BASICS OF RELIEF VALVES

Types of Relieving Devices

Pressure Relief Valve - A pressure relief device designed to re-close and prevent the further flow of fluid after normal conditions have been restored.

- **Safety Valve** - An automatic pressure relieving device actuated by the static pressure upstream of the valve, and characterized by rapid full opening or pop action. It is used for steam, gas or vapor service
- **Relief Valve** - An automatic pressure relieving device actuated by the static pressure upstream of the valve, opening in direct proportion to the pressure increase. It is used primarily for liquid service.
- **Safety Relief Valve** - An automatic pressure relieving device suitable for use as either a safety or relief valve, depending on application.
- **Conventional Safety Relief Valve** - A safety relief valve having its spring housing vented to the discharge side and which is directly affected by fluctuations in backpressure.
- **Balanced-Bellows Safety Relief Valve** - A safety relief valve incorporation in its design a means of compensation for fluctuations due to backpressure.
- **Pilot Operated Pressure Relief Valve** - A pressure relief valve in which the major relieving valve is combined with and is controlled by a self-actuated auxiliary pressure relief valve.

Temperature Relief Valve (P&T) - A pressure relief valve which may be actuated by external or internal temperature or by pressure o the inlet side.

Rupture Disc - A nonre-closing pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure containing disc.

Breaking Pin Device - A nonre-closing pressure relief device actuated by inlet static pressure and designed to function by the breakage of a load-carrying section of a pin which supports a pressure containing member.

Parts

Nozzle - The pressure containing element which constitutes the inlet flow passage and includes the fixed portion of the seat closure. The nozzle can be of two designs: Full-nozzle or Semi-nozzle.

- **Full Nozzle** - a single member extending from the face of the inlet flange to the valve seat.
- **Semi-Nozzle** - the lower part of the inlet throat is formed by the body casting and the upper part is valve seat threaded or welded into the valve body

Disc - The pressure containing movable element of a pressure relief valve which effects closure.

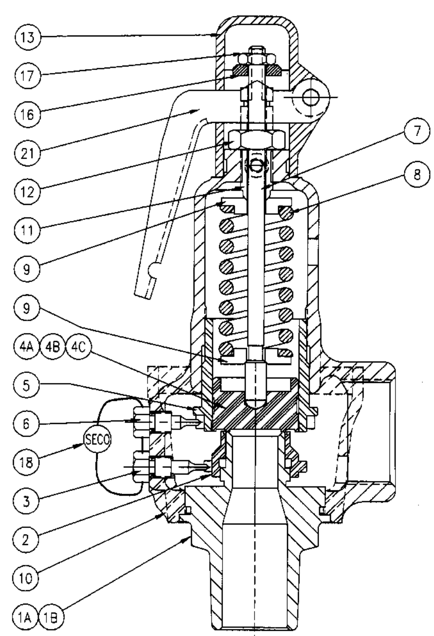
Trim - Internal parts. Specifically the seat (nozzle) & disc.

Orifice - A computed area of flow for use in flow formulas to determine the capacity of a pressure relief valve.

Huddling Chamber - The annular pressure chamber located beyond the valve seat for the purpose of generating a popping characteristic.

Lifting Device (Lever) - A device to manually open a pressure relief valve by the application of external force to lessen the spring loading which holds the valve closed. Lifting devices can be an open lever or a packed lever (fully enclosed design).

Balanced Bellows - A bellows designed so that the effective area of the bellow is equivalent to that of the valve seat, thereby canceling out the additive effect of the backpressure. Balanced bellows are used for the following reasons: Backpressure is excessive or variable, fluid is highly viscous or slurry, or the fluid is corrosive to the upper works of the valve.



BASICS OF RELIEF VALVES, CONT'D.

Operational Characteristics

Rated Capacity - The measured flow at an authorized percent overpressure permitted by the applicable code. Rated capacity is generally expressed in lbs/hr for Steam, SCFM for gases and GPM for liquids.

Operating Pressure - The pressure to which the vessel is usually subjected in normal service.

Set Pressure - The inlet pressure at which the valve is adjusted to open under service conditions. On a relief valve (liquid service), this is considered the point at which the first continuous stream of water starts to discharge and runs vertically down from the outlet of the valve. On a safety valve (Steam, air or gas) it is the inlet pressure at which the valve "pops" (not the point of first audible simmer or warning).

Cold Differential Test Pressure (CDTP) - The inlet static pressure at which a pressure relief valve is adjusted to open on the test stand. This test pressure includes corrections for service conditions of backpressure and/or temperature.

Simmer (Warn/Pre-Open) - The audible or visible escape of fluid between the seat and disc at an inlet static pressure below set pressure and at no measurable capacity. All pressure relief valves will have some simmer. Typically a metal seated valve will simmer at 90% of the set pressure and a soft seated valve will simmer at 95% of the set pressure.

Coefficient of Discharge - The ratio of the measured relieving capacity to the theoretical relieving capacity.

Maximum Allowable Working Pressure (MAWP) - The maximum gauge pressure permissible in a vessel at a designated temperature.

Overpressure - The pressure increase over the set pressure of a pressure relief valve, usually expressed as a percentage of the set pressure.

Accumulation - The pressure increase over the maximum allowable working pressure (MAWP) of the vessel during discharge through the pressure relief valve usually expressed as a percentage of the set pressure.

Blowdown - The difference between the actual set pressure of a pressure relief valve and the actual reseating pressure, expressed as a percentage of the set pressure or in pressure units.

Leak Test Pressure - The specified inlet static pressure at which a standard quantitative seat leakage test is performed.

Backpressure - Pressure from the discharge side of a pressure relief valve. There are two types of backpressure: Constant Backpressure and Variable Backpressure.

- **Constant Backpressure** - Backpressure which does not change appreciably under any condition of operation, whether or not the pressure relief valve is open or closed. A conventional relief valve may be used, provided the spring setting is reduced by the amount of the constant backpressure.
- **Variable Backpressure** - Pressure from the outlet side of the relief valve as a result of the Superimposed Variable Backpressure or Built-up Backpressure.
- **Superimposed Variable Backpressure** - A variable backpressure that is present before the pressure relief valve starts to open. It is usually the result of one or more valves discharging into a common header, causing a varying degree of backpressure on each valve connected to the system. It will cause the spring set pressure to be increased an amount equal to the backpressure. It can be negated by the use of a bellows-style relief valve.
- **Built-up Backpressure** - Pressure which develops at the valve outlet as a result of flow after the pressure relief valve has opened.

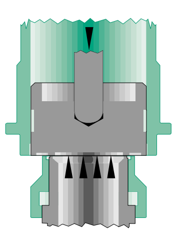
Lift - The actual travel of the disc away from the closed position when a valve is relieving.

Chatter - Abnormal, rapid reciprocation movement of the disc on the seat of a pressure relief valve.

DUAL RING CONTROL

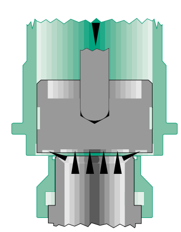
Safety Valves are pressure relief devices actuated by inlet static pressure and characterized by rapid opening or "pop" action. The difference between Safety Valves from different manufacturers is how well they do this.

Spence Figure 31 Safety Valves' Dual Ring Control allows for finer adjustment of the "popping" action and length of "blowdown". This allows exceptional flow efficiency and maximum lifting force while minimizing system energy loss.



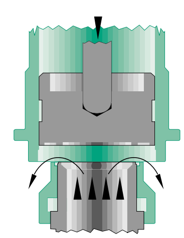
CLOSED

System pressure is pushing upward against the disk which is held closed by the downward force of the spring against the spindle.



OPENING

When system pressure rises above the set pressure of the spring, the disc begins to lift. This simmer/warn stage allows system pressure to enter the "huddling chamber" where it acts on a larger, secondary area of the disc. This magnified force causes the valve to "pop" open.



OPEN

As pressure increases, the disc continues to lift until fully open. When pressure is reduced to a level below the set point of the valve, the spring force against the spindle will snap shut the disc.

SIZING GUIDELINES

General

1. Recommend a 20% or 10 PSIG differential between operating and set pressure, whichever is greater. The set pressure of each pressure relief valve must be in conformance with limits specified in the appropriate ASME code.
2. Relieving Capacity
   a. ASME Section I - The minimum required relieving capacity of the pressure relief valve for all types of boilers shall not be less than the maximum designed steaming capacity as determined by the Manufacturer and shall be based on the capacity of all the fuel burning equipment as limited by other boiler functions. (ASME Section I, PG-67.2.1, 1998)
   b. ASME Section VIII - The minimum required relieving capacity shall be sufficient to carry off the maximum quantity that can be generated or supplied to the attached equipment without permitting a rise in pressure within the vessel with appropriate overpressure condition above the maximum allowable working pressure.
3. Pressure relief valves should not be oversized. Oversizing a pressure relief valve will cause chatter. A multiple valve selection should be used in order to eliminate the possibility of chattering. Use a multiple valve installation when:
   a. The maximum specified capacity requires selection of a pressure relief valve greater than 6 inch pipe size.
   b. When it is more economical to install two smaller valves than one very large one.
   c. If the normal operating capacity of the system is less than approximately 50% of the valve capacity. In this case the volume is not sufficient to keep the valve in its open position and the spring will push the valve closed causing chattering. The first pressure relief valve should be sized on the normal operating capacity and the remaining should be sized on the additional capacity that can be required during the maximum possible capacity of the system.

Single Valve Installation

1. Set pressure of the pressure relief valve shall be set at or below the Maximum Allowable Working Pressure (MAWP) of the weakest item in the system. This includes but is not limited to Steam Boilers, Pressure Vessels and Equipment and Piping Systems.
2. Overpressure
   a. ASME Section I - The pressure cannot rise more than 6% above the maximum allowable working pressure (ASME Section I, PG-67.2, 1998)
   b. ASME Section VIII - The pressure cannot rise more than 10% or 3 psi, whichever is greater, above the MAWP. (ASME Section VIII, UG-125 (c), 1998).

Multiple Valve Installation

1. Overpressure
   a. ASME Section I - The pressure cannot rise more than 6% above the maximum allowable working pressure (ASME Section I, PG-67.2, 1998)
   b. ASME Section VIII - The pressure cannot rise more than 16% or 4 psi, whichever is greater, above the maximum allowable working pressure (ASME Section VIII, UG-125 (c)(1), 1998).
2. Set Pressure
   a. ASME Section I - One or more safety valves shall be set at or below the maximum allowable working pressure. If additional valves are used the highest pressure setting shall not exceed the MAWP by more than 3%. The complete range of pressure settings of all the saturated steam safety valves shall not exceed 10% of the highest set pressure to which any valve is set. (ASME Section I, PG-67.3, 1998)
   b. Section VIII - One valve need to be set at or below the MAWP and the other valves can be set at a higher pressure not to exceed 105% of the MAWP of the weakest item in the system. (ASME Section VIII, UG-134, 1998)

Pressure Relief Valves In Pressure Reducing Stations

There has been much debate in regards to the sizing of Pressure Relief Valves in Pressure Reducing Stations. The sizing guidelines presented below are the recommendations of Spence Engineering. These recommendations are conservative and based on the worst case scenarios. The guidelines are in agreement with the ASME Section VIII code, the National Board Inspection Code and the Power Piping Code ASME B31.1. It is important to understand that each local jurisdiction may have its own set of approved practices and those practices should be followed.

All sizing is based on maximum capacity from the source and piping is in accordance with handling the maximum pressure from the source. Determination of capacity through a given pipe size is complicated. Spence recommends the computation of such values should be through published fluid dynamics reference materials. If the capacity through the pipe is unknown, Spence suggests that when sizing for the limiting value, use the maximum capacity of the first pressure reducing valve and by-pass in the system or maximum capacity from the source, whichever is less.

A. Single Stage Reducing Stations

1. Where pressure reducing valves are used, one or more pressure relief valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open ③ (ASME B31.1 section 122.5.1, 1995)

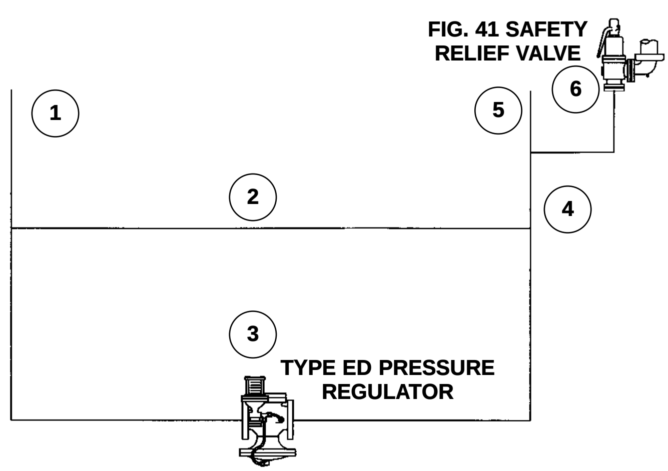


FIGURE A

SIZING GUIDELINES – CONT'D

2. Size SRV for pressure drop across regulator using regulator high side pressure and the safety relief valve set pressure.
3. Hand controlled bypass valves having a capacity no greater than the reducing valve may be installed around pressure reducing valves if the downstream piping is protected by relief valves as required in section ASME B31.1 Section 122.5.1 or if the design pressure of the downstream piping system and equipment is at least as high as the upstream pressure (ASME B31.1 section 122.5.2, 1995)
4. When a pressure reducing valve is installed, there are two possibilities of introducing boiler pressure into the low pressure system. It is necessary to determine the flow under both circumstances and check that the size of the pressure relief valve under either condition will be adequate. The two possibilities are:

   a) the failure of the pressure reducing valve so that it remains at 100% full travel ③

   b) the possibility of the by-pass valve being wide open ②

   (National Board Inspection Code ANSI/NB-23, Appendix G, 1999)

   When taking into consideration the worst possible scenario, Spence Engineering recommends that the pressure relief valve be sized for the maximum flow through both the pressure reducing valve ③ and the by-pass ② or the maximum possible flow through the downstream piping ④ whichever is less. Consideration should be given to the maximum capacity of the source ①.

   For unknown regulator and/or bypass valve capacities, see Section E for approximate sizing formulas
5. When calculating the maximum possible flow through the regulator, in all cases your sizing should be based on the largest orifice size available in the pipe size of the regulator ③. It may be possible that an originally supplied reduced orifice can be changed in the field to a full port orifice without any consideration to the effect on the capacity of the Pressure Relief Valve.
6. In determining the maximum flow through the pressure reducing valve when the valve fails, the failure mode should be considered when the valve plug has reached 100% full travel ③.

B. Parallel Pressure Reducing Stations

1. When sizing a pressure relief valve in a parallel pressure reducing station, the conditions listed above in (A) should all be met.
2. In the case of failure of the pressure reducing valve, the capacity shall be sized on the basis of the possibility that both valves ② & ④ would fail open at the same time plus the by-pass ③ or the maximum possible flow through the downstream piping, whichever is less ⑤. Consideration should be given to the maximum capacity of the source ①.
3. Size SRV for pressure drop across regulator using regulator high side pressure and the safety relief valve set pressure.

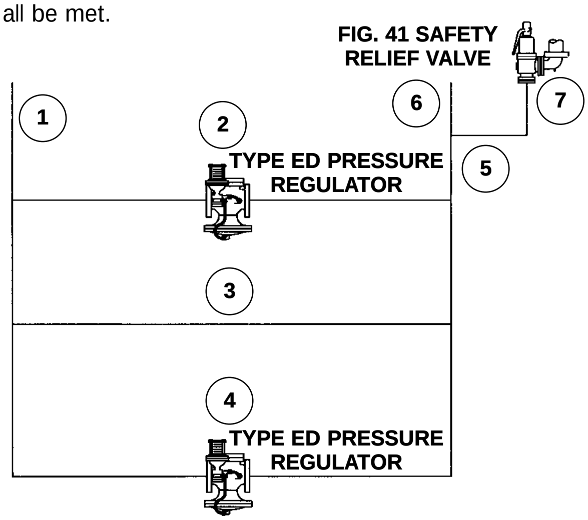


FIGURE B

C. Two Stage Pressure Reducing Stations

1. When sizing a pressure relief valve in a two stage pressure reducing station, the conditions listed above in (A) should all be met.
2. In the case of failure of the pressure reducing valve, the capacity shall be sized on the basis of the high side pressure regulator (National Board Inspection Code ANSI/NB-23, Appendix G, 1999) having the largest possible orifice size plus the bypass ② or the maximum possible flow through the downstream piping, whichever is less. Consideration should be given to the maximum capacity of the source ①.

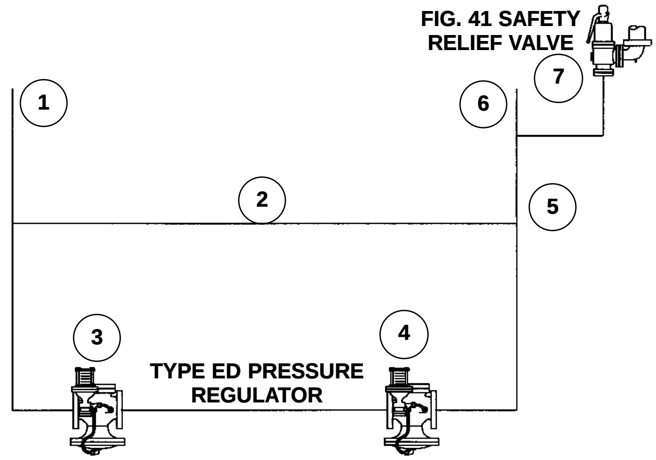


FIGURE C

3. If an intermediate pressure line is taken off between the pressure reducing valves then this line and the final low side shall be protected by pressure relief valves sized on the basis of the high side pressure and the largest possible orifice size of the first pressure reducing valve ③ in the line (National Board Inspection Code ANSI/NB-23, Appendix G, 1999) plus the bypass ② or the maximum possible flow through the downstream pipe ⑦, whichever is less. Consideration should be given to the maximum capacity of the source ①.

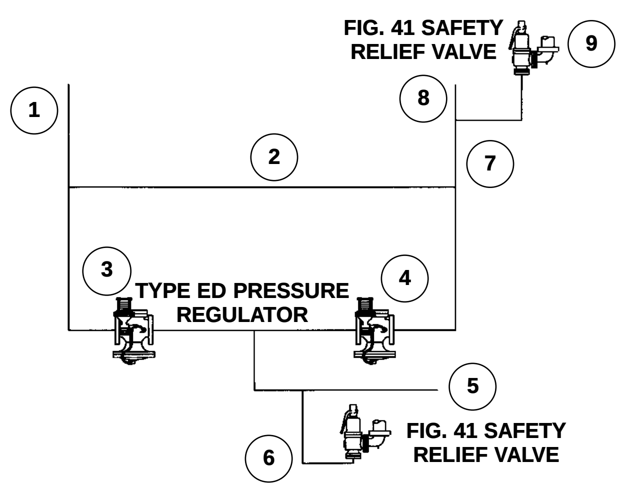


FIGURE D

SIZING GUIDELINES – CONT'D

4. If an intermediate by-pass line is designed in between the pressure reducing valves then the final low side shall be protected by a pressure relief valve sized on the basis of the high side pressure and the largest possible orifice size of the first of the two pressure reducing valves plus the bypass valves ②, ③ and ⑤ or the maximum possible flow through the downstream piping ⑦, whichever is less. Consideration should be given to the maximum capacity of the source ①.
5. Size SRV for pressure drop across regulator using regulator high side pressure and the safety relief valve set pressure.

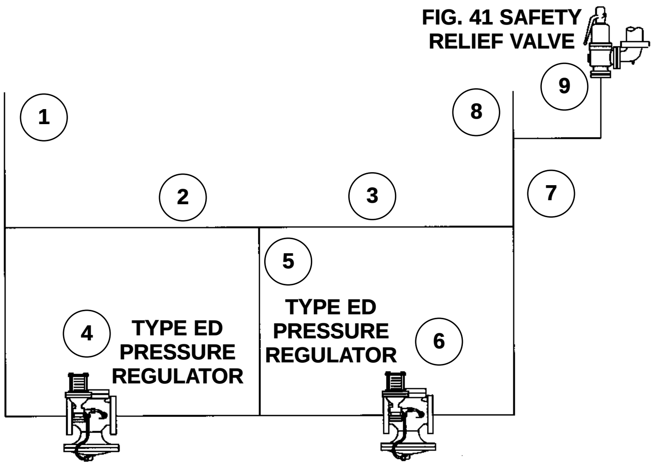


FIGURE E

D. Two Stage Parallel Pressure Reducing Station

1. Sizing is based whenever any condition from (B) and any condition from (C) applies.
2. In addition, all sizing should be based on maximum capacity from sources.

E. When Flow Coefficients Are Not Known

For sizing Spence regulators and/or control valves:

See Main Valve Sizing Formulas on page 111
See CV Data beginning on page 113

For all other manufacturer's valves where flow coefficients are not known, the following may be approximated.

It is possible that the flow coefficients K and K_1 may not be known and in such instances for approximating the flow, a factor of 1/3 may be substituted for K and 1/2 for K_1.

The formulas in E above then become:

W = 1/3AC for the capacity through the pressure reducing valve and

W = 1/2A_1 for the capacity through the by-pass valve

WHERE:

W = steam flow, in lbs/hr through the pressure reducing valve

A = internal area in sq. in. of the inlet pipe size of the pressure reducing valve (See Pipe Data Table)

A_1 = internal area in sq. in. of the pipe size of the bypass around the pressure reducing valve (See Pipe Data Table)

C = flow of saturated steam through a 1 sq. in. pipe at various pressure differentials (See Steam Capacity Table)

C_1 = flow of saturated steam through a 1 sp. In. pipe at various pressure differentials (See Steam Capacity Table)

Caution should be exercised when substituting these factors for the actual coefficients since this method will provide approximate values only and the capacities so obtained may in fact be lower than actual. It is recommended that the actual flow coefficient be obtained from the pressure reducing valve manufacture and reference books be consulted for the flow coefficient of the by-pass valve (National Board Inspection Code ANSI/NB-23, Appendix G, 1998).

PIPE DATA TABLE

Nominal Pipe Size, Inches	Actual external diameter, inches	Approx. internal diameter, inches	Approx. internal area square inches
3/8	0.675	0.49	0.19
1/2	0.840	0.62	0.3
3/4	1.050	0.82	0.53
1	1.315	1.05	0.86
1 ¼	1.660	1.38	1.5
1 ½	1.900	1.61	2.04
2	2.375	2.07	3.36
2 ½	2.875	2.47	4.78
3	3.500	3.07	7.39
3 ⅓	4.000	3.55	9.89
4	4.500	4.03	12.73
5	5.563	5.05	19.99
6	6.625	6.07	28.89
8	8.625	8.07	51.15
10	10.750	10.19	81.55
12	12.750	12.09	114.8

Note: In applying these rules, the area of the pipe is always based upon standard weight pipe and the inlet size of the pressure reducing valve.

Adapted from National Board Inspection Code ANSI/NB-23, Appendix G, 1998.

CAPACITY OF SATURATED STEAM TABLE

(lb/hr) per sq. in. of pipe area

Outlet pres. psi	PRESSURE REDUCING VALVE INLET PRESSURE, PSI												
	1500	1450	1400	1350	1300	1250	1200	1150	1100	1050	1000	950	900
1000	76560	72970	69170	64950	60540	55570	49930	43930	35230	25500	—	—	—
950	77430	74180	70760	67000	63100	58770	53920	48610	42380	34890	24910	—	—
900	77750	74810	71720	68340	64870	61040	56820	52260	47050	41050	33490	23960	—
850	77830	74950	72160	69130	66020	62610	58900	54930	50480	45470	39660	29080	23190
800	—	75070	72330	69490	66700	63680	60390	56910	53060	48800	43980	38340	31610
750	—	—	—	69610	66880	64270	61260	58200	54840	51170	47080	42420	37110
700	—	—	—	—	66900	64270	61520	58820	55870	52670	49170	45230	40860
650	—	—	—	—	—	—	61550	56260	56260	53480	50440	47070	43400
600	—	—	—	—	—	—	—	56270	56270	53660	51020	48470	45010
550	—	—	—	—	—	—	—	—	—	53810	51040	48470	45800
500	—	—	—	—	—	—	—	—	—	—	—	—	45850
450	—	—	—	—	—	—	—	—	—	—	—	—	45870

Outlet pres. psi	PRESSURE REDUCING VALVE INLET PRESSURE, PSI												
	850	800	750	700	650	600	550	500	450	400	350	300	250
800	22550	—	—	—	—	—	—	—	—	—	—	—	—
750	30600	21800	—	—	—	—	—	—	—	—	—	—	—
700	35730	29420	21020	—	—	—	—	—	—	—	—	—	—
650	39200	34250	28260	20190	—	—	—	—	—	—	—	—	—
600	41500	37470	32800	27090	19480	—	—	—	—	—	—	—	—
550	42840	39850	35730	31310	25940	18620	—	—	—	—	—	—	—
500	43330	40530	37610	33880	29760	24630	17720	—	—	—	—	—	—
450	43330	40730	38150	35260	31980	28080	23290	16680	—	—	—	—	—
400	—	40760	38220	35680	33050	29980	26380	21870	15760	—	—	—	—
350	—	—	—	—	33120	30690	27910	24570	20460	14790	—	—	—
300	—	—	—	—	33240	—	28140	25610	22620	18860	13630	—	—
250	—	—	—	—	—	—	28150	25650	23200	21000	17100	10800	—
200	—	—	—	—	—	—	—	—	—	21350	18250	15350	10900
175	—	—	—	—	—	—	—	—	—	—	18250	16000	12600
150	—	—	—	—	—	—	—	—	—	—	18250	16200	13400
125	—	—	—	—	—	—	—	—	—	—	18780	—	13600
110	—	—	—	—	—	—	—	—	—	—	—	—	13600
100	—	—	—	—	—	—	—	—	—	—	—	—	13600
85	—	—	—	—	—	—	—	—	—	—	—	—	13600
75	—	—	—	—	—	—	—	—	—	—	—	—	13600
60	—	—	—	—	—	—	—	—	—	—	—	—	13630

Outlet pres. psi	PRESSURE REDUCING VALVE INLET PRESSURE, PSI												
	200	175	150	125	100	85	75	60	50	40	30	25	0
175	7250	—	—	—	—	—	—	—	—	—	—	—	—
150	9540	6750	—	—	—	—	—	—	—	—	—	—	—
125	10800	8780	6220	—	—	—	—	—	—	—	—	—	—
110	11000	9460	7420	4550	—	—	—	—	—	—	—	—	—
100	11000	9760	7970	5630	—	—	—	—	—	—	—	—	—
85	11000	—	8480	6640	4070	—	—	—	—	—	—	—	—
75	11000	—	—	7050	4980	3150	—	—	—	—	—	—	—
60	11000	—	—	7200	5750	4540	3520	—	—	—	—	—	—
50	11000	—	—	—	5920	5000	4230	2680	—	—	—	—	—
40	11000	—	—	—	—	5140	4630	3480	2470	—	—	—	—
30	11050	—	—	—	—	—	—	3860	3140	2210	—	—	—
25	—	—	—	—	—	—	—	—	3340	2580	1485	—	—
15	—	—	—	—	—	—	—	—	—	2830	2320	1800	—
10	—	—	—	—	—	—	—	—	—	—	—	2060	—

Where capacities are not shown for inlet and outlet conditions, use the highest capacity shown under the applicable inlet pressure column.

Adapted from National Board Inspection Code ANSI/NB-23, Appendix G, 1998.

SAFETY VALVE SIZING BY COMPUTATION

FORMULA KEY

- A = Actual discharge area through the valve at developed lift, inches^2 *See formulas below*
- C = Constant for gas or vapor based on ratio of specific heats C_p/C_v *See Tables E2 and E3 beginning on page 263*
- G = Specific gravity of fluid (Relates the densities of a fluid to that of a standard fluid) *See Table E2 on page 263*
  1.0 for water @70°F and air at 14.7 psia and 60°F
- K_b = Dimensionless number used to correct for the reduction in capacity due to effect of backpressure:
  For conventional valves: *See Graph E5 on page 266*
  For balanced bellows valves: *See Graph E6 on page 267*
- K_d = Coefficient of discharge (including 90% de-rating) *See Table E1 on page 263*
- K_n = Napier steam correction factor for set pressures between 1423 and 2900 psig:
  $\leq$1423 psig $K_n = 1.00$
  >1423 psig $K_n = \dfrac{.1906P - 1000}{.2292P - 1061}$
- K_p = Correction factor for overpressure *See Table E7 on page 267*
  = 1.0 at 25% overpressure
- K_{sh} = Steam superheat correction factor (use 1.00 for saturated steam) *See Table E4 on page 265*
- K_v = Capacity correction factor for viscosity *See Graph E8 on page 268*
- K_w = Liquid capacity correction factor for backpressure service balanced bellows valves only *See Graph E9 on page 268*
- M = Molecular weight *See Table E2 on page 263*
- P = Stamped set pressure + overpressure + 14.7 psia *See Spence Testing Specification Chart page 269*
- ΔP = [Stamped set pressure + 3 psi or 10% (whichever is greater)] – backpressure, psi
- ΔP_1 = [Stamped set pressure + 3 psi or 25% (whichever is greater)] – backpressure, psi
- T = Absolute temperature at inlet, °R (degrees F + 460)
- W = Rated capacity, Steam (lbs/hr), Air (SCFM), Gas or Vapor (lbs/hr or SCFM), Liquid (GPM)
- Z = Compressibility factor corresponding to T and P for gas and vapor (If unknown, use 1.0)

ASME SECTION I POWER BOILERS

$$A = \frac{W}{51.45\,K_d P K_{sh} K_b K_n}$$

ASME SECTION IV HEATING BOILERS

$$A = \frac{W}{51.45\,K_d P K_b}$$

ASME SECTION VIII – PRESSURE VESSELS

STEAM (LBS/HR)

$$A = \frac{W}{51.5\,K_d P K_{sh} K_b K_n}$$

AIR (SCFM)

$$A = \frac{W\sqrt{T}}{418\,K_d P K_b}$$

GAS OR VAPOR (SCFM)

$$A = \frac{W\sqrt{G}\sqrt{T}\sqrt{Z}}{1.175\,C K_d P K_b}$$

GAS OR VAPOR (LBS/HR)

$$A = \frac{W\sqrt{T}\sqrt{Z}}{C K_d P\sqrt{M}\,K_b}$$

LIQUID–10% OVERPRESSURE (GPM) CODE

$$A = \frac{W\sqrt{G}}{38.0\,K_d\sqrt{\Delta P}\,K_v K_w}$$

LIQUID–25% OVERPRESSURE (GPM) NON CODE

$$A = \frac{W\sqrt{G}}{38.0\,K_d\sqrt{\Delta P_1}\,K_p K_v K_w}$$

All sizing equations are in compliance with API 520 Part I 1997. Please refer to that document for further information on sizing. The user is responsible for verifying that these are the currently accepted formulae and for contacting the manufacturer(s) for all applicable required coefficients. Neither Spence Engineering Company nor it's agents assume any liability for improperly sized valves.

TABLE E1–SPENCE VALVE COEFFICIENTS (K_D)

(90% de-rated, as required by ASME)

Model	Steam/Air/Gas/Vapor (Kd)	Liquid (Kd)
Figure 31 Series Bronze	.878	—
Figure 31 Series Cast Iron	.878	—
Figure 800 Series	.878	.752
Figure 10 Series	.800	—
Figure 15 Series	.711	—
Figure 50 Series	.624	—
Figure 710 Series	.604	—
Figure 760 Series	.604	—

TABLE E2–TYPICAL PROPERTIES OF GASES

Gas or Vapor	Ratio of Specific Heats (k) @14.7 psia	Coefficient (C)	Molecular Weight (M)	Specific Gravity (Air=1)
Acetylene	1.25	342	26.04	.899
Acetic Acid	1.15	332	60.05	2.073
Air	1.40	356	28.97	1.00
Ammonia	1.30	347	17.03	.588
Argon	1.66	377	39.94	1.379
Benzene	1.12	329	78.11	2.696
N-Butane	1.18	335	58.12	2.006
Iso-Butane	1.19	336	58.12	2.006
Carbon Dioxide	1.29	346	44.01	1.519
Carbon Monoxide	1.40	356	28.01	.967
Chlorine	1.35	352	70.90	2.447
Ethane	1.19	336	30.07	1.038
Ethyl Alcohol	1.13	330	46.07	1.590
Ethylene	1.24	341	28.03	0.968
Freon 11	1.14	331	137.37	4.742
Freon 12	1.14	331	120.92	4.742
Freon 22	1.18	335	86.48	2.985
Freon 114	1.09	326	170.93	5.900
Helium	1.66	377	4.02	0.139
Hydrochloric Acid	1.41	357	36.47	1.259
Hydrogen	1.41	357	2.02	0.070
Hydrogen Chloride	1.41	357	36.47	1.259
Methane	1.31	348	16.04	0.554
Methyl Alcohol	1.20	337	32.04	1.106
Natural Gas	1.27	344	19.00	0.656
Nitric Oxide	1.40	356	30.00	1.036
Nitrogen	1.40	356	28.02	0.967
Nitrous Oxide	1.31	348	44.02	1.520
Oxygen	1.40	356	32.00	1.105
Propane	1.13	330	44.09	1.522
Propylene	1.15	332	42.08	3.60
Sulfur Dioxide	1.27	344	64.04	2.211

TABLE E3–GAS CONSTANT (C)

k	C
1.00	315
1.02	318
1.04	320
1.06	322
1.08	324
1.10	327
1.12	329
1.14	331
1.16	333
1.18	335
1.20	337
1.22	339
1.24	341
1.26	343
1.28	345
1.30	347
1.32	349
1.34	351
1.36	352
1.38	354
1.40	356
1.42	358
1.44	359
1.46	361
1.48	363
1.50	364
1.52	366
1.54	368
1.56	369
1.58	371
1.60	372
1.62	374
1.64	376
1.66	377
1.68	379
1.70	380
2.00	400
2.20	412

The relationship of (C) to (k) is expressed by the following equation:

$$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

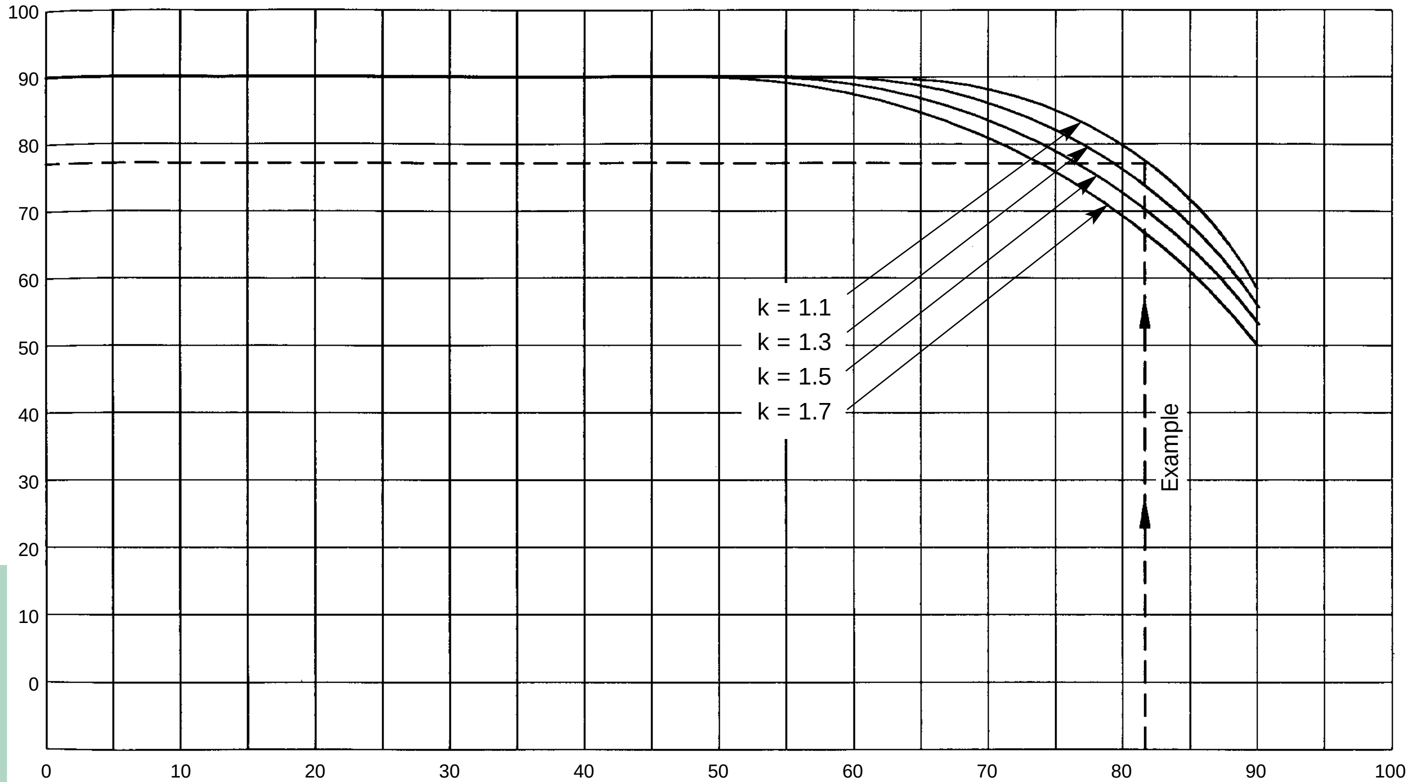
TABLE E3

TABLE E4–SUPERHEAT CORRECTION FACTOR (K_{SH})

Set Press. (psig)	Sat. Stm. Temp. °F	Total Temperature of Superheated Steam °F																																				
		280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780	800	820	840	860	880	900	920	940	960	980	1,000
15	250	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.75
20	259	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.96	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.75
40	287	—	1.00	1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.77	0.76	0.75	0.75
60	308	—	—	1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75
80	324	—	—	—	1.00	1.00	0.99	0.99	0.98	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75
100	338	—	—	—	—	1.00	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75
120	350	—	—	—	—	1.00	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75
140	361	—	—	—	—	—	1.00	1.00	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76	0.75
160	371	—	—	—	—	—	1.00	1.00	0.99	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75
180	380	—	—	—	—	—	—	1.00	0.99	0.98	0.97	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75
200	388	—	—	—	—	—	—	1.00	0.99	0.99	0.97	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76	0.75
220	395	—	—	—	—	—	—	1.00	1.00	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75
240	403	—	—	—	—	—	—		1.00	0.99	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75
260	409	—	—	—	—	—	—	—	1.00	0.99	0.98	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76	0.75
280	416	—	—	—	—	—	—	—	1.00	1.00	0.99	0.97	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75
300	422	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.75
350	436	—	—	—	—	—	—	—	—	1.00	1.00	0.99	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.77	0.76	0.76
400	448	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.95	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76	0.76
450	460	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.96	0.94	0.93	0.92	0.91	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76
500	470	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.76	0.76
550	480	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.94	0.92	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76	0.76
600	489	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76	0.76
650	497	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.94	0.92	0.91	0.90	0.89	0.87	0.86	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.77	0.76
700	506	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.96	0.94	0.93	0.91	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76
750	513	—	—	—	—	—	—	—	—	—	—	—	—	1.00	1.00	0.98	0.96	0.95	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.77	0.76
800	520	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.94	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.78	0.77	0.76
850	527	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77	0.76
900	533	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	1.00	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.79	0.78	0.77	0.77
950	540	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.94	0.92	0.91	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.77
1000	546	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.93	0.91	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.77
1050	552	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	1.00	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.77	0.77
1100	558	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.95	0.94	0.92	0.91	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77
1150	563	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.92	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77
1200	569	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.97	0.95	0.93	0.91	0.90	0.89	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78	0.77
1250	574	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.93	0.92	0.90	0.98	0.88	0.87	0.85	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77
1300	579	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.92	0.91	0.98	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77
1350	584	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.98	0.96	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.78
1400	588	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	1.00	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78
1450	593	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.95	0.94	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.78
1500	597	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.86	0.84	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.78
1600	606	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.97	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.78	0.77
1700	615	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.99	0.97	0.96	0.95	0.93	0.91	0.89	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.79	0.79	0.78	0.77	0.77
1800	622	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.99	0.98	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.85	0.84	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.76
1900	630	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.97	0.96	0.93	0.91	0.89	0.88	0.86	0.85	0.84	0.82	0.81	0.80	0.79	0.78	0.78	0.77	0.76
2000	636	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.96	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.76
2100	644	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.95	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.82	0.81	0.79	0.78	0.77	0.77	0.76	0.75
2200	650	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.95	0.93	0.91	0.89	0.87	0.85	0.84	0.82	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.74
2300	658	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.98	0.95	0.93	0.91	0.89	0.87	0.85	0.84	0.82	0.81	0.79	0.78	0.77	0.76	0.75	0.75	0.74
2400	663	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.98	0.95	0.93	0.91	0.89	0.87	0.85	0.83	0.82	0.80	0.79	0.78	0.77	0.76	0.75	0.74	0.73
2500	669	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.98	0.95	0.93	0.90	0.88	0.86	0.84	0.83	0.81	0.80	0.78	0.77	0.76	0.75	0.74	0.73	0.72
2600	675	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.96	0.93	0.90	0.88	0.85	0.84	0.82	0.80	0.79	0.77	0.76	0.75	0.74	0.73	0.72	0.71
2700	680	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.95	0.90	0.88	0.85	0.83	0.81	0.79	0.78	0.76	0.75	0.74	0.73	0.72	0.71	0.70
2800	686	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.95	0.90	0.88	0.85	0.82	0.80	0.78	0.76	0.75	0.74	0.73	0.72	0.71	0.70	0.69
2900	691	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.00	0.90	0.87	0.84	0.82	0.80	0.78	0.76	0.75	0.73	0.72	0.71	0.70	0.69	0.68

GRAPH E5–SUPERIMPOSED (CONSTANT) BACKPRESSURE SIZING FACTOR (K_B)

CONVENTIONAL VALVES (Vapors and Gases Only)



GRAPH E5

FORMULA KEY

P_b = Backpressure, psia
P_s = Set Pressure, psia
P_o = Overpressure, psi

$$\% \text{ of absolute backpressure} = \frac{P_b}{P_s + P_o} \times 100$$

EXAMPLE: (ASME SECTION VIII)

Set pressure	= 100 psig
Overpressure (10%)	= 10 psi
Superimposed backpressure	= 70 psig
k	= 1.3

SOLUTION:

$$\% \text{ of absolute backpressure} = \frac{(70+10+14.7)}{(100+10+14.7)} \times 100 = 76$$

K_b (follow dotted line) = .89 (from curve)

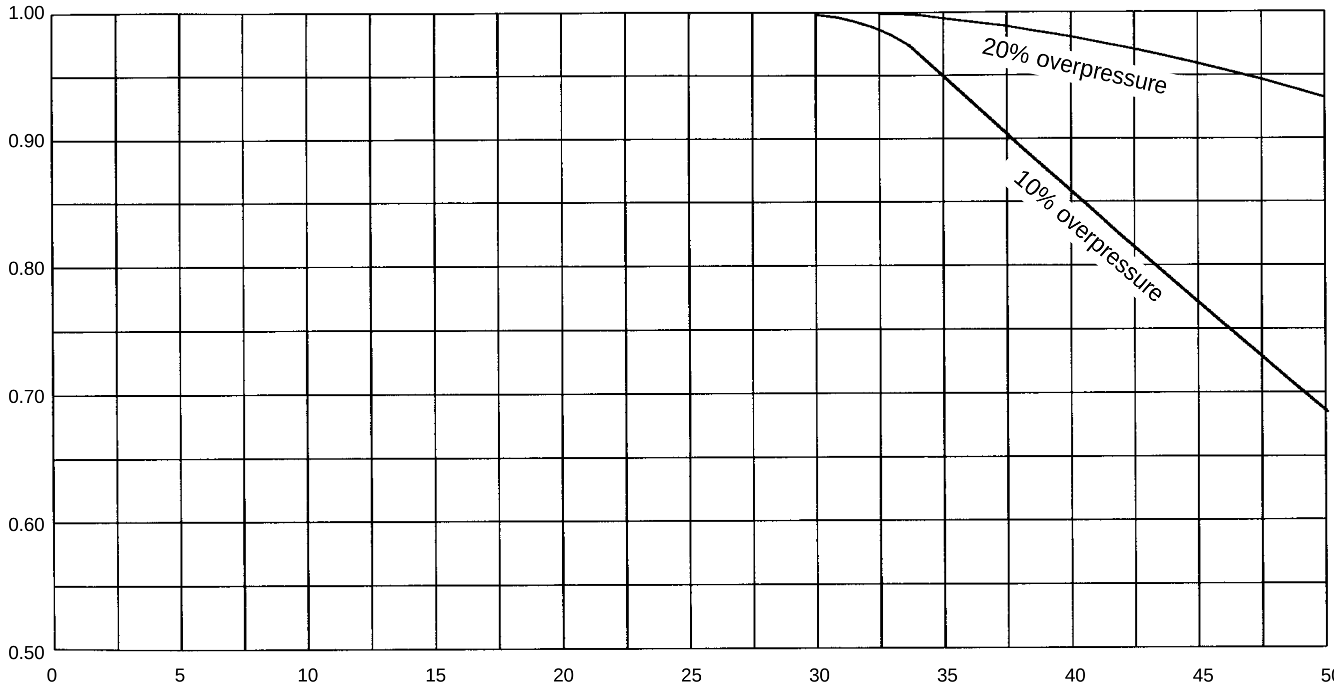
Capacity with backpressure = .89 (rated capacity without backpressure

Note: This chart is typical and suitable for use only when the make of the valve or the actual critical flow pressure point for the vapor or gas is unknown; otherwise, the valve manufacturer should be consulted for specific data. This correction factor should be used only in the sizing of conventional pressure relief valves that have their spring setting adjusted to compensate for the superimposed backpressure. It should not be used to size Balanced Bellow type valves (see next page).

Information from API 520 Part I, 1997

GRAPH E6–SUPERIMPOSED OR VARIABLE BACKPRESSURE SIZING FACTOR (K_B)

BELLOWS VALVES



FORMULA KEY

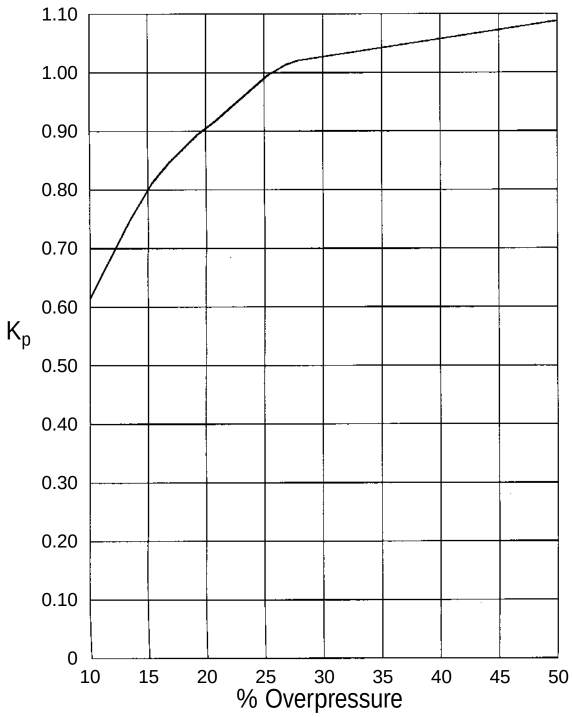
P_b = Backpressure, psia
P_s = Set Pressure, psia

$$\% \text{ of gauge backpressure} = \frac{P_b}{P_s} \times 100$$

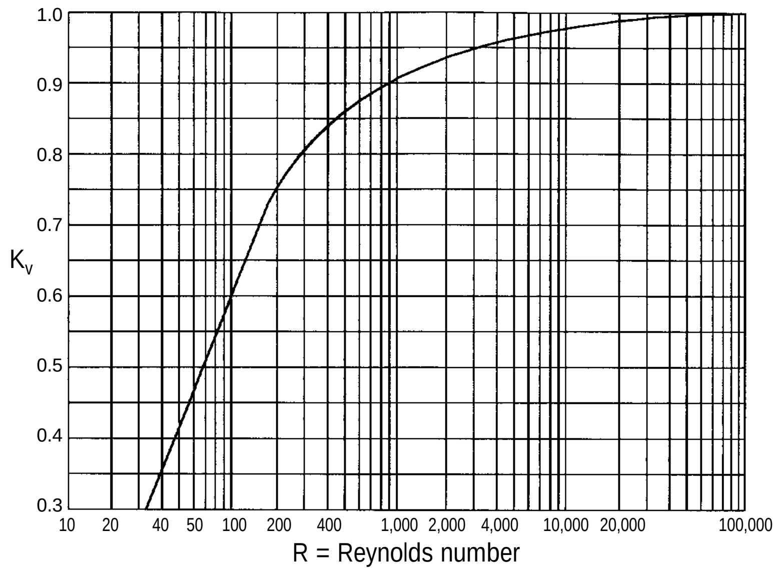
Note: The curves above represent a compromise of the values recommended by a number of relief valve manufacturers and may be used when the make of the valve or the actual critical flow pressure point for the vapor of the gas is unknown. When make is known, the manufacturer should be consulted for the correction factor. These curves are for set pressure of 50 psig and above. They are limited to backpressure below critical flow pressure for a given set pressure. For subcritical flow backpressure below 50 psig, the manufacturer must be consulted for values of K_b . Information from API 520 Part I, 1997

GRAPH E7–CAPACITY CORRECTION FACTORS DUE TO OVERPRESSURE

VALVES IN LIQUID SERVICE



Note: The curve on the left shows that, at 25% or less overpressure, capacity is affected by the change in lift, the change in orifice discharge coefficient and the change in over-pressure, Above 25% overpressure, capacity is affected only by the change in over-pressure. Valves operating at low overpressure tend to chatter, therefore, over-pressures of less than 10% should be avoided.
Information from API 520 Part I, 1997



GRAPH E8–CAPACITY CORRECTION FACTOR DUE TO VISCOSITY

When a relief valve is sized for viscous liquid service, it is suggested that it first be sized for nonviscous type application in order to obtain a preliminary required discharge area, (A). The next larger manufacturers' standard orifice orifice size should be used in determining the Reynold's number from either of the formulae below.

After the value of R is determined, the factor K_v is obtained from the graph on the left. K_v is applied to correct the preliminary required discharge area. If the corrected area exceeds the chosen standard orifice area, the above calculation should be repeated using the next larger standard orifice size.

Information from API 520 Part I, 1997

FORMULA KEY

A	=	Effective discharge area, inches²
G	=	Specific gravity of the liquid (referred to as water) at the flowing temperature, G = 1.00 at 70°F
Q	=	Flow rate at the flowing temperature, GPM
µ	=	Absolute viscosity at the flowing temperature, centipoises
U	=	Viscosity at the flowing temperature, Saybolt Universal seconds

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

Second equation not recommended for viscosities less than 100 Saybolt Universal seconds.

GRAPH E8
GRAPH E9

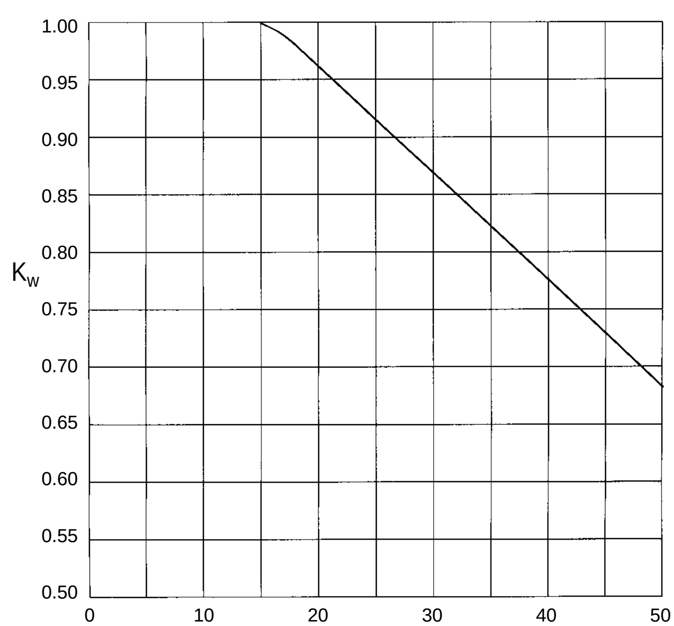
GRAPH E9–CAPACITY CORRECTION FACTOR DUE TO BACKPRESSURE (K_W)

BALANCED BELLOWS VALVES IN LIQUID SERVICE

$$\% \text{ of gauge backpressure} = \frac{P_b}{P_s} \times 100$$

FORMULA KEY

P_b	=	Backpressure, psia
P_s	=	Set Pressure, psia



Note: The curve above represents values recommended various manufacturers. This curve may be used when the manufacturer is not known. Otherwise, the manufacturer should be consulted for the applicable correction factor.

Information from API 520 Part I, 1997

SPENCE SRV TESTING SPECIFICATIONS

Spence Safety and Relief Valves (unlike some competitor's valves) are tested and conform to API 527. These Spence Testing Specifications are in conformance with applicable ASME Code ***and*** API 527.

Set Pressure Tolerance/Blowdown/Overpressure

Set Pressure psig or inches HG	Set Pressure Tolerance	Blowdown	Overpressure
ASME Section I – Power Boilers			
15 to 66	± 2 psig	2 to 4 psig	2 psig
67 to 70	± 2 psig	2 psig to 6%	3%
71 to 100	± 3%	2 psig to 6%	3%
101 to 250	± 3%	2% to 6%	3%
251 to 300	± 3%	2% to 15 psig	3%
301 to 375	± 10 psig	2% to 15 psig	3%
376 to 1000	± 10 psig	2% to 4%	3%
1001 and higher	± 1%	2% to 4%	3%
ASME Section IV – Heating Boilers			
Steam ≤ 15 psig	± 2 psig	2 to 4 psig	33.3%
Hot Water 15 to 60	± 3 psig	N/A *	10%
Hot Water 60 and higher	± 5%	N/A *	10%
ASME Section VIII – Pressure Vessels			
15 to 30	± 2 psig	N/A *	3 psig
31 to 70	± 2 psig	N/A *	10%
71 and higher	± 3%	N/A *	10%
Non-Code Set Pressure Tolerance			
5	± .5 psig	N/A *	3 psig
6 to 9	± 1 psig	N/A *	3 psig
10 to 14	± 2 psig	N/A *	3 psig
Vacuum Set Point Tolerances			
0 to 9	± 1 inch HG	N/A *	6 inch HG
10 to 19	± 2 inches HG	N/A *	6 inch HG
20 and higher	± 4 inches HG	N/A *	6 inch HG

* Contact factory for accurate blowdown setting.

Leak Testing (in accordance with API 527)

Test Pressures - ≤ 50 psig test at 5 psig below set pressure
> 50 psig test at 90% of set pressure

Service	Set Pressure psig	Size	Acceptable Leakage rate
Metal Seats			
Steam	15 – higher	All	No audible or visible leakage for 1 min
Air	15 – 1000	≤ .307 sq in orifice	40 bubbles/min
		> .307 sq in orifice	20 bubbles/min
Liquid	15 – higher	< 1" inlet	10 cc/hr per inch of inlet size
		≥ 1" inlet	10 cc/hr
Soft Seats			
Steam	15 – higher	All	No audible or visible leakage for 1 min
Air	15 – 1000	≤ .307" orifice size	0 bubbles/min
		> .307" orifice size	0 bubbles/min
Liquid	15 – higher	< 1" inlet size	0 cc/hr per inch of inlet size
		≥ 1" inlet size	0 cc/hr

SUMMARY OF ASME CODES & STANDARDS

The American Society of Mechanical Engineers (ASME) through its committees have established Boiler and Pressure Vessel codes for safety through rules and formulae indicating good practice.

The National Board of Boiler and Pressure Vessel Inspectors (NB) verify, administer and enforce the ASME codes wherever the codes have been adopted.

The ASME Codes are broken down into the following sections:

- **Sec I** - Power Boilers
- **Sec II** - Material Specifications
- **Sec III** - Nuclear Power Plant Components
- **Sec IV** - Heating Boilers (Low Pressure Steam & Hot Water)
- **Sec V** - Non-destructive Examination
- **Sec VI** - Recommended Rules for Care & Operation of Heating Boilers
- **Sec VII** - Recommended Rules for Care of Power Boilers
- **Sec VIII** - Pressure Vessels
- **Sec IX** - Welding and Brazing Qualifications
- **Sec X** - Fiberglass Reinforced Plastic Pressure Vessels
- **Sec XI** - Rules for in service Inspection of Nuclear Power Plant Components

The three codes that pertain to Spence Pressure Relief Valves are as follows:

Section I (Power Boilers) - This is a construction code covering power, electric and miniature boilers and high temperature boilers used in stationary service. This section includes power boilers used in locomotive, portable and traction service.

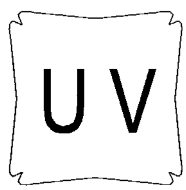
Section IV (Heating Boilers) - This is another construction code covering the design, fabrication, installation and inspection of steam heating, hot water heating and hot water supply boilers which are directly fired by oil, gas, electricity or coal.

Section VIII (Pressure Vessels) - Basic rules for the construction, design, fabrication, inspection and certification of pressure vessels. These rules have been formulated on the basis of design principles and construction practices applicable to vessels designed for pressures up to 3000 PSI. Stamping and coding are also covered in this section.

The appropriate symbols (below) are required on all ASME coded Pressure Relief Valves:

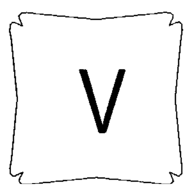
NB National Board Capacity Certified

And one of the following for the applicable ASME code:



Pressure vessel safety valves

Heating Boiler safety valves



Boiler safety Valve

COMPARISON OF ASME SECTION I TO SECTION VIII

CRITERIA	SECTION I	SECTION VIII
Set Point Tolerances	≤ 70 — 2 psig >70 & ≤ 300 — 3% > 300 & ≤ 1000 — 10 psig > 1000 — 1% (ASME Section I, PG-72.1, 1995)	≤ 70 — 2 psig > 70 — 3% (ASME Section VIII, UG-126 (d), 1995)
Blowdown Tolerances	< 67 — 4 psig > 67 & < 250 — 6% > 250 & < 375 — 15 psig > 375 — 4% minimum blowdown for all valves: 2 psi or 2%, whichever is greater (ASME Section I, PG-72.2, 1995)	No blowdown requirement in service.
Capacity Certifications	Full lift at no greater than 3% or 2 psig, (whichever is greater) above the set pressure without chattering. The published rated capacity is 90% of the average capacity of the valves tested. (ASME Section I, PG-69.1.4 & 69.2.1, 1995)	Full lift at no greater than 10% or 3 psig, (whichever is greater) above the set pressure without chattering. The published rated capacity is 90% of the average capacity of the valves tested. (ASME Section VIII, UG-131 (c)(1) & (d)(1), 1995)
Lifting Device	Lifting devices are required to enable lifting the disc while 75% of the set pressure is present. (ASME Section I, PG-73.1.3, 1995)	Lifting devices are required to enable lifting the disc while 75% of the set pressure is present for Air, Steam & Hot Water (over 140°F). (ASME Section VIII, UG-136 (a)(3), 1995)
Sealing of Adjustments	All external adjustments are to be (wire) sealed to prevent changing the adjustment without breaking the seal. It also serves to identify the manufacturer or his authorized assembler making the adjustment. (ASME Section I, PG-73.1.8, 1995)	All external adjustments are to be (wire) sealed to prevent changing the adjustment without breaking the seal. It also serves to identify the manufacturer or his authorized assembler making the adjustment. (ASME Section VIII, UG-136 (a)(7), 1995)
Markings on Valve	The markings shall be placed on the valve or on a nameplate securely fastened to the valve by the manufacturer or assembler. The markings shall include: the ASME Code "V" symbol, the name of the manufacturer and assembler, model number, inlet size, set pressure, rated capacity, year built and the "NB" symbol. (ASME Section I, PG-110, 1995)	The markings shall be placed on the valve or on a nameplate securely fastened to the valve by the manufacturer or assembler. The markings shall include: the ASME Code "UV" symbol, the name of the manufacturer and assembler, model number, inlet size, set pressure (if applicable, the CDTP),rated capacity in lbs/hr of steam, gal/min of water, SCFM or lb/min of air, year built and the "NB" symbol. (ASME Section VIII, UG-129) (a), 1995)
Materials	Seats, discs, springs and sliding surfaces shall be of corrosion resistant material and listed in ASTM specifications. Bodies and bonnets must be listed in ASME Section II. (ASME Section I, PG-73.2, 1995)	Seats, discs, springs and sliding surfaces shall be of corrosion resistant material and listed in ASTM specifications. Bodies and bonnets must be listed in ASME Section II. (ASME Section VIII, UG-136 (b), 1995)

SPENCE

INSTALLATION, MAINTENANCE & TROUBLESHOOTING GUIDELINES

Spence Pressure Relief valves are safety devices designed to protect pressurized vessels, lines or systems during an overpressure event. The recommendations below are general and it is the responsibility of the user to assure that installation and maintenance are in accordance with the applicable ASME Codes, API 520 Part II, local jurisdictional requirements and any other requirements. Neither Spence Engineering nor its agents assume any liability for valves improperly installed, maintained or troubleshot.

A. Installation - Single Valve

1. Installation must be performed by qualified service personnel only.
2. Pressure relief devices intended for use in compressible fluid service shall be connected to the vessel in the vapor space above any contained liquid or to piping connected to the vapor space in the vessel that is to be protected. Pressure relief devices intended for use in liquid service shall be connected below the normal liquid level (ASME Section VIII, UG-135 (a), 1998).
3. The operating pressure of the system should be a minimum of 20% or 10 PSI, whichever is greater, below the set pressure of the valve. The set pressure of each pressure relief valve must be in conformance with pressure limits of the system and of the limits specified in the appropriate ASME codes.
4. Valves must be installed in an upright position with the spindle vertical. (ASME Section VIII, Appendix M, 1998). Mounting valves in any other position will cause additional friction on the guiding surfaces and the valve performance will be affected. Mounting valves in other positions may allow dirt and other foreign substances to accumulate in the valve and adversely affect the valve action.
5. The connection to the vessel should be provided with a radius to permit smooth flow to the valve - sharp corners should be avoided.
6. Pressure Relief Valves for use on steam, air and water (over 140(F) shall be supplied with a lifting device (ASME Section VIII, UG-136 (a)(3), 1998).
7. Do not plug or cap any drain or vent openings. Remove any and all shipping plugs.
8. Test gags must be removed (if supplied). Failure to do so renders the valve inoperable and, due to overpressure may damage the Pressure Relief Valve, the system and/or cause personal injury.
9. Make sure the system is clean and free of any dirt, sediment or scale that might become lodged on the valve seats.
10. Apply a small amount of sealant only to the male threads and tighten valve by hand. Use the proper wrench on the hex area of the base, taking care not use excessive force during tightening.
11. The valve should be normally placed close to the protected equipment so that the valve will be fed properly under flowing conditions. However, valves should be mounted downstream from any device at a distance sufficient to avoid turbulence.
12. In a pressure reducing valve station, it is recommended that the pressure relief valve be installed a minimum of 20 pipe diameters from the outlet of the pressure reducing valve to avoid turbulent flow and an unstable condition.
13. When Pressure Relief Valves are left on line during an extended shutdown, the valves should be inspected and re-tested due to the potential of corrosion, fouling or tampering.

Inlet Piping

14. The opening through all pipe, fittings, and nonreclosing pressure relief devices (if installed) between a pressure vessel and its pressure relief valve shall have at least the area of the pressure relief valve inlet. (ASME Section VIII, UG-135 (b)(1), 1998).
15. The flow characteristics of the upstream system shall be such that the cumulative total of all nonrecoverable inlet losses shall not exceed 3% of the valve set pressure (ASME Section VIII, Appendix M-7(a), 1998)

Outlet Piping

16. Discharge pipes shall be at least of the same size as the pressure relief valve outlet (ASME Section VIII, Appendix M-8(a), 1998).
17. Where feasible, the use of a short discharge pipe or vertical riser, connected through long-radius elbows from each individual device, blowing directly to the atmosphere, is recommended (ASME Section VIII, Appendix M-8(a), 1998). Discharge piping should be designed to place the minimum load on the valve under all conditions of valve operation. See 16 of this Section.
18. When the nature of the discharge permits, whereby condensed vapor in the discharge line, or rain, is collected and piped to a drain, a Drip Pan Elbow (Spence DPE) is recommended. This construction has the further advantage of not transmitting discharge-pipe strains to the valve (ASME Section VIII, Appendix M, 1998).
19. The discharge piping should be anchored to prevent any swaying or vibration while the valve is discharging.
20. If excessive lengths of discharge piping and fittings are required, they should be sized larger than the valve outlet. Any discharge piping that appears to be excessive should be reviewed by calculation for back-pressure and piping strains.
21. Discharge lines from Pressure Relief Valves shall be designed to facilitate drainage or shall be fitted with drains to prevent liquid from lodging in the discharge side of the pressure relief device, and such lines shall lead to a safe place of discharge (ASME Section VIII UG-135(f), 1998).

INSTALLATION, MAINTENANCE & TROUBLESHOOTING GUIDELINES - CONT'D

Stop Valves

22. ASME Section I - No valve of any description shall be placed between the required safety valve or safety relief valve or valves and the boiler, nor on the discharge pipe between the safety valve or safety relief valve and the atmosphere (ASME Section I PG 71.2, 1998).

23. ASME Section VIII - There shall be intervening stop valves between the vessel and its pressure relief device or devices, or between the pressure relief device or devices and the point of discharge, except as under the conditions as stated in ASME Section VIII UG-135(d)(1) and in Appendix M.

B. Installation -Multiple Valves

1. All items listed above in the Installation of Single Valves should be followed.
2. When two or more required pressure relief devices are placed on one connection, the inlet internal cross-sectional area of this connection shall be either sized to avoid restricting flow to the pressure relief devices or made at least equal to the combined inlet areas of the safety devices connected to it. (ASME Section VIII UG-136 (c)1998)
3. The sizing of any section of a common-discharge header downstream from each of the two or more pressure relieving devices that may reasonably be expected to discharge simultaneously shall be based on the total of their outlet areas. The effect of the back-pressure that may be developed when certain valves operate must be considered (ASME Section VIII, Appendix M-8 (b), 1998).
4. It is recommended that the smaller orifice valve be set at the lower set pressure and that it is installed up stream of the other valves.

C. Maintenance

1. Valves are set and sealed to prevent tampering, guarantee is void if any seal is broken. The setting, adjustment or repair should be done only by an Authorized Pressure Relief Valve repair facility.
2. The valves should be checked periodically to see that they are not clogged or seized due to dirt or other foreign matter and that they will operate satisfactorily.
3. Installation conditions should be reviewed, seals should be checked to verify that they are not broken and no unauthorized adjustments have been made.
4. Valves may be manually operated by means of the lifting lever only when the system pressure is at least 75% of the nameplate set pressure. A Pressure Relief Valve should never be lifted without 75% of the nameplate set pressure.
5. Pressure Relief Valves should be re-tested as part a normal routine inspection program. The intervals between tests can vary in accordance with the severity of the service condition. Guidelines for inspection are provided in the API Inspection Code and the National Board Inspection Code. However, consideration should be given to your local jurisdictional policies, your insurance company polices and/or your company policies.
6. Only original, unmodified manufacturer parts should be used to assure safe and proper operation.

D. Troubleshooting

1. Valves are set and sealed to prevent tampering, guarantee is void if any seal is broken. The setting, adjustment or repair should be done only by an Authorized Pressure Relief Valve repair facility.
2. Occasionally a newly installed valve may leak as a result of shipping and handling or installation procedures. For valves with levers, apply pressure to the inlet side equal to 75% of the operating pressure so that the lift lever can be manually activated. For valves without lift levers, raise the system pressure to the point of valve operation. In most instances, the valve will properly reseat and the leakage will stop. *See page 258*
3. If a valve is leaking under normal operating conditions, the following three scenarios should be checked:
   a. Make sure that a minimum operating to set point differential is maintained according to the guidelines specified in the Spence Sizing Guidelines.
   b. It is possible that dirt or foreign material is lodged under the seat. Perform the check as outlined in part 2 of the troubleshooting.
   c. Valve seating surface could be worn or damaged. Please contact your local Pressure Relief Valve Repair Facility.
4. If a valve is chattering it may be the result of the following:
   a. Improper piping at valve inlet or outlet. See the appropriate ASME Codes and the Spence Installation Guidelines. *See page 109*
   b. Valves are oversized. Review the Spence Sizing Guidelines. *See page 111*
   c. Back-pressure may be present which may not have been accounted for in the original sizing. Review Sizing Formulas. *See page 111*
   d. Valve holes may be plugged. Check to make sure all holes are not plugged and any shipping plugs have been removed.
   e. Valve may be worn or damaged. Please contact your local Pressure Relief Valve Repair Facility.
5. If a valve is not popping at the set pressure as stamped on the nameplate, the following should be checked:
   a. All Pressure Relief Valves have tolerance built into the set pressure. Review the Spence Engineering Testing Specifications and/or the appropriate ASME codes to ensure the valve is operating within the allowed tolerances.

INSTALLATION, MAINTENANCE & TROUBLESHOOTING GUIDELINES - CONT'D

b. Make sure the gauge reading the pressure is properly installed and calibrated. Compensate for the water leg between the valve and gauge.

c. Review the inlet piping to make sure that the inlet piping is at least the area of the Pressure Relief Valve inlet. Review the inlet piping to ensure no other pressure drops can occur. See the Spence Installation Guidelines. *See page 109*

d. Review the outlet piping to ensure that backpressure has been accounted for in the original sizing and selection of the valve. See the Spence Installation Guidelines. *See page 109*

e. Valve may be worn or damaged. Please contact your local Pressure Relief Valve Repair Facility.

6. If a valve is not closing or has an excessive blowdown, the following should be checked:

   a. It is possible that dirt or foreign material is lodged under the seat. Perform the check as outlined in part 2 of this Section.

   b. Operating pressure may not be reduced below the reseating pressure of the valve. Reduce the operating pressure of the system to 50% of the normal operating pressure and then slowly bring the system back to the normal operating pressure. Make sure that a minimum operating to set point differential is maintained according the guidelines specified in the Spence Sizing Guidelines. *See page 111*

   c. Valve may be worn or damaged. Please contact your local Pressure Relief Valve Repair Facility.