

## ***Errata: Guidelines for Pressure Relief and Effluent Handling Systems***

| Page | Location                                    | Correction (changes are in bold)  |
|------|---|---|
| 42   | Last para, 7 <sup>th</sup> line             | ...Lai (1996), <b>Table 2.4-5 (Page 57)</b> ...   |
| 58*  | 1 <sup>st</sup> para.                       | ...valves should be...  |
| 64*  | 3 <sup>rd</sup> para.                       | ...set as high as <b>1.1</b> times the vessel MAWP.   |
| 71   | §2.5.8, 1 <sup>st</sup> line                | Refer to §5.3.4 for...  |
| 73*  | 4 <sup>th</sup> para.                       | Delete: the nozzle flow model with a discharge coefficient of 0.62 (see §3.6.5.2)   |
| 74*  | 2 <sup>nd</sup> para.                       | Add: ... options (see §3.6.5.2, page 209)   |
| 74*  | 2 <sup>nd</sup> para.                       | Delete: ...,either $K_r = 0.1$ , or...  |
| 81*  | 1 <sup>st</sup> para.                       | Delete the last two sentences: "There is ...  |
| 81   | 2 <sup>nd</sup> para., 3 <sup>rd</sup> line | ... $K_R$ values of <b>full-area</b> rupture disk devices <b>in gas service</b> has been...   |
| 81*  | After 2 <sup>nd</sup> para.                 | Insert paragraph P1   |
| 81*  | 3 <sup>rd</sup> para.                       | Delete: ...for both nozzle ... coefficient is 0.62.   |
| 81*  | 3 <sup>rd</sup> para.                       | Replace sentence: In the pipe flow model, current certified $K_R$ values (ASME PTC-25, 1994) represent the device flow resistance as that of a full-area flow element with the $K_R$ value included in the total flow resistance of the piping system                                 |
| 81*  | Last para.                                  | Delete the paragraph  |
| 82*  | 1 <sup>st</sup> para.                       | Delete the paragraph  |
| 82*  | 2 <sup>nd</sup> para.                       | Replace paragraph with P2   |
| 109  | ASME address                                | The American Society of Mechanical Engineers, <b>3 Park Avenue</b> , New York, NY <b>10016-5990</b>   |
| 125  | 3 <sup>rd</sup> para., last line            | ...in <b>§3B.4.2.1</b> .  |
| 129* | Eq. (3.3-2)                                 | $\beta = ((\rho_{\text{flow}} - \rho_2) / (T_{\text{flow}} - T_2)) / \rho_{\text{flow}}$  |
| 129* | 4 <sup>th</sup> para.                       | For a liquid, $\beta$ can be evaluated from the density change over a 5 °F temperature increment divided by the flowing density ( $\rho_{\text{flow}}$ ).   |
| 129* | Reference                                   | (1993) API RP 520-I, Appendix C (1997) API RP 521, para. 3.14   |
| 131* | References                                  | (1993) API RP 520-I, para. 3.3.2 (1997) API RP 521, para. 3.15.1.1<br>(1993) API RP 520-I, para 3.3.3 (1997) API RP 521, para. 3.15.1.2<br>(1993) API RP 520-I, para. D.3.2 (1997) API RP 521, para. 3.15.1.2<br>(1993) API RP 520-I, para. D.5.2.4 (1997) API RP 521, para. 3.15.2.2 |
| 133* | Table 3.3-2                                 | Vent Rate (SCFH* AIR) Valid at approximately One Atmosphere Pressure  |
| 134* | References                                  | (1993) API RP 520-I, Table D-2 (1997) API RP 521, Table 4<br>(1993) API RP 520-I, Table D-3 (1997) API RP 521, Table 5  |
| 137  | Eq. (3.3-10) and line above                 | ...are approaching zero: <b>(Simpson, 1995a)</b><br>$W = \frac{C q}{T v_g (dP / dT)_{\text{sat}}} \quad \{(dP / dT)_{\text{sat}} \text{ should be in the denominator}\}$  |
| 139  | 4 <sup>th</sup> para., 3 <sup>rd</sup> line | (Simpson, 1995a)  |
| 139  | 6 <sup>th</sup> para., 5 <sup>th</sup> line | ...component by <b>the following approximation (Simpson, 1995a)</b> :   |
| 147  | 3 <sup>rd</sup> para., 4 <sup>th</sup> line | ...(page <b>129</b> )...  |
| 148  | 2 <sup>nd</sup> para., 5 <sup>th</sup> line | ... Table <b>3.3-2</b> ...  |
| 157  | 1 <sup>st</sup> para., 3 <sup>rd</sup> line | ...vendors...   |
| 161  | 1 <sup>st</sup> para., 6 <sup>th</sup> line | ...point is illustrated... {omit be}  |
| 166  | 2 <sup>nd</sup> line                        | $\tau = \frac{7998}{335.5} - \left[ \frac{160.4 \times 1076}{13.69 \times 0.3451 \times 335.5} \right]^{1/2} = 13.4 \text{ s}$  |
| 166  | 3 <sup>rd</sup> line                        | = 3500 lbm {not lbm / s}  |
| 178  | 1 <sup>st</sup> line                        | §3B.2.2.5 (Page 269)  |

## ***Errata: Guidelines for Pressure Relief and Effluent Handling Systems***

|      |   |  |
|------|---|--|
| 178  | 2 <sup>nd</sup> para., 2 <sup>nd</sup> line                                 | §3B.4.2.3 (Page 284)   |
| 178  | §3.6.1.5, 1 <sup>st</sup> line  | See <b>§3B.3.1.6</b> (Page 277)  |
| 186  | Ex., bottom of page   | Ell $KF = 0.27$ ; total $KF = 0.83$ ; ...from COMFLOW is <b>66.99</b> psia {not 67.13}   |
| 194  | Table note, 3 <sup>rd</sup> line  | $66.82 = 129.9X + (-13.9)(1 - X)$ {delete extra = sign}  |
| 197* | Table   | Liquid Wt %: Acetone – 50, Ethanol – 30, Water – 20  |
| 198  | Last para., 1 <sup>st</sup> sentence  | Eq. (3B.2-14) (page 258) {not Eq. (3B.2-6) (page 255)}   |
| 199* | First two lines   | The first two lines are duplicated from page 198   |
| 199* | Eq. (3B.2-18) and (3B.2-19)   | Constant should be <b>0.93028</b> (3 places)   |
| 200  | 1 <sup>st</sup> line of Eq. (3B.2.21)                                       | $k = (v / P) [(\partial P / \partial T)_v^2 T / C_v - (\partial P / \partial v)_T]$ {missing – and $T$ should be $v$ }   |
| 201  | 1 <sup>st</sup> line  | Line is a duplicate of the last line on Page 200   |
| 201* | Eq. (3.6-8)   | Delete $\beta'$ in the denominator   |
| 202* | Definition of $\beta$   | Beta = ratio of the diameters of the nozzle throat to the inlet pipe   |
| 206  | 2 <sup>nd</sup> para, 7 <sup>th</sup> line                                  | Eq. <b>(3.6-8)</b> (page <b>201</b> )  |
| 208  | 3.6.5.1 Heading   | Delete GAS OR VAPOR  |
| 209  | 3.6.5.1   | Add following the nomenclature: See 3.6.3 for liquid flow in nozzles   |
| 209  | 3.6.5.2 Heading   | Delete GAS OR VAPOR  |
| 209* | After 1 <sup>st</sup> para.   | Insert paragraph P3  |
| 209* | 2 <sup>nd</sup> para.   | Delete “See 2.6.4 for...”  |
| 209  | Last para.  | Add ...through (r) for the given fluid ( $K_{RG}$ , $K_{RL}$ , $K_{RGL}$ )   |
| 210* | 1 <sup>st</sup> para.   | Replace paragraph with P4  |
| 213* | Footnote  | Where $D$ is i.d. (inches) of Schedule 40 standard pipe  |
| 231  | Line after Eq. (3A.3-6)   | ...data over a <b>limited</b> temperature range ( <b>Reid, et al., 1987</b> ).   |
| 238  | Eq. (3A.5-1)  | $dv = \left(\frac{\partial v}{\partial T}\right)_p dT + \left(\frac{\partial v}{\partial P}\right)_T dP$ {missing + ; misplaced + }  |
| 239  | Eq. (3A.5-6)  | $-\frac{dP}{dT} = \frac{(1 / \rho) (\partial \rho / \partial T)_p + 3\alpha}{(D C_1 / e E) + (1 / \rho) (\partial \rho / \partial P)_T}$ { $\rho$ in place of $P$ in partial derivative} |
| 239  | Middle of page  | The modulus of elasticity is <b>30</b> $\times 10^6$ {not $3 \times 10^6$ }  |
| 239  | Table 3A.5-1  | $dP/dT$ , psi / °C (acetic acid...water): <b>155, 155, 155, 166, 197, 164, 47</b>  |
| 246  | Eq. (3A.6-6)  | $\phi$ should be in the numerator, not the denominator   |
| 256  | Eq. (3B.2-8)  | $\frac{P_{in}^0}{P_{in}} = \left[ \frac{v_{in} G^2 (k-1)}{2 g_c k P_{in}} + 1 \right]^{k/(k-1)}$ { $v_{in}$ misplaced; no = sign}  |
| 258* | Reference   | (1993) API RP 520-I, para. 4.3.3.1 (2000) API RP 520-I, para. 3.6.3  |
| 259* | Eq. (3B.2-21)   | Last term should be $(dP / dT)r$   |
| 260* | References  | (1993) API RP 520-I, para. 4.3.3.1 (2000) API RP 520-I, para. 3.6.3<br>(1993) API RP 520-I, para. 4.3.3.1 (2000) API RP 520-I, para. 3.6.2   |
| 262  | Eq. (3B.2-29)   | $-dP = \frac{1}{g_c} G^2 dv + \left(\frac{dP}{dL}\right)_{fr} dL + \frac{g}{g_c} \frac{1}{v} dZ$ {fr subscript; also in $\left(\frac{dP}{dL}\right)_{fr}$ definition}                    |
| 265  | In place of text starting with “The Churchill values... and ending with Eq. | The friction factor is calculated from the following BASIC-like procedure:<br>$f_1 = 64 / N_{Re}$<br>If $N_{Re} < 1,000$ Then<br>$f = f_1 / 4$ (laminar $f$ ) (3B.2-36)                  |

## ***Errata: Guidelines for Pressure Relief and Effluent Handling Systems***

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|      | (3B.2-36b)  | <p>Else <math>(N_{Re} \geq 1,000)</math></p> $\phi = -2 \log_{10} [(\epsilon / D) / 3.7 + (7 / N_{Re})^{0.9}]$ $f_3 = \{-2 \log_{10} [(\epsilon / D) / 3.7 + 2.51 \phi / N_{Re}]\}^{-2}$ <p>If <math>N_{Re} &lt; 10,000</math> Then</p> $f_2 = (Re / 13,269)^2$ $f = [f_1^{12} + (f_2^{-8} + f_3^{-8})^{-3/2}]^{1/12} / 4 \quad \text{(transitional } f)$ <p>Else <math>(N_{Re} \geq 10,000)</math></p> $f = f_3 / 4 \quad \text{(turbulent } f)$ <p>End If <math>\text{(end of inner "If...Then...Else" statement)}</math></p> <p>End If <math>\text{(end of outer "If...Then...Else" statement)}</math></p> | (3B.2-36a)<br>(3B.2-36b)                                       |
| 270* | 1 <sup>st</sup> sentence                            | Add: For incompressible or two-phase flow, equation (3B.2-40) can be solved...  |  |
| 270* | 1 <sup>st</sup> para.                               | Delete: ...and close to unity for gas flow.<br>Add: Do not follow the common practice of using $\omega = 1$ for gas flow.   |  |
| 270* | 1 <sup>st</sup> para.                               | Delete the words: "For any fluid,"<br>Add: "Using physical property information, the value of ..."  |  |
| 270* | After 1 <sup>st</sup> para.                         | Insert paragraph P5   |  |
| 270  | 2 <sup>nd</sup> para., 1 <sup>st</sup> line         | If the flow is choked at $P_1$ ...  |  |
| 270  | 3 <sup>rd</sup> para., 1 <sup>st</sup> line         | Some designers follow the practice of...  | {delete conservative}  |
| 270  | Eq. (3B.2-42)                                       | $G_c^2 = (-\partial P / \partial v)_s$  | {inverted $P$ and $v$ ; subscript error; sq. rt. (t.)}         |
| 273  | 3 <sup>rd</sup> para., 1 <sup>st</sup> line         | ...program at each...   | {omit 2 <sup>nd</sup> the}                                     |
| 273  | Table 3B.3-1, Model C                               | $v / v_A - 1 = a [(P_A / P)^b - 1]$   | {missing bracket}  |
| 274  | 3 <sup>rd</sup> line                                | ✧ TPHEM then sets $b_1 = 1$ , $c_0 = 0$ , and computes $a_0$ and $b_0$  | { $c_1 \neq 0$ ; $b_0$ , not $bo$ }                            |
| 274  | 4 <sup>th</sup> - 6 <sup>th</sup> line (replace)    | <b>For frozen flow use the two-point Model E with <math>X_B = X_A</math> (see §3B.4.3.2.2).</b>   |  |
| 274  | 1 <sup>st</sup> para., 3 <sup>rd</sup> line         | <b>§3B.4.2.3</b>  |  |
| 274  | §3B.3.1.1, 3 <sup>rd</sup> line                     | (somewhat more rigorous for gas flow <b>through pipes</b> ).  |  |
| 274  | 3 <sup>rd</sup> to last line                        | Table <b>3B.3-1</b>   | {not Table 3B.23-1}  |
| 274  | 2 <sup>nd</sup> to last line                        | $X = 0$   |  |
| 275  | Table 3B.3-2  | Temperature $T_0 (P_0 / P)^{(k-1)/k}$   | $T_0$ {Error in power}   |
| 275  | Table 3B.3-2  | $v_g$ $v_0 (P / P_0)^{-1/k}$  | $v_0 (P / P_0)^{-1}$ {Error in power}                          |
| 279  | Last para., reference                               | Eq. (3B.2-29)   |  |
| 282  | Eq. (3B.4-7)  | $G_t^2 = \frac{2 g_c P_0}{v_t^2} \left\{ (1 - X) v_f \left( 1 - \frac{P_t}{P_0} \right) + \frac{X v_{g0} k^*}{k^* - 1} \left[ 1 - \left( \frac{P_t}{P_0} \right)^{(k^*-1)/k^*} \right] \right\}$  | {missing brackets and subscript 0 in $v_{g0}$ ; pressure term} |
| 282  | Below Eq. (3B.4-7)                                  | $v_t = (1 - X) v_f + X v_g (P_t / P_0)^{-1/k^*}$  | {last part should be raised to the power}                      |
| 283* | 1 <sup>st</sup> para.                               | Eq. (3B.2-18) should be Eq. (3B.2-44)   |  |
| 283  | Eq. (3B.4-8)  | $g_c G_c^{-2} = \frac{X v_g}{k P_c} + \frac{N_{ne} (v_{fg} / H_{fg})^2 (C_f T - X H_g)}{J}$   | {missing – in $-2$ power}                                      |
| 283  | 2 <sup>nd</sup> para., 2 <sup>nd</sup> to last line | ft ·lb <sub>m</sub> / BTU...  | {not ft ·lb <sub>m</sub> / (lb <sub>f</sub> ·s <sup>2</sup> )} |
| 292  | Table 3B.4-3  | Replace ITPS with <b>IPTS</b> (two places)  |  |
| 292  | 3 <sup>rd</sup> line                                | (Leung, <b>1995</b> )   |  |
| 292* | Table 3B.4-3  | For all options, see: "TPHEM – Supplement for Advanced Users" (attached)  |  |
| 294  | --  | Page is not numbered  |  |
| 294* | Table 3B.4-5  | For all options, see: "TPHEM – Supplement for Advanced Users" (attached)  |  |

## ***Errata: Guidelines for Pressure Relief and Effluent Handling Systems***

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| 294* | Table 3B.4-5  | Code IC, 3 = <b>Advanced User</b>   |
| 295  | Table 3b.4-6  | Table 3 <b>B</b> .4-6   |
| 295* | Table 3B.4-6  | For all options, see: “TPHEM – Supplement for Advanced Users” (attached)  |
| 296  | Table 3B.4-7  | <b>Enthalpy</b> {misspelled}  |
| 296  | Table 3B.4-7  | Lb <sub>m</sub> / ft <sup>3</sup> {heading}   |
| 296* | Table 3B.4-7  | Replace Data Set with <b>State</b>  |
| 368  | Fig. 5.4-3, 2 <sup>nd</sup> right box                               | Read value of y from Figure <b>5.4-4</b> {wrong number}   |
| 369  | 2 <sup>nd</sup> line  | ...(5.4.10) through (5.4.12)...   |
| 370* | Eqs. (5.4.4) and (5.4.5);<br>These equations are preferable.        | $D = \sqrt{\frac{4 Q_g (1 - y)}{\pi C u_t (1 - x)}} \quad (5.5.4)$ $C = L / D \text{ (a user-specified length-to-diameter ratio)} \quad (5.5.5)$  |
| 371  | 3 <sup>rd</sup> para., 1 <sup>st</sup> line                         | Figure <b>5.4-4</b>   |
| 386  | 3 <sup>rd</sup> line from bottom                                    | ...sum of <b>partial</b> pressures...   |
| 387  | $P_l, P_q$  | Should be partial pressures, except when the condensable and quench liquids are immiscible  |
| 388  | <ul style="list-style-type: none"> <li><i>Gas holdup</i></li> </ul> | Replace bullet text with: <ul style="list-style-type: none"> <li><i>Gas holdup</i> is the gas trapped in the bubbling liquid.</li> <li><i>Entrainment</i>. An allowance for additional gas volume (freeboard) is also needed to minimize entrainment losses.</li> </ul> |
| 393  | Last symbol   | $H_{q0}$ = enthalpy of quench liquid at initial temperature   |
| 396  | $P_l, P_q$  | Should be partial pressures, except when the condensable and quench liquids are immiscible  |
| 397  | 3 <sup>rd</sup> line  | Equation (5.6.5)...   |
| 403  | 2 <sup>nd</sup> para., 4 <sup>th</sup> line                         | ... <b>partial</b> pressure...  |
| 403  | $P_{v1}, P_{v2}$  | = <b>partial</b> pressure of pool... {not vapor pressure}   |
| 434  | Eq. (5.9.3)   | $M_2 = 1.702 \times 10^{-5} \left( \frac{W}{P D^2} \right) \left( \frac{Z T}{k M_w} \right)^{1/2}$ {missing ½ power}  |
| 461  | Complete page   | May be a duplicate of Pg. 460; see correct page (attached)  |
| 469* | 2 <sup>nd</sup> para.   | ...each component in <b>the</b> vapor leaving...  |
| 487* | Reference   | API RP 520-I, <b>7<sup>th</sup> Ed. (Jan 2000)</b>  |
| 488* | 6 <sup>th</sup> entry   | ASME BPVC. Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels, <b>2001</b> , ASME, New York, NY  |
| 490* | Reference   | Bluhm, W. C. (1962)   |
| 492  | Bottom of page  | Some may have poor print quality; see correct page (attached)   |
| 506* | Reference   | Add: Schmidt, J. and Giesbrecht, H., “Design of Cyclone Separators for Emergency Relief Systems”, PSP, 20(1), 6-16 (March 2001)   |

\* New Addition Since 4/13/2002

## CCPS Guidelines – Part II

### 1. Paragraph P1 (Page 81, Insert after 2<sup>nd</sup> 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 2<sup>nd</sup> 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). The  $K_R$  values are so 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
- 

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 1<sup>st</sup> 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

$$r = P_o / P_1$$

$P_o$  = 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

$$\rho_o = Z R T / M P_o$$

Z = compressibility as determined in 3B.2.1.3, page 258 (Z = 1 for ideal gas)

R = gas law constant

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

4. Paragraph P4 (Page 210, Replace 1<sup>st</sup> 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 1<sup>st</sup> 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:

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

$$m_1 = [-y + (y^2 - 4xz)^{1/2}] / [2x] \quad (I)$$

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

$$y = m_2^2 + 1$$

$$z = -m_2 / A_r$$

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

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  $M_1 < 1$ :

$$v_1 = v_2 A_r m_1 / m_2$$

$$T_1 = T^0 / [1 + (k - 1) M_1^2 / 2]$$

If  $M_1 = 1$ :

$$T_1 = T^0 / [1 + (k - 1) / 2]$$

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

In either case:

$$P_1 = Z R T_1 / mw \quad v_1$$

where:

$k$  = isentropic expansion coefficient

$M$  = mach number =  $G v / c$

$c$  = sonic velocity =  $(g_c k R T Z / mw)^{1/2}$

$A$  = duct flow area, ft<sup>2</sup>

$m$  = modified mach number

$T$  = temperature, °R

$T^0$  = stagnation temperature, °R (constant throughout an adiabatic system; use upstream vessel temperature)

$R$  = 1544 (ft<sup>3</sup>·lbf / ft<sup>3</sup>) / (lbmol·°R)

$Z$  = compressibility

$mw$  = molecular weight

other parameters as defined above

## TPHEM – SUPPLEMENT FOR ADVANCED USERS

Several latent feature are incorporated into TPHEM, including options to handle Non-Equilibrium and Slip (NES) models for nozzles, a viscous correction option, and additional IPTS options. All IPTS options in Ref. 2 are implemented in TPHEM. They are summarized in the following table.

| DATA |        |                           |
|------|--------|---------------------------|
| IPTS | STATES | MODEL                     |
| -5   | 3      | D <sup>(2)</sup>          |
| -4   | 3      | B <sup>(2)</sup>          |
| -3   | 3      | C <sup>(2)</sup>          |
| -2   | 2      | A <sup>(2)</sup>          |
| -1   | 1      | Omega type <sup>(2)</sup> |
| 1    | 1      | Omega type <sup>(1)</sup> |
| 2    | 2      | E <sup>(2)</sup>          |
| 3    | 3      | F <sup>(2)</sup>          |

### REFERENCES

1. Simpson, L. L., Chem. Eng., pp 98-102, Aug. (1991).
2. Simpson, L. L., Navigating the Two-Phase Maze, "Proc. of International Symposium on Runaway Reactions and Pressure Relief Design," G. A. Melhem and H. G. Fisher eds., AIChE/DIERS, New York (1995).

### FILE INPUT FOR TPHEM.EXE

```

LINE 1
All cases                                CASE DESCRIPTION TEXT

LINE 2
All cases                                IU, IC, IPTS, IV (a)
IF IC = 3 (b)                             INES
    IF INES = 1                           KNE
    ELSE IF INES = 2                       S
    ELSE IF INES = 5                       KS
    ELSE IF INES = 11                     KNE, S
IF IV = 4                                B (c)

LINE 3
IF IC = 1, 3
    IF IV = -1 (d)                          P0, P3, N, DH
    ELSE IF IV = 1                        P0, P3, N
    ELSE IF IV (e) = ±2, 4                    P0, P3, AN, K
    ELSE IF IV = ±3 (f)                    P0, P3, L, D, KF, MF, DH, ES
ELSE IF IC = 2
    IF IV = ±1                            G, P3, N
    ELSE IF IV = ±2, 4                    W, P3, AN, K
    ELSE IF IV = ±3                      W, P3, L, D, KF, MF, DH, ES
ELSE IF IC = 4 (g)
    IF IV = -1                            P0, G, N, DH
    ELSE IF IV = 1                        P0, G, N
    ELSE IF IV = ±3                      P0, W, L, D, KF, MF, DH, ES
ELSE IF IC = 5 (h)
    IF IV = -1                            P1, G, N, DH
    ELSE IF IV = 1                        P1, G, N
    ELSE IF IV = ±3                      P1, W, L, D, KF, MF, DH, ES

LINE 4
IF IV = ±1, -2, -3                      PA, XA, RGA, RLA
ELSE IF IV = 2, 3, 4                    PA, XA, RGA, RLA, ZGA, ZLA

LINE 5
IF IPTS = ±1                            TA, CPLA, HFGA
ELSE IF IPTS = ±2, ±3, -4, -5
    IF IV = ±1, -2, -3                    PB, XB, RGB, RLB
    ELSE IF IV = 2, 3, 4                  PB, XB, RGB, RLB, ZGB, ZLB

LINE 6
IF IPTS = ±3, -4, -5
    IF IV = ±1, -2, -3                    PC, XC, RGC, RLC
    ELSE IF IV = 2, 3, 4                  PC, XC, RGC, RLC, ZGC, ZLC
ELSE                                     BLANK LINE

```

<sup>(a)</sup> Use commas or spaces between adjacent data entries.

<sup>(b)</sup> IPTS must be greater than zero for INES to be active. For INES =

1. Homogeneous Non-Equilibrium model described in Reference 1. The weight fraction vapor  $XNE = XA + KNE (X^2 - XA^2)$ , where  $KNE = 1$  will yield results similar to those from the Henry-Fauske model.

2. Input fixed slip ratio.  $S = 1.5$  works well for safety valves with two-phase entry (not liquid).

3. Slip ratio  $S = (RL / RG)^{1/3}$  (Moody model), where  $RL / RG$  is the local density ratio in the nozzle.

4. Slip ratio  $S = (RL / RG)^{1/4}$  (Chisholm slip), where  $RL / RG$  is the local density ratio in the nozzle.

5. Slip ratio  $S = (1 - X + X * RL / RG)^{KS}$ . For nozzles with two phase entry, KS is expected to be close to 0.25.

11. Combination of INES = 1 and INES = 2; a fixed-slip non-equilibrium model.

<sup>(c)</sup> B is ID of nozzle divided by ID of upstream pipe.

<sup>(d)</sup> TPHEM uses the simple algorithm described in Reference 1.

<sup>(e)</sup> TPHEM uses API viscous correction if  $IV = \pm 2$ , Darby-Molavi when  $IV = 4$ .

<sup>(f)</sup> Use this combination only when  $IC = 1$ .

<sup>(g)</sup> Use this option to calculate irreversible pressure losses from a reservoir into piping.

<sup>(h)</sup> Use this option to calculate pressure drop in piping, given the upstream pressure.