Surge Pressures in Piping Systems

IPEX INC.
Tol l Free: (866) 473-9462
ipexna.com

MUNICIPAL PIPING SYSTEMS

Surge pressures (water hammer) in piping systems are generated by changes in the velocity of flow in a system. These sudden velocity changes can be caused by the operation of valves and pumps, or by expulsion of air from the piping system. With proper planning and design, the effects of surge pressures in a system can be minimized.

Controlling Surge Pressures

Surge events, particularly those caused by the rapid expulsion of air are capable of damaging almost any pipeline. There are, however, a number of ways of reducing the risk:

- Take proper precautions to avoid air entrapment during initial filling and testing of a pipeline
- Ensure proper sizing and placement of combination air/vacuum release valves
- Design systems with flexible pipe materials

Surge Pressures and Pipe Materials

Flexible pipes like PVC generate much lower surge pressures than rigid materials like concrete or iron.

Consider a water pipeline flowing at a constant velocity of 2 ft/s (0.6 m/s). If that flow was instantaneously stopped by a valve slamming shut, the surge pressures generated among various different pipe materials would vary significantly:

Material	Surge Pressure psi (kPa)
DR25 PVC Pressure Pipe	29.4 (202)
CL 16 Concrete Cylinder Pipe	96.4 (665)
CL250 Ductile Iron Pipe	97.3 (670)

PVC Pipe – The “Surge” Safety Factor

PVC has a unique ability to withstand extremely high short-duration stresses without incurring damage. This is why SDR18 pipe, while pressure rated at 235 psi for long-term service, routinely withstands over 1000 psi during burst testing. In fact, it has been proven that exposure to these extremely high stresses does not affect the long term pressure rating of the pipe.

This “surge” or short-term safety factor can be calculated by a method recommended in the AWWA Manual of Water Supply Practices: M23 – PVC Pipe – Design and Installation.

The key concept is that PVC has a short-term strength defined by the short-term hydrostatic design basis and a long-term strength defined by the long-term hydrostatic design basis.

Long-Term Hydrostatic Design Basis = 4000 psi

The material will withstand this stress virtually forever.

Short-Term Hydrostatic Design Basis = 6400 psi

This is the minimum “quick-burst” stress of the material that will resist surge pressures.

Calculating Pressure Ratings

The pressure rating of a thermoplastic pipe can be easily calculated using the ISO Equation R161-1960, which is based on work first published by Lamé in 1852:

$$P = \frac{2S}{DR - 1}$$

where:

- P = pressure rating of the pipe
- S = hydrostatic design basis / safety factor
- DR = standard dimension ratio of the pipe

The recommended safety factors are 2:1 for long-term ratings, and 2.5:1 for short-term ratings:

Example: What is the maximum flow velocity permissible in an SDR25 pressure pipe that will allow it to operate at a constant pressure of 165 psi?

Answer: First, calculate the long-term pressure rating (LTR) of SDR25 pipe:

$$LTR = \frac{2(4000/2)}{25 - 1} = 165 \text{ psi*}$$

Next, calculate the short term rating (STR):

$$STR = \frac{2(6400/2.5)}{25 - 1} = 213 \text{ psi}$$

The question is at what point does the fluid velocity create a potential instantaneous surge pressure greater than the short-term rating (STR) of the pipe? To calculate this, subtract the working pressure from the STR to get the allowable instantaneous surge pressure:

STR - LTR = 213 – 165 = 48 psi

A ΔV of 1 ft/s will generate a surge pressure of 14.7 psi in SDR25 pipe. Therefore the maximum velocity which will allow a working pressure of 165 psi for SDR25 is:

Max ΔV = 48/14.7 = 3.3 ft/s

SDR	Working Pressure psi (kPa)*	Short-Term Rating psi (kPa)*	Maximum Velocity at Full Pressure Rating ft/s	(m/s)
51	80 (550)	103 (710)	2.0	(0.6)
41	100 (690)	128 (880)	2.5	(0.75)
32.5	125 (860)	163 (1120)	3.0	(0.9)
25	165 (1140)	213 (1470)	3.3	(1.0)
18	235 (1620)	301 (2075)	3.8	(1.1)

Note that these maximum velocities apply only if the pipe is operating at its maximum rated pressure. If an SDR25 pipe is operating at 130 psi, the maximum surge pressure becomes:

STR-130 = 213 – 130 = 83 psi

Max ΔV = 83/14.7 = 5.6 ft/s

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