Safety Relief Valves

The primary function of a safety valve is to protect property and life.
Because a safety valve is often the last device to prevent catastrophic failure under pressure conditions, it is important that the valve works at all times i.e. it must be 100% reliable.
Safety valves should be installed wherever the maximum allowable working pressure of a system or pressure containing vessel is likely to be exceeded, in particular under fault conditions due to the failure of another piece of equipment in the system.
Pressure excess can be generated in a number of different ways including:

- Failure of a cooling system allowing vapour or fluid to expand
- Compressed air or electrical power failure to control instrumentation
- Plant fires
- During the start-up conditions of a plant

The term “**Safety Valve**” and “**Relief Valve**” are generic terms to describe a variety of pressure relief devices. A wide range is available based on the application and required performance criteria. The different designs are required to meet numerous national standards.

The images below show the devastating results of a failed Safety valve (due to poor maintenace) or ones which have been incorrectly sized, installed or maintained.

Air Receiver Explosion

High School Boiler

Industrial Boiler Explosion

Implosion of a Rail Tanker (failed Vac Valve)

Explosion at an Oil Refinery

BP Deep Water Horizon Explosion

Definitions

ASME / ANSI PTC 25.3 standards (USA)

Pressure relief valve – (This is a general term, which includes safety valves, relief valves and safety relief valves.)
A spring-loaded pressure relief valve which is designed to open to relieve excess pressure and to reclose and prevent the further flow of fluid after normal conditions have been restored. It is characterised by a rapid-opening 'pop' action or by opening in a manner generally proportional to the increase in pressure over the opening pressure. It may be used for either compressible or incompressible fluids, depending on design, adjustment, or application.
Safety valve - A pressure relief valve actuated by inlet static pressure and characterised by rapid opening or pop action.
Relief valve - A pressure relief device actuated by inlet static pressure having a gradual lift generally proportional to the increase in pressure over opening pressure.
Safety relief valve - A pressure relief valve characterised by rapid opening or pop action, or by opening in proportion to the increase in pressure over the opening pressure, depending on the application, and which may be used either for liquid or compressible fluid.

European standard EN ISO 4126-1

Safety valve - A valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a quantity of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent further flow of fluid after normal pressure conditions of service have been restored.

A Standard Valve

The images below show a standard Relief valve and a standard Safety valve from a well-known UK manufacturer (https://www.flowstarvalveshop.com/collections/nabic). Each manufacturer does things slightly differently however all of the basic components and principles of operation are the same. As described previously, a safety valve differs from a relief valve in that it opens rapidly once the set pressure has been reached. For the same inlet size and with the valve in the closed position, the surface area that the pressure on the inlet side will see is the same. When the set pressure is reached and the valve starts to open, the disk on a Safety valve is larger (see the diagrams below) and hence the same pressure then sees a much larger surface area and consequently the force increases greatly causing the valve to open quickly and hence the characteristic pop action.

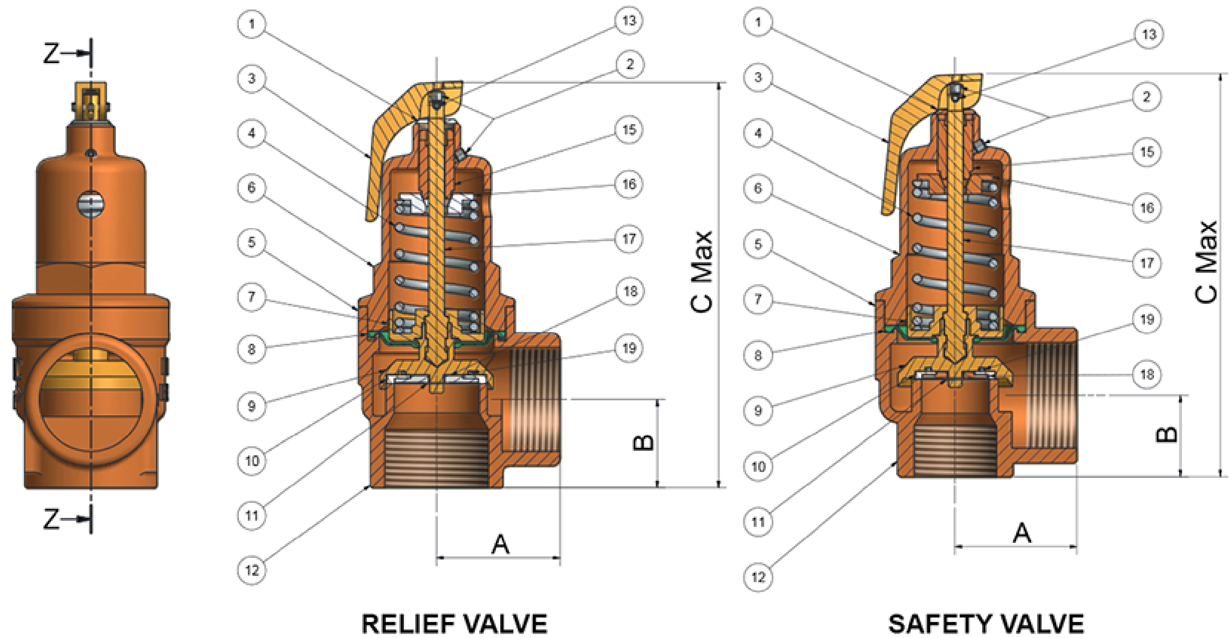
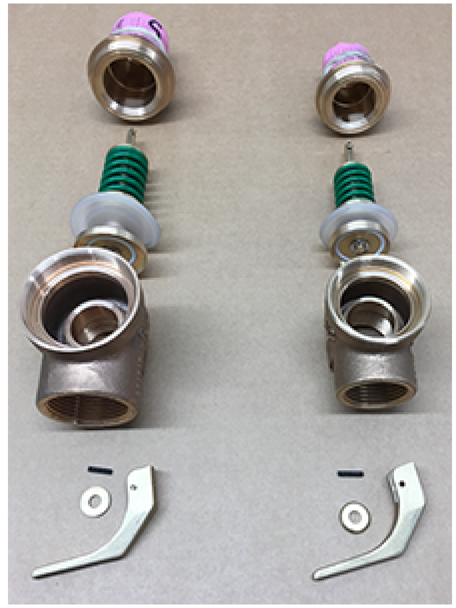


Figure 1 - Lifting lever (3), Spring (4), Spindle (17), Bonnet (6), Inlet body (12), Disk (9), Spring Carrier (16)

The image below shows the above Safety valves and Relief valves dismantled. The disk diameter on the 1" (DN25) Safety valve is only 7mm larger than on the Relief valve which doesnt sound like much, but when you calculate the areas it is an increase of 36%.



A dismantled 1" (DN25) Safety Valve and a dismantled 1" (DN25) Relief Valve from the same Manufacturer

Basic Safety Valve Principles

This diagram represents a Safety valve in its very simplest form. The force acting on the inlet side of the disk is acting against the force applied by the spring plus the force applied by the back pressure on the top of the disk.

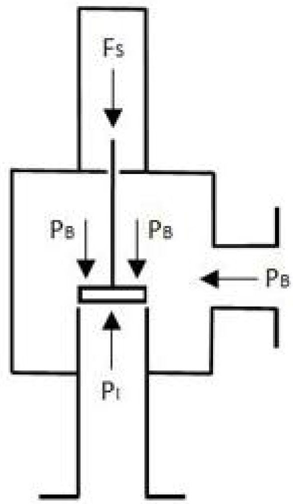


Figure 2 - Simple Valve Model

The valve remains closed when(PI x Ab) < Fs + (PB x At), is in equilibrium when(PI x Ab) = Fs + (PB x At) and opens when(PI x Ab) > Fs + (PB x At) were PI = Inlet pressure, PB = Back pressure, At = Top of disk area, Ab = Bottom of disk area. Things to notice from this design are that if PB is variable and quite large relative to PI, then this will cause the pressure at which the valve opens to vary which is undesirable. The following two designs (Fig 3 & Fig 4) are available that eliminate the effect of back pressure on the set pressure.

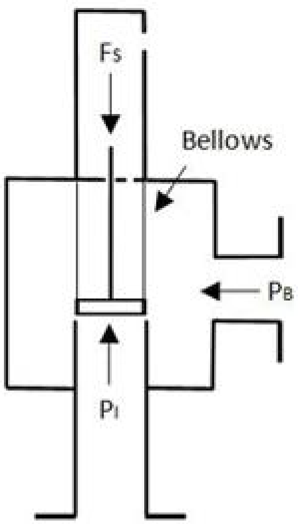


Figure 3 - Fitted with belows

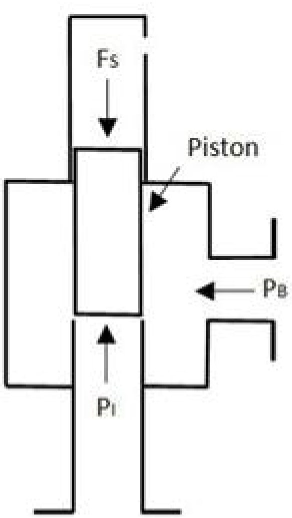


Figure 4 - Piston design

The bellows prevents backpressure acting on the top side of the disk. In relation to the piston there is no top side within the main body of the valve hence again the back pressure cannot affect the set pressure. Bellows failure is an important concern in critical applications where a very precise set pressure is required. In these cases some mechanism to detect a leak of process medium out of the top vent would be implemented. Piston designs are not usually found in conventional Safety valves but are more common in Pilot Operated Safety valves.

Guidance on when to use Bellows

API 520 Practice Guidelines: a conventional design should not typically be used when the built-up backpressure is greater than 10% of the set pressure at 10% over pressure. European standard EN ISO 4126: the built-up backpressure should be limited to 10% of the set pressure when the valve is discharging at the certified capacity.
Other Backpressure concerns
A large PB will also affect the flowrate of the valve when open.
The total backpressure is generated from two components, superimposed backpressure and the built-up backpressure

- Superimposed back pressure: the static pressure that exists on the outlet side of a closed valve.
- Built-up back pressure: the additional pressure generated on the outlet side when the valve is discharging.

In a conventional design (no bellows), the superimposed backpressure will affect the opening characteristic and set value, but the combined backpressure will alter the closing (blowdown) and re-seat value.

Performance Summary

Overpressure is the percentage over the set pressure by which the valve is fully open. The blowdown is the percentage below the set pressure by which the valve is fully closed.

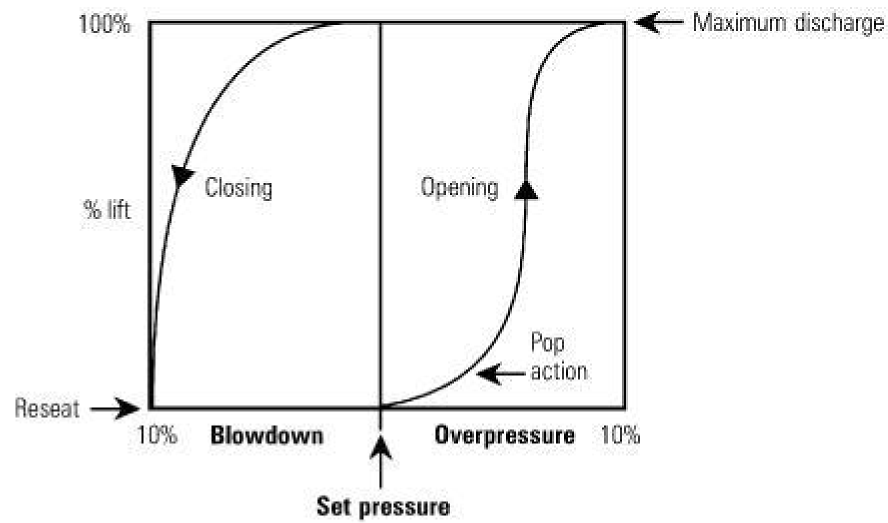


Figure 5 – Relationship between pressure and lift for a typical safety valve

Standard		Overpressure	Fluid	Blowdown
A.D. Merkblatt A2		Standard 10% full lift 5%	Steam	10%
		Standard 10% full lift 5%	Air or gas	10%
		10%	Liquid	20%
ASME	I	3%	Steam	2-6%
	VIII	10%	Steam	7%
		10%	Air or gas	7%
		10% **(see Note 2 below)**	Liquid	
EN ISO 4126		Value stated by manufacturer but not exceeding 10% of set pressure or 0.1 bar whichever is greater.	Compressible	Minimum 2% Maximum 15% or 0.3 bar whichever is greater.
			Incompressible	Minimum 2.5% Maximum 20% or 0.6 bar whichever is greater.

Notes:

1. ASME blowdown values shown are for valves with adjustable blowdown.

2. 25% is often used for non-certified sizing calculations and 20% can be used for fire protection of storage vessels.

Table 1 – Safety Valve Performance Summary

Country	Standard No.	Description
Australia	SAA AS1271	Safety valves, other valves, liquid level gauges and other fittings for boilers and unfired pressure vessels
European Economic Area	EN ISO 4126	Safety devices for protection against excessive pressure
	EN ISO 4126 is a harmonised European Standard and has replaced many National Standards of which British Standard BS 6759 and the French Standard AFNOR NFE-E 29-411 to 416 and 421 are examples.	
Germany	AD-Merkblatt A2	Pressure Vessel Equipment safety devices against excess pressure - safety valves
	TRD 421	Technical Equipment for Steam Boilers Safeguards against excessive pressure - safety valves for steam boilers of groups I, III & IV
	TRD 721	Technical Equipment for Steam Boilers Safeguards against excessive pressure - safety valves for steam boilers of group II
Japan	JIS B 8210	Steam boilers and pressure vessels - spring loaded safety valves
Korea	KS B 6216	Spring loaded safety valves for steam boilers and pressure vessels
USA	ASME I	Boiler Applications
	ASME III	Nuclear Applications
	ASME VIII	Unfired Pressure Vessel Applications
	ANSI/ASME PTC 25.3	Safety and Relief Valves - performance test codes
	API RP 520	Sizing selection and installation of pressure-relieving devices in refineries
		Part 1 Design
		Part 2 Installation
	API RP 521	Guide for pressure relieving and depressurising systems
	API STD 526	Flanged steel pressure relief valves
	API STD 527	Seat tightness of pressure relief valves

Table 2 – Safety Valve Standards

Components of an API Safety Valve

Please note depending upon the manufacturer they may differ slightly to that shown below.

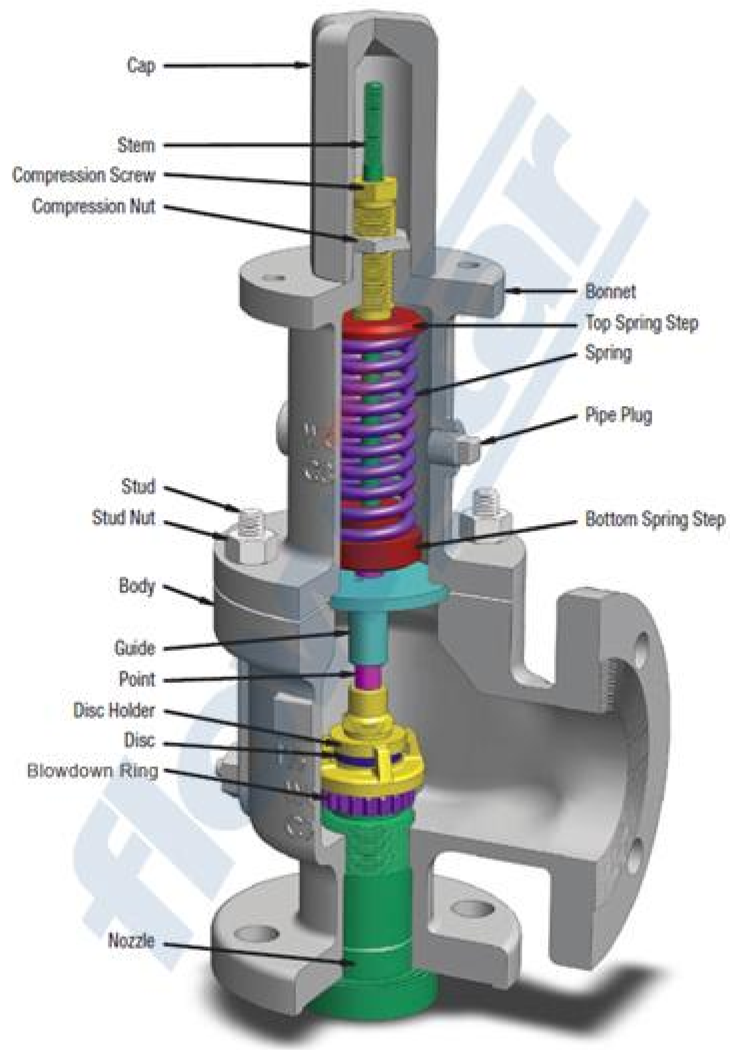


Figure 6 – Typical Safety Valve Components

The basic elements of the design are right angle pattern valve body, inlet can be either a full nozzle or a semi-nozzle type. With a full nozzle design has the "wetted" inlet tract formed from one piece (as per figure 6) with the seat integrated into the top of the nozzle. The internal bore of the nozzle and the disc is the only part of the valve that is exposed to the process fluid with the valve in the closed position. A semi-nozzle design consists of a seating ring fitted into the body.The disc is held onto the seat by the stem, with the downward force coming from the compression on the spring mounted in the bonnet. The amount of compression on the spring is adjusted by the spring adjuster under the cap.

Bonnet Types

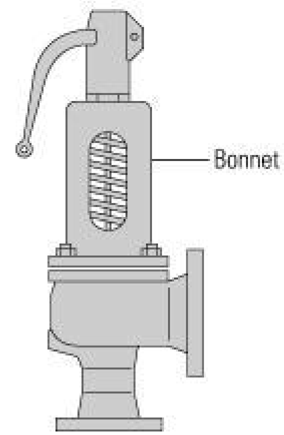


Figure 7 - Open Bonnet

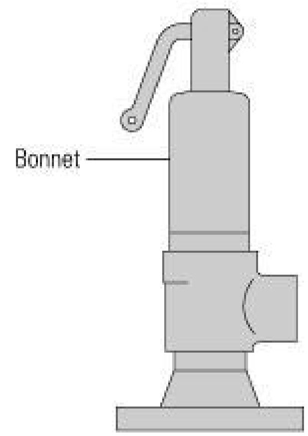


Figure 8 - Closed Bonnet

Unless bellows or diaphragm sealing is used, process fluid will enter the spring housing (or bonnet). The amount of fluid depends on the particular design of safety valve. If emission of this fluid into the atmosphere is acceptable, the spring housing may be vented to the atmosphere - an open bonnet. This is usually advantageous when the safety valve is used on high temperature fluids or for boiler applications as, otherwise, high temperatures can relax the spring, altering the set pressure of the valve. However, using an open bonnet exposes the valve spring and internals to environmental conditions, which can lead to damage and corrosion of the spring.

When the fluid must be completely contained by the safety valve (and the discharge system), it is necessary to use a closed bonnet, which is not vented to the atmosphere. This type of spring enclosure is almost universally used for small screwed valves and, it is becoming increasingly common on many valve ranges since, particularly on steam, discharge of the fluid could be hazardous to personnel.

Typical Cap Options

Open Lifting Lever

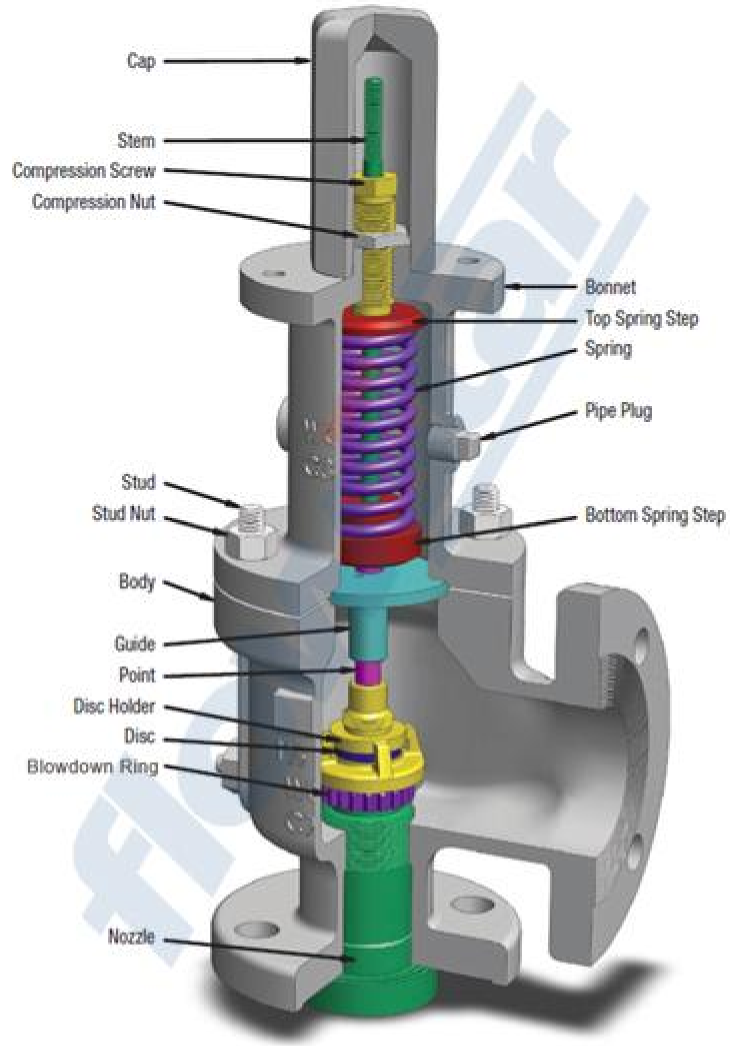


Figure 9 - With a Lifting Lever Fitted

A lifting mechanism is recommended to test for correct valve operation at all times where corrosion, caking, or any deposit could prevent the opening operation.
Foreign particles can lodge under the seat of the valve when it discharges. The lifting lever allows you to lift the valve and flush the obstruction. Pressure relief valves for Section VIII require a lift lever on all air,

steam, and hot water valves used at temperatures over 60 degC. Typically used where periodic testing of the valve in location is desired to assure its operation. With an Open lifting lever design, when the valve discharges, fluid media will escape into the atmosphere around the open lifting lever assembly. If this is not desirable or when back pressure is present you would select a Packed Lifting Lever design.

Packed Lifting Lever

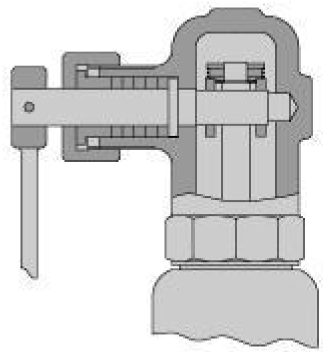


Figure 10 - Packed Lifting Lever

As described above, this type is selected where leakage of the media to the atmosphere during valve discharge or during back pressure would be un-desirable. A packed lever design is a completely sealed assembly.

Bolted Cap

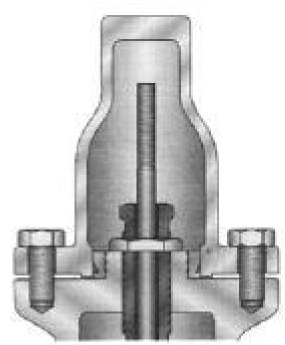


Figure 11 - Bolted Cap

Some people consider a bolted and gasketed design better to the standard screw cap for applications with back pressure and / or vibration hence some manufacturers offer this as an option.

Gag Screw / Test Gag

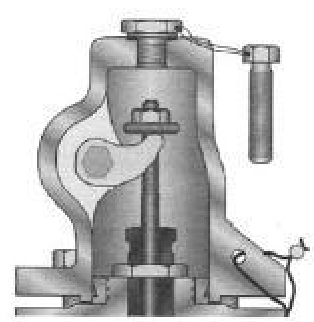


Figure 12 - Gag Screw / Test Gag

Under certain circumstances i.e. under the start-up conditions of a plant or to pressure test the system in a controlled environment, it may be required that the valve is prevented from opening.This is achieved by screwing the bolt (shown on the wire) into the cap which screws down onto the stem and prevents it lifting. Obviously it is important that test gags are removed prior to placing the valve into service.

Other Typical Options Available

Balanced Bellows

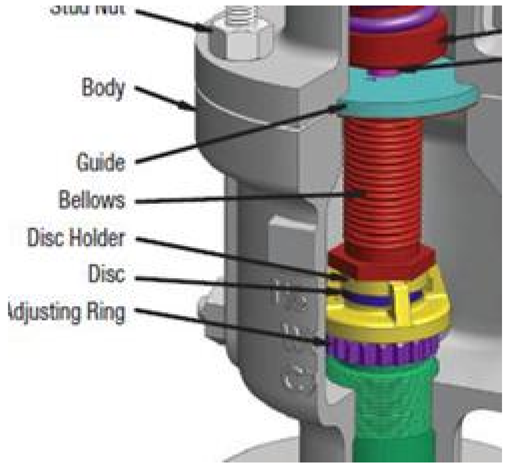


Figure 13 - Balanced Bellows

The bellows is designed to cover the same area on the back of the disc equal to the seat area hence the back pressure will have no effect on the set pressure. See the previous section "Basic Safety Valve Principles". Bellows also protects the spindle, spindle guide and spring from the process medium.

Operation Indicator

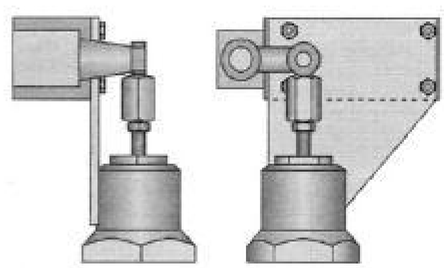


Figure 14 - Operation Indicator

A micro switch is fitted on the exterior of the valve which is activated when the stem rises in the valve.

Steam Jackets

A bolt on steam jacket for preserving the valve body temperature. Typically used on fluids to prevent solidification of the flowing viscous fluids.

Safety Valve Operation

A disc is held against the nozzle by a spring, which is contained in a cast bonnet. The spring is adjusted by a compression screw to permit the calibration of opening or set pressure. An adjustable nozzle ring, threaded onto the nozzle, controls the geometry of the fluid exit control chamber (also known as a huddling chamber). The control chamber (huddling chamber) geometry is very important in controlling valve opening and closing pressures and stability of operation. The nozzle ring is locked into position by a ring pin assembly as shown in Figure 15 below.

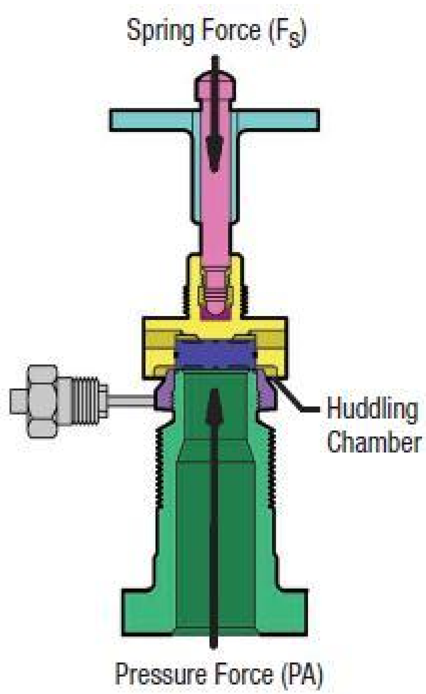


Figure 15

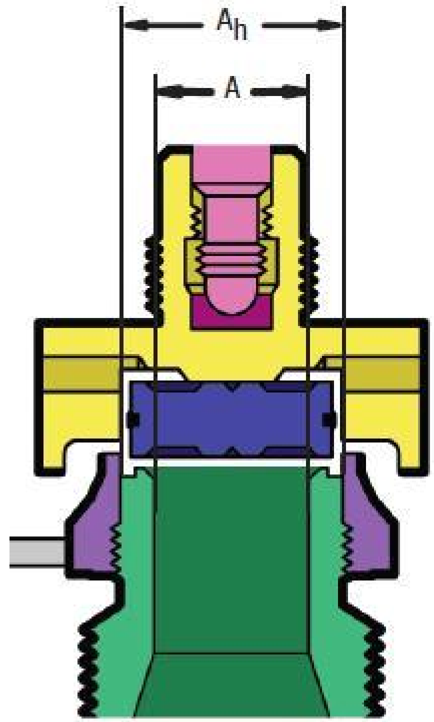


Figure 16 - Relationship of Nozzle Area to Control Chamber (Huddling Chamber)

Under normal system operation the valve remains in the closed position because the spring force (Fs) is greater than the system pressure acting on the internal nozzle seating area (PA). If system pressure increases to a point when these forces are equal, then the set pressure is reached. The disc lifts and fluid flows through the valve. When pressure in the system returns to a safe level, the valve closes.
Just prior to reaching set point, the pressure relief valve leaks system fluid into the huddling chamber. The fluid now acts on a larger area of the disc inside the huddling chamber (PAh), causing the valve to experience an instantaneous increase in the opening force. Refer to the figure 16 above to see relationship between Nozzle Area (A) and the Huddling Chamber Area (Ah). System pressure acting on the larger area will suddenly open the safety relief valve at a rapid rate.
Although the opening is rapid and dramatic, the valve does not open fully at set point. The system pressure must increase above set point to open the valve to its full lift and capacity position. Maximum

lift and certified flow rates will be achieved within the allowable limits (overpressure) established by various codes and standards. All pressure relief ales are allowed an overpressure allowance to reach full rated flow. The allowable over pressure can vary from 10% to 21% on unfired vessels and systems, depending on the sizing basis, number of valves, and whether a fire condition is encountered.

Once the valve has controlled the pressure excursion, system pressure will start to reduce. Since the huddling chamber area is now controlling the exit fluid flow, system pressure must reduce below the set point before the spring force is able to close the valve. The difference between the set pressure and the closing pressure is called blowdown, and is usually expressed as a percentage of set pressure. The typical blowdown can vary from 7% to 10%, the industry standard.

The nozzle ring adjustment changes the shape and volume of the huddling chamber, and its position will affect both the opening and the closing characteristics of the valve. When the nozzle ring is adjusted to its top position, the huddling chamber is restricted to its maximum. The valve will usually pop very distinctly with a minimum simmer (leakage before opening), but the blowdown will increase. When the nozzle ring is lowered to its lowest position, minimal restriction to the huddling chamber occurs. At this position, simmer increases and the blowdown decreases. The final ring position is somewhere between these two extremes to provide optimal performance.

Liquid Service Operation

On liquid service, a different dynamic situation exists. Liquids do not expand when flowing across orifices, and a small amount of fluid flow across the nozzle will produces a large local pressure drop at the nozzle orifice. This local pressure drop causes the spring to reclose the valve if the fluid flow is minimal. Liquids leaking into the huddling chamber can quickly drain out by gravity and prevent fluid pressure from building up in the secondary area of the huddling chamber. Liquid relief valves are thus susceptible to a phenomenon called chatter, especially at low fluid flow rates. Chatter is the rapid opening and closing of the pressure relief valve and is always destructive.

Because of the difference in the characteristics of gases and liquids, some valve designs require a special liquid trim in order to meet ASME Code Section VIII performance criteria of full rated liquid flow at 10% overpressure. With liquids since no visible or audible pop is heard at set point, the set pressure is defined as the pressure when the first heavy flow occurs (a pencil sized steady stream of water that remains unbroken for approximately one inch).

Budenberg (https://www.flowstarvalveshop.com/collections/budenberg-pressure-gauges-and-instrumentation-valves)
Coi Technology (/collections/co)
Flowstar (/collections/fs)
Honeywell (/collections/ho)
Medenus (http://www.flowstarvalveshop.com/collections/medenus/gs)
NABIC (/collections/nabic)
Niezgodka (/collections/niezgodka)
Rhodes (/collections/rhodes-sight-glasses-flow-indicators)
TLV (/collections/tlv)
Valfonta (/collections/va)
Watts (/collections/watts)

Self Actuated Control Valves (/pages/self-actuated-pressure-control-valves)
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