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}).

Critical Pressure for Pipe $P_{cr} = .447\ PS/(1-v^2)$

where: P_{cr} = *Critical pressure (psi)*

PS = *Pipe stiffness (psi)*

v = *Poisson's Ratio = 0.38 for PVC pipe*

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

Buckling Pressure for Pipe in Soil $P_b = 1.15\sqrt{(P_{cr}E')}$

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

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