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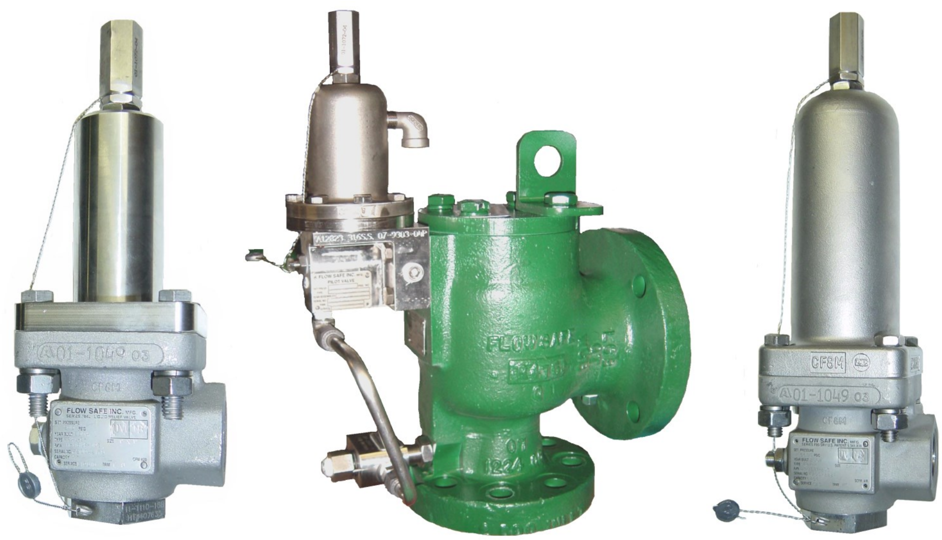

Pressure Relief Valve
Technical Manual

Bulletin# TECK 596 Rev C 0818

"EXPERTS IN SOFT SEAT VALVE TECHNOLOGY"

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1.0 GLOSSARY OF PRESSURE RELIEF VALVE TERMINOLOGY

PRESSURE RELIEF VALVE: An engineered device designed to open with a system pressure upset and then close to prevent further flow of a fluid after normal conditions have been restored.

SAFETY VALVE: A pressure relief valve actuated by inlet static pressure, characterized by rapid opening or pop action.

RELIEF VALVE: A pressure relief valve actuated by inlet static pressure, characterized by opening in proportion to inlet pressure increase.

SAFETY RELIEF VALVE: A pressure relief valve with opening characteristics of a safety valve or relief valve, depending on application.

SET PRESSURE: The measure of opening of a safety relief valve in lb./sq. inch gauge, detectable by sound, sight or touch. Also defined as opening pressure, popping pressure, pop-off pressure or start-to-discharge pressure.

SIMMER: Applied to safety or safety relief valves in compressible fluid service, the audible or visible fluid escape between seat and spindle at an inlet static pressure below popping pressure and at no measurable capacity.

BLOWDOWN: The difference between set pressure and reseat pressure expressed as a percentage of set pressure; i.e., a valve set at 100 psig, reseating at 95 psig has a 5% blowdown.

RESEAT PRESSURE: That pressure at which the safety relief valve closes. Most fixed blowdown style safety relief valves reseat at 30-40% of set pressure, with adjustable blowdown valves reseating at 5-10% of set pressure.

OVERPRESSURE: The percentage of pressure applied to an open PRV measured over and above the set pressure. ASME Code Section VIII safety valves must develop full capacity with overpressure of no more than 10% or 3 psi, whichever is greater.

ACCUMULATION: The pressure increase above maximum allowable working pressure of the vessel during discharge through a relief valve expressed as a percentage of that pressure in psig.

SUPERIMPOSED BACKPRESSURE: As transferred back through the discharge system, the static pressure at the outlet of a PRV at the time the device is required to operate. Also referred to as a secondary pressure source imposed on the outlet of the PRV.

BUILT-UP BACKPRESSURE: Pressure at the outlet caused by flowing forces through that device toward the discharge system.

EFFECTIVE DISCHARGE AREA: Used in flow formulas to determine capacity and is the nominal or computed flow area at the nozzle of a relief valve.

COEFFICIENT OF DISCHARGE: The ratio of the measured relieving capacity of a valve to the theoretical relieving capacity.

MEASURED RELIEVING CAPACITY: Expressed gravimetrically or volumetrically, the relieving capacity of a pressure relief device measured at actual flowing pressure and temperature, or at standard conditions.

COLD DIFFERENTIAL TEST PRESSURE (CDTP): The inlet static pressure at which a relief valve is set to open on the test stand, which includes corrections for service conditions including backpressure and temperature.

CHATTER: Abnormal, uncontrolled, rapid reciprocating movement of the spindle (disk) on the seat of a pressure relief valve.

2.0 TYPES OF PRESSURE RELIEF VALVES

2.1 Conventional Pressure Relief Valve:

A pressure relief valve utilizing spring force as primary control, directly affected by fluctuations in backpressure, commercially available with fixed or adjustable blow-down. Backpressure affects set pressure on a 1:1 ratio.

- Self-draining when mounted vertically.
- Advantageous in handling "dirty" services.
- Cost-effective 1/2 NPT—2 NPT.
- Economical valve selections for typical non-lift applications.
- Commercially available to handle large variety of temperatures and pressures.
- Set pressure affected by backpressure at a 1:1 ratio.
- Seat loading decreases as inlet pressure increases, resulting in simmer before set pressure is reached.

2.2 "Enhanced Performance" Conventional Pressure Relief Valve:

A pressure relief valve utilizing both spring force as a primary control and a pressurized spring chamber to achieve enhanced opening, closing, and lift characteristics. This style, like the Flow Safe F84/F85 Series, is characterized by immediate full lift at set pressure, maintained until reseat.

- Full lift at set point, maintained until reseat.
- Full flowing performance throughout relieving cycle.
- Self-draining when mounted vertically.
- Advantageous in handling "dirty" service.
- Cost-effective 1/4 NPT—2 NPT.
- Commercially available to handle large variety of temperatures and pressures.
- Set pressure affected by superimposed back pressure at a 1:1 ratio.

2.3 Balanced Pressure Relief Valve:

A pressure relief valve incorporating in its design a means of compensating for fluctuations due to backpressure.

- Balanced against the effects of backpressure.
- Most balanced pressure relief valves use bellows. These are expensive to purchase and maintain.
- Flow Safe F88 Series uses internally balanced spindle (disk) with all PTFE seals.

2.4 Pilot Operated Safety Relief Valve (POSRV):

A safety relief valve consisting of a main valve assembly and a controlling pilot valve, combined in one stand-alone unit. Operating characteristics include both snap-action style or modulation style pilots. The main valve seat is held closed or allowed to open by the system pressure itself acting downward on top of the piston, as controlled by the pilot.

- Main valve seat loading force increases with inlet pressure.
- Low profile.
- Provides the user with many advantages of accessories, such as field test connections, backflow preventers, inlet filters, manual or auto unloaders and remote pressure pick-up.
- Modulating pilots provide the operator the ability to operate close to set point which minimizes process upsets and saves product through their zero blowdown characteristic.
- Can be serviced with main valve in place.

2.5 Weight Loaded (Pallet Type) Valve:

A valve utilizing weights in lieu of a spring to establish set pressure. These valves are characterized by requiring 100% overpressure to achieve full lift. This style valve is used often in combined service for both pressure and vacuum applications.

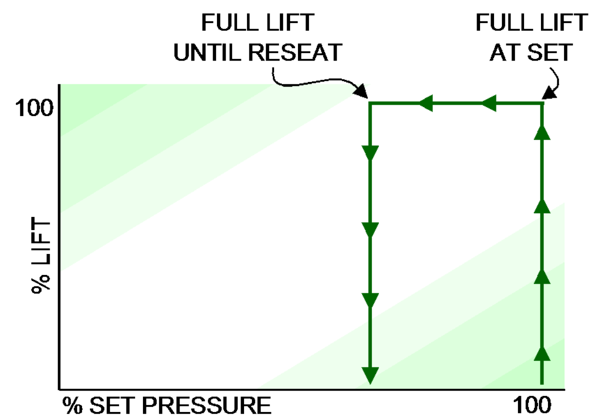
- Set-pressure size-dependent to 15 psig.
- Commercially available to handle large required flow volumes.
- Typically, main valve seats tight to 70% of nameplate set pressure.
- Require extensive overpressure to achieve full lift (100%).
- Long simmer period before opening. Seat subject to freezing with cryogenic temperatures and humid atmospheres.

3.0 FLOW SAFE ENHANCED PERFORMANCE VS. CONVENTIONAL LIFT CHARACTERISTICS

3.1 Flow Safe F84/F85 SRV or Snap Action-Style Pilot Operated SRV's

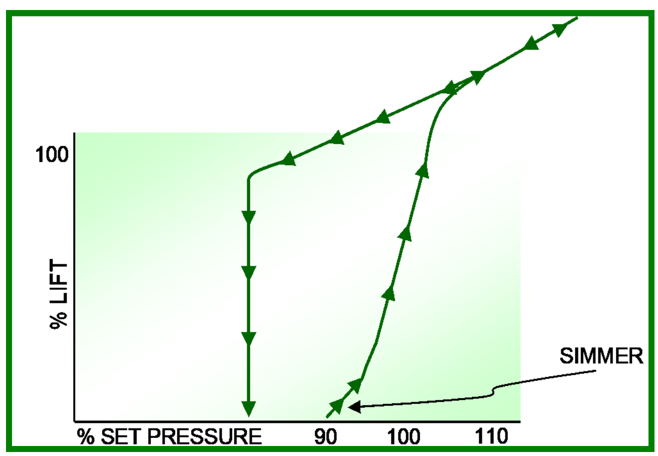
The Flow Safe F84/F85 goes into 100% full lift at set pressure. The valve stays at full lift until the reseat point. This is the same characteristic of snap-action POSRV'S.

- Value-added allowing user to operate close to valve nameplate set pressure.
- Provides full capacity relief throughout the flowing cycle.
- Strong closing force at reseat providing bubble-tight reseating.



3.2 Conventional SRV

Typical conventional style balanced or unbalanced SRV's crack at approximately 90% of set (simmer) then advance to full lift at 100% of set (10% overpressure). These style valves move towards reseat on a similar downward proportion. Because a pressurized spring chamber is not incorporated, an inverse relationship exists between set and blowdown, i.e., the stronger the set, the weaker (longer) blowdown and vice versa. A fixed blowdown valve will not have this interface, but will typically have long blowdown (30-40%).



4.0 POP ACTION AND MODULATING ACTION

There are two kinds of valve opening characteristics. They are explained as follows:

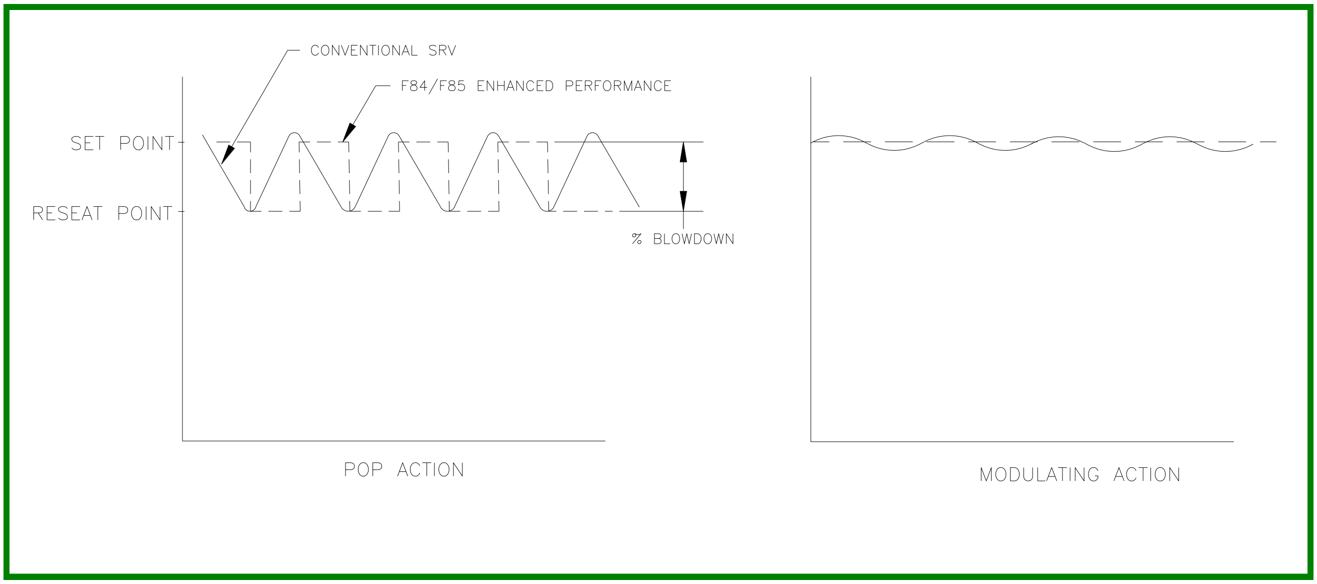
4.1 Modulating Action:

This differs from pop action in that the SRV tends to open slowly, behaving like a backpressure regulator or control valve. Do **not** confuse this with direct spring operated relief valves, such as the Flow Safe Type F84L, which exhibit, at very low flow rate, gradual opening behavior when applied in liquid service.

4.2 Pop Action (Sometimes called "Snap Action"):

This is a rapid opening of the valve. It does not necessarily mean that the valve goes into full lift at set pressure and, in fact, most direct spring operated SRV's require overpressure to attain full lift. An exception to this is the Flow Safe F84/F85 series, and F7000/8000 with snap-acting pilot, which do go into full lift at set pressure. Pop action SRV's are intended for compressible fluids (gases, vapors, and steam).

When referring to pop action in the Flow Safe F84/F85 or F7000/8000 Series, we mean full opening at set. Because the reseat point of pop action type SRV's is below set pressure, the valve must discharge some amount of gas or vapor in order for pressure to be reduced to the reclosing pressure. This means that when a pop action valve opens due to system pressure upset, it must flow an amount based on the magnitude of the upset plus an additional amount due to system volume. For this reason, it is desirable to keep blowdown as short as possible.



5.0 CODE REQUIREMENTS

5.1 Background

The need for valves with an ASME Stamp is driven by regulators, insurance companies, and states or municipalities who adopt the Code and require compliance before a building permit or insurance is issued. Woe to the user whose valve has no stamp and is the unhappy target of contingency motivated lawyers! Therefore, around the world most applicable valves do bear the ASME Stamp. Of course, there are applications like gas distribution where other codes such as DOT are applicable and ASME is not required. In Europe, Pressure Equipment Directive 97/23/EC became mandatory in 2002 and has since been superseded by Directive 2014/68/EU.

5.2 Design and Applications

In Section VIII paragraphs **UG-125** thru **UG-136**, the code provides users and valve designers guidelines for design, material selection, application, and certification procedures. Both mandatory rules and non-mandatory appendices give the user guidance for installation.

UG-125 addresses the general need for PRV's and their application.

UG-126(a) Requires that PRV's be of the direct spring loaded type; (b) allows POSRV's if the main valve flows fully open should an essential part of the pilot fail.

Section UG-126(c) provides set pressure tolerances, while UG-125 (c) and UG-134 describe allowable pressure setting and overpressure limits for pressure relief valve installations. Refer to Figures 5.1 and 5.2 for examples of valve settings and basic operational parameters.

UG-129 provides specific requirements for nameplates. The nameplate must include the manufacturer and assembler (if applicable), the valve type, size, set pressure, certified capacity, year built or other code to allow for traceability, and certification mark (ASME Code symbol stamp with UV designator, in the case of ASME Sec. VIII).

5.3 Code Stamping

UG-130 is very important and requires that each valve to which the code symbol is attached shall have been fabricated or assembled by a manufacturer or assembler holding a valid certificate of authorization and capacity certified in accordance with the requirements of this division. This paragraph is your security blanket but surely does not mean that all valves bearing the ASME Stamp are created or perform equally in all applications.

5.4 Valve Certification

UG-131 spells out several methods of capacity certification. For the valve manufacturer all are important but most valves are certified by the coefficient of discharge (K_d) method. Nine valves are required, three each of three sizes at three set pressures. In practice, we coordinate selection of the sizes manufactured for certification with the NB to cover the widest range of sizes and set pressures compatible with the test facility to be used. Test facilities are rather limited relative to large valves at high pressure. Testing records set pressure, reseat pressure, and capacity at 10% overpressure. Coefficients of discharge K_d (Actual Flow divided by Theoretical Flow) for the nine valves are averaged and all coefficients must be within +/- 5% of the average. The average coefficient K_d is then assigned provisionally to the manufacturer for further confirmation of production valve capacity per UG-136(c)(3). For capacity calculations, this coefficient K_d is multiplied by 0.90 and the coefficient K of the design shall not be greater than 0.878 (i.e., the product of 0.9 x 0.975) [(UG-131(e)(2)].

5.5 Valve Mechanical Characteristics

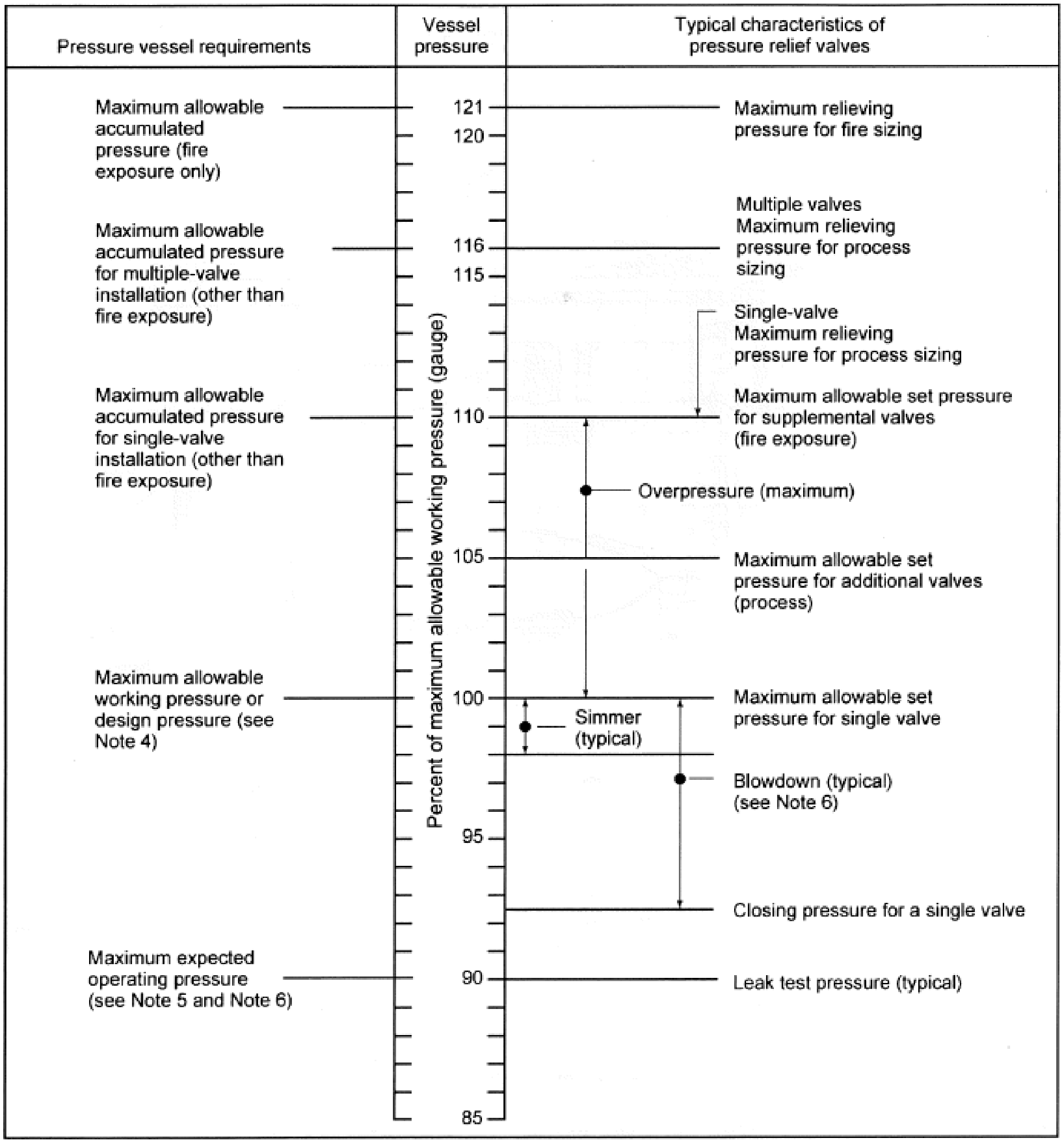
UG-136 addresses minimum requirements for PRV's and requires proper guidance for consistent operation, sets limits on spring compression, and further requires that lift levers be available for steam, air, or water over 140°F and they be functional when pressure under the valve is 75% of set pressure.

Other requirements of this paragraph include wrench flats on screwed valves, means for sealing initial adjustments such as set pressure and blowdown, means for draining the disc, that materials for bodies, bonnets, yokes, and pressure-retaining bolting be listed in Sections II and VIII and that other materials be listed in Section II, ASTM or be controlled by the manufacturer.

5.6 Production Testing

UG-136(c) and **(d)** define specific requirements for manufacturing, production, testing, and inspection, and mandate periodic 6-year retesting of production valves. This testing is a check that manufactured valves continue to meet certified capacities.

Figure 5.1: ASME VIII RELIEF VALVE SETTINGS



NOTE 1 This figure conforms with the requirements of Section VIII of the *ASME Boiler and Pressure Vessel Code for MAWPs* greater than 30 psig.

NOTE 2 The pressure conditions shown are for pressure relief valves installed on a pressure vessel.

NOTE 3 Allowable set-pressure tolerances will be in accordance with the applicable codes.

NOTE 4 The maximum allowable working pressure is equal to or greater than the design pressure for a coincident design temperature.

NOTE 5 The operating pressure may be higher or lower than 90%.

NOTE 6 Section VIII, Division 1, Appendix M of the *ASME Code* should be referred to for guidance on blowdown and pressure differentials.

Ref: API 520, Part I, 9th Ed., July 2014

5.7 Installation Recommendations

UG-135(b) The pressure drop through the inlet piping should not reduce the valve relieving capacity below the required value or adversely affect pressure relief valve operation.

Appendix M: Inlet piping pressure losses to the pressure relief valve should not exceed 3%.

UG-135(d) The use of intervening block valves between the vessel and the relief device, or between the relief device and point of discharge, is permitted only under the following conditions:

A. Block valves are constructed or positively controlled so that when the maximum number of valves are closed at one time, the relieving capacity provided by the unaffected relieving devices is not reduced below the required relieving capacity or

B. Block valves are set up in accordance with conditions described in Appendix M:

   Block valves are allowed for the purpose of inspection and repair, or other special conditions. The valve should be a full-area design. It should have a full round port area and be equal to or greater than the pressure relief valve inlet. The valve should be locked in the full open position, and should not be closed except by an authorized person. When the valve is closed during any period of the vessel's operation, an authorized person should remain stationed at the block valve.

5.8 Pressure Relief Valve Set Pressure vs. Operating Pressure

System design must consider the differential between the set pressure of the pressure relief valve and the vessel operating pressure. The blowdown characteristic is essential to proper selection of a compatible valve and operating margin. After a release of pressure, the valve must be capable of closing above the normal operating pressure.

ASME Section VIII, Div. 1, Appendix M, offers the following recommendations for pressure differential:

A. **Set pressures up to 70 psig (4.83 barg)**

   The minimum differential is 5 psi (0.34 bar).

B. **Set pressures from 71-1000 psig (4.9-69 barg)**

   The minimum differential is 10%.

C. **Set pressures above 1000 psig (69 barg)**

   The minimum differential is 7%.

   Please note that the user can optimize system pressure by utilizing Flow Safe pressure relief valves, thus being able to operate at system pressures greater than 90% of set pressure because of premium soft-seat designs.

Figure 5.2: ASME CODE SECTION COMPARISON OF PRESSURE RELIEF VALVE REQUIREMENTS

Code Section	Set Pressure (psig)	Set Pressure Tolerance	Blowdown (Min.)	Overpressure (Max.)
POWER BOILER SECTION I, Certification Mark "ASME / V"	SECTION I			
	15-70	± 2 psi	2 psi	3%
	71-100	± 3%	2 psi	3%
	101-300	± 3%	2%	3%
	301-1000	± 10 psi	2%	3%
	> 1000	± 1%	2%	3%
HEATING BOILER SECTION IV, Certification Mark "ASME / HV"	15 PSIG STEAM			
	15	± 2 psi	2-4 psi	5 psi
	HOT WATER			
	15-60	± 3 psi	NA	10%
	61-160	± 5%	NA	10%
PRESSURE VESSEL SECTION VIII, Certification Mark "ASME / UV"	15-30	± 2 psi	NA	3 psi
	31-70	± 2 psi	NA	10%
	> 70	± 3%	NA	10%

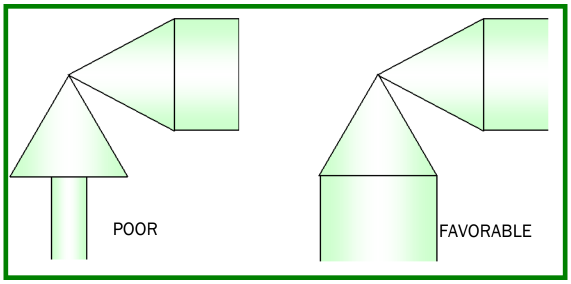
6.0 GENERAL PRV INSTALLATION AND PIPING RECOMMENDATIONS

A pressure relief valve is installed to protect the user's personnel and equipment. Installing a pressure relief valve without regard for the surrounding piping does not necessarily mean the above has been accomplished.

The PRV must be properly sized and selected for the intended application and installed properly.

The following provides some guidelines:

A. Make sure inlet and discharge piping is large enough! If piping is too small, either inlet pressure loss and/or built up backpressure will cause the PRV to chatter or cycle excessively and will reduce purchased capacity. ASME Section VIII recommends no more than a 3% pressure drop between the vessel being protected and the PRV.



B. Keep PRV's as close to the pressure source as possible. Avoid long lengths of piping and elbows.

   Note: An elbow is equivalent to a L/D of 8 or higher in terms of frictional losses.

C. Make sure PRV is not oversized. An oversized valve is the same as undersized inlet piping—You may have a chatter problem. An oversized valve wastes money and will cycle more frequently.

D. Avoid incorrect flange gaskets at PRV inlet or outlet. They may create a restriction.

E. If using block valves, use a full-bore device with a locking mechanism. Also see Section 5.7.

F. When redundant PRV's are used (one for backup), avoid tees. If possible, use individual inlets or a selector valve designed for twin PRV installations.

G. Make sure discharge piping is vented or drained to avoid moisture build-up at outlet. Water may freeze at lower temperatures.

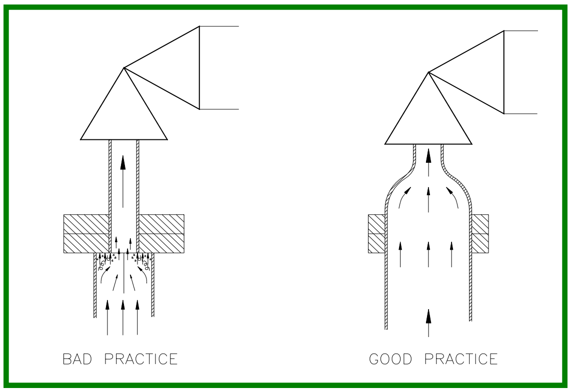
H. If two or more PRV's are utilized for capacity requirements, set the first PRV at no more than MAWP and stagger the remaining at a set pressure 5% higher (also see Fig. 5.1). This allows for conservation of product in the event of a minor overpressure occurrence and minimizes interaction.

I. Mount PRV's in the vertical position whenever possible. Both API 520 and ASME VIII suggest that the valve be installed vertically.

J. Make sure PRV's are properly braced to protect against discharge thrust.

K. Avoid the use of reducing flanges at PRV inlet and outlets. If possible, use concentric reducers. If not possible, increase piping diameter.

L. The valve orifice should **never** be larger than the inlet piping. Otherwise, the flow capacity is controlled by the pipe bore, not the relief valve orifice as it should be.



SUMMARY

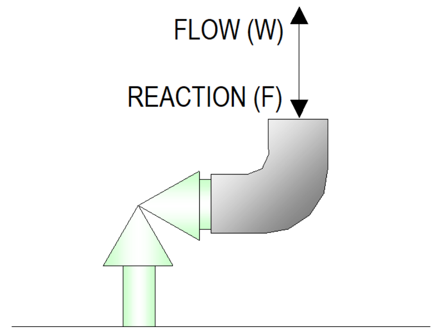
1. Keep piping **large**.
2. Avoid long runs of pipe.
3. Minimize the number of turns.
4. Minimize inlet loss at pipe junctions by use of reducers or special fittings.

   Remember, if you must use piping with turns and long runs, keep piping large, especially at PRV inlets, to minimize pressure drop.

7.0 INSTALLATION GUIDELINES IN CONSIDERATION OF DISCHARGE THRUST ON PRV'S

7.1 Piping to and from PRV's is critical to the proper functioning of the PRV and safety of the installation. When possible, keep PRV located as close to the vessel or pipeline as possible. A long inlet run of pipe may require pipe bracing, especially if handling high pressure. A PRV exhausting at a direct right angle will provide for a worst-case bending stress at the valve inlet.

The API RP 520 formula for reaction force (for vertical discharge of gases and vapors):



$$F = \frac{W}{366}\sqrt{\frac{kT}{(k+1)M}} + (AP)$$

Where:

F = Reaction force at the point of discharge to the atmosphere, lbf

W = Flow of any gas or vapor, lbm/hr

k = Ratio of specific heats (C_p/C_v) at the outlet conditions

C_p = Specific heat at constant pressure

C_v = Specific heat at constant volume

T = Temperature at the outlet, °R

M = Molecular weight of the process fluid

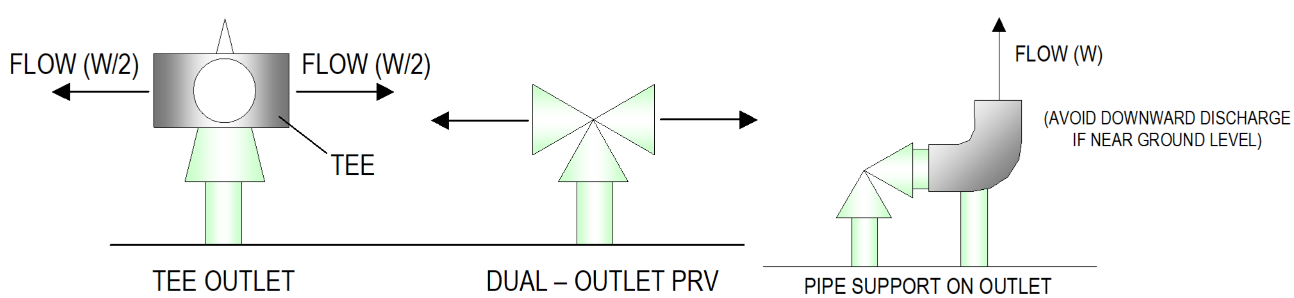
A = Area of the outlet at the point of discharge, in^2

P = Static pressure within the outlet at the point of discharge, psig

A non-scientific but approximate calculation:
Exhaust Thrust = Set Pressure x Orifice Area

7.2 Some concepts to minimize inlet bending stress at PRV inlets using tail pipe configurations and/or bracing are shown below. (Note: An outlet tee may cause unacceptably high backpressure.)

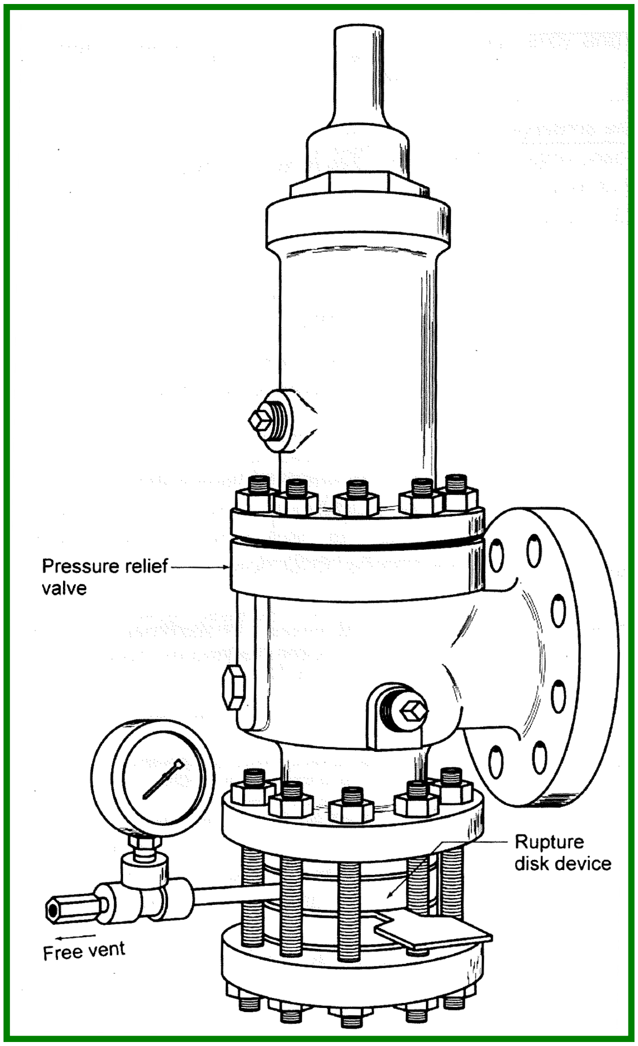
7.3 Pressure relief valves that relieve under steady-state flow conditions into a closed system usually do not create large forces and bending moments on the exhaust system. Only at points of sudden expansion will there be any significant reaction forces to be calculated. Closed-discharge systems, however, do not lend themselves to simplified analytic techniques. A complex time-history analysis of the piping system may be required to obtain the true values of the reaction forces and associated moments.



METHODS TO MINIMIZE THE EFFECT OF VALVE THRUST

8.0 PRESSURE RELIEF VALVES AND RUPTURE DISKS IN SERIES

Oftentimes when sealing with corrosive conditions and/or fugitive emissions, PRV's are used in conjunction with rupture disks. When used together, and pressure higher than atmospheric (superimposed back pressure) between devices can cause the rupture disk not to fail at the appropriate pressure. For example, if both rupture disks and PRV's are set at 100 psig with backpressure of 10 psig, the disk won't fail until the system pressure reaches 110 psig.



The following are guidelines with reference to ASME Section VIII, Division 1:

UG-127(a)(3), to be considered when using a rupture disk at the PRV inlet.

1. The relief valve capacity must be derated by 10%, or the combination of relief valve and rupture disk must be capacity-certified per ASME VIII UG-132.

2. The rupture disk and relief valve combination must deliver adequate capacity per code requirements.

3. A free vent or excess flow valve with a pressure gauge or telltale indicator must be installed to sense/relieve backpressure (see diagram).

For discharge (PRV outlet side), rupture disk may also be used for corrosive protection. In general, the burst pressure on this rupture disk should be as low as possible. The space between the PRV and disk must be vented if operation of the PRV may be affected. Also, downstream piping should not be obstructed by the disk or fragments. If the PRV is exhausting into a common discharge header, however, the disk should be selected accordingly.

9.0 PRESSURE RELIEF VALVE SIZING (GASES & VAPORS)

Ref.: API 520, Part I, 9th Ed., July 2014

Described below are criteria and equations used to calculate the flow capacities of pressure relief valves on gas or vapor. Equations are based on API 520 Part I. Capacities for air and natural gas at various set pressures are tabulated on Page 17 for easy reference.

To size a relief valve for gas or vapor service, the following information is required:

- Required flow capacity
- Required set pressure
- Backpressure (pressure at valve outlet)
- Acceptable overpressure [10% or 3 psi per ASME Sec. VIII, or 5% per DOT installation practices]
- Operating pressure, to assure that it is below valve reseat pressure
- Gas properties, including molecular weight, specific heat ratio or gas constant, and compressibility factor

To select the required orifice size for a gas or vapor application, the below equations should be used. Depending on the gas, critical flow generally exists at pressures above 11 to 12 psig with zero backpressure, or at higher pressures where backpressure is less than approximately 50% of inlet pressure. If backpressure is less than or equal to P_{cf} in the following equation, critical flow will occur:

$$P_{cf} = P_1 \left[\frac{2}{k+1} \right]^{\frac{k}{k-1}}$$

Critical Flow

In US customary units:

$$A = \frac{V\sqrt{MTZ}}{6.32CK_dP_1K_bK_c}$$

- OR -

$$A = \frac{W}{CK_dP_1K_bK_c}\sqrt{\frac{TZ}{M}}$$

In SI units:

$$A = \frac{2.676V\sqrt{MTZ}}{CK_dP_1K_bK_c}$$

- OR -

$$A = \frac{W}{CK_dP_1K_bK_c}\sqrt{\frac{TZ}{M}}$$

Subcritical Flow

In US customary units:

$$A = \frac{V}{4645F_2K_dK_c}\sqrt{\frac{MTZ}{P_1(P_1-P_2)}}$$

- OR -

$$A = \frac{W}{735F_2K_dK_c}\sqrt{\frac{TZ}{MP_1(P_1-P_2)}}$$

In SI units:

$$A = \frac{47.95V}{F_2K_dK_c}\sqrt{\frac{MTZ}{P_1(P_1-P_2)}}$$

- OR -

$$A = \frac{17.9W}{F_2K_dK_c}\sqrt{\frac{TZ}{MP_1(P_1-P_2)}}$$

A	=	Required discharge orifice area, in^2 or mm^2
V	=	Required flow rate, scfm or Nm^3/min
W	=	Required flow rate, lb/hr or kg/hr
K_d	=	Certified (derated) discharge coefficient
C	=	Gas constant, dependent on specific heat ratio $k = C_p/C_v$ (See Fig. 9.1)
P_1	=	Relieving pressure (set pressure plus overpressure plus atmospheric pressure), psia or kPaa
P_2	=	Backpressure, psia or kPaa
P_a	=	Inlet pressure + accumulation, psig
K_b	=	Backpressure correction factor, for balanced bellows valves only (otherwise, use 1.0)
K_c	=	Rupture disk correction factor: 1.0 with no disk; 0.9 with disk in combination
M	=	Molecular weight at inlet relieving Conditions (See Fig. 9.1)
T	=	Relieving temperature, °R (°F + 460) or °K (°C + 273)
Z	=	Compressibility factor at inlet relieving conditions, 1.0 if unknown
F_2	=	Coefficient of subcritical flow (See Fig. 9.2)
k	=	Specific heat ratio, C_p/C_v (See Fig. 9.1)
P_{cf}	=	Critical flow nozzle pressure

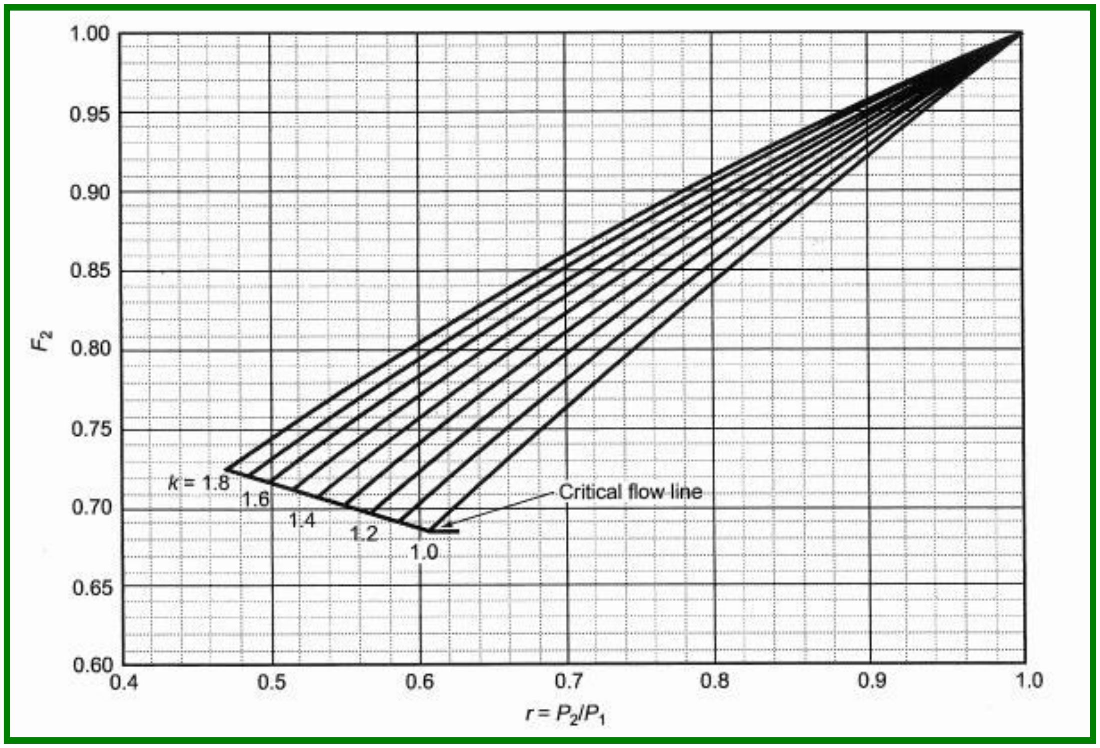
FLOWSAFE

Figure 9.1: Molecular Weights and Gas Constants for Various Gases & Gas Constants as a Function of Specific Heat Ratio

Gas	Mol.Wt.	Cp/Cv	C (US)	C (SI)
Acetylene	26	1.28	345	0.0262
Air	29	1.40	356	0.0270
Ammonia	17	1.30	347	0.0263
Argon	40	1.66	377	0.0286
Benzene	78	1.12	329	0.0250
Carbon Disulfide	76	1.21	338	0.0257
Carbon Dioxide	44	1.29	346	0.0263
Carbon Monoxide	28	1.40	356	0.0270
Chlorine	71	1.36	353	0.0268
Cyclohexane	84	1.08	325	0.0246
Ethylene	28	1.24	341	0.0259
Freon 22	86	1.16	333	0.0253
Helium	4	1.66	377	0.0286
Hexane	86	1.06	322	0.0245
Hydrochloric Acid	36.5	1.40	356	0.0270
Hydrogen	2	1.41	357	0.0271
Hydrogen Sulfide	34	1.32	349	0.0265
Iso-Butane	58	1.10	327	0.0248
Methane	16	1.31	348	0.0264
Methyl Alcohol	32	1.20	337	0.0256
Methyl Chloride	50.5	1.20	337	0.0256
N-Butane	58	1.09	326	0.0247
Natural Gas (0.6)	19	1.27	344	0.0261
Nitrogen	28	1.40	356	0.0270
Oxygen	32	1.40	356	0.0270
Pentane	72	1.08	325	0.0246
Propane	44	1.13	330	0.0251
Sulphur Dioxide	64	1.27	344	0.0261

Specific Heat Ratio (Cp/Cv)	C (US)	C (SI)	Specific Heat Ratio (Cp/Cv)	C (US))	C (SI)
1.00	315	0.0239	1.52	366	0.0278
1.02	318	0.0241	1.54	368	0.0279
1.04	320	0.0243	1.56	369	0.0280
1.06	322	0.0245	1.58	371	0.0282
1.08	325	0.0246	1.60	373	0.0283
1.10	327	0.0248	1.62	374	0.0284
1.12	329	0.0250	1.64	376	0.0285
1.14	331	0.0251	1.66	377	0.0286
1.16	333	0.0253	1.68	379	0.0287
1.18	335	0.0254	1.70	380	0.0289
1.20	337	0.0256	1.72	382	0.0290
1.22	339	0.0258	1.74	383	0.0291
1.24	341	0.0259	1.76	384	0.0292
1.26	343	0.0261	1.78	386	0.0293
1.28	345	0.0262	1.80	387	0.0294
1.30	347	0.0263	1.82	389	0.0295
1.32	349	0.0265	1.84	390	0.0296
1.34	351	0.0266	1.86	391	0.0297
1.36	353	0.0268	1.88	393	0.0298
1.38	354	0.0269	1.90	394	0.0299
1.40	356	0.0270	1.92	395	0.0300
1.42	358	0.0272	1.94	397	0.0301
1.44	360	0.0273	1.96	398	0.0302
1.46	361	0.0274	1.98	399	0.0303
1.48	363	0.0276	2.00	400	0.0304
1.50	365	0.0277			

Figure 9.2: Values of F_2 for Subcritical Flow (for equations on p. 14)



10.0 BACKPRESSURE CONSIDERATIONS FOR PRV'S

10.1 General Discussion

When backpressure exists in the outlet of a relief valve, caused by either superimposed or built-up pressure during a discharge, the effects on set pressure and backflow must also be considered. See the glossary for the definitions of superimposed and built-up backpressure.

If the relief valve is unbalanced, superimposed backpressure will increase the set pressure on a one-to-one psig ratio. Built-up backpressure will not affect the set pressure. For example, a relief valve set at 150 psig with 43 psig superimposed backpressure will lift at 193 psig (ASME nameplate requirements provide for set pressure correction due to backpressure).

Also, on some manufacturer's valves (not Flow Safe's F7000 Series), excessive backpressure may cause the valve to partially close, further reducing the capacity. This is particularly true on bellows-style valves.

Backpressure in excess of the inlet system pressure may cause the valve to open unless there are design features in the valve that can compensate for this, i.e., backflow preventer, split piston, etc.

All discharge flanges and associated piping and fittings must be able to withstand these backpressures and the associated loads (forces and moments).

To roughly estimate the built-up backpressure (P_2), multiply the ratio of the inlet area (A_1) / outlet area (A_2) times the inlet pressure (P_1): $P_2 = P_1 \times A_1 / A_2$. See example below.

This is a very rough estimate and does not take into account the specific fluid properties at pressure, or pressure losses due to the discharge piping arrangement. It is also less accurate at higher pressures. See Sec. 10.2 for a more detailed method for determining backpressure.

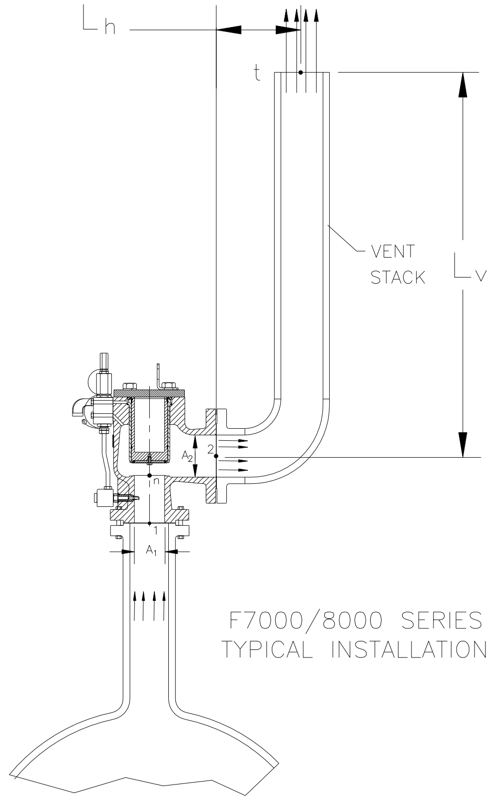
Example: Backpressure at valve outlet

2 x 3 PRV, 2.95 sq.in. nozzle, set at 150 psig,
10% Overpressure, Air (k = 1.40)

Backpressure (P_2) = P_1 x 2" Inlet Area/3" Outlet Area
= (1.10 x 150 + 14.7) x 2.95 / 7.40
= 72 psia (57 psig)

10.2 Determination of Backpressure on PRV's

To more accurately determine the built-up backpressure and its effects at discharge, the methods described by R.W. Zappe in Valve Selection Handbook, 3rd Edition, Gulf Publishing Co., are recommended. The significant equations under sonic flow conditions are listed below. Equations under subsonic conditions can also be found in this book.



Terminal Pressure, Point 't' (Pt) (psia):

$$P_t = K_d \times K_b \times A_n / A_t \times P_1 \times (2 / (k + 1))^{(k/(k-1))} (1/Z)^{1/2}$$

K_d = Flow coefficient

K_b = Backpressure coefficient

A_n = Area at nozzle bore (in^2)

A_t = Area at Point t (in^2)

Z = Compressibility factor

k = Ratio of specific heats (C_p/C_v)

P_1 = Inlet pressure (psia) = P_{set} + Overpressure + P_{atm}

Pressure at Valve Discharge, Point 2 (P_2) (psia):

$$P_2 = [P_t^2 + (2\ln (P_2 / P_t) + \sum(r) + fL / d_t) \times (K_d \times K_b \times A_n \times P_1 / A_t)^2 \times (k / Z) \times (2 / (k + 1))^{2k/(k-1)}]^{1/2}$$

P_{set} = Set pressure (psig)

P_{atm} = Atmospheric pressure (psia) (14.7, if unknown)

P_2 = Pressure at valve outlet (psia)

$\sum(r)$ = Sum of resistance coefficients

f = Pipe friction factor

L = Length of pipe (inches) = $L_h + L_v$; d_t = internal diameter at pipe outlet, point 't'

Note: If no vent stack attached, $P_2 = P_t$

Example:

PRV, size 2 x 3, 2.95 sq.in. nozzle, set at 150 psig, 10% OP

With 1-1/2 ft. horizontal x 6 ft. vertical vent stack (3" Sch.40), Air (k=1.40, Z=1.0)

P_t = $.915 \times 1.0 \times 2.95/7.40 \times (1.1 \times 150 + 14.7) \times (2/(1.4 + 1))^{1.4/(1.4-1)} (1/1.0)^{1/2}$ = 34.6 psia

f = 0.19, $\sum(r)$ = 0.35 (elbow) [Ref.: Crane Technical Paper No. 410, Flow of Fluids, A-24 thru A-31]

P_2 = $[34.6^2 + (2l_n(P_2/34.6) + 0.35 + (.019)(18" + 72")/3.07) \times (.915 \times 1.0 \times 2.95 \times 179.7/7.40)^2 \times (1.4/1.0) \times (2/(1.4 + 1))^{2.8/.4}]^{1/2}$

= 71.9 psia (57.2 psig)

This result compares fairly closely with the example on page 16.

11.0 PRESSURE RELIEF VALVE SIZING (LIQUIDS)

The ASME Boiler & Pressure Vessel Code, Section VIII, requires that capacity certification be obtained for pressure relief valves designed for liquid service. Certification tests include determination of the rated coefficient of discharge for the PRVs at an overpressure of 10% or 3 psi, whichever is greater.

To size a liquid service relief valve, the following information is required:

- Required flow capacity
- Required set pressure
- Backpressure (pressure at valve outlet)
- Acceptable overpressure (10% or 3 psi max.)
- Operating pressure, to assure that it is below valve reseat pressure
- Fluid properties, including viscosity and specific gravity

To select the required orifice size for a liquid application, the following equations should be used:

In US customary units:

$$A = \frac{Q}{38 K_d K_w K_c K_v} \sqrt{\frac{G}{P_1 - P_2}}$$

In SI units:

$$A = \frac{11.78\,Q}{K_d K_w K_c K_v} \sqrt{\frac{G}{P_1 - P_2}}$$

For viscous liquid service, determine preliminary orifice area A using 1.0 for K_v in the above equations. Then select the next larger available orifice area for determining Reynolds number (Re) below. Using Re, determine K_v from Fig. 11.1 for final calculation of A.

In US customary units:

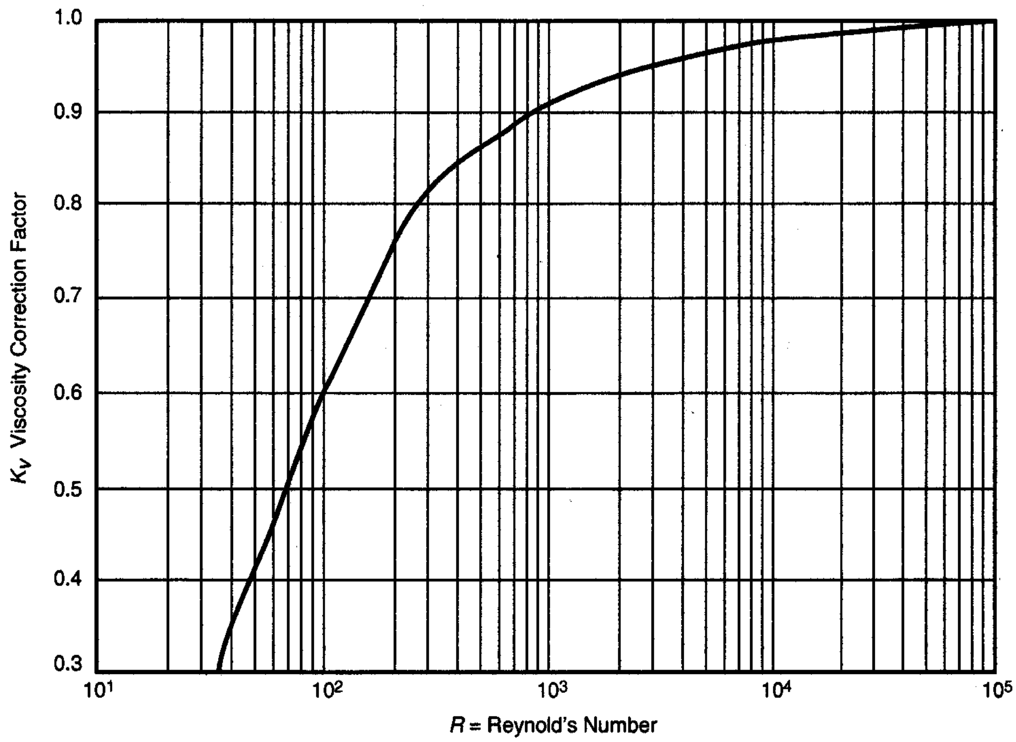
$$Re = \frac{Q(2800G)}{\mu\sqrt{A}} \quad \text{or} \quad Re = \frac{12{,}700Q}{U\sqrt{A}}$$

In SI units:

$$Re = \frac{Q(18{,}800G)}{\mu\sqrt{A}} \quad \text{or} \quad Re = \frac{85{,}220Q}{U\sqrt{A}}$$

A	=	Required discharge orifice area, in^2 or mm^2
Q	=	Required flow rate, US gpm or liters/min
K_d	=	Rated ASME discharge coefficient
K_w	=	Backpressure correction factor, for balanced bellows valves only (otherwise, use 1.0)
K_c	=	Rupture disk correction factor: 1.0 with no disk; 0.9 with disk in combination
K_v	=	Viscosity correction factor (from Fig. 11.1)
G	=	Specific gravity (water = 1.0 at standard conditions)
P_1	=	Inlet pressure (including overpressure), psig or kPag
P_2	=	Total backpressure, psig or kPag
Re	=	Reynolds number
μ	=	Absolute viscosity at flowing temperature, centipoise (cP)
U	=	Kinematic viscosity at flowing temperature, Saybolt universal seconds (SUS or SSU)

Figure 11.1: Viscosity Correction Factor (for equations on p. 18)



12.0 THERMAL RELIEF VALVES

Whenever a closed section of piping filled with liquid is exposed to warming by the sun or ambient temperature rise, the liquid expands, creating a very slow but substantial increase in internal pressure. This temperature increase may also be seen in the cold side of a heat exchanger that is blocked in, where flow in the hot side continues. If the additional pressure is not relieved, vessel or piping rupture or yielding can occur. Fortunately, very little liquid normally needs to be relieved, so a very small relief valve, called a "thermal relief," is used.

Formulas for computing flow rates for thermal relief can be found in API RP521, if a heat transfer rate is known for the system or vessel subjected to the heat absorption. When such information is not available, thermal relief applications can easily be handled with a 1/2" or 3/4" valve (a -4 orifice) in most cases.

As required for ASME Code applications, a liquid relief valve should normally be selected for use where the fluid being relieved is primarily in the liquid state. Fluids that flash to vapor may be handled by a relief valve intended for gas or vapor service.

13.0 RELIEF VALVE SIZING FOR VESSELS EXPOSED TO FIRE

Substantial vapor generation can occur if a liquid-filled vessel is exposed to an external fire. The amount of heat absorbed by the vessel depends on the type of fuel feeding the fire, the extent of flames around the vessel, and any installed insulation.

Sizing methods and equations found in API RP521 can be used to calculate the required relief load (capacity) generated from the heat absorption. This capacity can then be used in the standard sizing equations in Section 9.1 to derive the necessary relief valve orifice area.

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