ERRATA
CRANE FLOW OF FLUIDS
THROUGH VALVES, FITTINGS AND PIPE
TECHNICAL PAPER NO. 410
U.S. VERSION

CONTACT

Please address questions and possible errata to solutions@flowoffluids.com

FRONT MATTER	CORRECTION PRINTED
No errata at this time	
TEXT	
PAGE 2-5 Steam Flow Tests - Curves 19 to 31, Key – Curve No. 26 is repeated, the first should be 25	11/2012
PAGE 2-7 "...sum of the inverses of the individual resistance of each component:" should be "...sum of the square roots of the inverse of the individual..."	08/2011
Eq. 2-6 $\frac{1}{K_{Total}} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \cdots \frac{1}{K_n}$ should be $\frac{1}{\sqrt{K_{Total}}} = \frac{1}{\sqrt{K_1}} + \frac{1}{\sqrt{K_2}} + \frac{1}{\sqrt{K_3}} + \cdots \frac{1}{\sqrt{K_n}}$	08/2011
PAGE 2-11 Eq. 2-16 $K_1 = 0.5\left(1 - \frac{d_1^2}{d_2^2}\right)^2$ should be $K_1 = 0.5\left(1 - \frac{d_1^2}{d_2^2}\right)$	10/2010
PAGE 2-13 "...expansion bend up of continuous 90 degree..." should be "...bend made up of..."	10/2010

PAGE 2-15

Column for values of G added to table 2-3: — 10/2010

Table 2-3: Constants for K_{branch} in Equation 2-37			
Angle (α)	G	H	J
0-60°	Table 2-4	1	2
$\alpha = 90° \ at \ \beta_{branch} \leq \frac{2}{3}$	1	1	2
$\alpha = 90° \text{ at } \beta_{branch} = 1$ *	$G = 1 + 0.3\left(\frac{Q_{branch}}{Q_{comb}}\right)^2$	0.3	0

Replace Tables 2-2 and 2-4: — 08/2011

Table 2-2: Values of C for Equation 2-35

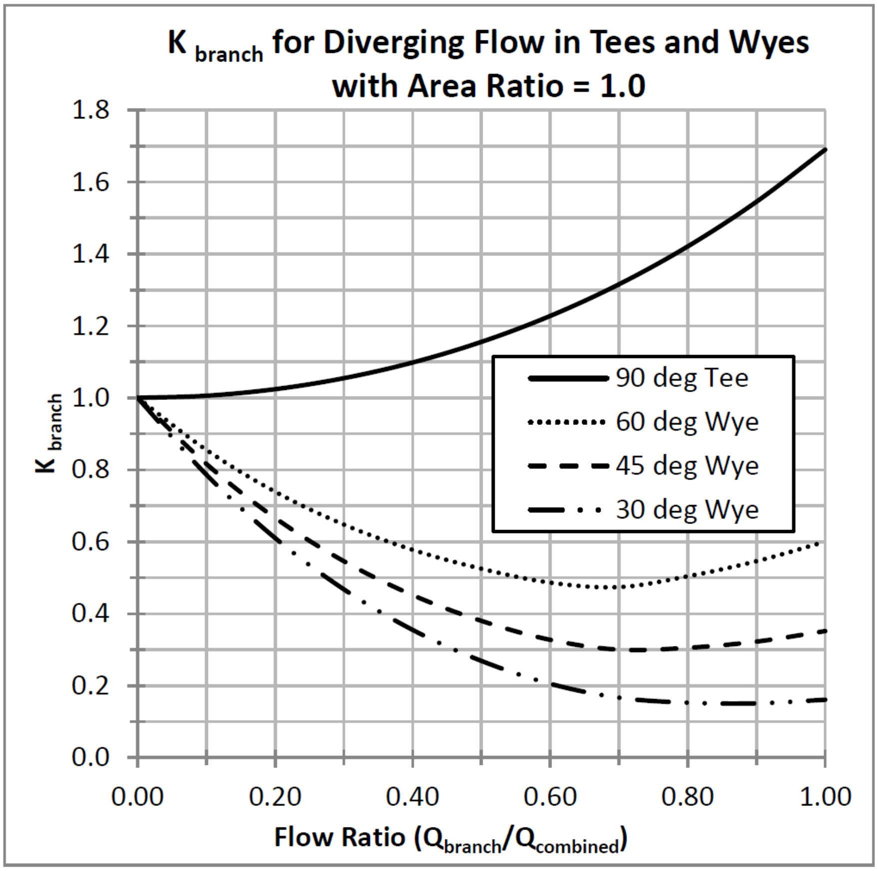
<table>
<tr><td colspan="2"></td><td colspan="2">Q branch / Q comb</td></tr>
<tr><td colspan="2"></td><td>≤ 0.4</td><td>> 0.4</td></tr>
<tr><td rowspan="2">β^2_{branch}</td><td>≤ 0.35</td><td colspan="2">$C = 1$</td></tr>
<tr><td>> 0.35</td><td>$C = 0.9\left(1 - \frac{Q_{branch}}{Q_{comb}}\right)$</td><td>$C = 0.55$</td></tr>
</table>

Table 2-4: Values of G for Equation 2-37 — 08/2011

<table>
<tr><td colspan="2"></td><td colspan="3">Q branch / Q comb</td></tr>
<tr><td colspan="2"></td><td>≤ 0.4</td><td colspan="2">> 0.4</td></tr>
<tr><td rowspan="2">β^2_{branch}</td><td>≤ 0.35</td><td>$G = 1.1 - 0.7\frac{Q_{branch}}{Q_{comb}}$</td><td colspan="2">$G = 0.85$</td></tr>
<tr><td>> 0.35</td><td colspan="2">$G = 1.0 - 0.6\frac{Q_{branch}}{Q_{comb}}$</td><td>$G = 0.6$</td></tr>
<tr><td colspan="2"></td><td colspan="2">≤ 0.6</td><td>> 0.6</td></tr>
<tr><td colspan="2"></td><td colspan="3">Q branch / Q comb</td></tr>
</table>

PAGE 2-16

New Figure 2-16: — 08/2011



PAGE 3-4

Eq. 3-4 should be: $F_P = \frac{1}{\sqrt{1+\frac{\sum K}{890}\left(\frac{C_V}{d_{nom,v}^2}\right)^2}}$ — 11/2012

The definition should be: $K_{B1} = 1 - \left(\frac{d_{nom,v}}{d_{nom1}}\right)^4$ — 11/2012

The definition should be: $K_{B2} = 1 - \left(\frac{d_{nom,v}}{d_{nom2}}\right)^4$ — 11/2012

The definition should be: "$d_{nom,v}$ = nominal valve size (in)" — 11/2012

The definition should be: "d_{nom} = nominal pipe size (in) (1=upstream, 2=downstream)" — 11/2012

Eq. 3-5 should be: $K_{reducer}^{inlet} = 0.5\left[1 - \left(\frac{d_{nom,v}}{d_{nom1}}\right)^2\right]^2$ — 11/2012

Eq. 3-6 should be: $K_{reducer}^{outlet} = 1.0\left[1 - \left(\frac{d_{nom,v}}{d_{nom2}}\right)^2\right]^2$ — 11/2012

Eq. 3-7 should be: $\sum K = 1.5\left[1 - \left(\frac{d_{nom,v}}{d_{nom}}\right)^2\right]^2$ — 11/2012

Updates to Errata available online at: http://www.flowoffluids.com/publications/crane-tp-410/errata.aspx

Eq. 3-10 should be: $F_{LP} = \frac{F_L}{\sqrt{1+F_L^2\frac{\sum K_i}{890}\left(\frac{C_V}{d_{nom,v}^2}\right)^2}}$	11/2012
	11/2012
Footnote added: "*For use only with control valves per ANSI/ISA 75.01.01, for reducers in pipelines see page 2-11"	
	10/2010
PAGE 3-5	
Eq. 3-13 Definition of x should read: "x = pressure drop ratio = $\Delta P/P'_1$"	04/2010
Eq. 3-14 should be $x_{TP} = \frac{x_T/F_P^2}{1+x_T\frac{\sum K_i}{1000}\left(\frac{C_V}{d_{nom,v}^2}\right)^2}$	11/2012
The definition should be: "$d_{nom,v}$ = assumed nominal valve size (in)" "$\sum K_i = K_1 + K_{B1}$"	11/2012
PAGE 4-5	
Eq. 4-7b $J = \frac{19000\beta}{Re}$ should read: $J = \left(\frac{19000\beta}{Re}\right)^{0.8}$	08/2011
PAGE 4-6	
"The data is also plotted on page A-21 of this reference" should be "…page A-22"	04/2010
"Equation 4-16 may be used for orifices…" should be "…Equation 4-14 may…"	04/2010
The paragraph beginning "The expansibility factor has been experimentally determined…" should have the following added at the end: "For the purposes of accurate metering, the expansibility factor equations should be limited to conditions when the pressure ratio is greater than 0.80 ($P'_2/P'_1 \geq 0.80$) per the ASME standard. There are some critical flow applications discussed in the next section where stringent metering accuracy is not a requirement, and therefore the charts on page A-22 reflect a greater range of pressure ratios."	08/2011
The paragraph beginning "The critical pressure ratio is the largest ratio…" shall be rewritten as follows: "The critical pressure ratio r_c is the largest ratio of downstream pressure to upstream pressure capable of producing sonic velocity. Values of critical pressure ratio which are a function of the ratio of nozzle diameter to upstream diameter as well as the specific heat ratio γ are plotted on page A-22, and are derived from the following relationship[46]:"	08/2011
Add Eq. 4-17: $r_c^{\frac{1-k}{k}} + \left(\frac{k-1}{2}\right)\beta^4 r_c^{\frac{2}{k}} = \frac{k+1}{2}$	08/2011

The paragraph beginning "Flow through nozzles and venturi meters…" shall be rewritten as follows: "Flow through nozzles and venturi meters is limited by the critical pressure ratio. Other applications which require the determination of a mass flow rate under critical conditions include equipment ruptures and pressure relief valves. In these cases, the stringent accuracy of metering applications is not required, and therefore the expansibility factors can be taken at pressure ratios below 0.80. Minimum values of Y to be used in Equation 4-14 for this condition, are indicated on the plots on page A-22 by the termination of the curves at $P'_2/P'_1 = r_c$."	11/2012
PAGE 6-2 Viscosity Conversion should be $\nu = \frac{\mu}{\rho\prime} = \frac{\mu}{S_{4°C}} = \frac{62.428\mu}{\rho}$	08/2011
PAGE 6-4 Eq. 6-23 $P = S\left(\frac{Q}{C_V}\right)^2$ should be $\Delta P = S\left(\frac{Q}{C_V}\right)^2$ $C_V = Q\sqrt{\frac{S}{\Delta P}} = 1.266\,Q\sqrt{\frac{\rho}{\Delta P}}$ … should be $C_V = Q\sqrt{\frac{S}{\Delta P}} = 0.1266\,Q\sqrt{\frac{\rho}{\Delta P}}$ …	08/2011 08/2011
PAGE 6-5 Eq. 6-25 $\frac{1}{K_{Total}} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \cdots \frac{1}{K_n}$ should be $\frac{1}{\sqrt{K_{Total}}} = \frac{1}{\sqrt{K_1}} + \frac{1}{\sqrt{K_2}} + \frac{1}{\sqrt{K_3}} + \cdots \frac{1}{\sqrt{K_n}}$	08/2011
PAGE 6-6 Eq. 6-34 should be: $F_P = \frac{1}{\sqrt{1+\frac{\sum K}{890}\left(\frac{C_V}{d^2_{nom,v}}\right)^2}}$ $K_B = 1 - \left(\frac{d_{nom,v}}{d_{nom}}\right)^4$ Eq. 6-35 should be: $K^{inlet}_{reducer} = 0.5\left[1 - \left(\frac{d_{nom,v}}{d_{nom1}}\right)^2\right]^2$ $K^{outlet}_{reducer} = 1.0\left[1 - \left(\frac{d_{nom,v}}{d_{nom2}}\right)^2\right]^2$ Eq. 6-36 should be: $\sum K = 1.5\left[1 - \left(\frac{d_{nom,v}}{d_{nom}}\right)^2\right]^2$ Eq. 6-37 should be: $F_{LP} = \frac{F_L}{\sqrt{1+F_L^2\frac{\sum K_i}{890}\left(\frac{C_V}{d^2_{nom,v}}\right)^2}}$ Eq. 6-38 should be: $x_{TP} = \frac{x_T/F_P^2}{1+x_T\frac{\sum K_i}{1000}\left(\frac{C_V}{d^2_{nom,v}}\right)^2}$	11/2012 11/2012 11/2012 11/2012 11/2012 11/2012 11/2012

PAGE 7-2	
Ex. 7-2 3. "d^4=1352.8" should be "d^4=1353.1"	11/2012
4. should be $K = \frac{890.3 \times 1353.1}{600^2} = 3.35$	
Ex. 7-3 3. "$f_{T=0.016}$" should be "f_T = 0.0165 page A-26"	10/2010
4. should read k = 150 x 0.0165 = 2.475	
5. In the denominator 2.40 should be 2.475 The result 282.0 should be 277.7	
6. L/D = 2.475/0.0165 = 150	
7. Remove text "for graphical solution of step 5 through 7, use pages A-31&A-32"	
Ex. 7-4 3. "f_T = 0.015" should reference A-26 rather than A-27	10/2010
PAGE 7-3	
Ex. 7-6 "200 feet – 3" Schedule go pipe" should be "...Schedule 40..."	10/2010
PAGE 7-4	
Ex. 7-8 "S.A.E. 50 Oil..." should be "S.A.E. 30 Oil..."	11/2012
2. Should read: $S = 0.887\ at\ 60°F$	
$S = 0.87\ at\ 100°F$	11/2012
$\mu = 130$	
3. Should read: $\rho = 62.364 \times 0.87 = 54.26$	11/2012
$Re = 50.66 \frac{420 \times 54.26}{7.981 \times 130} = 1112.7$	
4. Should read: $f = \frac{64}{1112.7} = 0.058$	11/2012
$K = \frac{0.058 \times 200 \times 12}{7.981} = 17.44$	
$K = 4.76 + 17.44 = 22.2$	
5. Should read: $\Delta P = 1.801 \times 10^{-5} \frac{22.2 \times 54.26 \times 420^2}{7.981^4}$	11/2012
$\Delta P = 0.943$	
PAGE 7-5	
Ex. 7-9 "S.A.E. 50 Oil..." should be "S.A.E. 30 Oil..."	11/2012
"...600 gallons per minute..." should be "...400 gallons per minute"	
3. Should read: $S = 0.887\ at\ 60°F$	11/2012
$S = 0.87\ at\ 100°F$	
$\mu = 130$	
$\rho = 62.364 \times 0.87 = 54.26$	
4. Should read: $Re = 50.66 \frac{400 \times 54.26}{5.047 \times 130} = 1675.8$	11/2012
5. Should read: $f = \frac{64}{1675.8} = 0.038$	11/2012
6. Should read: $K = 0.015\ (8 + 150 + 20) + \frac{0.038 \times 300 \times 12}{5.047} = 29.77$	11/2012
7. Should read: $v = 0.4085 \frac{400}{5.047^2} = 6.41$	11/2012
8. Should read: $\Delta P = 1.801 \times 10^{-5} \frac{29.77 \times 54.26 \times 400^2}{5.047^4} + \frac{50 \times 54.26}{144}$	
$\Delta P = 26.01$	11/2012

Page 7-6 Ex. 7-10 "…6" Schedule 8o pipe…" should be "…Schedule 80…"	10/2010
"…as described in Example 6-4…" should be "…Example 7-4…"	10/2010
4. "$\bar{V} = 1.430$" should be "$\bar{V} = 1.217$" "f_T = 0.015" should reference A-26 rather than A-27	08/2011 10/2010
8. should be: $\Delta P = \frac{2.799\times10^{-7}\times16\times9^2\times10^8\times1.217}{5.761^4}$	08/2011
$\Delta P = 40.1$	08/2011
Ex. 7-11 3. Should be "f=0.024" … "pipe;page A-26" … 18" straight pipe should be "18ft straight pipe"	11/2012 11/2012
Page 7-7 Ex. 7-12 10. "∴ use β = 0.68" should be "∴ use β = 0.665"	04/2010
11. "Orifice size ≌ 11.938 x 0.68 = 8.1" should be "…x 0.665 = 7.94"	04/2010
Page 7-8 Ex. 7-14 5. "f_T=0.018" should be "f=0.018"	11/2012
Page 7-9 Ex. 7-15 5. "…page A-26" should be "…page A-27" 6. Should be: $v = 0.4085\frac{100}{3.068^2} = 4.34$ f=0.021….page A-26	11/2012
Page 7-14 Ex. 7-21 7. Should read: $\Delta P = 0.657 \times P_1' = 0.657 \times 139.7 = 91.8$	08/2011
Page 7-17 Ex. 7-26 23. "f = 0.0155" should reference page A-25 rather than A-24	10/2010
Page 7-18 Ex. 7-27 5. should be: $\sum K = 1.5\left[1-\left(\frac{d_{nom,v}}{d_{nom}}\right)^2\right]^2 = 1.5\left[1-\left(\frac{3}{4}\right)^2\right]^2 = 0.287$ $F_P = \frac{1}{\sqrt{1+\frac{\sum K}{890}\left(\frac{C_V}{d_{nom,v}^2}\right)^2}} = \frac{1}{\sqrt{1+\frac{0.287}{890}\left(\frac{114}{3^2}\right)^2}} = 0.975$	11/2012

...effective Cv of (114)(0.975)=111	
6. should be: $F_P = \frac{1}{\sqrt{1+\frac{0.287}{890}\left(\frac{78.98}{3^2}\right)^2}} = 0.988$	11/2012
7. should be: $C_V = \frac{Q}{F_P\sqrt{\frac{P'_1-P'_2}{S}}} = \frac{250}{0.988\sqrt{\frac{80.6-70.8}{0.978}}} = 79.94$	11/2012
8. "will be throttled to a C_v = 89.6" should be "C_v =79.94"	11/2012
PAGE 7-19 Ex. 7-28 2. Should be: $\sum K_i = 0.5\left[1-\left(\frac{d_{nom,v}}{d_{nom1}}\right)^2\right]^2 + \left[1-\left(\frac{d_{nom,v}}{d_{nom1}}\right)^4\right]$ $\sum K_i = 0.5\left[1-\left(\frac{3}{4}\right)^2\right]^2 + \left[1-\left(\frac{3}{4}\right)^4\right]$ $\sum K_i = 0.0957 + 0.6836 = 0.7793$	11/2012
3. Should be: $F_{LP} = \frac{F_L}{\sqrt{1+F_L^2\frac{\sum K_i}{890}\left(\frac{C_V}{d^2_{nom,v}}\right)^2}}$ $F_{LP} = \frac{0.9}{\sqrt{1+0.9^2\frac{0.7793}{890}\left(\frac{79.94}{3^2}\right)^2}} = 0.8758$	11/2012
4. Should be: $Q_{max} = \left(\frac{0.8758}{0.988}\right)(79.94)\sqrt{\frac{80.6-(0.9492\times4.75)}{0.978}}$ $Q_{max} = 625\ gpm$	11/2012
5. should be: $\Delta P_{max} = \left(\frac{0.8758}{0.988}\right)[80.6-(0.9492\times4.75)]$ $\Delta P_{max} = 59.8\ psi$	11/2012
APPENDICES	
PAGE A-18 Total Temp headings: 350, 400, 500, 600, 700, 800, 900, 1000, 1100, 1300, 1500 Should be: 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500	04/2010
PAGE A-19 Total Temp headings: 350, 400, 500, 600, 700, 800, 900, 1000, 1100, 1300, 1500 Should be: 650, 700, 750, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500	04/2010

PAGE A-21

Flow Coefficient C for Venturi Nozzles :

Should be: "...equations presented in ASME MFC-3Ma-2007"

11/2012

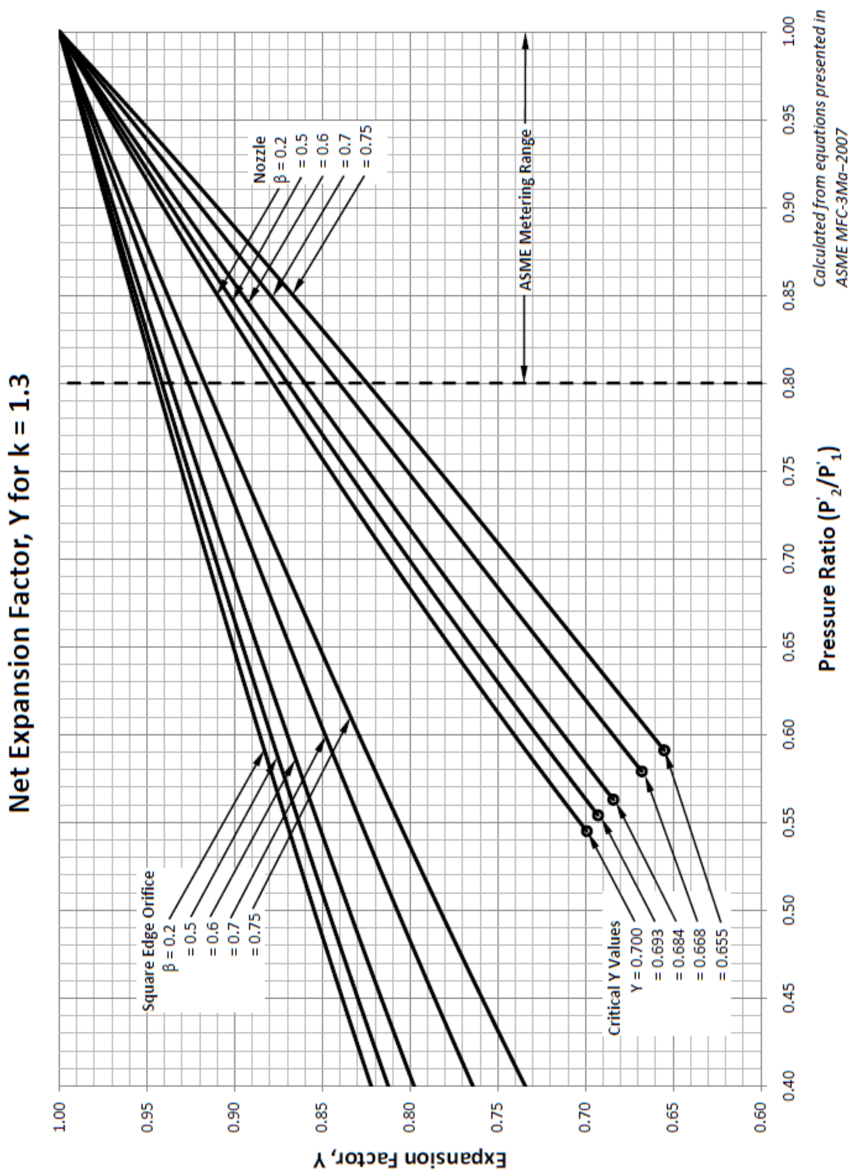
PAGE A-22

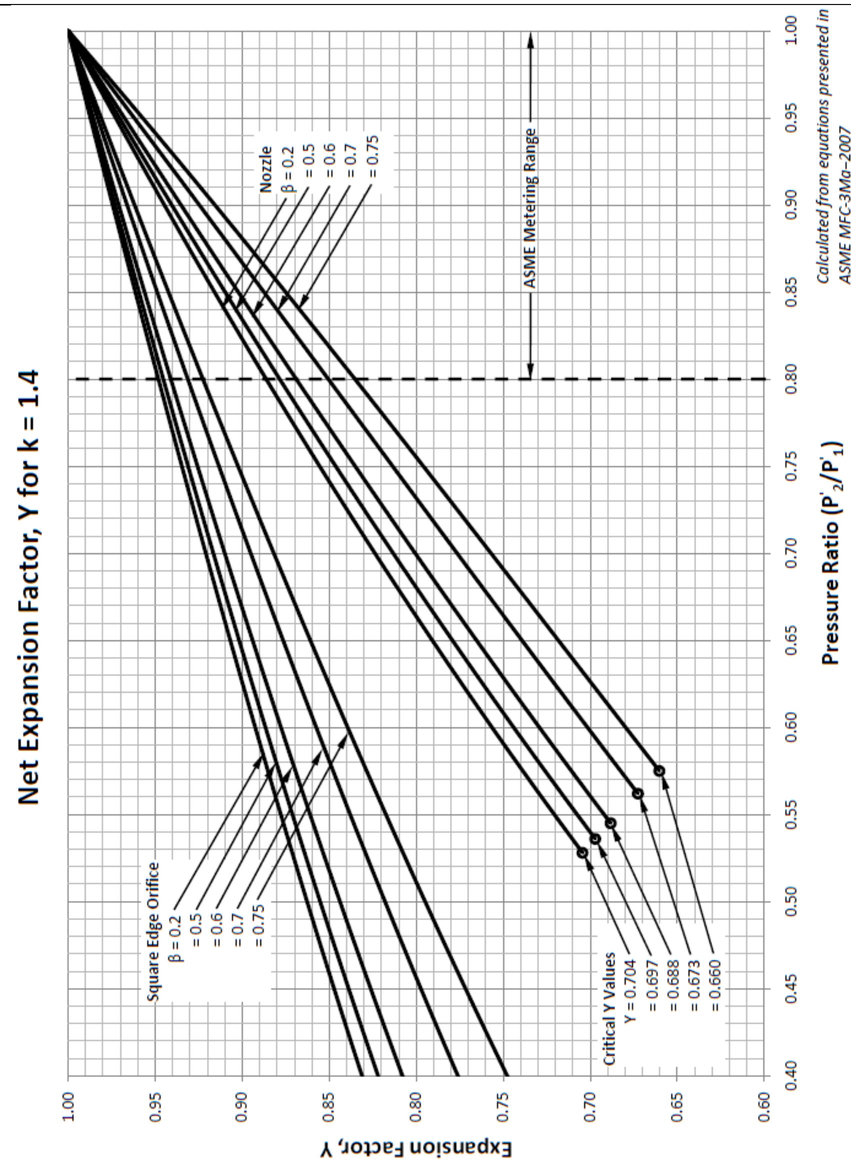
Page title should cite reference 27 and also 46

04/2010

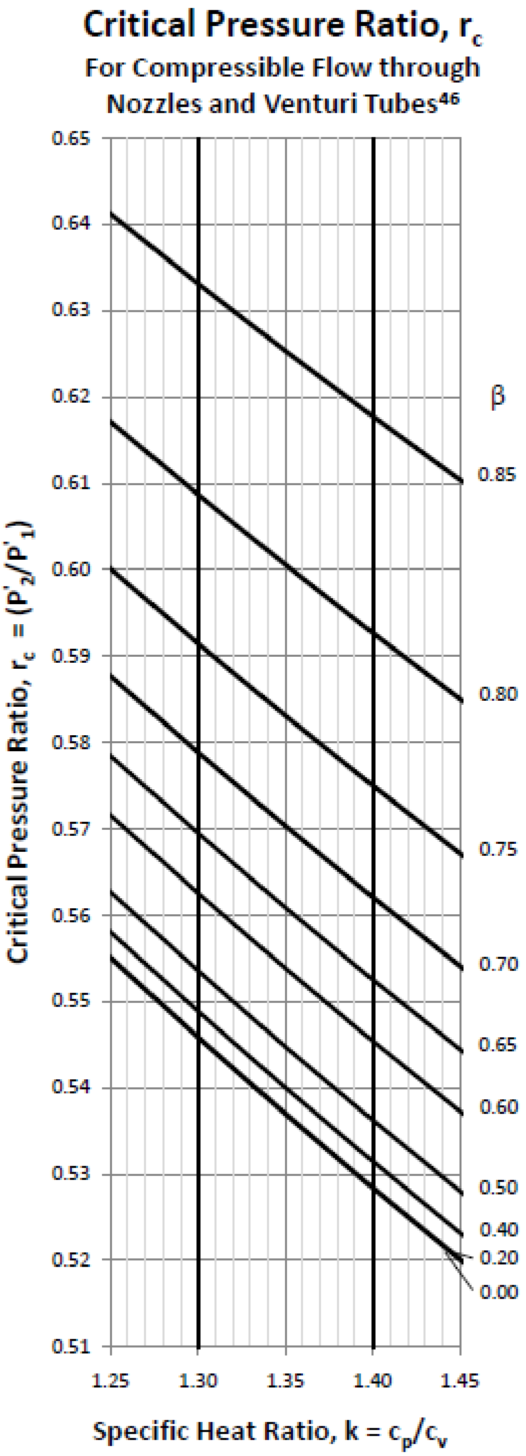
Graphs should change to the following:

10/2010




Net Expansion Factor, Y for k = 1.4
Calculated from equations presented in ASME MFC-3Ma–2007
Nozzle
β = 0.2
= 0.5
= 0.6
= 0.7
= 0.75
ASME Metering Range
Square Edge Orifice
β = 0.2
= 0.5
= 0.6
= 0.7
= 0.75
Critical Y Values
Y = 0.704
= 0.697
= 0.688
= 0.673
= 0.660
Pressure Ratio (P'2/P'1)
Expansion Factor, Y

10/2010

<table>
<tr><td>


</td><td>8/2011</td></tr>
<tr><td>PAGE A-24
Y axis label should read: “f_T – For Complete Turbulence, Rough Pipes</td><td>11/2012</td></tr>
<tr><td>PAGE A-30
Under STANDARD TEES AND WYES delete “For Converging or Diverging Flow:”</td><td>10/2010</td></tr>
<tr><td></td><td></td></tr>
</table>

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