

DESIGN MANUAL
SPD0010EIE
Instrument Design
Control Valve Noise And Velocity

REV. : 0

DATE : 2013. 10. 30

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1. General

1.1 Purpose

This manual defines standards to predict valve noise and outlet velocity for control valve sizing.

1.2 Scope

Valve outlet velocity is applied for valve sizing, and noise limitation is applied by job requirements.

1.3 Nomenclature

1) Valve Diameter

Control valve nominal inside diameter.

2) Noise

Noise is unwanted sound.

Sound is a form of vibration which propagates through elastic media such as air by alternately compressing and rarefying the media. Sound can be characterized by its frequency, spectral distribution, amplitude and duration.

3) Sound Pressure

Sound Pressure is the level of sound that the receiver(human ear) actually perceives.

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4) Sound Pressure Level

The sound level pressure, in decibels, of a sound is 20 times the logarithm to the base 10 of ratio of the pressure of the sound to the reference pressure.

The reference pressure is usually taken as $2 \times 10^{-5} \text{ N/m}^2$

$$\text{SPL} = 20 \log \frac{P_e}{P_{oe}} \text{ (dB)}$$

Where, $P_{oe} : 2 \times 10^{-5} \text{ (N/m}^2\text{)}$

5) Sound Intensity

Sound intensity is defined as the energy transmitted per unit area in the direction of propagation. This factor is also proportional to loudness.

6) Sound Intensity Level

$$\text{SIL} = 10 \log \frac{I}{I_o} \text{ (dB)}$$

Where, $I_o : 10^{-16} \text{ (W/Cm}^2\text{)}$

7) Sound Power

The sound power of a source is the total acoustic energy radiated by the source per unit of time.

8) Sound Power Level

The sound power level of a sound source, in decibels, is 10 times the logarithm to the base 10 of the ratio of the sound power radiated by the source to a reference power. The reference power is usually taken as 10~12 Watt.

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$$PWL = 10 \log \frac{W}{W_0} \quad (\text{dB})$$

where, $W_0 : 10^{-12} \text{ (W)}$

9) dBA

Perception of sound by many human subjects over the frequency spectrum when compared to a pure tone of 1000Hz frequency has resulted in mapping the ear response. The resulting weighting correction numbers representing human ear response is called the A weighting networks, and the corresponding decibel level is called a dBA.

1.4 Reference

- 1) KEM-6002
- 2) Masoneilan Handbook for Control Valve Sizing
- 3) Masoneilan Noise Control Manual
- 4) Noise Abatement (Fisher Controls)
- 5) JIS C1502
- 6) ISA Handbook of Control Valve

2. Control Valve Outlet Velocity

2.1 Valve Diameter

Noise can be generated by a control valve both in the throttling area by the valve trim and in the valve outlet when fluid velocities are high. For valid noise Calculations, valves should be sufficiently large so that sonic outlet velocities are avoided.

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The following equations indicate the valve outlet diameter which will produce sonic outlet velocity. For noise sensitive applications, or where vibration is of concern, the actual outlet diameter should be larger than d.

(1) Steam

$$d \geq 37.1 \sqrt{\frac{W(1+0.00126Tsh)}{P_2}}$$

(2) Gas (Volumetric Basis)

$$d \geq 37.1 \sqrt{Q \sqrt{\frac{GT}{P_2}}}$$

Notes : Actual diameter should be larger than d.

2.2 Valve Outlet Noise

The valve outlet velocity becomes increasingly important when low noise valve or static restrictors are utilized. The acoustical advantage of the unit can be reduced or eliminated if excessive outlet velocities are present.

- 1) Calculate the valve outlet Mach number. If less than 0.33 Mach, the sound generated at the outlet can be considered negligible, and no further calculation is required. If ≥ 1 , a larger valve size or static restrictor must be used.
- 2) If $0.33 < M < 1$, calculate the sound level associated with this outlet velocity.
- 3) Compare with the sound level computed for the valve trim.

2.2.1 The following two equations (Mach number and valve outlet noise level) are used in conjunction to determine valve outlet noise level.

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(1) Mach Number

. Gas (Volumetric Basis)

$$M = \frac{0.062 Q \sqrt{G T}}{P_2 d_2}$$

. Steam

$$M = \frac{1380 W (1 + 0.00126 T_{sh})}{P_2 d_2}$$

(2) Valve Outlet Noise

. All gases except steam

$$SL = 10 \log \left(\frac{2.8 P_2^2 d_2^2 M^2 \sim 8T}{t^3} \right) + SL_g$$

. For steam

$$SL = 10 \log \left(\frac{662 P_2^2 d_2^2 M^2 \sim 8 (1+0.00126T_{sh}) \sim 6}{t^3} \right)$$

Where,

M = Fluid Mach number

Q = Gas flowrate(M³/hr)

G = Gas specific gravity (air= 1.0)

T = Absolute temperature

D = Downstream nominal pipe diameter (mm)

d = Valve outlet diameter (mm)

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SLg = Gas property factor (dBA)

SL = A- weighted sound level, 1m downstream and 1m from the pipe surface (dBA)

Tsh = Steam superheat temperature (°C)

3. Control Valve Noise

3.1 Noise Source

The three major source of noise in control valve are as follows :

- . Mechanical Vibration
- . Hydrodynamic Noise
- . Aerodynamic Noise

(1) Mechanical Vibration

Mechanical noise is caused by the response of internal components within a valve to turbulent flow through the valve.

Noise from mechanical vibration does not occur in control valves, especially since the introduction top and cage guided valves. Should it occur, steps must be taken to eliminate that resonant condition, to reduce the noise but more importantly to preclude fatigue failure. Possible cures for this type of noise include reduction of guide clearances, larger stem size, change in plug mass, and sometimes reversal of flow direction.

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(2) Hydrodynamic Noise

Liquid flow noise, and flashing noise can be generated by the flow of a liquid through a valve and piping system. Of the three noise sources, cavitation is the most serious because noise produced in this manner can be sign the damage is occurred at some point in the valve or piping.

(3) Aerodynamic Noise

Aerodynamic noise is a direct resulting of the conversion of the mechanical energy of the flow into acoustic energy as the fluid passes through the valve restriction. The proportionality of conversion is called acoustical efficiency and is resulted to valve pressure ratio and design.

3.2 Aerodynamic Noise Prediction Technique.

3.2.1 Numerical Method

(1) For all gases except steam :

$$SL = 10 \log \left(\frac{2.5 \times 10^{-5} C_v C P P D^2 \eta T}{t^3} \right) + SL_g$$

(2) For steam :

$$SL = 10 \log \left(\frac{5.8 \times 10^{-5} C_v C_f P P D^2 \eta (1 + 0.00126 T_{sh})}{t^3} \right)$$

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Where,

SL : A-weighted sound level, 1m downstream and 1m from the pipe surface (dBA)

Cv : Actual required flow coefficient

Cf : Critical flow factor

D : Down stream nominal pipe diameter(mm)

P₁ : Valve upstream pressure (Kg/Cm² abs)

P₂ : Valve downstream pressure (Kg/Cm² abs)

η : Acoustical efficiency

T : Absolute Temperature (K)

Tsh : Steam superheat temperature (°C)

t : Pipe wall thickness (mm)

SLg : Gas property factor (dBA)

Notes : When sound level predictions at points other than the standard

positions are required, use the following equation :

$$SL_e = SL - 10 \log \ell (\text{dBA})$$

Where, SL_e : Distance (ℓ_m) - corrected sound level(dBA)

ℓ : Distance (m)

3.2.2 Graphical Methods (Refer to Appendix I)

(1) For all gases except steam :

$$SL = SL_e + SL_p + SL_t + SL_v + SL_g + SL_a$$

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(2) For steam :

$$SL = SL_e + SL_p + SL_v + SL_a + SL_s$$

Where,

SL_e = Acoustical efficiency factor (dBA)

SL_p = Valve Inlet pressure factor (dBA)

SL_t = Fluid temperature factor (dBA)

SL_v = Flow capacity factor (dBA)

SL_g = Gas property factor (dBA)

SL_a = Pipe attenuation factor (dBA)

SL_s = Steam temperature factor (dBA)

3.3 Hydrodynamic Noise Prediction Technique

Noise produced by the flow of liquid through a control valve and associated piping is called hydrodynamic noise. It can be classified into the following three categories :

(1) Flow Noise

If actual $P < P_i$, use the following equation to predict hydrodynamic noise :

$$SL = 10 \log Cv + 20 \log P - 30 \log (t) + 70.5$$

(2) Incipient Cavitation Noise

If $P_i < P \leq P_c$, use the following formula to predict hydrodynamic noise :

$$SL = 10 \log Cv + 20 \log P + 5 \left(\frac{\frac{P}{P_1 - P_2} - K_c}{Cf^2 - K_c} \right) \times \log 14.5 (P_2 - 0.07 - P_v) - 30 \log(t) + 70.5$$

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(3) Full Cavitation Noise

If $P > P_c$ and $P_2 > P_v$, subtract the following term from the incipient cavitation noise formula.

$$5 \log (P + 0.07 - P_c) + 6$$

Where,

P : Pressure drop

P_v : Fluid vapor pressure

C_f : Critical flow factor

P_1 : Valve upstream pressure (Kg/cm² abs)

P_2 : Valve downstream pressure (Kg/cm² abs)

K_c : Coefficient of incipient cavitation

t : Pipe wall thickness (mm)

3.4 Noise

In the field of control equipment, noise produced by valves has become a focal point of attention triggered in part by enforcement of the Occupational Safety and Health Act(OSHA), Limits the duration of exposure to noise in industrial locations to the levels shown in the following tables.

노출시간 (시간)	음압 Level (dBA)
8	90
4	95
2	100
1	105
1.5	110
1/40이하	115

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3.5 Noise Reduction

Reduction of control valve aerodynamic noise can be achieved by either source treatment (preventing the noise generation) or path treatment (pipe insulation, silencers, or increasing pipe schedule). Because sound, once generated, propagates virtually unattended in downstream pipe, source treatment often becomes the preferable method.

3.5.1 Source Treatment

- (1) By reducing the size of the fluid jets (and consequently the size of the eddies), the efficiency of conversion between mechanical and acoustic power is reduced.
- (2) The smaller eddies shift the acoustic energy generated where transmission through the pipe walls is sharply reduced.
- (3) The higher frequency sound, if raised above 10,000 Hz, is deemphasized by both the A-weighting filter network and the human ear.

3.5.2 Path Treatment

- (1) Silencers

Silencers can be effective in reducing control valve noise provided they are installed directly downstream of the valve.

- (2) Increase in Pipe Schedule

Since noise, once generated, does not dissipate rapidly with downstream pipe length, this method most normally be used throughout the downstream system.

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(3) Pipe Insulation

This method, like that of increasing pipe thickness, can be an effective means to reduce radiated noise.

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4. History of this manual

Rev. No.	Date of Rev.	Rev. page	Basis of revision
0	OCT. 30, 2013	Whole pages	- Establish environmental design criteria in accordance with SECL standard manual - Department : Environmental Engineering Dept. - Written by : Y.J.Yoon - Checked by : S.K.Kang - Approved by : Y.Y.Koo

Appendix I : Related Table and Drawings

APPENDIX I

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1. Comparison of Energy, Sound Pressure Level (SPL) and Common Sounds

Relative Energy	Decibels	Example
1×10^{14}	140	Proximity to jet aircraft
1×10^{13}	130	Threshold of pain
1×10^{12}	120	Large chipping hammer
1×10^{11}	110	Near elevated train
1×10^{10}	100	Outside auto on highway
1×10^9	90	Voice — shouting
1×10^8	80	Inside auto at high speed
1×10^7	70	Voice — conversational
1×10^6	60	Voice — face-to-face
1×10^5	50	Inside general office
1×10^4	40	Inside private office
1×10^3	30	Inside bedroom
1×10^2	20	Inside empty theater
1×10^1	10	Anechoic chamber
1	0	Threshold of hearing

2. Change in Sound Level

Increase in Sound Level	Human Subjective Response
3 dBA	Just perceptible
5 dBA	Clearly noticeable
10 dBA	Twice as loud
20 dBA	Much louder

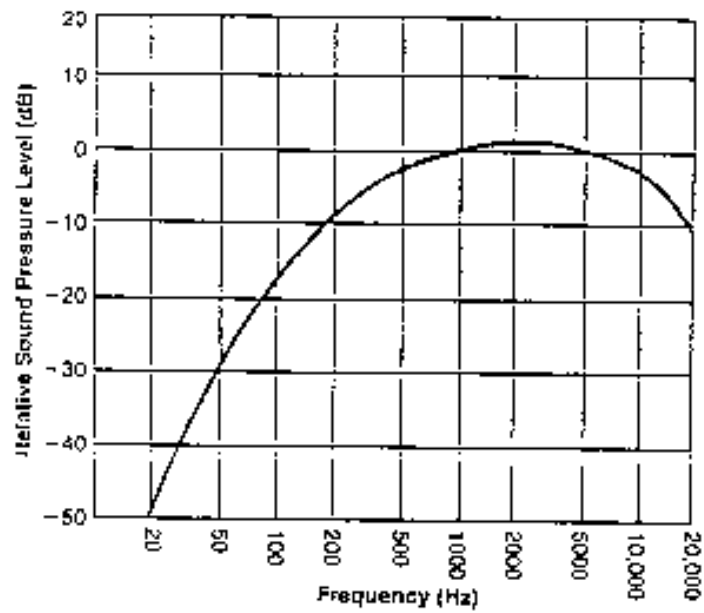
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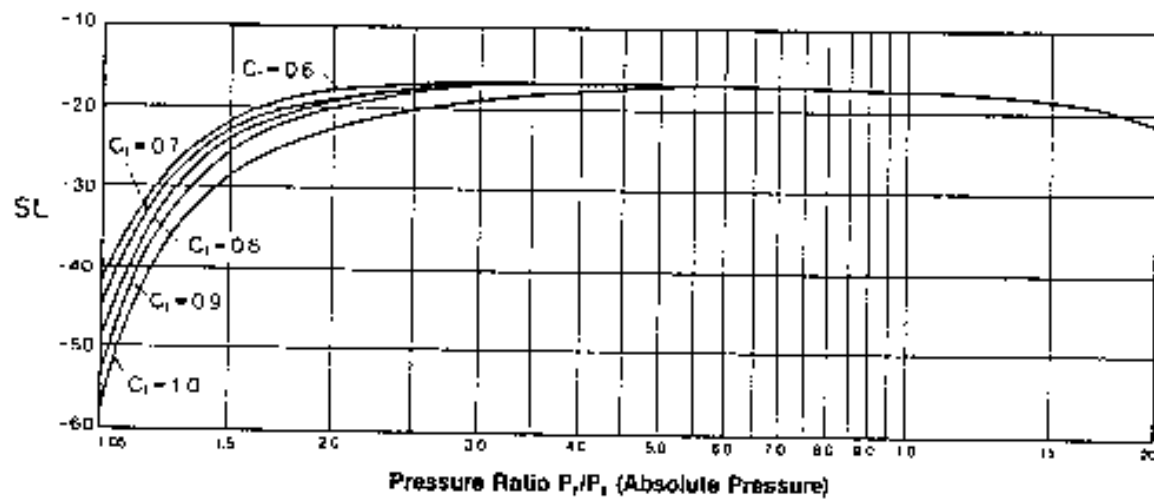
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3. IEC Standard A-weighting Curve for Sound Level Meters



4. SL_e Factor : Conventional Valves



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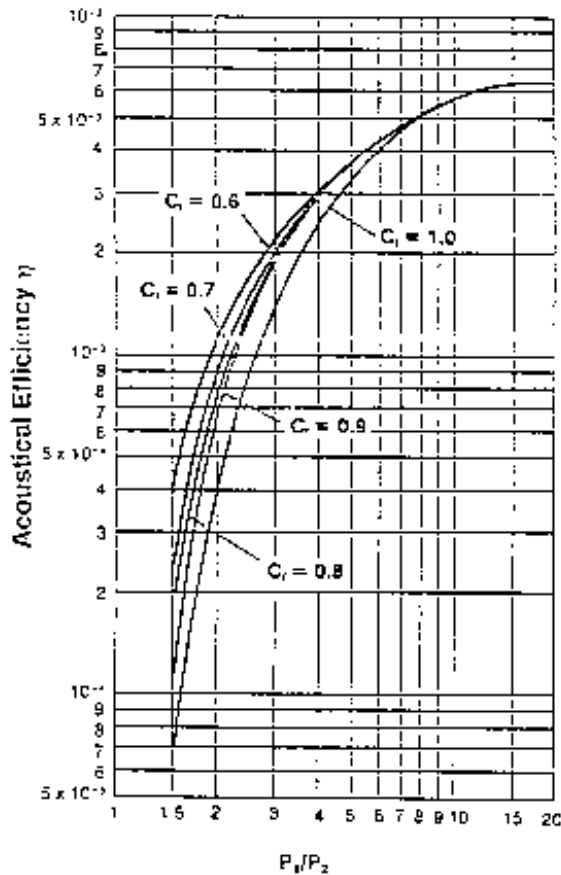
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5. Acoustical Efficient η : Conventional Valves

$$P_1/P_2 > 1.5$$



Aerodynamic noise prediction for conventional valves.

Acoustical Efficiency $P_1/P_2 \leq 1.5$

P_1/P_2	η				
	$C_1 = 1$	$C_1 = 0.9$	$C_1 = 0.8$	$C_1 = 0.7$	$C_1 = 0.6$
1.50	7.0×10^{-5}	1.4×10^{-4}	2.1×10^{-4}	2.4×10^{-4}	3.8×10^{-4}
1.40	3.6×10^{-5}	6.4×10^{-5}	1.0×10^{-4}	1.5×10^{-4}	2.1×10^{-4}
1.30	1.5×10^{-5}	2.9×10^{-5}	4.9×10^{-5}	7.5×10^{-5}	1.1×10^{-4}
1.25	8.6×10^{-6}	1.7×10^{-5}	3.1×10^{-5}	5.0×10^{-5}	7.3×10^{-5}
1.20	4.5×10^{-6}	9.3×10^{-6}	1.7×10^{-5}	2.9×10^{-5}	4.5×10^{-5}
1.15	1.8×10^{-6}	4.0×10^{-6}	8.3×10^{-6}	1.4×10^{-5}	2.3×10^{-5}
1.10	5.2×10^{-7}	1.3×10^{-6}	2.8×10^{-6}	5.4×10^{-6}	9.2×10^{-6}
1.05	5.8×10^{-8}	1.8×10^{-7}	4.5×10^{-7}	9.7×10^{-7}	1.8×10^{-6}
1.01	3.5×10^{-10}	1.7×10^{-8}	6.0×10^{-8}	1.8×10^{-7}	4.3×10^{-7}

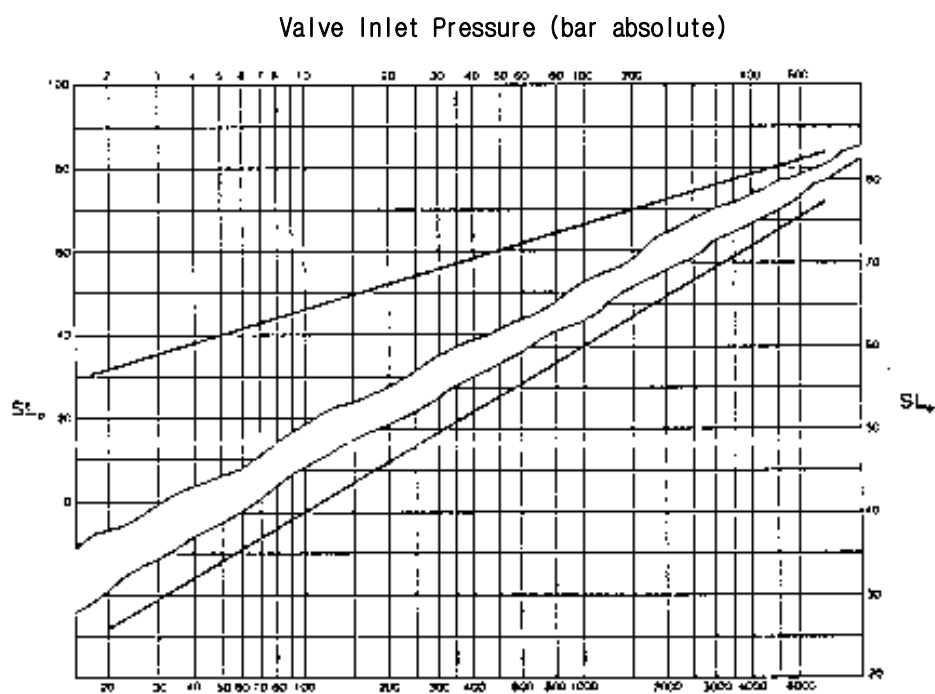
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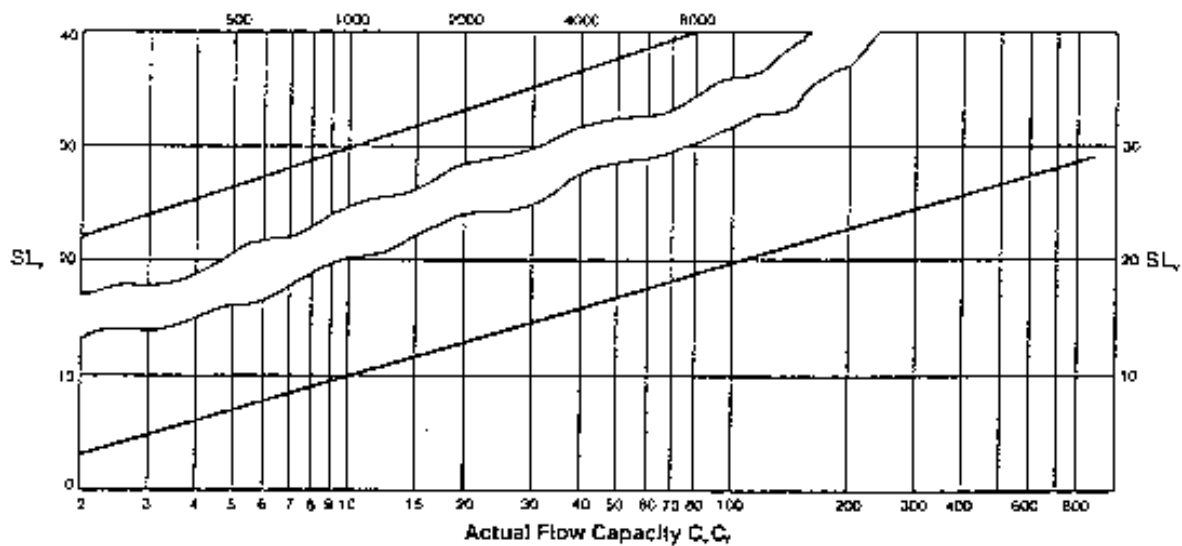
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6. Valve Inlet Pressure Factor SL_p



7. Flow Capacity Factor SL_v



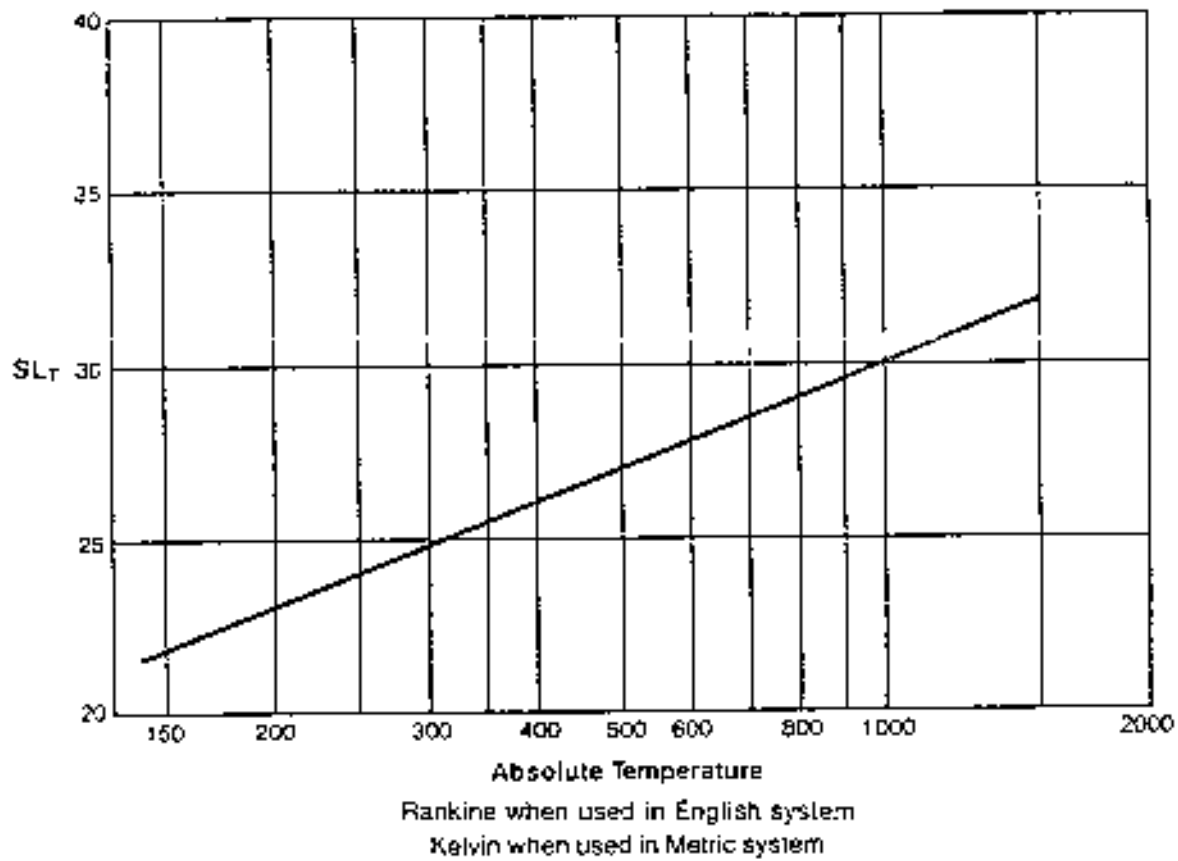
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8. Fluid Temperature Factor SL_T



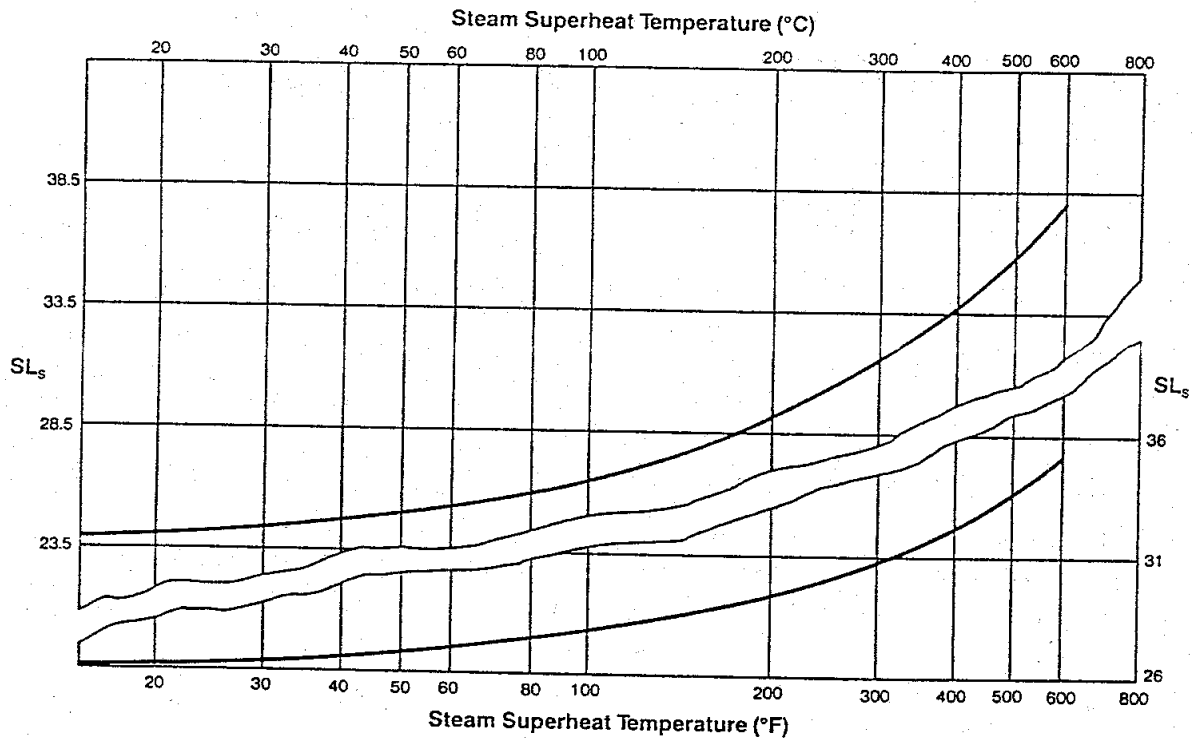
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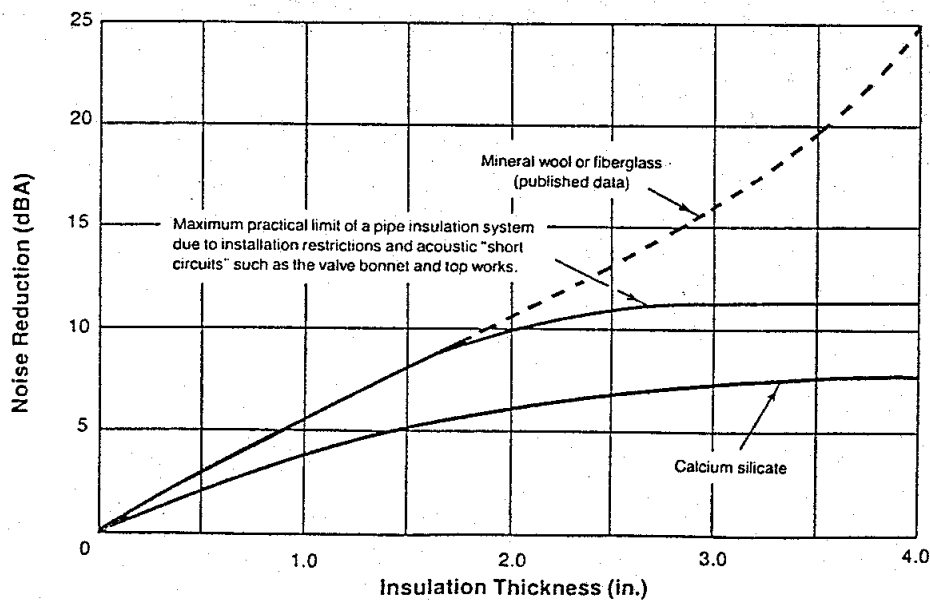
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9. Steam Temperature Factor SL_s



10. Additional Noise Reduction from Typical Pipe Insulation Systems



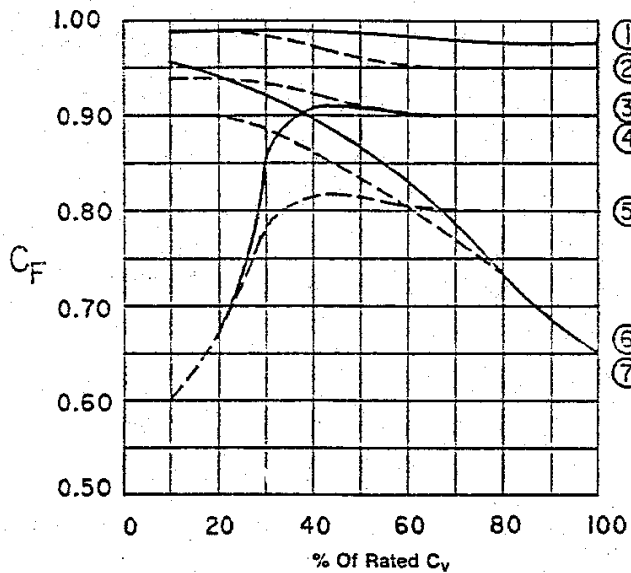
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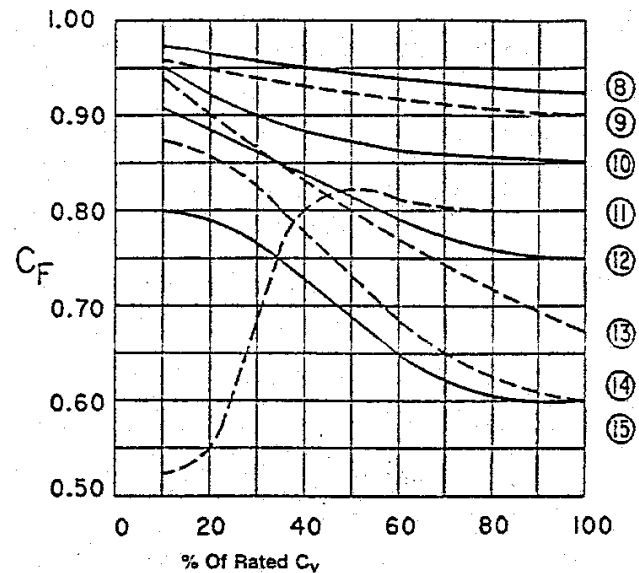
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11. Variation of (C_F) with Valve Opening



- ① 10130 & 11130 Series, Full Area
- ② 10130 & 11130 Series, Reduced Area
- ③ 41011 & 41021 Series, FTC & FTO
- ④ 10170 & 11170 Series, Full Area
- ⑤ 10170 & 11170 Series, Reduced Area
- ⑥ 39002 Series
- ⑦ 37002 Series



- ⑧ 28000 Series
- ⑨ 21110 & 21120 Series, FTO
- ⑩ 35002 Series, FTO
- ⑪ 2600 & 26000 Series, FTC
- ⑫ 2600 & 26000 Series, FTO
- ⑬ 35002 Series, FTC
- ⑭ 36002 Series
- ⑮ 38002 Series

12. Gas Property Factor SL_g

Gas	SL_g	Gas	SL_g
Acetylene	-0.5	Hydrogen	-9.0
Air	0	Hydrogen Chloride	-1.0
Ammonia	1.5	Isobutane	-6.0
Argon	1.0	Methane	2.0
Butane	-6.0	Natural Gas	0.5
Carbon Dioxide	-3.0	Nitrogen	0
Carbon Monoxide	0	Oxygen	-0.5
Chlorine	-2.5	Pentane	-7.5
Ethane	-2.0	Propane	-4.5
Ethylene	-1.5	Propylene	-4.5
Helium	-9.0	Sulphur Dioxide	-5.0

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13. Attenuation Factor SL_a (Not equal to TL)

Pipe Size (in.)	Pipe Schedule		
	40	80	160
1	14.5	17	19
1½	15	17.5	20
2	15.5	18	21.5
3	18	20.5	23
4	18.5	21	24.5
6	20	23	27
8	21	24.5	28.5
10	22	25.5	30.5
12	22.5	26.5	31.5
14	23	27	32
16	24	28	33
18	25	29	33.5
20	25	29.5	34.5
24	26.5	31	35.5

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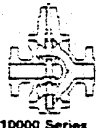
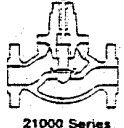
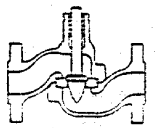
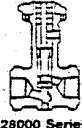
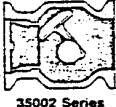
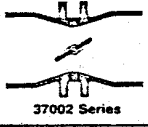
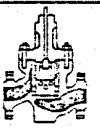
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14. Critical Flow Factor at Full Opening

Valve Type	Trim Size	Flow To	C_v (F_v)	K_c^*	C_{tr} (F_{LP}) $D/d = 1.5$ or greater	x_T
 10000 Series	A	Contoured V-Port	0.90 0.98	0.70 0.80	0.86 0.91	0.68 0.81
	B	Contoured V-Port	0.80 0.95	0.50 0.73	0.80 0.94	0.54 0.76
 21000 Series	A	Close Open	0.85 0.90	0.58 0.65	0.81 0.86	0.61 0.68
	B	Close Open	0.80 0.90	0.52 0.65	0.80 0.90	0.54 0.68
 2600 and 28000 Series	A	Close Open	0.80 0.75	0.51 0.46	0.77 0.72	0.54 0.47
	B	Close Open	0.80	0.51	0.80	0.54
 28000 Series	A B	Open	0.87	0.59	0.93	0.64
 35002 Series	A	Close Open	0.68 0.85	0.35 0.60	0.65 0.80	0.39 0.61
	B	Close Open	0.70 0.88	0.39 0.62	0.70 0.87	0.41 0.65
 36002 Series	A	Open	0.60	0.24	0.55	0.30
 37002 Series	A	Flow in Either Direction	0.65	0.32	0.60	0.35
 39002 Series	A	Flow in Either Direction	0.65	0.33	0.60	0.35
 41000 Series	1½"-16"	Close Open	0.90	0.63	0.86	0.68
	1½"-16" LO-DB*	Close Open	0.94	0.80	0.87	0.74
 72000 Series	A	Open	0.94	0.83	0.90	0.74

(A) Full capacity trim, orifice dia. = 3 valve size.
(B) Reduced capacity trim 50% of (A) and below.
† Refer to Specification Data CH 4500 for additional C_v values.

*See page 8

NOTE $x_T = 0.84C_v$