed. In the event we are assured that valve closure time will equal or exceed thirty (30) seconds we can safely assume that the computed waterhammer pressure can be reduced to twenty percent of the values obtained from Figure 1. In Example 2, if the waterhammer pressure were reduced by 80%, it would permit the use of SDR 51 (80 psi) pipe. (26 x 0.20 + 65 = 70 psi.)

Other factors than valve manipulation will contribute to waterhammer pressures. The movement of air pockets will also cause waterhammer. Air pockets will be more prevailent in long flat lines than in a line with a steep gradient.

In the design of the short, relatively simple systems, the selection of an adequate pressure rated pipe becomes a matter of sound judgement based on the design and operation of the system. Under no condition, should we assume that waterhammer pressures will not occur.

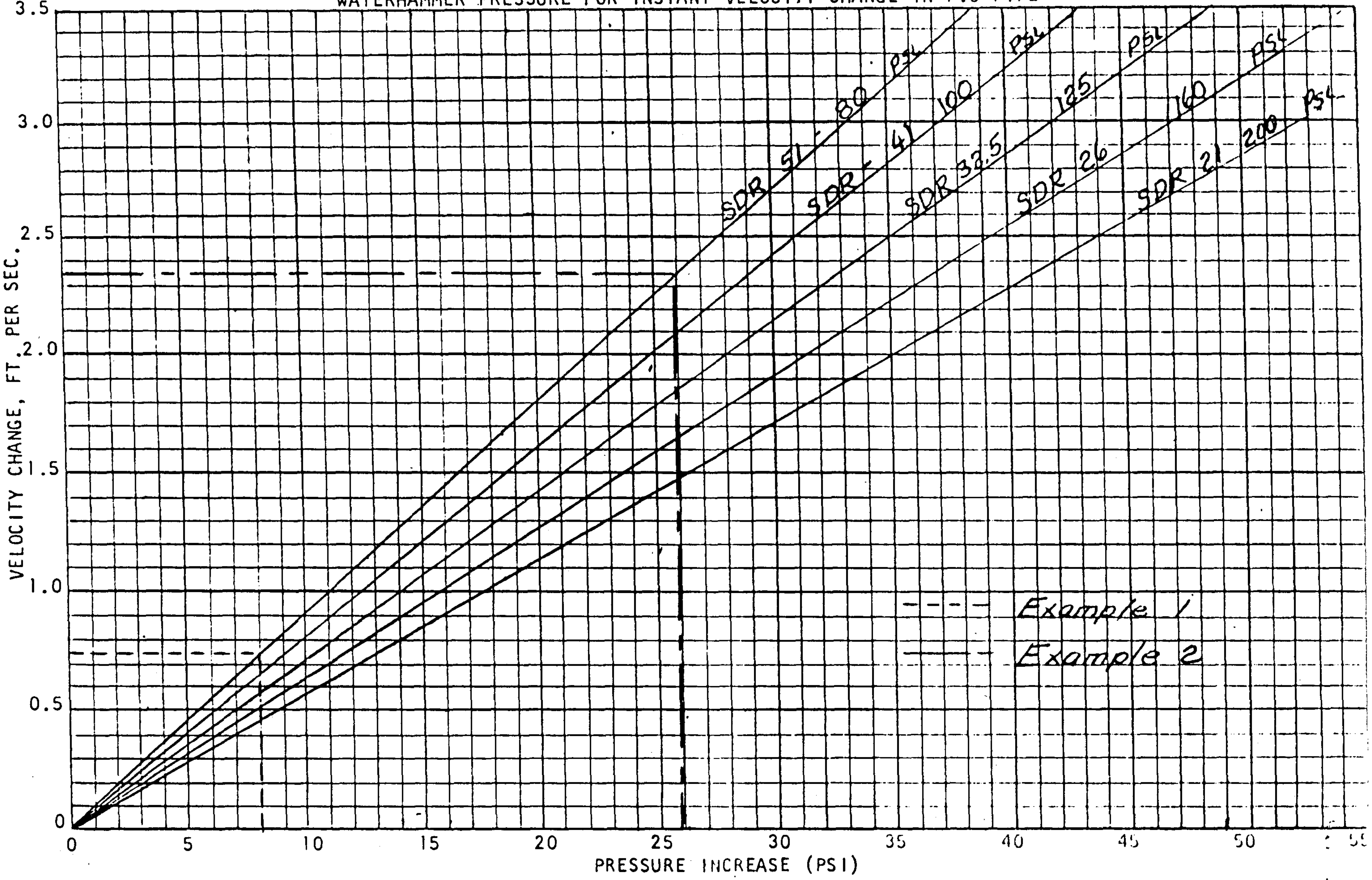
Design Considerations to Reduce Waterhammer

The design of any high pressure underground PVC pipeline shall be in conformance with Engineering Standard 430-DD.

The construction drawings and specifications should specify minimum requirements for the appurtenances that will be installed within the system. Some of the items to be considered are:

1. Avoid the use of lever actuated butterfly valves.
2. Always specify automatic air and/or air vacuum release valves. Never use manual controlled valves.
3. Specify continuous acting air vacuum release valves.
4. On long lines with a small amount of gradient ($S \leq 0.003$), install air vacuum relief valves at an interval not to exceed 1300 feet.
5. Specify a non-slam and preferably a controlled closing-rate check valve at the pump discharge, if required.
6. If surge chambers are used, they must be properly sized, correctly located and adequately maintained.

FIGURE 1
WATERHAMMER PRESSURE FOR INSTANT VELOCITY CHANGE IN PVC PIPE



7. Use O-ring gasketed joints where possible. If solvent welded joints are used, specify expansion joints at frequent intervals, not to exceed 500 feet.
8. Velocity in pipelines should not exceed 5 feet per second and in no case shall the velocity exceed 10 feet per second.

<u>Operation of System</u>

We have an obligation to inform the owners of the conditions and operating procedures that were assumed during the design. The owners should be made fully aware of the correct procedure that should be followed in operating the system and the consequences of not following the recommended procedures. Some of the items that must be considered in the operation of a system are:

1. Filling the System.
   (a) Open the riser valve at the end of the lines.
   (b) On long lines, open riser valves at 1300 ± foot interval. Even better, open all risers.
   (c) Check air and/or air vacuum relief valves to insure they are open.
   (d) Check drains to insure they are closed.
   (e) Fill pipeline at velocity not to exceed one (1) foot per second.
   (f) After water reaches end of lines, allow it to run for a few minutes to insure the release of all air. Close riser valve slowly. Never close a valve in less than 30 seconds.
   (g) Proceed up the line closing valves in not less than 30 seconds.
   (h) Observe air and/or air vacuum release valves to insure that they are operating.
   (i) Bring system up to operating pressure slowly.
   (j) In a pump energized system, if possible, connect the planned number of field laterals to the system and operate them during the filling process.

2. Operation of System.
   (a) When charging or shutting down a field lateral, never open or close a riser valve in less than 30 seconds.
   (b) If the system includes butterfly or gate valves, allow 30 seconds for every 1000 foot of line for actuating the valve.
   (c) Frequently observe all appurtenances to insure that they are functioning as planned.

3. Winterizing the System.
   (a) Avoid a rapid draining of the system. If sump drains are involved, apply as much water to the fields as possible. Avoid over charging the sump drains.

(b) After the pipelines have been drained, close valves to prevent recharging during winter months.
(c) Open pipe drains and leave open.
(d) Close riser valves.

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