Paul David Process Ltd

Problem PSV sizes

Engineers who carry out a lot of relief valve calculations know that some PSV sizes give more inlet line pressure drop problems than others. Inlet line pressure drops are calculated with rated flow (i.e. based on PSV capacity).

PSVs are usually supplied in standard sizes per API 526 e.g. 1D2. The PSV "orifices" come in discrete sizes and inlet pipes are only available in standard sizes. If the inlet pipe is the same size sa the PSV inlet flange, the ratio of orifice flow area to pipe flow area varies significantly.

If the inlet pipe arrangement has a constant resistance factor (K) then the inlet line pressure drop is

$$\Delta P = 0.5\ K\ \rho\ u_1^{\ 2} = 0.5\ K\ W^2 / \rho_1 A_p^{\ 2} \qquad (1)$$

The standard API formula for relief valve sizing (gas critical glow) can be reduced to the following expression (where constants have been collected into C)

$$A_o = (W/C\ P_1) * \text{sqrt}\ (T_1 Z/M)$$

Squaring this formula

$$A_o^{\ 2} = (W^2/C'P_1)(T_1 Z/MP_1)$$

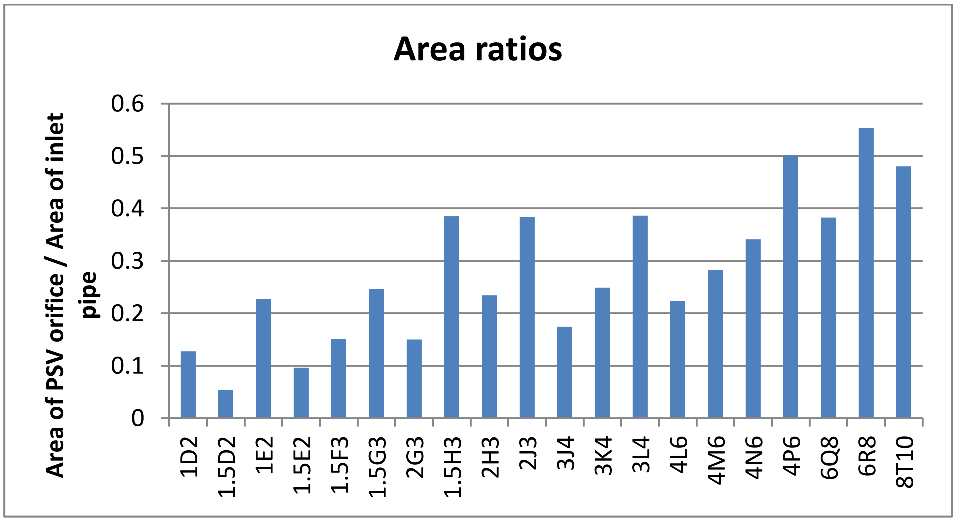
Since MP_1/TZ is directly proportional to density ρ then

$$A_o^{\ 2} = W^2/C''P_1\rho \qquad (2)$$

Combine (1) and (2) to eliminate W, divide by the set pressure (abs) and combine all constants into K''

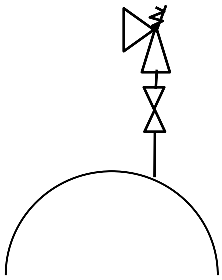
$$\Delta P\ (\%\ \text{of abs set pressure}) = K''\ (A_o / A_p)^2$$

This shows that the inlet line pressure drop is approximately proportional to the square of the area ratio. It would be expected that the "problem valves" would be those with a large A_o / A_p. The following chart shows A_o/A_p for API 526 standard valves sizes, the inlet line is assumed to be the same size as the inlet flange.

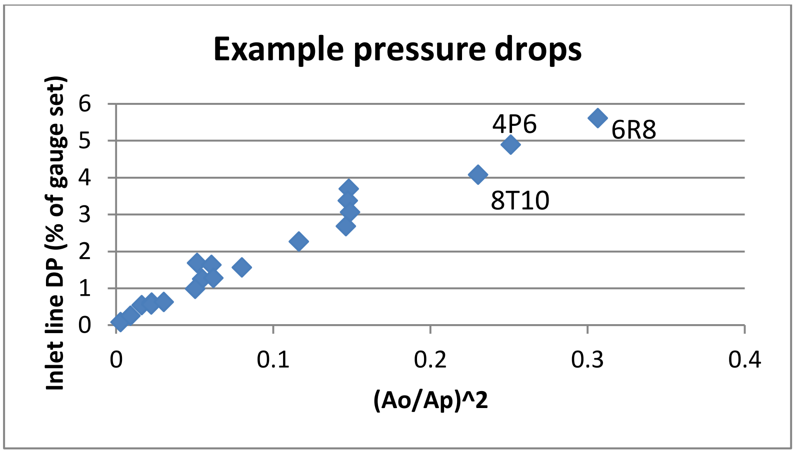


The 4P6, 6R8 and 8T10 sizes stand out as potential problem valves with a second group (including $1^{1}/_{2}$ H3, 2J3, 3L4 and 6Q8) also a concern.

An example case was used to calculate inlet line pressure drops pressure drops for various PSV sizes (air, 8 barg set pressure, 25°C relief temperature). A typical simple inlet line was assumed with a short (0.5m including vessel nozzle) connection directly off a vessel plus one gate valve. The exit loss from the vessel was taken as 0.5 velocity heads. The inlet line is the same size as the PSV inlet flange.



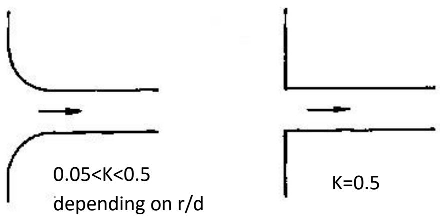
The results of the calculations are shown in the following chart.



These pressure drops clearly indicate the “linear trend” vs area ratio even though in this example the simplification that inlet resistance factor is constant is not strictly true.

The 4P6, 6R8 and 8T10 are the obvious “bad actors” but other valves also exceed the API limit of 3% of set pressure.

The results show how difficult it can be to meet the 3% rule even for a short, simple, inlet configuration. The biggest single resistance to flow is the vessel exit loss where a square edged exit has been assumed. The 3% rule can be met in the example calculations for <u>all</u> the PSV sizes with a well-rounded nozzle.



Conclusions

1. Inlet line lengths should be severely limited for the “problem sizes” of PSV.
2. For the “problem sizes” of PSV (particularly 4P6, 6R8, 8T10) a rounded vessel nozzle is mandatory unless an inlet line larger than the PSV inlet size is used.
3. Care is needed in specifying the vessel nozzle size – it may be necessary to place a new vessel on order before detailed inlet line pressure drops calculations have been completed.

Nomenclature

A_o	API effective orifice area for PSV
A_p	Cross sectional area of PSV inlet pipe
C	Constant (various superscripts)
K	Constant (various superscripts)
M	Molecular weight
P	Pressure (absolute)
T	Temperature (absolute)
u	pipe average velocity
W	Mass flowrate
ΔP	PSV inlet pipe pressure drop
ρ	density

Subscripts

1	PSV inlet conditions

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