TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

INTRODUCTION

Scope

This design guideline covers the sizing and selection methods of pressure relief valves used in the typical process industries. It helps engineers and designers understand the basic design of different types of pressure relief valves and rupture disks, and increase their knowledge in selection and sizing.

The selection section contains the explanation for the suitability of types of pressure relief valve used in various applications.

All the important parameters used in this guideline are explained in the definition section which helps the reader understand the meaning of the parameters and the terms.

The theory section includes the sizing theory for the pressure relief valves for gas, steam, and liquid services and several methods of installation for pressure relieving devices.

In the application section, four cases examples are included by guiding the reader step by step in pressure relief valve sizing for difference applications.

In the end of this guideline, example specification data sheets for the pressure relief valve are included which is created based on an industrial example. Calculation spreadsheet is included as well to aid user to understand and apply the theory for calculations.

Important of Pressure Relief System

In the daily operation of chemical processing plant, overpressure can happen due to incidents like a blocked discharge, fire exposure, tube rupture, check valve failure, thermal expansion that can happen at process heat exchanger, and the failures can occur. This can lead to a major incident in plant if the pressure relief system is not in place or not functional.

Is very important to properly select, size, locate and maintain the pressure relief systems to prevent or minimize the losses from major incident like fire or other issues. Detail of selection and sizing of pressure relief valve is illustrated in the following sections.

Pressure relief system is used to protect piping and equipment against excessive over-pressure for equipment and personnel safety. Pressure relief systems consist of a pressure relief device, flare piping system, flare separation drum and flare system. A pressure relief device is designed to open and relieve excess pressure; it is re-closed after normal conditions have been restored to prevent the further flow of fluid (except for a rupture disk).

Overpressure situation can be solved by installed a pressure relief valve or a rupture disk. The differences between a pressure relief valve and a rupture disk are further discussed in the following section.

Pressure Relief Devices Design Consideration

(A) Cause of overpressure

Overpressures that occur in chemical plants and refineries have to be reviewed and studied, it is important in preliminary steps of pressure relief system design. It helps the designer to understand the cause of overpressure and to minimize the effect. Overpressure is the result of an unbalance or disruption of the normal flows of material and energy that causes the material or energy, or both, to build up in some part of the system. [1]

As mentioned earlier, blocked discharge, fire exposure, tube rupture, check valve failure, thermal expansion happen at process line heat exchanger, and utility failure can cause over pressure in process equipment.

(I) Blocked Discharge

Blocked discharge can be defined as any vessel, pump, compressor, fired heater, or other equipment item which closure of block valve at outlet either by mechanical failure or human error. This will expose the vessel to a pressure that exceeds the maximum allowable working pressure, and a pressure relief device is required unless administrative procedures to control valve closure such as car seals or locks are in place.

(II) Fire Exposure

Fire may occur in a gas processing facilities, and create the greatest relieving requirements. All vessels must be protected from overpressure with protected by pressure relief valves, except as bellow

(i) A vessel which normally contains no liquid, since failure of the shell from overheating would probably occur even if a pressure relief valve were provided.

(ii) Vessel (drums or towers) with 2 ft or less in diameter, constructed of pipe, pipe fittings or equivalent, do not require pressure relief valves for protection against fire, unless these are stamped as coded vessels.

(iii) Heat exchangers do not need a separate pressure relief valve for protection against fire exposure since they are usually protected by pressure relief valves in interconnected equipment or have an open escape path to atmosphere via a cooling tower or tank.

(iv) Vessels filled with both a liquid and a solid (such as molecular sieves or catalysts) not require pressure relief valve for protection against fire exposure. In this case, the behavior of the vessel contents normally precludes the cooling effect of liquid boiling. Hence rupture discs, fireproofing and de-pressuring should be considered as alternatives to protection by pressure relief valves.

(III) Check Valve Failure

A check valve is normally located at a pump outlet. Malfunction of the check valve can lead to overpressure in vessel. When a fluid is pumped into a process system that contains gas or vapor at significantly higher pressures than the design rating of equipment upstream of the pump, failure of the check valve from this system will cause reversal of the liquid flow back to pump. When the liquid has been displaced into a suction system and high-pressure fluid enters, serious overpressure will result.

(IV)Thermal Expansion

If isolation of a process line on the cold side of an exchanger can result in excess pressure due to heat input from the warm side, then the line or cold side of the exchanger should be protected by a relief valve.

If any equipment item or line can be isolated while full of liquid, a relief valve should be provided for thermal expansion of the contained liquid. Low process temperatures, solar radiation, or changes in atmospheric temperature can necessitate thermal protection. Flashing across the relief valve needs to be considered.

(V)Utility Failure

Failure of the utility supplies to processing plant will result in emergency conditions with potential for overpressure of the process equipment. Utilities failure events include; electric power failure, cooling water failure, steam supply failure, instrument air or instrument power system failure.

Electric power failure normally causes failure of operation of the electrical drive equipment. The failure of electrical drive equipment like electric pump, air cooler fan drive will cause the reflux to fractionator column to be lost and lead to the overpressure at the overhead drum.

Cooling Water failure occurs when there is no cool water supply to cooler or condenser. Same as electric power failure it will cause immediate loss of the reflux to fractionator and vapor vaporized from the bottom fractionator accumulated at overhead drum will lead to overpressure.

Loss of supply of instrument air to control valve will cause control loop interrupted and lead to overpressure in process vessel. To prevent instrument air supply failure the multiple air compressors with different drivers and automatic cut-in of the spare machine is require and consideration of the instrument air the pressure relief valve should be proper located.

(B) Application of Codes, Standard, and Guidelines

Designed pressure relieving devices should be certified and approved under Code,

1. ASME- Boiler and Pressure Vessel Code Section I, Power Boilers, and Section VIII, Pressure Vessels.
2. ASME- Performance Test Code PTC-25, Safety and Relief Valves.
3. ANSI B31.3, Code for Petroleum Refinery Piping.

API standards and recommended practices for the use of Safety Relief Valves in the petroleum and chemical industries are:

1. API Recommended Practice 520 Part I - Sizing and selection of components for pressure relief systems in Refineries.
2. API Recommended Practice 520 Part II – Installation of pressure relief systems in Refineries.
3. API Recommended Practice 521 – Guide for Pressure-Relieving and Depressuring Systems.
4. API Standard 526 - Flanged Steel Pressure Relief Valves
5. API Recommended Practice 527 - Seat Tightness of Pressure Relief Valves
6. API Standard 2000 - Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated
7. API Standard 2001- Fire Protection in Refineries.

(C) Determination of individual relieving rates [1]

Table 1: Determination of individual relieving rates

Item	Condition	Pressure Relief Device (Liquid Relief)	Pressure Relief Device (Vapor Relief)
1	Closed outlet on vessels	Maximum liquid pump-in rate	Total incoming steam and vapor plus that generated therein at relieving conditions
2	Cooling water failure to condenser	-	Total vapor to condenser at relieving condition
3	Top-tower reflux failure	-	Total incoming steam and vapor plus that generated therein at relieving condition less vapor condensed by sidestream reflux
4	Sidestream reflux failure	-	Difference between vapor entering and leaving section at relieving conditions
5	Lean oil failure to absorber	-	None, normally
6	Accumulation of non-condensable	-	Same effect in towers as found for Item 2; in other vessels, same effect as found for Item 1
7	Entrance of highly volatile material Water into hot oil Light hydrocarbons into hot oil	 - -	 For towers usually not predictable For heat exchangers, assume an area twice the internal cross-sectional area of one tube to provide fro the vapor generated by the entrance of the volatile fluid due to tube rupture
8	Overfilling storage or surge vessel	Maximum liquid pump-in rate	-
9	Failure of automatic control	-	Must be analyzed on a case-by case basis
10	Abnormal heat or vapor input	-	Estimated maximum vapor generation including non-condensable from overheating
11	Split exchanger tube	-	Steam or vapor entering from twice the cross-sectional area of one tube; also same effects found in Item 7 for exchangers
12	Internal explosions	-	Not controlled by conventional relief devices but by avoidance of circumstance
13	Chemical reaction	-	Estimated vapor generation from both normal and uncontrolled conditions
14	Power failure (steam, electric, or other)	-	Study the installation to determine the effect of power failure; size the relief valve for the worst condition that can occur
15	Fractionators	-	All pumps could be down, with the result that reflux and cooling water would fail
16	Reactors	-	Consider failure of agitation or stirring, quench or retarding steam; size the valves for vapor generation from a run-away reaction
17	Air-cooled exchangers	-	Fans would fail; size valves for the difference between normal and emergency duty
18	Surge vessels	Maximum liquid inlet rate	-

Design Procedure

General procedure in the design of protection against overpressure as below,

(i) Consideration of contingencies: all condition which will result in process equipment overpressure is considered; the resulting overpressure is evaluated and the appropriately increased design pressure; and each possibility should be analyzed and the relief flow determined for the worse case.

(ii) Selection of pressure relief device: the appropriate type for pressure relief device for each item of equipment should be proper selection based on the service required.

(iii) Pressure relief device specification: standard calculation procedures for each type of pressure relief device should be applied to determine the size of the specific pressure relief device.

(iv) Pressure relief device installation: installation of the pressure relief valve should be at the correct location, used the correct size of inlet and outlet piping, and with valves and drainage.

DEFINITION

Accumulation- A pressure increase over the set pressure of a pressure relief valve, expressed as a percentage of the set pressure.

Back Pressure - Is the pressure on the discharge side of a pressure relief valve. Total back pressure is the sum of superimposed and built-up back pressures.

Balanced Pressure Relief Valve- Is a spring loaded pressure relief valve that incorporates a bellows or other means for minimizing the effect of back pressure on the operational characteristics of the valve.

Built-Up Back Pressure- Is the increase pressure at the outlet of a pressure relief device that develops as a result of flow after the pressure relief device opens.

Burst Pressure – Inlet static pressure at which a rupture disc device functions.

Conventional Pressure Relief Valve- Is a spring loaded pressure relief valve which directly affected by changes in back pressure.

Maximum Allowable Working Pressure (MAWP) - Is the maximum (gauge) pressure permissible at the top of a vessel in its normal operating position at the designated coincident temperature and liquid level specified for that pressure.

Disc – Movable element in the pressure relief valve which effects closure.

Effective Discharge Area – A nominal area or computed area of flow through a pressure relief valve, differing from the actual discharge area, for use in recognized flow formulas with coefficient factors to determine the capacity of a pressure relief valve.

Nozzle – A pressure containing element which constitutes the inlet flow passage and includes the fixed portion of the seat closure.

Operating Pressure- The operating pressure is the gauge pressure to which the equipment is normally subjected in service.

Overpressure- Overpressure is the pressure increase over the set pressure of the relieving device during discharge, expressed as a percentage of set pressure.

Pilot Operated Pressure Relief Valve- Is a pressure relief valve in which the major relieving device or main valve is combined with and controlled b a self actuated auxiliary pressure relief valve (called pilot). This type of valve does not utilize an external source of energy and is balanced if the auxiliary pressure relief valve is vented to the atmosphere.

Pressure Relief Valve – This is a generic term applying to relief valves, safety valves or safety relief valves. Is designed to relief the excess pressure and to recluse and prevent the further flow of fluid after normal conditions have been restored.

Relief Valve - Is a spring loaded pressure relief valve actuated by the static pressure upstream of the valve. Opening of the valve is proportion to the pressure increase over the opening pressure. Relief valve is used for incompressible fluids / liquid services.

Rupture Disk Device – Is a non-reclosing pressure relief device actuated by static differential pressure between the inlet and outlet of the device and designed to function by the bursting of a rupture disk.

Rupture Disk Holder- The structure used to enclose and clamps the rupture disc in position.

Relieving Pressure- The pressure obtains by adding the set pressure plus overpressure/accumulation.

Safety Valve- Pressure relief valve with spring loaded and actuated by the static pressure upstream of the valve and characterized by rapid opening or pop action. A safety valve is normally used for compressible fluids /gas services.

Safety Relief Valve- Is a spring loaded pressure relief valve. Can be used either as a safety or relief valve depending of application.

Set Pressure- Is the inlet pressure at which the pressure relief valve is adjusted to open under service conditions.

Superimposed Back Pressure- The static pressure from discharge system of other sources which exist at the outlet of a pressure relief device at the time the device is required to operate.

Variable Back Pressure – A superimposed back pressure which vary with time.

NOMENCLATURE

A	Effective discharge area relief valve, in^2
A_D	Disk area
A_N	Nozzle seat area
A_w	Total wetted surface of the equipment, ft^2
C_1	Critical flow coefficient, dimensionless
F	Environmental factor
F_2	Coefficient of subcritical flow, dimensionless
Fs	Spring force
G	Specific gravity of the liquid at the flowing temperature referred to water at standard conditions, dimensionless
k	Ratio of the specific heats
K_b	Capacity correction factor due to back pressure, dimensionless
Kc	Combination correction factor for installations with a rupture disk upstream of the pressure relief valve, dimensionless
K_d	Effective coefficient of discharge, dimensionless
K_N	Correction factor for Napier equation, dimensionless
K_p	Correction factor due to overpressure, dimensionless
K_{SH}	Superheat steam correction factor, dimensionless
K_w	Correction factor due to back pressure, dimensionless
K_v	Correction factor due to viscosity, dimensionless
M_W	Molecular weight for gas or vapor at inlet relieving conditions.
Q	Flow rate, US.gpm
q	Heat input to vessel due to external fire, BTU/hr
P	Set pressure, psig
P_1	Upstream relieving pressure, psia
P_2	Total back pressure, psia
P_b	Total back pressure, psig
P_{cf}	Critical flow Pressure, psia
P_V	Vessel gauge pressure, psig
r	Ratio of back pressure to upstream relieving pressure, P_2/P_1
R	Reynold's number, dimensionless
T_1	Relieving temperature of the inlet gas or vapor, R (^oF+460)
W	Flow through the device, Ib/hr
Z	Compressibility factor for gas, dimensionless

Greek letters

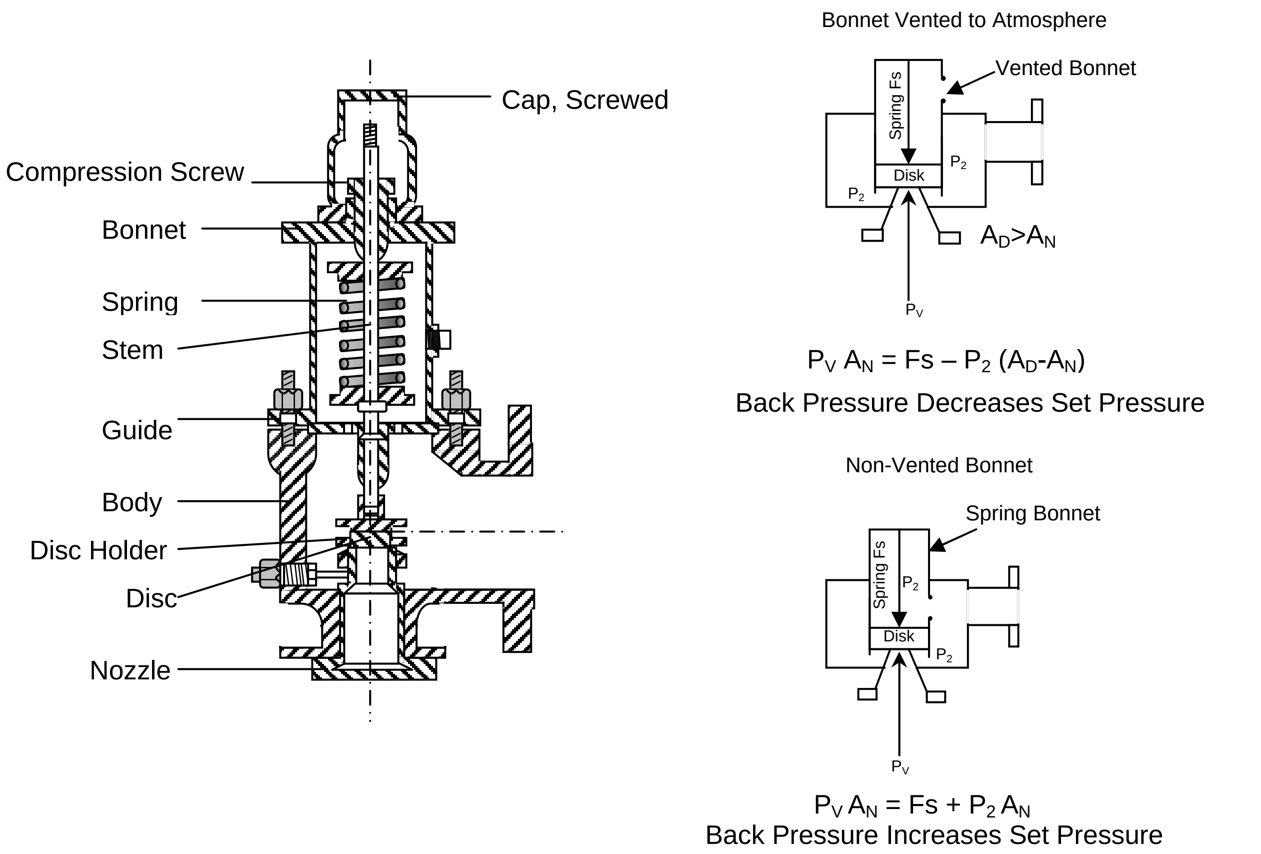
μ	Absolute viscosity at the flowing temperature, centipoise
λ	Heat absorbed per unit mass of vapor generated at relieving conditions, BTU/lb (as latent heat)
ρ_L	Liquid density at relief conditions, lb/ft^3
ρ_V	Vapor density at relief conditions, lb/ft^3

THEORY

Selection of Pressure Relief Valve

(A) Conventional Pressure Relief Valve

The type of pressure relief valves generally utilized in refinery and chemical processing plants are the spring loaded, top-guided, high lift, nozzle type pressure relief valve, which classified as conventional relief valve. (Refer Figure 1.)



Valve Cross Section

Effect of Back Pressure on Set Pressure

Figure 1: Conventional Safety-Relief Valve

Basic elements of spring-loaded pressure relief valve included an inlet nozzle connected to the vessel to be protected, movable disc which controls flow through the nozzle, and a spring which control the position of disc.

Working principal of the conventional relief valve is the inlet pressure to the valve is directly opposed by a spring force. Spring tension is set to keep the valve shut at normal operating pressure. At the set pressure the forces on the disc are balanced and the disc starts to lift and it full lifted when the vessel pressure continues rise above set pressure.

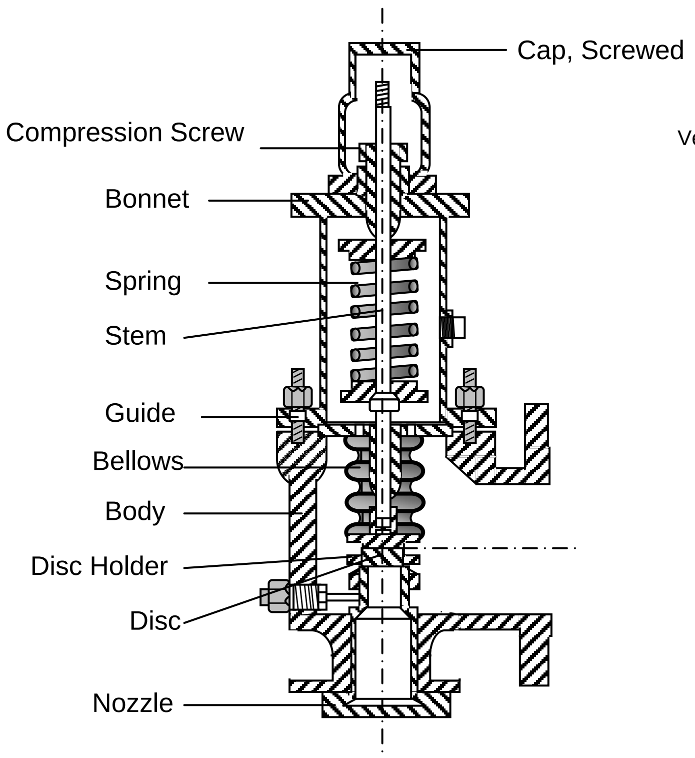
In spring operated pressure relief valves, leakage between the valve seat and disc or called “simmer” typically occurs at about 95% of set pressure. However, depending upon valve maintenance, seating type, and condition, simmer free operation may be possible at up to 98% of set pressure. “Simmer” is normally occurs for gas or vapor service pressure relief valve before it will “pop”.

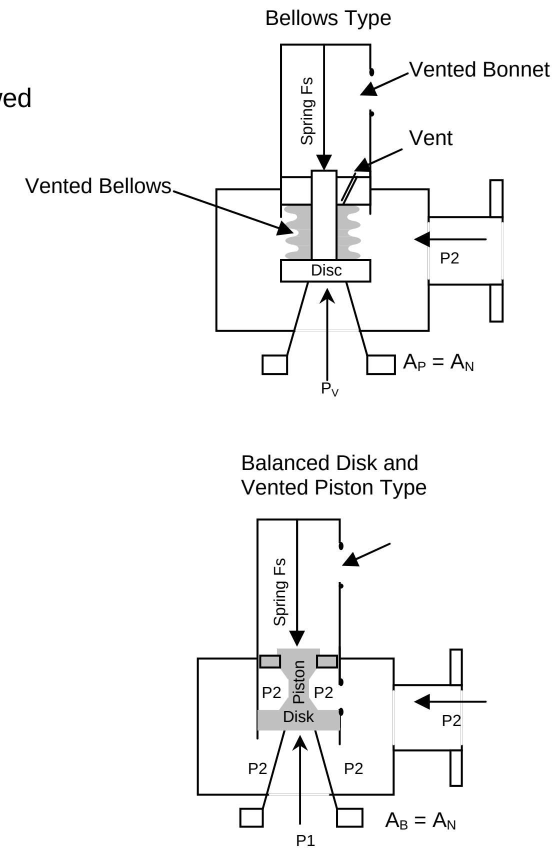
Spring-loaded pressure relief valve is designed to pass its rated capacity at the maximum allowable accumulation. For conditions other than fire, the maximum allowable accumulation is 10% of the MAWP or 3psi, whichever is greater if a single pressure relief valve is provided. For fire, the maximum allowable accumulation is 21% of MAWP. For system with multiple relief valves, the provided maximum allowable accumulation is 16% of MAWP or 4psi, whichever is greater.

The conventional relief valve used in refinery industrial normally is designed with the disc area is greater that nozzle area. Back pressure has the difference effect on such valve, based on the difference design for the bonnet at valve. The effect of back pressure on spring-loaded pressure relief valve is illustrated in Figure 1.

Advantage of this valve compare to rupture disc is the disc of the valve will resets when the vessel pressure reduce to pressure lower than set pressure, not replacement of disc is required.

(B) Balanced Relief Valves





$P_V A_N = F_s$

$$\text{Set Pressure, } P = P_V = \frac{F_s}{A_N} = \frac{\text{Spring Force}}{\text{Nozzle Seat Area}}$$

Bellows Valve Cross Section   Effect of Back Pressure on Set Pressure

Figure 2: Balanced Pressure Relief Valve

Balanced pressure relief valve is a spring-loaded pressure relief valve which is consisted of bellows or piston to balance the valve disc to minimize the back pressure effect on the performance of relief valve.

Balanced pressure relief valve is used when the built-up pressure (back pressure caused by flow through the downstream piping after the relief valve lifts) is too high for conventional pressure relief or when the back pressure varies from time to time. It can typically be applied when the total back pressure (superimposed + build-up) does not exceed <50% of the set pressure.

Typical balanced pressure relief valve is showed in Figure 2. Based on API RP 520(2000) the unit of the balanced pressure relief valve to overcome the back pressure effect is explained as when a superimposed back pressure is applied to the outlet of valve, a pressure force is applied to the valve disc which is additive to the spring force. This added force increases the pressure at which an unbalanced pressure relief valve will open. If the superimposed back pressure is variable then the pressure at which the valve will open will vary (Figure 1).

In a balanced-bellows pressure relief valve, a bellows is attached to the disc holder with a pressure area, A_B, approximately equal to the seating area of the disc, A_N. This isolates an area on the disc, approximately equal to the disc seat area, from the back pressure. With the addition of a bellows, therefore, the set pressure of the pressure relief valve will remain constant in spite of variations in back pressure. Note that the internal area of the bellows in a balanced-bellows spring loaded pressure relief valve is referenced to atmospheric pressure in the valve bonnet. [1] The interior of the bellows must be vented through the bonnet chamber to the atmosphere. A 3/8 to 3/4 in. diameter vent hole is provided in the bonnet for this purpose. Thus, any bellows failure or leakage will permit process fluid from the discharge side of the valve to be released through the vent.

(C) Pilot Operated Relief Valves

A pilot operated relief valve consists of two principal parts, a main valve (normally encloses a floating unbalanced piston assembly) and a pilot (Figure 3). Piston is designed with a larger area on the top compare to the bottom. During the operation, when the pressure is higher than the set pressure, the top and bottom areas are exposed to the same inlet operating pressure. The net force from the top holds the piston tightly against the main valve nozzle. When the inlet pressure increases, the net seating force increased and tends to make the valve tighter. At the set pressure, the pilot vents the pressure from the top of the piston; the resulting net force is now upward causing the piston to lift, and process flow is established through the main valve. After the over pressure, re-establishing pressure condition can be achieve when the pilot has closed the vent from the top of the piston, and net force will cause the piston to reseat.

The advantages of pilot-operated pressure relief valves are

(a) capable of operation at close to the set point and remains closed without simmer until the inlet pressure reaches above 98% of the set pressure;

(b) once the set pressure is reached, the valve opens fully if a pop action pilot is used;

(c) a pilot-operated pressure relief valve is fully balanced, when it exhausts to the atmosphere;

(d) pilot-operated pressure relief valves may be satisfactorily used in vapor or liquid services up to a maximum back pressure (superimposed plus built-up) of 90% of set pressure, provided that the back pressure is incorporated into the sizing calculation;

(e) A pilot operated valve is sufficiently positive in action to be used as a depressuring device. By using a hand valve, a control valve or a solenoid valve to exhaust the piston chamber, the pilot-operated PR valve can be made to open and close at pressures below its set point from any remote location, without affecting its operation as a pressure relief valve.

(f) Pilot-operated pressure relief valves can be specified for blowdown as low as 2%.

(g) It applications involving unusually high superimposed back pressure.

The disadvantages of pilot-operated pressure relief valves are

(a) Not recommended for dirty or fouling services, because of plugging of the pilot valve and small-bore pressure-sensing lines. If the pilot valve or pilot connections become fouled, the valve will not open.

(b) A piston seal with the “O” ring type is limited to a maximum inlet temperature of 450^{o}F and the newer designs are available for a maximum inlet temperature of about 1000^{o}F in a limited number of valve sizes and for a limited range of set pressures.

(c) Vapor condensation and liquid accumulation above the piston may cause the valve to malfunction.

(d) Back pressure, if it exceeds the process pressure under any circumstance (such as during start-up or shutdown), would result in the main valve opening (due to exerting pressure on the underside of the piston that protrudes beyond the seat) and flow of material from the discharge backwards through the valve and into the process vessel. To prevent this backflow preventer must be installed in the pilot operated pressure relief valve.

(e) For smaller sizes pilot operated pressure relief valve, it is more costly than spring-loaded pressure relief valve.

Pilot-operated relief valves are commonly used in clean, low-pressure services and in services where a large relieving area at high set pressures is required. The set pressure of this type of valve can be close to the operating pressure. Pilot operated valves are frequently chosen when operating pressures are within 5 percent of set pressures and a close tolerance valve is required.

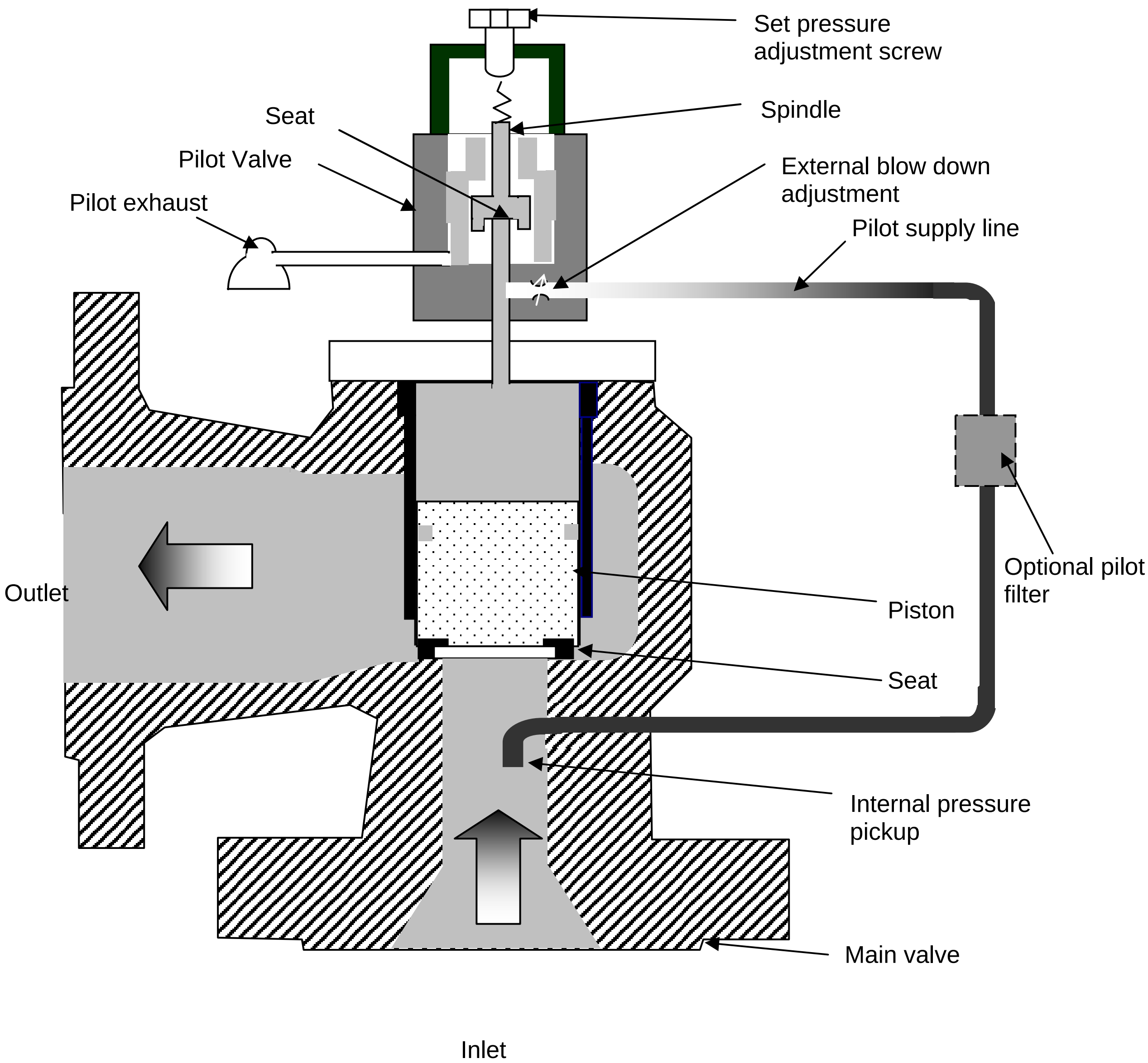


Figure 3: Pilot Operated Relief Valve

(D) Rupture Disk

Rupture disk structure consists of a thin diaphragm held between flanges. It is a device designed to function by the bursting of a pressure-retaining disk (Figure 4). This assembly consists of a thin, circular membrane usually made of metal, plastic, or graphite that is firmly clamped in a disk holder. When the process reaches the bursting pressure of the disk, the disk ruptures and releases the pressure.

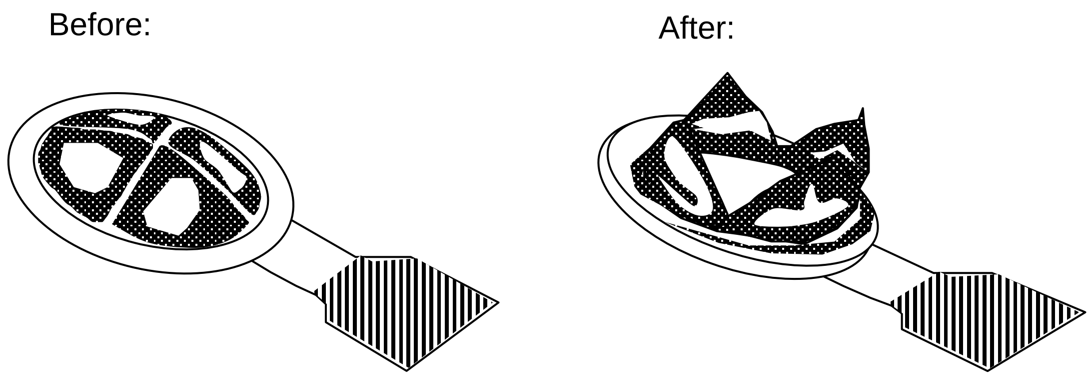
Rupture disks can be installed alone or in combination with other types of devices. Once blown, rupture disks do not reseat; thus, the entire contents of the upstream process equipment will be vented. Rupture disks are commonly used in series (upstream) with a relief valve to prevent corrosive fluids from contacting the metal parts of the valve. In addition, this combination is a re-closing system. The burst tolerances of rupture disks are typically about 5 percent for set pressures above 40 psig.

Rupture disks can be used in any application, it can use single, multiple and combination used with other pressure relief valve (either installed at the inlet / outlet of a pressure relief valve). Rupture disk is installed at inlet of pressure relief valve when to provide corrosion protection for the pressure relief valve and to reduce the valve maintenance. When it installed at outlet of a pressure relief valve, it is functioning to protect the valve from atmospheric or downstream fluids. When used in highly corrosive fluid, two rupture disks are requiring installing together. It can use for process with high viscosity fluid, including nonabrasive slurries.

There have 3 types rupture disk in market which are forward-acting (tension loaded), reverse-acting (compression loaded), and graphite (shear loaded). Refer to Table 2 for the selection of the rupture disks and applications.

Table 2: Rupture Disk Selection and Applications

Type of Rupture Disk	Applications
Forward-Acting (a) Forward-Acting Solid Metal (b) Forward-Acting Scored (c) Forward-Acting Composite	(a) Operating pressure up to 70% of the marked burst pressure of the disk; not suitable for installation upstream of a pressure relief valve (b) Operating pressure up to 85%-90% of the marked burst pressure of the disk; withstand vacuum conditions without a vacuum support; acceptable for installation upstream of a pressure relief valve (c) Designed to burst at a rated pressure applied to the concave side; some designs are non-fragmenting and acceptable for use upstream of a pressure relief valve
Reverse-Acting (Formed solid metal disk designed to reverse and burst at a rated pressure applied on the convex side.)	(a) Designed to open by some methods such as shear, knife blades, knife rings, or scored lines. (b) Suitable for installation upstream of pressure relief valves. (c) Provided satisfactory service life with operating pressure 90% or less of marked burst pressure.
Graphite Rupture Disks (Machined from a bar of fine graphite that has been impregnated with a binding compound.)	(a) Provided satisfactory service life for operating pressure up to 80% of the marked burst pressure and can used for both liquid and vapor service, but not suitable fro installation upstream of a pressure relief valve. (b) Used for vacuum or back pressure conditions with furnished with a support to prevent reverse flexing.



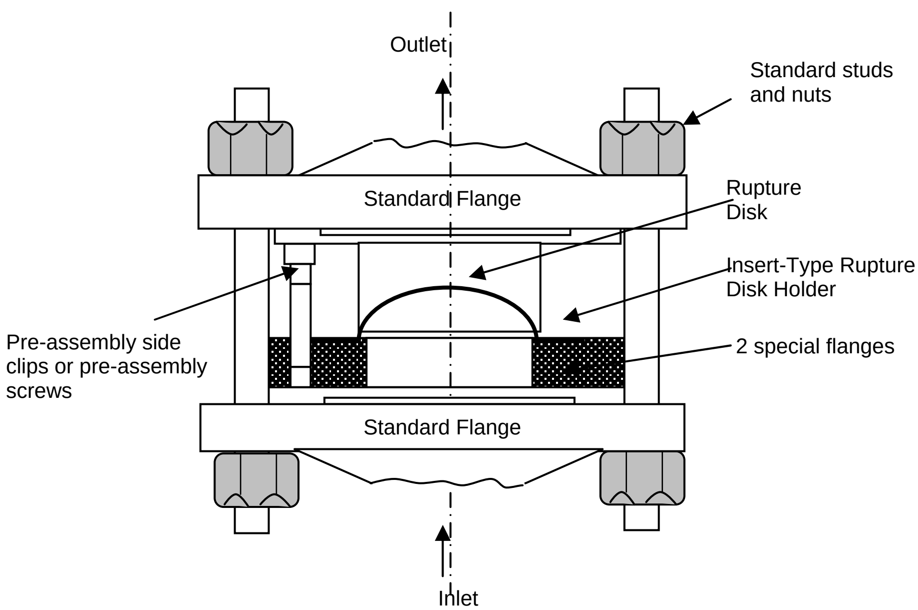


Figure 4: Forward-Acting Solid Metal Rupture Disk Assembly

Standard Relief Valve Designation

Table 3: API Standard Nozzle Orifice Designation

Standard Orifice Designation	Orifice Area, In^2	Valve Body Size (Inlet Diameter X outlet Diameter) (inch x inch)										
		1X2	1.5X2	1.5X2.5	1.5X3	2X3	2.5X4	3X4	4X6	6X8	6X10	8X10
D	0.110	√	√	√								
E	0.196	√	√	√								
F	0.307	√	√	√								
G	0.503			√	√	√						
H	0.785				√	√						
J	1.280					√	√	√				
K	1.840							√				
L	2.850							√	√			
M	3.600								√			
N	4.340								√			
P	6.380								√			
Q	11.050									√		
R	16.000									√	√	
T	26.000											√

Table 4: Typical Saturated Steam Capacity of Orifice Designation for Specific Set Pressure

Set Pressure (psig)	Orifice Designation													
	D	E	F	G	H	J	K	L	M	N	P	Q	R	T
10	141	252	395	646	1009	165	10	3666	4626	5577	8198	14200	20550	33410
20	202	360	563	923	1440	2362	3373	5235	6606	7964	11710	20280	29350	47710
30	262	467	732	1200	1872	3069	4384	6804	8586	10350	15220	26350	38200	62010
40	323	575	901	1476	2304	3777	5395	8374	10570	12740	18730	32430	47000	76310
50	383	683	1070	1753	2736	4485	6405	9943	12550	15120	22230	38510	55800	90610
60	444	791	1939	9030	3167	5193	7416	11510	14530	17510	25740	44590	64550	104900
70	504	899	1408	2306	3599	5901	8427	13080	16510	19900	29250	50660	73400	119200
80	565	1005	1576	2583	4031	6609	9438	14650	18490	22290	32760	56740	82100	133500
90	625	1115	1745	2860	4463	7317	10450	16220	20470	24670	36270	69890	90900	147800
100	686	1220	1914	3136	4894	8024	11460	17790	22450	27060	39780	68900	99700	162110
120	807	1440	2252	2690	5758	9440	13480	20930	26410	318300	46800	81050	117000	190710
140	998	1655	2590	4943	6621	10860	15550	24070	30370	36610	53290	93210	13500	
160	1050	1870	2927	4796	7485	12270	17530	27200	34330	41380	60830	105400	152500	
180	1170	2085	3265	5349	8348	136900	19550	30340	38290	46160	67850	117500	170000	
200	1290	2300	36030	5903	9212	15100	21570	33480	42250	50930	74870	129700	188000	
220	1410	2515	3940	6456	10080	16520	23590	36620	46210	55700	81890	141800	205500	
240	1535	2730	4278	7009	10940	17930	25610	39760	50170	60480	88910	154000	223000	
260	1655	2945	4616	7563	11800	19350	27630	49890	54130	65250	95920	166100	240500	
280	1775	3160	4953	8116	12670	20770	29660	46030	58090	70030	102900	178300	258000	
300	1895	3380	5291	8669	13530	22180	31680	49170	62050	74800	110000	190400	276000	
320	2015	3595	5629	9223	14390	23600	33700	52310	66010	79570	117000	202600		
340	2140	3810	5967	9776	15260	25010	35720	55450	69970	84350	124000	214800		
360	2260	4025	6304	10330	16120	26430	37740	58590	73930	89120	131000	226900		
380	2380	4240	6642	10880	16980	27840	39770	61720	77890	93900	138000	239100		
400	2500	4455	6980	1440	17850	29260	41790	64860	81850	98670	145100	251200		
420	2620	4670	7317	11990	18710	30680	43810	68000	85810	103400	152100	263400		
440	2745	4885	7655	12400	19570	32090	45830	71140	89770	108200	159100	275500		
460	2865	5105	7993	13100	20440	33510	47850	74280	93730	113000	166100	287700		
480	2985	5320	8330	13650	21300	34920	49870	77420	97690	117800	173100	29980		
500	3105	5535	8668	14200	22160	36340	51900	80550	101600	122500	180100	31200		
550	3410	6075	9512	15590	24390	39880	56950	88400	111500	134500	197700	343400		
600	3710	6610	103600	169700	26480	43490	62000	96250	121400	146400	215200	372800		
650	4015	7150	11200	18350	28640	46960	67060	104100	131300	158300	232800			
700	4315	7690	12050	19740	30800	50500	72110	111900	141200	170300	250300			
750	4620	8230	128900	21120	32960	54030	77170	119800	151100	182200	267900			

* Capacity in Ib/hr at Set Pressure Plus 10% Overpressure.

Procedure for Sizing

(A) Sizing for Gas or Vapor Relief for Critical Flow

Formula below is used to estimate the required effective discharge area for relief valve when the flow into the relief valve is critical flow.

$$A = \frac{W\sqrt{(T_1)(Z)}}{(C_1)(K_d)(P_1)(K_b)(K_c)\sqrt{M_W}} \qquad \text{Eq (1)}$$

Where,

A : Effective discharge area relief valve, in^2
W : Flow through the device, Ib/hr
C_1 : Coefficient determined from an expression

$$C_1 = 520\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \qquad \text{Eq (2)}$$

$k = C_p/C_v$

K_d :Effective coefficient of discharge. For preliminary sizing, the following values are used:

:0.975 when a pressure relief valve is installed with/without a rupture disk in combination,
:0.62 when a pressure relief valve is not installed and sizing is for a rupture disk in accordance with pressure relief valve.

P_1 :Upstream relieving pressure, psia, is the set pressure plus the allowable overpressure plus atmospheric pressure.

K_b :Capacity correction factor due to back pressure. It applies for balanced bellows valves only, for the conventional and pilot operated valves, use a value for K_b equal to 1.0.

K_c : Combination correction factor for installations with a rupture disk upstream of the pressure relief valve. Value is 1.0 when a rupture disk is not installed and is 0.9 when a rupture disk is installed in combination which does not have a published value.

T_1 : Relieving temperature of the inlet gas or vapor, R (^oF+460)
Z : Compressibility factor for gas.
M_W : Molecular weight for gas or vapor at inlet relieving conditions.

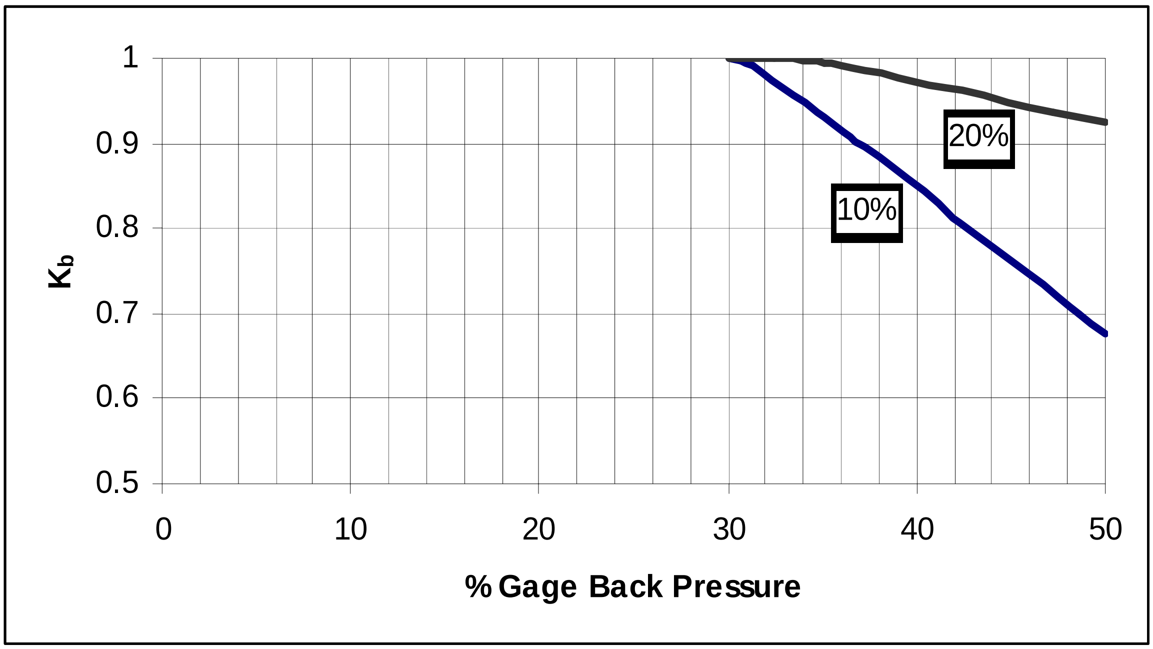


Figure 5: Constant Total Back Pressure Factor, K_b for Balanced Bellows Pressure Relief Valve (Vapors and Gases) Critical Flow.

(B) Sizing for Gas or Vapor Relief for Subcritical Flow

Subcritical flow is occurred when the ratio of back pressure to inlet pressure exceeded the critical pressure ratio Pcf/P1.

$$\frac{P_{cf}}{P_1} = \left[\frac{2}{k+1}\right]^{k/(k-1)} \qquad \text{Eq (3)}$$

Where,

P_{cf} : Critical flow Pressure, psia

Under this condition the formula used for calculation the required effective discharge area of device is

$$A = \frac{W\sqrt{(T_1)(Z)}}{735(F_2)(K_d)(K_c)\sqrt{M_W P_1 (P_1 - P_2)}} \qquad \text{Eq (4)}$$

$$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{2/k}\left[\frac{1-r^{(k-1)/k}}{1-r}\right]} \qquad \text{Eq (5)}$$

Where,

F_2 : Coefficient of subcritical flow
k : Ratio of the specific heats
r : Ratio of back pressure to upstream relieving pressure, P_2/P_1
P_2 : Total back pressure, psia

The Equation (4) is use for sizing for conventional and Pilot-operated pressure relief valves under subcritical condition. Balanced pressure relief valves should be sized using Equation (1).