PVC PRESSURE PIPE – NOT SUBJECT TO COLLAPSE FROM FIRE-FLOW PUMPING

Some pipeline designers mistakenly contend that PVC pipe must be DR18 or thicker to resist collapse due to vacuum caused by fire-flow conditions. This technical brief refutes that misconception.

The potential mode of failure is wall buckling. Calculations for buckling are simple, requiring only two equations:

**Equation 1** – For a pipe subjected to uniform external pressure or internal vacuum, the pressure at which buckling failure occurs is called the “Critical Buckling Pressure” ($P_{cr}$).

\[ P_{cr} = 0.447 \frac{PS}{(1-\nu^2)} \]

where:
- $P_{cr}$ = Critical pressure (psi)
- $PS$ = Pipe stiffness (psi)
- $\nu$ = Poisson’s Ratio = 0.38 for PVC pipe

**Equation 2** – For buried pipe, the soil surrounding the pipe provides support that increases buckling resistance.

\[ P_b = 1.15 \sqrt{(P_{cr}E')} \]

where:
- $P_b$ = Critical pressure (psi)
- $E'$ = Modulus of soil reaction (psi)

Pipe that is significantly out-of-round or deflected has a lower critical pressure than pipe that is round. To account for the pipe’s in-service shape, a reduction factor (“C”) is used in Equation 1. See Chapter 7 of the *Handbook of PVC Pipe* for a reduction factor chart.

**CALCULATING PVC PIPE’S RESISTANCE TO BUCKLING**

For the examples below, the following very conservative parameters are used:
- Design pressure = full vacuum = one atmosphere of external pressure = 14.7 psi
- Pipe deflection = 5% (A more reasonable value would be less than 2%).
- Modulus of soil reaction for compacted backfill $E'$ = 1000 psi ($E'$ = 2000 or 3000 psi is more typical.)

**Example 1:** AWWA C900 – DR18 PC 235 psi (the most commonly used municipal PVC pipe)

Using 5% deflection and no soil support, $P_{cr}$ is 122 psi. Thus DR18 provides a factor of safety of 8.3 against vacuum-related collapse (compared to the typical required SF = 2.0).

For buried DR18 pipe with $E'$ = 1000 psi, $P_b$ is 401 psi – providing a safety factor of 27.3.

**Example 2:** ASTM D2241 – SDR41 PR 100 psi (thinner than typical SDR26 and SDR21 used for rural water projects)

Using 5% deflection and no soil support, $P_{cr}$ is 9.3 psi – less than the design pressure. This means that the misconception has an element of validity – an unsupported, deflected SDR41 pipe would not have the capacity to resist full vacuum.

Fire-service pipe is buried, however, so the pipe receives soil support. Using 5% deflection and $E'$ = 1000 psi, $P_b$ = 111 psi (more than ten times the value for the pipe alone). This provides a factor of safety of 7.6 against vacuum-caused buckling.

Since SDR41 pipe is not subject to fire-flow collapse, SDR26 & SDR21 rural water pipes are also adequate for fire applications.

To summarize, designers of buried PVC pipe for fire-flow applications need not consider collapse from fire-flow pumping.

References: “Vacuum,” Wikipedia; *Handbook of PVC Pipe Design and Construction*, Uni-Bell PVC Pipe Association