

OWNER

Control Valve Sizing and Noise

Calculation



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CONTENTS

1. OBJECTIVE.....1

2. METHODOLOGY 1

3. DESIGN INPUTS.....1

4. ASSUMPTIONS.....2

5. REFERENCES 2

6. CALCULATION.....2

6.1. VALVE CONDITIONS 2

6.2. FLOW COEFFICIENT, CASE C1 3

6.3. TRAVEL AND RANGEABILITY.....4

6.4. NOISE AND TRIM SELECTION 4

6.5. LCV-104 AND THE FUEL GAS REGULATORS.....6

7. RESULTS AND CONCLUSIONS 6

FIGURES AND TABLES

Figure 6-1. Predicted Noise by Trim for the Cases with the Largest Pressure Drop 5

Table 3-1: Design Inputs.....1

Table 6-1: FCV Inlet and Outlet Conditions 3

Table 6-2: FCV Sizing by Case 3

Table 6-3: FCV Travel and Outlet Velocity 4

Table 6-4: Predicted Noise at 1 m by Trim, dBA.....5

Table 6-5: Other Control Valves and Regulators 6

1. OBJECTIVE

This calculation sizes the station flow control valves FCV-131 and FCV-132 (duty and standby, each for 100 % of flow) for operating cases C1 to C7, checks for choked flow and for the effect of the reducers around the valve, sets the valve opening and rangeability for a candidate NPS 8 Class 600 valve, and predicts the aerodynamic noise to select the trim. It also summarizes the sizing of LCV-104 (PRO-CAL-005) and of the fuel gas regulators PCV-161 and PCV-162 (PRO-CAL-010).

2. METHODOLOGY

The valve inlet and outlet conditions come from the station hydraulic model (PRO-CAL-002). The required flow coefficient was calculated with the ANSI/ISA-75.01.01 compressible flow equation. The expansion factor uses the isentropic exponent $\kappa = pc^2/p$ from the GERG-2008 speed of sound, which is the exponent the equation assumes; at pipeline pressure the real-gas c_p / c_v would overstate it by about 19 %. The piping geometry factor F_p and the modified pressure differential ratio x_{TP} account for the concentric reducers on either side of the valve, and were iterated with the flow coefficient.

Valve travel was found from the inherent equal-percentage characteristic. Because the valve takes nearly all the station pressure drop, the installed characteristic stays close to the inherent one.

Aerodynamic noise was predicted with the IEC 60534-8-3 method: vena contracta conditions, flow regime, acoustic efficiency, internal sound pressure, peak frequency, pipe wall transmission loss and the external A-weighted level at 1 m. Multistage trims were modeled as two or three stages in series with equal pressure ratios, each evaluated with its own flow coefficient, and the stage levels added on an energy basis. This is a screening approach; the vendor's calculation with its own trim data governs.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Valve conditions	Cases C1 to C7, heater mode per basis	PRO-CAL-002
Candidate valve	NPS 8 Class 600 globe, cage-guided, equal percentage (R = 50)	GEN-DB-001; type selected
Rated C_v at full travel	550	Typical, HOLD H-15
F_L and x_T	0.9 and 0.75	Typical, HOLD H-15

Input	Value	Source
Jet diameter factor F_d	0.46 standard cage; 0.14 single-stage drilled-hole; 0.1 multistage multi-hole	IEC 60534-2-1 typical values
Installation	12 x 8 concentric reducer and expander at the valve, NPS 12 STD branches	PRO-CAL-002
Downstream pipe for noise	NPS 12 STD, 0.375 in wall	MEC-CAL-001
Noise limit	85 dBA at 1 m	OSHA action level

4. ASSUMPTIONS

1. Rated C_v , F_L , x_T and F_d are typical for the valve type. *Verification required (HOLD H-15)*. A valve with a rated C_v between 450 and 700 keeps every case between 10 % and 90 % travel.
2. The multistage noise model is a screening estimate. *Verification required*: the vendor shall confirm with the IEC 60534-8-3:2010 method.
3. The acoustic power ratio for a globe valve is 0.25.

5. REFERENCES

1. ANSI/ISA-75.01.01-2012 (IEC 60534-2-1:2011), Flow Equations for Sizing Control Valves.
2. IEC 60534-8-3:2010, Industrial-process control valves, Part 8-3: Noise considerations, Control valve aerodynamic noise prediction method.
3. OSHA 29 CFR 1910.95, Occupational noise exposure.
4. GEN-DB-001, Basis of Design.
5. PRO-CAL-002, Line Sizing and Station Hydraulics; PRO-CAL-005, Filter Separator; PRO-CAL-009, Overpressure Protection Analysis; PRO-CAL-010, Fuel Gas System.
6. MEC-CAL-001, Pipe Wall Thickness.

6. CALCULATION

6.1. VALVE CONDITIONS

Table 6-1 gives the valve inlet and outlet conditions. The dirty-filter cases take the filter separator at its 10 psi change-out differential, which gives the smallest valve pressure drop at maximum flow.

Table 6-1: FCV Inlet and Outlet Conditions

Case	Flow, MMSCFD	Inlet, psig	Inlet, °F	Outlet, psig	Outlet, °F	Inlet density, lb/ft ³	κ
C1	120	1,140	67	752	44	4.63	1.400
C2	90	1,050	70	951	64	4.14	1.374
C3	10	1,000	60	950	57	4.07	1.370
C4	120	1,090	120	1,000	115	3.73	1.351
C5	120	890	60	752	51	3.55	1.347
C6	120	1,140	45	752	18	5.08	1.428
C7	120	1,090	68	852	52	4.88	1.373
C4, dirty filter	120	1,090	119	1,000	115	3.71	1.350
C5, dirty filter	120	882	59	752	51	3.52	1.346

6.2. FLOW COEFFICIENT, CASE C1

In case C1 the inlet is 1,157.0 psia at 67.4 °F and the outlet 765.9 psia, with $W = 244,000$ lb/h, $\rho_1 = 4.632$ lb/ft³ and $\kappa = 1.400$. For the 12 x 8 reducers the sum of the loss coefficients is 0.463, which gives $F_p = 0.999$ and $x_{TP} = 0.750$:

ISA-75.01.01, compressible flow

$$x = \frac{P_1 - P_2}{P_1} = 0.338 < F_k x_{TP} = \frac{1.400}{1.40}(0.750) = 0.750$$

so the flow is not choked, and

$$Y = 1 - \frac{x}{3F_k x_{TP}} = 0.850$$

$$C_v = \frac{W}{63.3 F_p Y \sqrt{x P_1 \rho_1}} = \frac{244,000}{63.3(0.999)(0.850)\sqrt{0.338(1157.0)(4.632)}} = 107$$

Table 6-2 gives the result for every case. No case is choked.

Table 6-2: FCV Sizing by Case

Case	x	x_{TP}	$F_k x_{TP}$	Y	F_p	Required C_v
C1	0.338	0.750	0.750	0.850	0.999	107
C2	0.090	0.749	0.735	0.959	0.999	152
C3	0.049	0.750	0.734	0.978	1.000	23
C4	0.082	0.748	0.722	0.962	0.997	218

Case	x	x_{TP}	$F_k x_{TP}$	Y	F_p	Required C_v
C5	0.153	0.749	0.720	0.929	0.998	188
C6	0.339	0.750	0.764	0.852	0.999	101
C7	0.217	0.749	0.735	0.901	0.999	134
C4, dirty filter	0.076	0.748	0.722	0.965	0.997	228
C5, dirty filter	0.145	0.749	0.720	0.933	0.998	194

6.3. TRAVEL AND RANGEABILITY

With the inherent equal-percentage characteristic, travel is $h = 1 + \ln(C_v/C_{v, rated})/\ln R$. Table 6-3 shows that the required C_v ranges from 23 (C3) to 228 (C4, dirty filter), a rangeability of 9.9 to 1, and that travel stays between 19 % and 78 %, inside the 10 % to 90 % controllable band.

Table 6-3: FCV Travel and Outlet Velocity

Case	Required C_v	Percent of rated C_v	Travel, %	Velocity at NPS 8 valve outlet, ft/s	Velocity in NPS 12 pipe, ft/s
C1	107	19	58	69	28
C2	152	28	67	43	17
C3	23	4	19	5	2
C4	218	40	76	62	25
C5	188	34	73	71	29
C6	101	18	57	63	26
C7	134	24	64	60	24
C4, dirty filter	228	41	78	62	25
C5, dirty filter	194	35	73	71	29

If the branches were NPS 8, the size of the valve, the outlet velocity would reach 71 ft/s, above the 60 ft/s station limit and the erosional velocity (PRO-CAL-002). The valve is therefore installed between 12 x 8 reducers in NPS 12 branches.

FCV-131 and FCV-132 are NPS 8 Class 600 cage-guided globe valves with equal-percentage trim, rated C_v about 550. The required C_v is 23 to 228, at 19 % to 78 % travel.

6.4. NOISE AND TRIM SELECTION

Case C1 has the largest pressure drop and governs noise. With the single-stage drilled-hole cage the flow is in regime I, the vena contracta Mach number is 0.82, the internal sound pressure level is 160.5 dB, the peak frequency is 10,400 Hz and the pipe wall transmission loss is -66.4 dB:

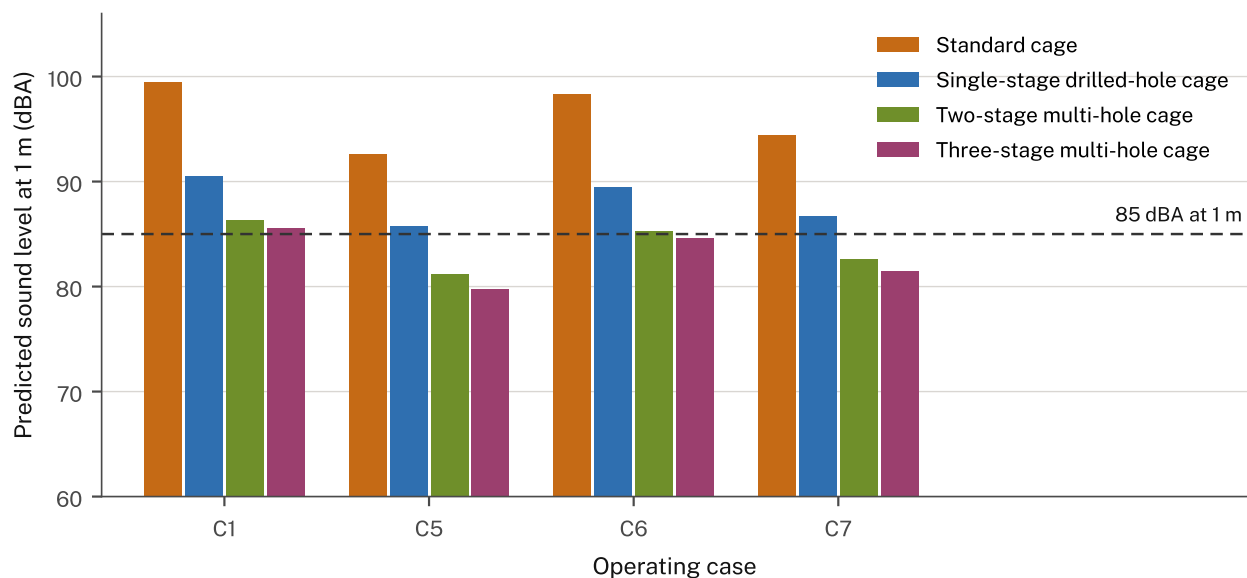
$$L_{pAe, 1m} = 5 + L_{pi} + TL - 10 \log_{10} \frac{D_i + 2t_s + 2}{D_i + 2t_s} = 5 + 160.5 + (-66.4) - 8.6 = 90.5 \text{ dBA}$$

Table 6-4 and Figure 6-1 compare the four trims. A standard cage predicts 99.4 dBA and a single-stage drilled-hole cage 90.5 dBA, both well above the limit. The three-stage multi-hole cage is the quietest, at 85.6 dBA in case C1. With the 0.375 in NPS 12 STD wall this is still above the 85 dBA limit, so acoustic insulation is added. A mineral wool jacket with a mass-loaded barrier typically gives 10 to 15 dB, which brings the level well below the limit.

Table 6-4: Predicted Noise at 1 m by Trim, dBA

Case	Flow regime	Standard cage	Single-stage drilled-hole	Two-stage multi-hole	Three-stage multi-hole
C1	I	99.4	90.5	86.3	85.6
C2	I	83.3	78.3	73.9	72.4
C3	I	64.1	56.0	52.1	51.3
C4	I	83.0	81.1	76.7	75.2
C5	I	92.6	85.7	81.2	79.8
C6	I	98.3	89.5	85.3	84.6
C7	I	94.4	86.7	82.6	81.4
C4, dirty filter	I	81.4	80.5	76.0	74.6
C5, dirty filter	I	92.2	85.3	80.8	79.3

Figure 6-1. Predicted Noise by Trim for the Cases with the Largest Pressure Drop



Both FCVs shall have a three-stage multi-hole low-noise cage and acoustic insulation on the valve body and the first 10 ft of NPS 12 pipe downstream. The vendor shall guarantee 85 dBA at 1 m in cases C1 and C6 by the IEC 60534-8-3:2010 method.

6.5. LCV-104 AND THE FUEL GAS REGULATORS

The other control valves in the station are sized in their own calculations. Table 6-5 summarizes them.

Table 6-5: Other Control Valves and Regulators

Tag	Service	Required C_v	Selected	Source
LCV-104	V-101 liquid dump, flashing	2.53	NPS 2 Class 600 angle, rated C_v 4.0	PRO-CAL-005
PCV-161	Fuel first cut to 150 psig	0.18	1 in pilot-operated, C_v 0.6	PRO-CAL-010
PCV-162	Fuel second cut to 15 psig	1.00	1 in, C_v 4.0	PRO-CAL-010

7. RESULTS AND CONCLUSIONS

TORUS draws the following conclusions:

1. FCV-131 and FCV-132 are NPS 8 Class 600 globe valves, equal percentage, rated C_v about 550, with electric modulating actuators that fail as-is and have handwheels. No case is choked.
2. The valves are installed between 12 x 8 concentric reducers in NPS 12 branch piping. For PRO-CAL-009, the wide-open valve has $F_p = 0.981$ and $x_{TP} = 0.740$.
3. The trim is a three-stage multi-hole low-noise cage, predicted at 85.6 dBA at 1 m. Acoustic insulation of the valve body and 10 ft of downstream pipe is required on both valves.
4. The trim shall be hardened (CoCr or 17-4 H1150). The filter separator upstream keeps particles above 1 micron out of the multistage trim.
5. Full stroke shall be 30 s or less for normal control. The FCVs are not overpressure protection devices; SDV-102 is.

The following items remain open: vendor confirmation of rated C_v , F_L , x_T and F_d , and the vendor noise calculation (HOLD H-15).