ATTACHMENT B

Calculation DRE-96-0252
"Unit 3 Backup Nitrogen Inerting Flow"

DE&S Duke Engineering & Services	**CALCULATION PACKAGE**	FILE NO: VD0801.F02 PROJECT NO: VD0801 CALC. NO: DRE96-0252

PROJECT NAME: Dresden NRC ISI Support	**CLIENT:** Commonwealth Edison Co.

CALCULATION TITLE

Unit 3 Backup Nitrogen Inerting Flow

PROBLEM STATEMENT OR OBJECTIVE OF CALCULATION

The objective of this calculation is to calculate the flow through the backup nitrogen inerting line for Dresden unit 3 using valve characteristic information from for PCV 8527.

NUCLEAR SAFETY-RELATED

System Code: 2500

DOCUMENT REVISION	AFFECTED PAGES	REVISION DESCRIPTION	PROJECT ENGINEER APPROVAL/DATE	NAMES AND INITIALS OF PREPARERS AND CHECKERS
0	1-13 Attachments: A1-A2 B1-B4 C1-C3 D1-D4	Initial Issue	13Dec96	PREPARER / DATE Stephen C. Huddleston 12/13/96 CHECKER / DATE Ray Rosten 12/13/96

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CLIENT Dresden Nuclear Station
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1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to evaluate the flow rates through the backup nitrogen inerting line for Dresden unit 3 using valve characteristic information from Fisher for PCV 8527 and system line and fitting losses from Reference 5.1.

2.0 METHODOLOGY/ACCEPTANCE CRITERIA

2.1 Background

Reference 5.1 and 5.2 determined flow rates through the backup nitrogen inerting line for Dresden and Quad Cities units. A single conservative "generic" configuration was analyzed for all units. Recent modifications have replaced these lines except for Dresden unit 3.

Reference 5.1 determined that the largest line loss was across PCV 8527. The following information was provided by the station based on field inspection of the unit 3 PCV valve body: [5.3]

Serial no. :	4603950
Type:	512RB
Size:	1/2" Trim 316
Plug Type:	1/4 SPM-Flute (3 flute)
Travel:	3/4" Guide - Top
PSI:	3 to 15
Order No. :	3447-215

This information was matched to Fisher supply records to obtain flow characteristic coefficients. The coefficients are as follows for the triple flute design: [5.4]

C_g = 33.6 (100% open)

C_1 = 31.4 (100% open)

2.2 Analysis Method

2.2.1 Introduction

This analysis will use the flow coefficients (above) for a 100% open PCV 8527 and the remaining line loss coefficients from Reference 5.1 to calculate the flow between the nitrogen supply point at 125 psig and the drywell at 31 psig.

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Flow is calculated for the PCV for a given pressure potential. Using an iterative process explained Section 2.2.5, conditions in the upstream (see Section A, fig. 1)and downstream (see Section B, fig. 1) line are calculated until a match is obtained for flow and pressure drop between the system and the valve.

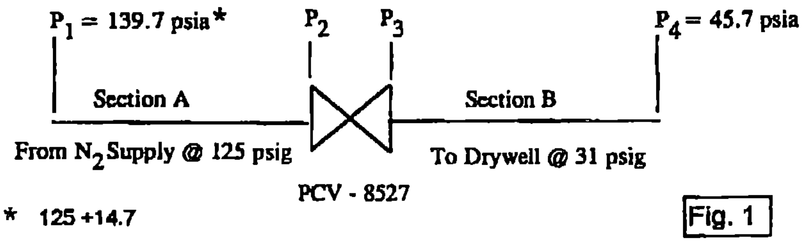

Fig. 1

2.2.2 PCV Flow (Q)

$$Q = \sqrt{\frac{520}{GT}}\, C_g P_2\, SIN\left[\frac{59.64}{C_1}\sqrt{\frac{\Delta P}{P_2}}\right]_{RAD} \qquad \text{Eq. 1}$$

[5.5,p.71]

Q = gas flow, scfh
G = N_2 specific gravity = .967 [5.6,pA-8]
T = gas temperature, ^{o}R
C_g = gas coefficient
C_1 = gas/liquid sizing coefficient ratio
ΔP = pressure drop across valve (P_2 - P_3), psi
P_2 = valve inlet pressure, psia

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2.2.3 Line Section Calculations

The line is subdivided into subsections. Each subsection is tested for density change. For small density changes (<10%) the flow can be treated as incompressible. Mass flow for incompressible flow, W is given by: [5.6,p1-7]

$$W = 1891\, d^2 \sqrt{\frac{dP\rho}{K}} \qquad \text{Eq. 2}$$ [5.6,p3-4]

W = flow, lbm/hr
d = line diameter, 1.5 in (1-1/2" sh.80) [5.1,p5]
dP = inlet pressure minus outlet pressure, psi
K = resistance loss coefficient
ρ = fluid density, lbm/ft^3, given by:

ρ = average subsection density from inlet and outlet = $(\rho_i + \rho_o)/2$

$$\rho_i = P_i' M/(1545 \times T) \qquad \text{Eq. 3}$$ [5.6,p3-5]

M = N_2 Molecular weight = 28
$P_i' = P_i \times 144$ lbf/ft^2

2.2.4 Section Loss coefficients

Loss coefficients for each section are taken from Reference 5.1 as follows:

The total loss from Reference 5.1 is K_t:

$K_t = (K_{up} + K_v + K_{dn}) + K_L$

K_{up} = total fittings loss coefficients upstream of the PCV valve

K_{dn} = total fittings loss coefficients downstream of the PCV valve

K_L = Line loss

K_v = PCV valve loss

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From above:

K_A = Section A loss coefficient = $K_{up} + (K_L/2)$ Eq. 4

K_B = Section B loss coefficient = $K_{dn} + (K_L/2)$ Eq. 5

Sub section loss coefficient for a given differential pressure is found after rearranging equation 2:

$$K = (1891\, d^2)^2 \left[\frac{dP\, \rho}{W^2}\right] \qquad \text{Eq. 6}$$

2.2.5 Iteration process

An iterative process is required since the PCV upstream (P_2) and downstream pressure (P_3) is not known. These pressures are affected by the remaining line losses. The iteration is completed when the flow in each section and the PCV are equal and the total pressure drop across the valve and line sections is equal to the total pressure drop of 125 psig minus 31 psig.

Iteration steps:

1. Select P_2 (use 125 psig as first guess)
2. Select P_3 (use 31 psig as first guess)
3. Calculate flow rate from the Fisher equation
4. Input flow from step 3 into the spreadsheet for Section A
5. Try selected trial input pressure drops (dP) across subsections of Section A until the calculated total K of the subsections equals K_A of the section
6. Repeat step's 3 through 5 for Section B
7. Repeat step's 1 through 6 using new P_2 and P_3 obtained from step 5 and 6 until calculated flow between iteration trials (1- 6) remains unchanged

2.2.6 Miscellaneous Equations used:

Line area, A:

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$$A = pi * (d/(2*12))^2 \ \mathrm{ft}^2 \qquad \text{Eq. 7}$$

Volumetric Flow Rate, scfm:

$$q = Q/60 \ \text{scfm} \qquad \text{Eq. 8}$$

Line velocity, v:

$$v = W / (roave*A*3600) \ \text{ft/sec} \qquad \text{Eq. 9}$$

roave = average line subsection density

Sonic velocity for section, c:

$$c = [k*g*R*T]^{1/2} \ \text{ft/sec} \qquad \text{Eq. 10}$$ [5.6,p3-3]

$k = 1.4$
$g = 32.2$
$R = 1545/M$

Mass Flow Rate, W:

$$W = .0727*q*60 \ \text{lbm/hr} \qquad \text{Eq. 11}$$

(standard density = .0727 $\mathrm{lbm/ft^3}$) [5.2,p2]

2.2.7 Acceptance Criteria

Nitrogen backup inerting flow equal to or greater than the flows of Reference 5.1 and 5.2. Those flows are 65 scfm at a drywell pressure of 0.1 psig and 51 scfm at 31 psig. These flow rates are greater than 32 scfm required by Reg. Guide 1.7 . [5.2,p3] [5.8]

3.0 ASSUMPTIONS

3.1 Isothermal process at 135 ^{o}F (595 ^{0}R). Flow through the pipe sections with small density change is near isothermal. Maintaining a constant temperature to the inlet of the PCV is conservative as a lower temperature (due to expansion) will result in a higher calculated flow through the valve (see Equation 1 above).

[5.8]

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3.2 Drywell pressure at 31 psig. This is half the design pressure (62 psig) per Reg. Guide 1.7.

4.0 DESIGN INPUT

PARAMETERS	VALUE	REFERENCE
Nitrogen Supply from PRV3-8599-625	125 psig	[5.7]

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5.0 REFERENCES

5.1 DE&S (ABB Impell) Calc. No. 0591-479-001, Rev. 0

5.2 DE&S (ABB Impell) Calc. No. 0591-479-05, Rev. 0

5.3 FAX, 12-04-96, PCV 8527 Field Inspection Info. (Attachment A)

5.4 FAX, 12-05-96, General Meters & Controls (Fisher rep.) Valve Info. (Attachment B)

5.5 Control Valve Handbook, 2nd edition, 1977, Fisher Controls (Attachment C)

5.6 Crane Technical Paper No. 410, 1981

5.7 P&ID No. M - 356, Rev. BE

5.8 Reg. Guide 1.7

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6.0 CALCULATION

6.1 Line Loss Coefficients

$K_{up} = .127 + 5.38 + .127 + 1.58 + 1.58 + .127 + 5.38 + .127 + .127 + 10.76 + 11.39$ [5.1,p10]

$K_{up} = 36.705$

$K_{dn} := 14.58 + 76.9 + 106.7$ [5.1,p10]

$K_{dn} = 198.18$

$K_L := 4 \cdot 42$ [5.1,p12]

$K_L = 168$

$$K_A := K_{up} + \frac{K_L}{2}$$

$K_A = 120.705$

$$K_B = K_{dn} + \frac{K_L}{2}$$

$K_B = 282.18$

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6.2 System Flow

6.2.1 Fisher Control Valve Equation:

$P_2 := 138.5756$ psia
$P_3 := 53.104$ psia
$P := P_2$
$dP := P_2 - P_3$
$\mathbf{dP = 85.472}$ psid
$T = 595$ ^{0}R
$c_g := 33.6$
$c_1 := 31.4$
$G = .967$

$$Q = \sqrt{\frac{520}{G \cdot T}} \cdot c_g \cdot P \cdot \sin\left(\frac{59.64}{c_1} \cdot \sqrt{\frac{dP}{P}}\right)$$

$\mathbf{Q = 4.413\,10^{3}}$ scfh

$$q = \frac{Q}{60}$$

$\mathbf{q = 73.543}$ scfm

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7.0 SUMMARY & CONCLUSIONS

7.1 Results:

7.1.1 The flow determined for the Dresden Unit 3 backup nitrogen inerting line, accounting for the characteristics of a 100% open PCV 8527 is **73.5 scfm** for an upstream pressure of 125 psig and a drywell pressure of 31 psig.

7.1.2 Choked flow in the PCV is given by:

$$Q_{critical} = C_g P (520/GT)^{1/2} = 33.6*138.5756*(520/(.967*595))^{1/2}$$ [5.5,p70]

$$Q_{critical} = 4426.5 \text{ scfh} = 73.8 \text{ scfm}$$

Therefore the flow will be choked and a lower drywell pressure (< 31 psig) will not increase the flow.

7.2 Conclusion:

The backup nitrogen inerting flow is found to be greater than the 65 scfm determined in reference 5.1 and 5.2 (which is greater than the requirments of Reg. Guide 1.7), therefore the results of those calculations remain conservative.

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ATTACHMENT A

Field Inspection Information

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FISHER CONTROLS

N2 FILL VALVE
NAME PLATE

SERIAL # 4603950 ← THIS # ALSO STAMPED
TYPE 512 RB
SIZE ½" TRIM 316
PLUG TYPE 1/4 SPM-FLUTE (3 FLUTE)
TRAVEL 3/4" GUIDE-TOP
P.S.I. 3 TO 15
ORDER # 3447-215

TO: STEVE HUDDLESTON
FROM: R GOBBETT

CALC. NO. DRE96-0252
A-2 OF 2

[redacted]

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ATTACHMENT B

Fisher Valve Information

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Fax Message

Total pages: 3 Date: 12-5-96

Steve Huddleston

From: Carl Munger

Company Duke

General Meters & Controls Co.
Elk Grove Village, Illinois
847-956-8020
Fax: 847-956-9870

Fax No. 630-778-4343

Ref: 5N 4603950

Message:

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SUPERMARK

3447-215 16-32363 / 4603950

GENERAL ELECTRIC COMPANY
P.O. BOX 425
MORRIS, ILLINOIS 60450
ATTN: MR. [illegible]

SHIP TO: [illegible] UNITED [illegible] & CONSTRUCTORS, INC. DRESDEN NUCLEAR POWER STATION UNITS 2 & 3 MORRIS, ILLINOIS

FEB 14 1969

REM 4/7

BY [illegible] BILL

3447-215

QUANTITY 2 | 1

S 1 512R-3 1/2 DCU

BODY STYLE
NO. 522 X 25
GLOBE X ANGLE ☐

BODY END CONNECTIONS
SCREWED X

BODY MATERIAL 160
CARBON STEEL X
CAST IRON
NO. OF PORTS
1 2 3 WAY

TRIM MATERIAL
DWG. & NO. AN 7304 #2
316 ST. ST. & BRO. L.

RING & VALVE
PORT SIZE 1/4"
RING SIZE
DWG.
VALVE SIZE 1720
DWG. [illegible]

STEM
SIZE 3/8" NO.
MATERIAL 316 S.S.
[illegible] Welded

VALVE PLUG
THROTTLE
NO. OF FLUTES X
CONN. [illegible] RING

VALVE PLUG GUIDING
TOP & BOTTOM
TOP X
[illegible] TO CLOSE X
OPEN
[illegible] TO CLOSE
OPEN X
Heavy Duty Spec
ETO
X

STUFFING BOX PACKING
TFE X
[illegible] X
Plugged X

ACTUATOR
NO. 733X1 SIZE
DIAPH. MAT'L
SPR. RNG.
TRAVEL 3/8" [illegible] X
AIR FAILURE: VVE. OPENS ☐
VVE. CLOSES X

HANDJACK
NO.
TOP ☐ [illegible] ☐
SIDE MOUNTED ☐

POSITIONER
NO.
3582 ☐ ☐
BYPASS ☐ GAUGES ☐
DIRECT ☐ REVERSE ☐
SPG. [illegible]
AIR TO BELLOWS
MFG. NO.
CONTR. BY 546
SERIAL NO. 4603952

ACCESSORIES YOKE MTD
AIR SET OR [illegible]
[illegible] YOKE NIPPLE
[illegible] ☐ ☐
[illegible] ☐ ☐

SERVICE

AIR TO SIGNAL 3-15#

SPECIAL CONSTRUCTION AND/OR EXTRAS 512RQ.
[illegible] -9

	BODY	
	[illegible]	
	VALVE PLUG	
	BONNET	6
	BOTTOM FLG.	
D	TOP WORK	7/3
	HANDJACK	
	[illegible]	
	POSITIONER	
	PILOT	
	FLOAT CAGE	
	FLOAT	
	FLOAT ROD	
D	[illegible]	7/3
	REGULATOR	
	[illegible]	
	[illegible]	

CALL. NO. DR96-0152
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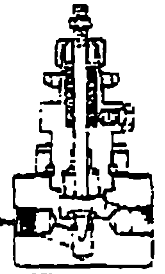
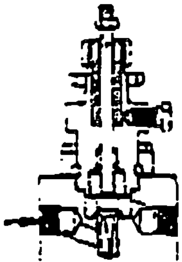
Design B

Micro-Form™ and Micro-Flute™ Valve Plugs

Flow Up


Micro-Form


Micro-Flute

Flow Coefficients

For additional information, see Bulletin 51.1:B

Micro-Form™ — Equal Percentage Characteristic

Coefficients	Valve Size, Inches	Port Diameter, Inches	Maximum Travel, Inches	Valve Opening—Percent of Total Travel										K_m(1) and C_1
				10	20	30	40	50	60	70	80	90	100	
C_v (Liquid)	1/2	1/4	3/4	.036	.070	.12	.19	.28	.41	.58	.80	1.1	1.4	.75
		3/8	3/4	.10	.19	.30	.43	61	.85	1.2	1.6	2.1	2.5	.60
	3/4(2)	3/8	3/4	.13	.22	.33	.48	.67	.94	1.3	1.8	2.5	3.0	.70
		1/2	3/4	.18	.32	.51	.75	1 1	1.5	2.1	3.0	3.7	4.0	.80
	1(2)	1/2	3/4	.17	.31	.50	74	1.1	1.5	2.1	2.9	3.9	4.7	.85
		3/4	3/4	.41	.56	.95	1.3	2.1	3.0	4.3	5.6	7.0	7.4	.60
C_g (Gas)	1/2	1/4	3/4	1.4	2.5	4 0	6.1	8.9	13	19	27	37	48	34.3
		3/8	3/4	3.8	6.8	9.3	13	19	27	37	53	72	87	34.8
	3/4	3/8	3/4	4.6	7.3	11	15	21	30	41	58	82	100	33.3
		1/2	3/4	6.2	11	18	23	33	48	67	93	120	140	35.0
	1	1/2	3/4	5.9	10	15	22	31	45	65	92	130	170	38.2
		3/4	3/4	13	20	30	44	65	95	140	190	240	280	38.1

Micro-Flute™ — Equal Percentage Characteristic

Coefficients	Valve Size, Inches	Port Diameter, Inches	Maximum Travel, Inches	10	20	30	40	50	60	70	80	90	100	K_m(1) and C_1
C_v (Liquid)	All Sizes	1/4 1 Flute	3/4	.0385	.0455	.0560	.0719	.0942	.124	.162	.212	.278	.364	.75
	1/2 - 1	1/4 3 Flutes	3/4	.0526	.0725	.101	.148	.216	.312	.433	.588	.802	1.07	.81
C_g (Gas)	All Sizes	1/4 1 Flute	3/4	1.35	1.55	1.85	2.31	3.00	3.93	5.14	6.71	8.79	11.4	32.2
	1/2 - 1	1/4 3 Flutes	3/4	1.74	2.32	3.21	4.59	6.65	9.50	13.3	18.3	25.1	33.6	31.4

1. This column lists the K_m values for the C_v coefficients and the C_1 values for the C_g and C_s coefficients at 100% travel.
2. For smaller ports in 3/4 and 1 inch valves, use coefficients applying to port diameter desired.

Note: $C_s = 1/20\ (C_g)$. C_s is applicable for inlet pressures of 1000 psig and less.

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Catalog 10

May 1995

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ATTACHMENT C

Fisher Handbook Pages

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gas. The resulting equation can be written:

$$Q_{scfh} = 59.64\, C_v P_1 \sqrt{\frac{\Delta P}{P_1}} \sqrt{\frac{520}{GT}} \quad (A)$$

The equation shown above, while valid at very low pressure drop ratios, has been found to be very misleading when the ratio of pressure drop (ΔP) to inlet pressure (P_1) exceeds 0.02. The deviation of actual flow capacity from the calculated flow capacity is indicated in Figure 3-23 and results from compressibility effects and critical flow limitations at increased pressure drops.

Critical flow limitation is the more significant of the two problems mentioned. Critical flow is a choked flow condition caused by increased gas velocity at the vena contracta. When velocity at the vena contracta reaches sonic velocity, additional increases in ΔP by reducing downstream pressure produce no increase in flow. So after critical flow condition is reached (whether at a pressure drop/inlet pressure ratio of about 0.5 for globe valves or at much lower ratios for high recovery valves) the equation above becomes completely useless. If applied, the C_v equation gives a must higher indicated capacity than actually will exist. And in the case of a high recovery valve which reaches critical flow at a low pressure drop ratio (as indicated in Figure 3-24), the critical flow capacity of the valve may be over-estimated by as much as 300 percent.

The problems in predicting critical flow with a C_v-based equation led to establishing a separate gas sizing coefficient based on air flow tests. The coefficient (C_g) was developed experimentally for each type and size of valve to relate critical flow to absolute inlet pressure. By including the correction factor used in the previous equation to compare air at 60°F with other gases at other absolute temperatures, the critical flow equation can be written:

$$Q_{critical} = C_g P_1 \sqrt{520/GT} \quad (B)$$

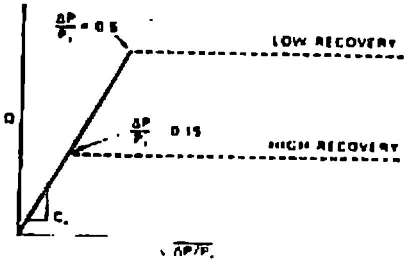

Figure 3-24. Critical Flow for High and Low Recovery Valves with Equal C_v

Universal Gas Sizing Equation

To account for differences in flow geometry among valves, equations *(A)* and *(B)* were consolidated by the introduction of an additional factor (C_1). C_1 is defined as the ratio of the gas sizing coefficient and the liquid sizing coefficient and provides a numerical indicator of the valve's recovery capabilities. In general, C_1 values can range from about 16 to 37, based on the individual valve's recovery characteristics. As shown in the example, two valves with identical flow areas and identical critical flow (C_g) capacities can have widely differing C_1 values dependent on the effect internal flow geometry has on liquid flow capacity through each valve.

Example:

High Recovery Valve

$C_g = 4680$
$C_v = 254$
$C_1 = C_g/C_v$
$= 4680/254$
$= 18.4$

Low Recovery Valve

$C_g = 4680$
$C_v = 135$
$C_1 = C_g/C_v$
$= 4680/135$
$= 34.7$

So we see that two sizing coefficients are needed to accurately size valves for

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gas flow · C_g to predict flow based on physical size or flow area, and C_1 to account for differences in valve recovery characteristics. A blending equation, called the Universal Gas Sizing Equation, combines equations *(A)* and *(B)* by means of a sinusoidal function, and is based on the "perfect gas" laws. It can be expressed in either of the following manners:

$$Q_{scfh} = \sqrt{\frac{520}{GT}}\, C_g P_1\, \text{SIN} \left[\left(\frac{59.64}{C_1}\right) \sqrt{\frac{\Delta P}{P_1}}\right] \text{rad.} \quad (C)$$

or

$$Q_{scfh} = \sqrt{\frac{520}{GT}}\, C_g P_1\, \text{SIN} \left[\left(\frac{3417}{C_1}\right) \sqrt{\frac{\Delta P}{P_1}}\right] \text{Deg.} \quad (D)$$

In either form, the equation indicates critical flow when the sine function of the angle designated within the brackets equals unity. The pressure drop ratio at which critical flow occurs is known as the critical pressure drop ratio. It occurs when the sine angle reaches π/2 radians in equation *(C)* or 90 degrees in equation *(D)*. As pressure drop across the valve increases, the sine angle increases from zero up to π/2 radians (90°). If the angle were allowed to increase further, the equations would predict a decrease in flow. Since this is not a realistic situation, the angle must be limited to 90 degrees maximum.

Although "perfect gases," as such, do not exist in nature, there are a great many applications where the Universal Gas Sizing Equation, *(C)* or *(D)*, provides a very useful and usable approximation.

General Adaptation for Steam and Vapors

The density form of the Universal Gas Sizing Equation is the most general form and can be used for both perfect and non-perfect gas applications. Applying the equation requires knowledge of one additional condition not included in previous equations, that being the inlet gas, steam, or vapor density (d_1) in pounds per cubic foot. (Steam density can be determined from tables beginning on page 136 or 148 of this book.)

Then the following adaptation of the Universal Gas Sizing Equation can be applied:

$$Q_{lb/hr} = 1.06 \sqrt{d_1 P_1}\, C_g\, \text{SIN} \left(\frac{3417}{C_1}\right) \sqrt{\frac{\Delta P}{P_1}} \text{ Deg.} \quad (E)$$

Special Equation Form for Steam Below 1000 Psig

If steam applications do not exceed 1000 psig, density changes can be compensated for by using a special adaptation of the Universal Equation. It incorporates a factor for amount of superheat in degrees Fahrenheit (T_{sh}) and also a sizing coefficient (C_s) for steam. Equation *(F)* eliminates the need for finding the density of superheated steam, which was required in Equation *(E)*. At pressures below 1000 psig, a constant relationship exists between the gas sizing coefficient (C_g) and the steam coefficient (C_s). This relationship can be expressed: $C_s = C_g/20$. For higher steam pressure applications, Equation *(E)* must be used.)

$$Q_{lb/hr} = \left[\left(\frac{C_s P_1}{1 + 0.00065 T_{sh}}\right)\right] \text{SIN} \left[\left(\frac{3417}{C_1}\right) \sqrt{\frac{\Delta P}{P_1}}\right] \text{Deg.} \quad (F)$$

Gas and Steam Sizing Summary

The Universal Gas Sizing Equation can be used to determine the flow of gas through any style of valve. Absolute units of temperature and pressure must be used in the equation. When the critical pressure drop ratio causes the sine angle to be 90 degrees, the equation will predict the value of the critical flow. For service conditions that would result in an angle of greater than 90 degrees, the equation must be limited to 90 degrees in order to accurately determine the critical flow that exists.

Most commonly, the Universal Gas Sizing Equation is used to determine proper valve size for a given set of service conditions. The first step is to calculate the required C_g by using the Universal Gas Sizing Equation. The second step is to select a valve from the manufacturer's catalog. The valve selected should have a C_g which equals or exceeds the calculated value. Be certain that the assumed C_1 value for the C_g calculation matches the C_1 value for the valve selected from the catalog.

It is apparent that accurate valve sizing for gases requires use of the dual coefficients C_g and C_1. A single coefficient is not sufficient to describe both the capacity and the recovery characteristics of the valve.

Proper selection of a control valve for gas service is a highly technical problem with many factors to be considered. Leading valve manufacturers provide technical information, test data, sizing catalogs, nomographs, sizing slide rules, and computer or calculator programs that make valve sizing a simple and accurate procedure.

Summary of Gas and Steam Sizing Nomenclature

$C_1 = C_g/C_v$

C_g = gas sizing coefficient

C_s = steam sizing coefficient

C_v = liquid sizing coefficient

d_1 = density of steam or vapor at inlet, pounds/cu. foot

G = gas specific gravity (air = 1.0)

P_1 = valve inlet pressure, psia

ΔP = pressure drop across valve, psi

$Q_{critical}$ = critical flow rate, scfh

Q_{scfh} = gas flow rate, scfh

$Q_{lb/hr}$ = steam or vapor flow rate, pounds per hour

T = absolute temperature of gas at inlet, degrees Rankine

T_{sh} = degrees of superheat, °F

Summary of Gas and Steam Sizing Equation Applications

(A)—Use only at very low pressure drop ($\Delta P/P_1$) ratios of 0.02 or less.

(B)—Use only to determine critical flow capacity at a given inlet pressure.

(C) or *(D)*—Universal Gas Sizing Equation. Use to predict flow for either high or low recovery valves, for any gas adhering to the perfect gas laws, and under any service conditions.

(E)—Use to predict flow for perfect or non-perfect gas sizing applications, for any vapor including steam, at any service condition when fluid density is known.

(F)—Use only to determine steam flow when inlet pressure is 1000 psig or less.

Sizing for Liquid-Gas Mixtures

Procedure

Special consideration is required when sizing valves handling mixtures of liquid and gas or liquid and vapor. The equation for required valve C_v for liquid-gas or liquid-vapor mixtures is:

$$C_{vr} = (C_{vl} + C_{vg})(1 + F_m) \qquad (I)$$

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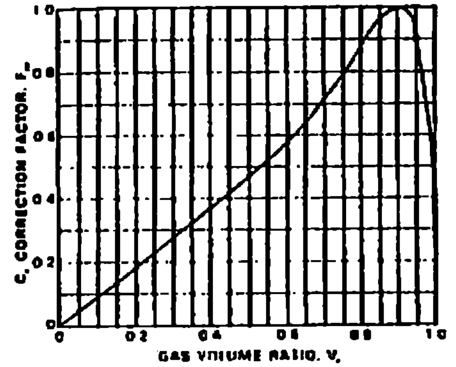


Figure 3-25. C_v Correction Factor, F_m

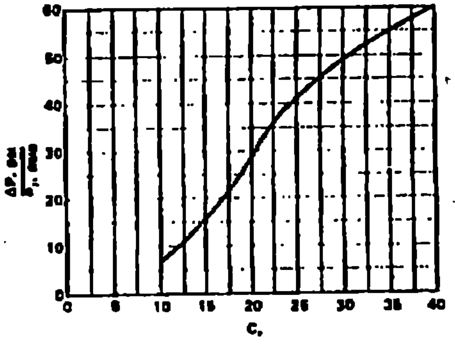


Figure 3-26. Pressure Drop Ratio Resulting in Critical Gas Flow

The value of the correction factor, F_m, is given in Figure 3-25 as a function of the gas volume ratio, V_r. The gas volume ratio for liquid-gas mixtures may be obtained by the equation:

$$V_r = \frac{V_g}{V_l + V_g} = \frac{Q_g}{\dfrac{284\, Q_l P_1}{T_1} + Q_g} \qquad (II)$$

or for liquid-vapor mixtures:

$$V_r = \frac{v_g}{v_g + v_f\left(\dfrac{1 - x}{x}\right)} \qquad (III)$$

If the pressure drop ratio ($\Delta P/P_1$) exceeds the ratio required to give 100% critical gas flow as determined from Figure 3-26, the liquid sizing drop should be limited to the drop required to give 100% critical gas flow.

Because of the possibility of choked flow occurring, the liquid sizing drop may also have to be limited by the equation:

$$\Delta P_{allow} = K_m(P_1 - r_c P_v)^*$$

Summary of Liquid-Gas Mixture Sizing Nomenclature

C_v = Standard liquid sizing coefficient

C_{vr} = C_v required for mixture flow

C_{vl} = C_v for liquid phase

C_g = C_g for gas phase

C_{vg} = C_v required for gas phase = C_g/C_1

C_1 = C_g/C_v ratio for valve

F_m = C_v correction factor

K_m = Valve recovery coefficient

ΔP = Valve pressure drop, psi

P_1 = Valve inlet pressure, psia

P_v = Liquid vapor pressure, psia

Q_g = Gas flow, scfh

Q_l = Liquid flow, gpm

Q_s = Steam or vapor flow, lb/hr

r_c = Critical pressure ratio

T_1 = Inlet temperature, °Rankine (°R = °F + 460°)

V_g = Gas flow, ft³/sec

V_l = Liquid flow, ft³/sec

V_r = Gas volume ratio

v_g = Specific volume of gas phase, ft³/lb

v_f = Specific volume of liquid phase, ft³/lb

x = Quality, lb vapor/lb mixture

DE&S

Naperville, Illinois

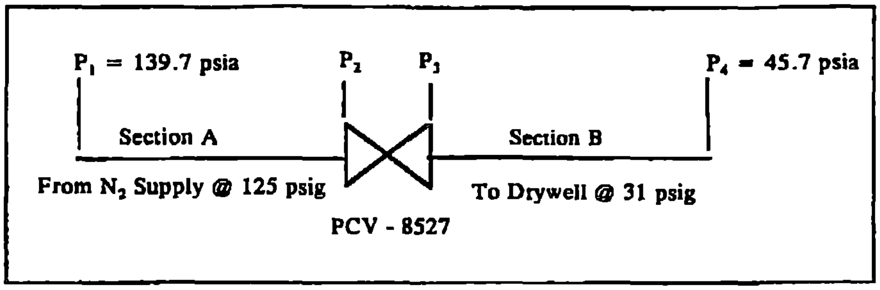
PROJECT Dresden NRC ISI Support
File No: VD0801.F02
OWNER Commonwealth Edison Co.
Calc No: DRE96-0252
CLIENT Dresden Nuclear Station

REFERENCE

ATTACHMENT D

Spreadsheet Calculations

REVISION	0					PAGE D1 OF 4
PREPARED BY/DATE	12/13/96					
CHECKED BY/DATE	12/13/96					



Spread sheet formulas:

P1 = Psupply +14.7
P4 = Pdrywell + 14.7
P1' = P1 - dP
P3' = P4 + dP
A = pi*(d/(2*12))^2
c = sqrt(k*32.2*(1545/M)*T)
ro = fluid density = 144*P/(T*(1545/M))
roave = (ro1+ro2)/2
W = .0727*scfm*60
cfm = (W / roave)/60
v = cfm/(A*60)
K = dP*roave*((1891*d^2)^2)/W^2, dP = sub section pressure drop
%diff= (roave-roave')/((roave+roave')/2)

Section A

Input Constants

T=	595	R	Ktot=	120.7
d=	1.5	in	M=	28
Psupply=	125	psig	k=	1.41

Iterative Trial Inputs

scfm=	73.543	dP=	0.5622	psi

W=	320.7946	lbm/hr	cfm=	8.761038					
A=	0.012272	ft2	v(ft/sec)=	11.89856	ft/sec	c=	1220.903	ft/sec	

P1 = Psupply + 14.7

P1 (psia)	ro1 lbm/ft3	dP psi	P1' psia	ro1' lbm/ft3	roave lbm/ft3	K
139.7	0.612733	0.5622	139.1378	0.610267	0.6115	60.4758

P1' (psia)	ro1' lbm/ft3	dP psi	P2 psia	ro2 lbm/ft3	roave' lbm/ft3	K	% diff
139.1378	0.610267	0.5622	138.5756	0.607802	0.609035	60.23194	0.40%
Total =		1.1244				120.7077	

Section B

Input Constants

T=	595	R	Ktot=	282.2
d=	1.5	in	M=	28
Ptorus	31	psig	k=	1.41

Iterative Trial Inputs

scfm=	73.543	dP=	3.702	psi

W=	320.7946	lbm/hr	cfm =	25.63545				
A=	0.012272	ft2	v(ft/sec)=	34.81608	ft/sec	c=	1220.903	ft/sec

P4	ro4	dP	P3'	ro3'	roave	K
(psia)	lbm/ft3	psi	psia	lbm/ft3	lbm/ft3	
45.7	0.200443	3.702	49.402	0.21668	0.208562	135.8205

P3'	ro3'	dP	P3	ro3	roave'	K	% diff
(psia)	lbm/ft3	psi	psia	lbm.ft3	lbm/ft3		
49.402	0.21668	3.702	53.104	0.232918	0.224799	146.3945	7.49%

Total =		7.404				282.215	