CCPS Guidelines – Part II

1. Paragraph P1 (Page 81, Insert after 2nd Paragraph)

The calculation method of ASME PTC-25 (1994) uses the area of the nominal pipe size of the device as the minimum net flow area basis for determining the K_R value from the flow test data (air or gas flow). The method was developed for use with essentially full-area devices (no structural elements remaining in the flow path after complete burst of the disk). Current practice is to apply this calculation method to reduced-area devices as well. When so applied to devices with a ratio of device flow area to pipe area ("area ratio") less than about 0.8, the apparent K_R value increases with test pressure in the lower pressure ranges, becoming constant at higher pressures. This constant value is appropriate for current K_R certifications. Relief system designs based on such K_R values must use the same device area basis as specified in the certification tests (area of nominal pipe size of the device per current practice).

The apparent pressure dependency of K_R for reduced-area devices is not observed if the calculation method is based on the specified minimum net flow area of the fully-blown device rather than on the nominal pipe size. On this basis, conditions of maximum flow in the device area (sonic, critical, "choked" flow) are recognized and treated rigorously. See Huff, J. E., "Restrictive Rupture Disc Devices: A Calculation Method for Certification and Design" (Topical Conference Proceedings of the 2001 Process Plant Safety Symposium, AIChE Spring National Meeting, pp. 578-584, April 2001) for an early version of such a calculation method. Since the present PTC-25 calculation method does not recognize flow-limiting critical flow, calculated flows can be several percent on the high side for restrictive devices under conditions of high operating pressure and/or short lengths of associated piping. However, the specified 0.9 reduction for calculated flows assures a conservative result for selecting an adequate relief device size. The present method is inherently conservative for subcritical flow.

The certification and design approach based on actual flow area may well be adopted as the supporting technology matures and PTC-25 evolves. Relief system design with such K_R values must use the specified minimum net flow area when calculating the pressure loss in the device. For devices with area ratios less than about 0.65, vena contracta effects appear to reduce the effective minimum flow area to some extent in subcritical flow. The designer must have information to account for this effect if significant for a given device.

2. Paragraph P2 (Page 82, Replace 2nd Paragraph)

In the code certification procedure, the K_R values are determined from flow tests with air or gas. The choice of fluid used for burst tests depends on the intended service (ASME BPVC 2001, U-131(l)) and the K_R values are designated:

- K_{RG}: burst with air or gas
- K_{RL}: burst with water
- K_{RGL}: At least one of the included specimens burst with water
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Note that some styles of rupture disk devices are not recommended for liquid service. Consult manufacturers for a suitable style.

The Code design methods are formulated to give conservative results (under-estimate of flow to give ample relief size). While appropriate for relief sizing purposes, this rated flow capacity may well be under-conservative for purposes of effluent handling system sizing, particularly when reduced-area devices are used. See §3.6.5.2 for considerations in relating the best estimate flow to the rated relieving capacity.

3. Paragraph P3 (Page 209, Insert After 1st Paragraph)

Use Equation (3B.2-9) if the flow is critical (choked) at the minimum flow area. If the flow is not choked, use Equation 3B.2-23, p. 260 (with K added as in Equation (3B.3-9) above), where

* $r = P_1 / P_o$
P_o = stagnation pressure at device inlet flange (see equation (3B.2-8), page 256, or use the pressure in the relieving vessel)
P_1 = pressure at minimum flow area
* $\rho_o = (MW\ P_o) / (Z\ R\ T)$
Z = compressibility as determined in 3B.2.1.3, page 258 (Z = 1 for ideal gas)
R = gas law constant
* MW = molecular weight

Do not use the following test for critical flow (conventional practice for pressure relief valves):

$$P_2 / P_o < [2 / (k + 1)]^{k / (k-1)}$$

where P_2 = back pressure in piping at device. This criterion presumes that there are no losses in the device (ideal nozzle) and that $P_1 = P_2$. This is true only if the discharge is from an ideal nozzle to atmosphere (or to a large reservoir). Instead, calculate P_1 from the known value of P_2 using the pressure-recovery technology of 3B2.2.5, p. 269. See: Huff, J. E., "Flow Models for Reduced-Area Rupture Disc Devices: Accounting for Pressure Recovery in Tests for Choking" presented at the DIERS Users Group Meeting, Albuquerque, NM, October 15, 2001

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4. Paragraph P4 (Page 210, Replace 1st Paragraph)

The rated relieving capacity so calculated is intended to give a conservative (low) estimate of the actual capacity (in order to assure adequate relief sizing). Some upward adjustment is required to obtain the best estimate flow for effluent handling system design. This adjustment depends on the ratio of the actual flow area of the device to that of the piping ("area ratio"). Current PTC-25 practice is to determine certified K_R values as if the area ratio were unity. Flows calculated from such values are suitable for determining best estimate flow for actual area ratios of about 0.8 or higher. However, the 0.9 reduction in the rated relieving capacity must be removed.

The appropriate upward adjustment for area ratios less than 0.8 depends on both the area ratio and the length of the associated piping. Consider the case of a relief system with a vacuum support, area ratio of 0.4, which remains in the flow path after complete device rupture. Calculations based on the conditions in the actual flow area of the device show that gas flow can be sonic in typical relief system configurations, particularly at the higher relieving pressures and/or shorter tail pipe lengths. The design method as used with current K_R values does not account for this flow limitation, and thus yields estimates as much as 10% higher than the sonic-flow result for very short tail piping. For systems with longer tailpipes, the present method yields estimates on the low side (almost 10% low at about 150 diameters of tail pipe for low relieving pressures). Estimates remain conservative for long tail pipes (about 5% low at 800 diameters). Thus, merely removing the mandatory 0.9 reduction from the rated relieving capacity does not yield a uniformly good best-estimate flow. Obtain the services of an experienced consultant if 10% uncertainty in the best estimate flow, plus or minus, is not acceptable for effluent handling design.

5. Paragraph P5 (Page 270, Insert After 1st Paragraph)

For gas flow, use the following equations to calculate the conditions at the exit of the smaller duct from the conditions in the larger duct (Hall and Orme, 1955). The values in the larger duct are determined by calculating back up from a downstream point of known conditions. Using subscript 1 for the smaller duct and 2 for the larger:

$$m_2 = \{(k + 1)\, M_2^2 / [(k - 1)\, M_2^2 + 2]\}^{1/2}$$

$$m_1 = [-y + (y^2 - 4\,x\,z)^{1/2}] / [2x] \qquad \text{(I)}$$

where $x = m_2\, [(k - 1) / A_r - 2k] / [k + 1]$

$y = m_2^2 + 1$

$z = -m_2 / A_r$

$$M_1 = \{2m_1^2 / [(k + 1) - (k - 1)\, m_1^2]\}^{1/2} \qquad \text{(II)}$$

If this recovery calculation is attempted when the flow from the smaller duct is sonic (choked), then either the argument of the square root in Equation (I) will be negative or M_1 from Equation (II) will be greater than one. The expansion calculation is thus not needed since the flow is controlled by conditions in the smaller pipe. Set $M_1 = 1$.

If $M_1 < 1$:

$v_1 = v_2\, A_r\, m_1 / m_2$

$T_1 = T^o / [1 + (k - 1)\, M_1^2 / 2]$

If $M_1 = 1$:

* $T_1 = T^o / [1 + (k - 1) / 2] = T^o\, [2 / (k + 1)]$

$v_1 = (g_c\, k\, R\, T_1\, Z / mw)^{1/2} / G_1$

In either case:

* $P_1 = (Z\, R\, T_1) / (MW\, v_1)$

where:

k = isentropic expansion coefficient
* M = Mach number = $(G\, v) / c$
* c = sonic velocity = $(g_c\, k\, R\, T\, Z / MW)^{1/2}$, (ft / sec)
* A_r = duct flow area ratio = A_1 / A_2
m = modified Mach number
T = temperature, ^oR
T^o = stagnation temperature, ^oR (constant throughout an adiabatic system; use upstream vessel temperature)
* R = gas law constant = 1544 $(ft^3 \cdot lb_f / ft^2) / (lbmol \cdot {}^oR)$
Z = compressibility
* MW = molecular weight, $(lb_m / lbmole)$
* G_1 = mass flux, $(lb_m / (ft^2\, sec))$
* v_1 = specific volume, (ft^3 / lb_m)
* g_c = gravity constant, $(lb_m\, ft) / (lb_f\, sec^2)$
other parameters as defined above

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