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TECHNICAL BULLETIN

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VACUUM/EXTERNAL PRESSURE APPLICATIONS FOR PVC PIPE

Applications for PVC pipe can sometimes include vacuum and/or external pressure. An example of a vacuum application could be when a length of PVC pipe is used on the suction end of a pump. Examples of external pressure include pipe submerged in water and some well-casing applications.

In terms of forces acting on the pipe, there is no difference between vacuum and external pressure. In either case, greater pressure exists on the outside of the pipe than on the inside. However, it should be remembered that the maximum external pressure achievable from vacuum alone is the atmospheric pressure, or about 15 lbs/in^2 at sea level.

The mode of failure for cases of external pressure is wall buckling. The external pressure at which failure occurs is called the Critical Pressure, or Pcr. Pcr can be calculated for different types of PVC pipe. The following three cases show how this can be done.

CALCULATIONS FOR CRITICAL PRESSURE

Case 1: Unsupported, Unburied Pipe With No Diametric Deflection

Equation 1:

Note: Applicable for solid wall pipes only. See Equation 2 for profile wall pipes.

$$\mathbf{Pcr} = \frac{2E}{0.856\,(DR-1)^3}$$

Where:

Pcr = Critical Pressure (lbs/in^2)

Dr = Dimension Ratio of PVC Pipe
= Average OD/Minimum Wall

E = Modulus of Elasticity for PVC Pipe material (lbs/in^2)

At 73°F, **E** has the following values:

PVC Cell Class 12454: 400,000 (lbs/in^2)
PVC Cell Class 12364: 440,000 (lbs/in^2)

The PVC value for **E** decreases with increasing temperature. For higher temperatures, multiply the value at 73° by the correction factors in Table 1.

Table 1

TEMPERATURE CORRECTIONS FOR E		
At 90° F	Multiply by	0.93
At 100° F	Multiply by	0.88
At 110° F	Multiply by	0.84
At 120° F	Multiply by	0.79
At 130° F	Multiply by	0.75
At 140° F	Multiply by	0.70

For profile wall pipes (e.g. JM Eagle Rib), the equation becomes:

Equation 2:

$$\mathbf{Pcr} = 0.522 \times (PS)$$

Where:

PS = Pipe Stiffness (lbs/in/in)

Note: Obtain **PS** from manufacturer's literature or contact the manufacturer.

For temperatures above 73°F, multiply the result from Equation 2 by the appropriate E correction factor from Table 1.

Case 2: Buried Pipe With Soil Support

Proper soil support will improve a PVC pipe's resistance to buckling. Use the following equation for buried PVC pipes:

Equation 3:

$$\mathbf{Pb} = 1.15 \sqrt{Pcr \times E'}$$

Where:

Pb = Buckling Pressure of buried PVC pipe (lbs/in2)

Pcr = Critical Pressure for PVC pipe (found from Equation 1 or Equation 2)

E' = Modulus of Soil Reaction (Table 2 below)

Table 2

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'				
Soil type-pipe bedding material (Unified Classification System[a]) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch			
	Dumped (2)	Slight < 85% Proctor, < 40% relative density (4)	Moderate 85%-95% Proctor, 40%-70% relative density (4)	High > 95% Proctor, > 70% relative density (5)
Fine-grained Soils (LL>50)[b] Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E'=0			
Fine-grained Soils (LL<50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coarsegrained particles	50	200	400	1,000
Fine-grained Soils (LL<50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coursegrained particles. Coarse-grained soils with Fines GM, GC, SM SC[c] contains more than 12% fines	100	400	1,000	2,000
Coarse-grained Soils with Little or No Fines GW, GP, SW, SPc contains less than 12% fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000

[a] ASTM Designation D 2487, USBR Designation E-3
[b] LL = Liquid limit
[c] Or any borderline soil beginning with one of these symbols (i.e. GM-GC,GC-SC)

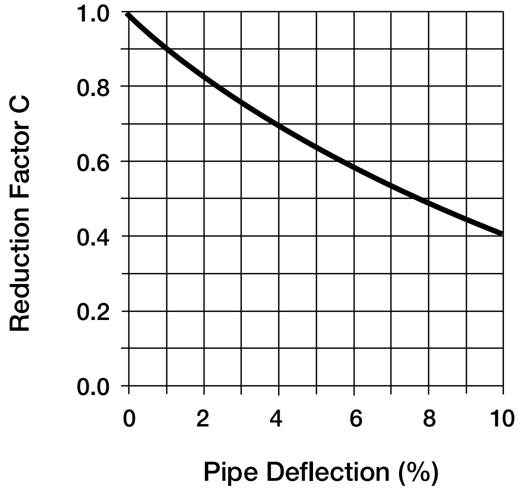
SOURCE: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver, Colorado. Reprinted with permission from the UniBell PVC Pipe Association.

Case 3: Pipe with Diametric Deflection

PVC pipes that are deflected diametrically or that are otherwise out-of-round have less resistance tobuckling. In these cases, multiply the result of Equation 1, 2, or 3 by the correction factor C found in Figure 1 in the next column.

Figure 3

CRITICAL BUCKLING PRESSURE REDUCTION FACTOR C FOR SHAPE



Reference: *"Uni-Bell Handbook of PVC Pipe."*

Example:

This example calculates whether vacuum could cause failure in a sewer pipe application.

Given:

1. 15" SDR 35 ASTM D 3034 PVC sewer pipe with cell class 12454
2. Operating temperature is 120° F
3. Pipe is deflected 5%
4. Pipe is bedded in dumped CL soil with < 25% coarse-grained particles

Solution:

$$\mathbf{E} \text{ at } 73°F = 400{,}000 \text{ lbs/in}^2$$

$$\mathbf{E} \text{ at } 120°F = 400{,}000 \text{ lbs/in}^2 \times 0.79$$

$$= 316{,}000 \text{ lbs/in}^2$$

$$\mathbf{E'} = 50 \text{ lbs/in}^2$$

$$\mathbf{C} = 0.63$$

$$\mathbf{Pcr} = \frac{2(316{,}000 \text{ lbs/in}^2)}{0.856 \times (35-1)^3}$$

$$= 18.8 \text{ lbs/in}^2$$

$$\mathbf{Pb} = 1.15 \sqrt{18.8 \times 50 \text{ lbs/in}^2}$$

$$\textbf{Corrected Pb} = 35.3 \text{ lbs/in}^2 \times 0.63$$

$$= 22.2 \text{ lbs/in}^2$$

22.2 lbs/in² is more than the maximum achievable vacuum (15 lbs/in²), so it is not possible for vacuum to cause failure in this case.