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KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru Malaysia	Process Equipment Design Guidelines Chapter Ten PRESSURE RELIEF VALVE SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINES)	Co Authors Rev 01 Ai L Ling Rev 02 K Kolmetz Rev 03 Reni Mutiara Sari
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INTRODUCTION

Scope

Safety is the most important factor in designing a process system. Some undesired conditions might happen leading to damage in a system. Control systems might be installed to prevent such conditions, but a second safety device is also needed. One kind of safety device which is commonly used in the processing industry is the relief valve. A relief valve is a type of valve to control or limit the pressure in a system by allowing the pressurised fluid to flow out from the system.

The pressure in a system can build up by a process upset, instrument or equipment failure, or fire. When considering safety factors to minimizing the damage in industrial plant, it is important to properly select the pressure relief valve to be utilized. This design guideline covers the sizing and selection methods of pressure relief valves used in the typical process industries. It assist engineers and operations personnel to understand the basic design of the different types of pressure relief valves and rupture disks, and increase their knowledge in selection and sizing.

Pressure relief valves controls the pressurised fluid by direct contact; hence it should be designed with materials compatible with the process fluids. There are some codes and standards to govern the design and use of pressure relief valves, but there are also some additional parameters used to select the design in a typical process.

In material selection, some important parameters are based on fluid properties and process requirements; such as temperature, pressure, chemical attack by process fluid, or corrosiveness.

There are many available guidelines developed to aid engineers in selecting and sizing the relief valves, but mostly these guidelines are developed by certain companies and might only be suitable for the application of the valves provided by their own companies. Hence, it is important to obtain a general understanding of pressure relief valve sizing and selection first. Later, whenever changes are needed in a process system, this basic knowledge is still

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applicable. This guideline is made to provide that fundamental knowledge and a step by step guideline; which is applicable to properly select and size pressure relief valves in a correct manner.

INTRODUCTION

General Consideration

Important of Pressure Relief System

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

Is very important to properly select the size and the location and to maintain the pressure relief system to prevent or minimize the losses from major incident like a fire. The pressure relief system is used to protect piping and equipment against excessive over-pressure and insure personnel safety. Pressure relief systems consist of the pressure relief device, the flare piping system, flare separation drum and flare system. A pressure relief device is designed to open and relieve the excess pressure and then it recloses after normal conditions have been restored to prevent the further flow of fluid.

Pressure Relief Devices Design Consideration

Several things have to be considered to design a pressure relief valve such as cause of overpressure (to determine the maximum or minimum required valve in such conditions), valid codes and standards, and general cases of individual relieving rates.

(A) Cause of overpressure

Overpressure incidents in chemical plants and refinery plants have to be reviewed and studied. This is important in preliminary step of pressure relief system design. It helps the designer to understand the causes 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)

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(I) Blocked Discharge

Blocked discharge can be defined as any vessel, pump, compressor, fired heater, or other equipment item in which the closure of block valve at outlet either by mechanical failure or human error. This will expose the vessel to a pressure that may exceed the maximum allowable working pressure (MAWP), 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 an oil and gas processing facility, and create 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, may not require pressure relief valves for protection against fire, unless these are stamped as coded vessels.
- (iii) Heat exchangers may 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) may 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.

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(III) Check Valve Failure

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 may 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 the process equipments. Utilities failure event are included, electric power failure, cooling water failure, steam supplier 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 immediate loss and lead to the overpressure at the overhead drum.

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Cooling Water failure may occur 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 interruptions and may lead to overpressure in process vessel. To prevent instrument air supply failure 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 are 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

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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

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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 conditions 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 require.
- (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.

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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.

Chatter, simmer or flutter - Abnormal, rapid reciprocating motion of the movable parts of a pressure relief valve in which the disc makes rapid contacts with the seat. This results in audible and/or visible escape of compressible fluid between the seat and the disc at an inlet static pressure around the set pressure and at no measurable capacity, damaging the valve rapidly.

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.

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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 by 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.

Pop action - An opening and closing characteristic of an safety relief valve in which the valve immediately snaps open into high lift and closes with equal abruptness.

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 reclude 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.

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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.

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NOMENCLATURE

A	Effective discharge area relief valve, in ²
A _D	Disk area
A _N	Nozzle seat area
A _{wet}	Total wetted surface of the equipment, ft ²
B	Effective liquid level angle, degrees
c	Specific heat, kJ/kg·K
C ₁	Critical flow coefficient, dimensionless
E	Effective liquid level, ft
F	Environmental factor
F ₂	Coefficient of subcritical flow, dimensionless
F _s	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	Effective height liquid level
K _b	Capacity correction factor due to back pressure, dimensionless
K _c	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 (°F+460)

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- V_o Specific volume of the two-phase system inlet (ft³/lb)
- W Flow through the device, lb/hr
- x_o Vapor mass fraction (quality) inlet.
- 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/ft³
- ρ_V Vapor density at relief conditions, lb/ft³
- ϕ Total heat input to system, Btu/h
- α_V Cubic expansion coefficient of liquid, dimensionless
- χ Isothermal compressibility coefficient of liquid, dimensionless
- η_c Critical flow ratio

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THEORY

Selection of Pressure Relief Valve

To select a suitable pressure relief valve for a particular application it was not an easy task especially with the wide variety of pressure relief valve in the market, it requires considerable evaluation such the contingency, advantages and disadvantages each pressure relief device, operation and characteristic pressure requirements.

Pressure Relief Devices

This section gives detail of the pressure relief devices commonly used to relieving liquids and gases with various causes.

I. Reclosing Pressure Relief Devices

(A) Conventional Pressure Relief Valve

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

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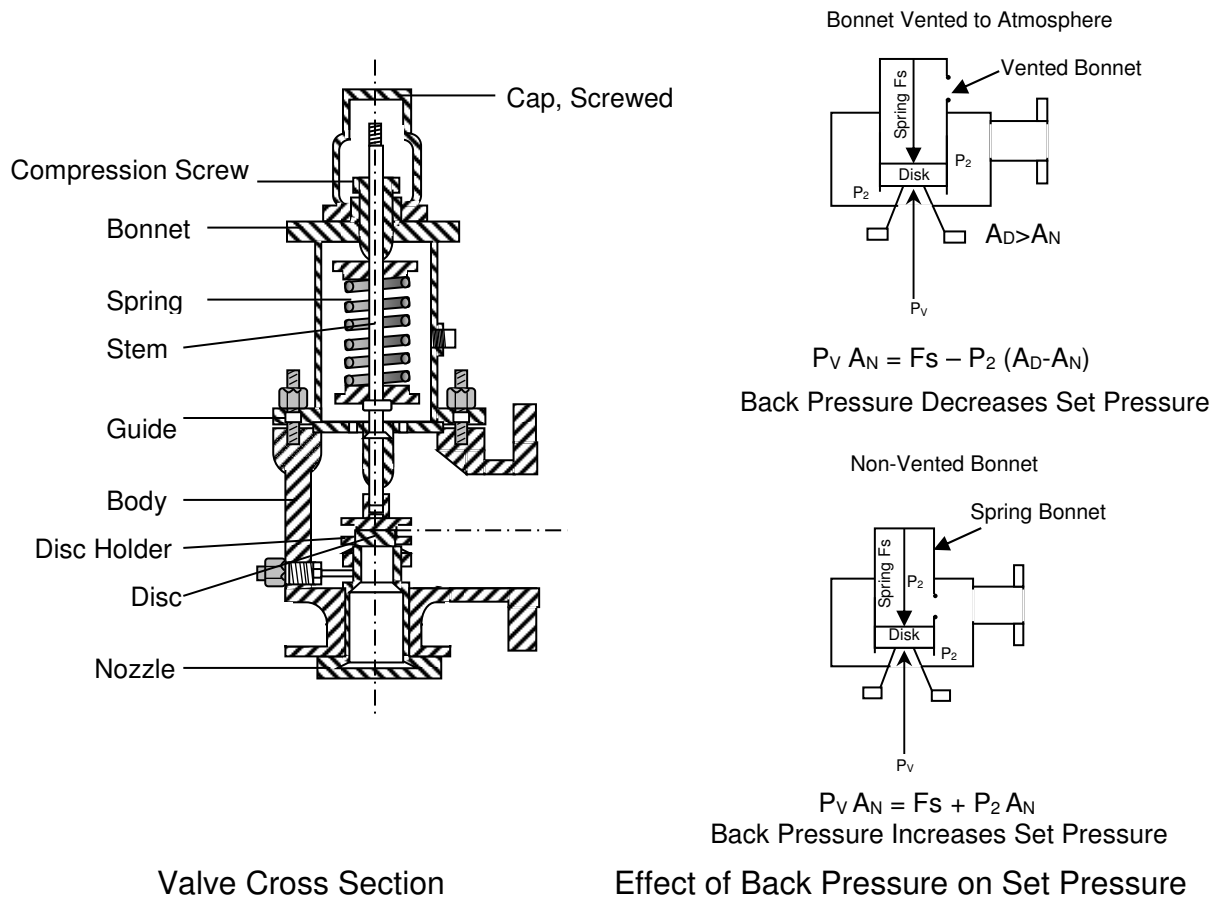


Figure 1: Conventional Safety-Relief Valve

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.

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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”.

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.

Conventional type relief valves can be used when the back pressure is relatively constant or the maximum relieving back pressure is not greater than 10% of the set pressure, since changes in back pressure seriously affect the valve performance of this type.

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.

Thermal Relief Valve

When a liquid filled system is blocked in and heated, the resulting expansion can cause very high pressures. The heat source of thermal expansion can be a heater, heat exchanger, or heat tracing, or it can be solar or other radiant heat or external fire. Examples of such occurrences are:

- Piping or vessels are blocked-in while there are filled with a cold liquid and are subsequently heated by heat tracing and coils.
- A heat exchanger is blocked-in on the cold side with flow in the hot side.
- Piping or vessels are blocked-in while there are filled with a cold liquid at lower than ambient temperature and are heated by direct solar radiation.

If the blocked in liquid has a potential to vaporize because of its high vapor pressure, the pressure relief valve should be capable of handling generated vapor. This will result in tremendous internal hydraulic forces inside the pipe or pressure vessel, as the liquid is non-compressible and needs to be evacuated. This section of pipe then needs thermal relief.

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Thermal relief valves are small, usually liquid relief valves designed for very small flows on incompressible fluids. There are included self-actuated spring-loaded pressure relief valve, which classified as conventional relief valve. They open in some proportion of the overpressure. Thermal expansion during the process only produces very small flows, and the array of orifices in thermal relief valves is usually under the API-lettered orifices, with a maximum orifice D or E. It is, however, recommended to use a standard thermal relief orifice (e.g. 0.049 in²)^[9]. The valve shown in Figure 2 is available in small sizes commonly used for thermal relief valve applications.

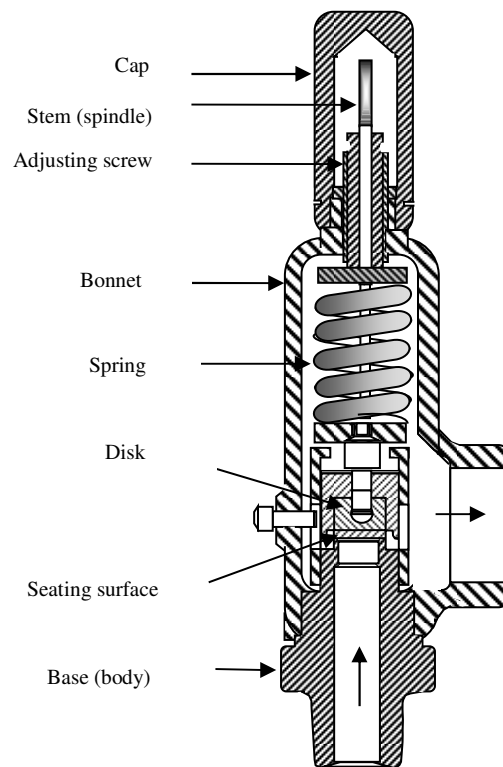


Figure 2 : Conventional pressure relief valve with threaded connections

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Thermal relief valves should be installed if a section of the process can be blocked in during maintenance or shutdown. The installation of thermal relief valves is recommended when the blocked-in section contains toxic or environmentally hazardous materials.

On the other hand, no metal seated block valve can provide 100% bubble-tight closure. Therefore, if the blocked-in pipe section is of small diameter and less than 100 ft in length, the required thermal expansion relieving capacity is less than the leakage of the block valve, so a thermal relief valve may not be required. Thermal relief valves are not required for process plant piping, storage or transport piping sections which are not normally shut in for operational or emergency purposes lines in which there is normally a two-phase flow.

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(B) Balanced Relief Valves

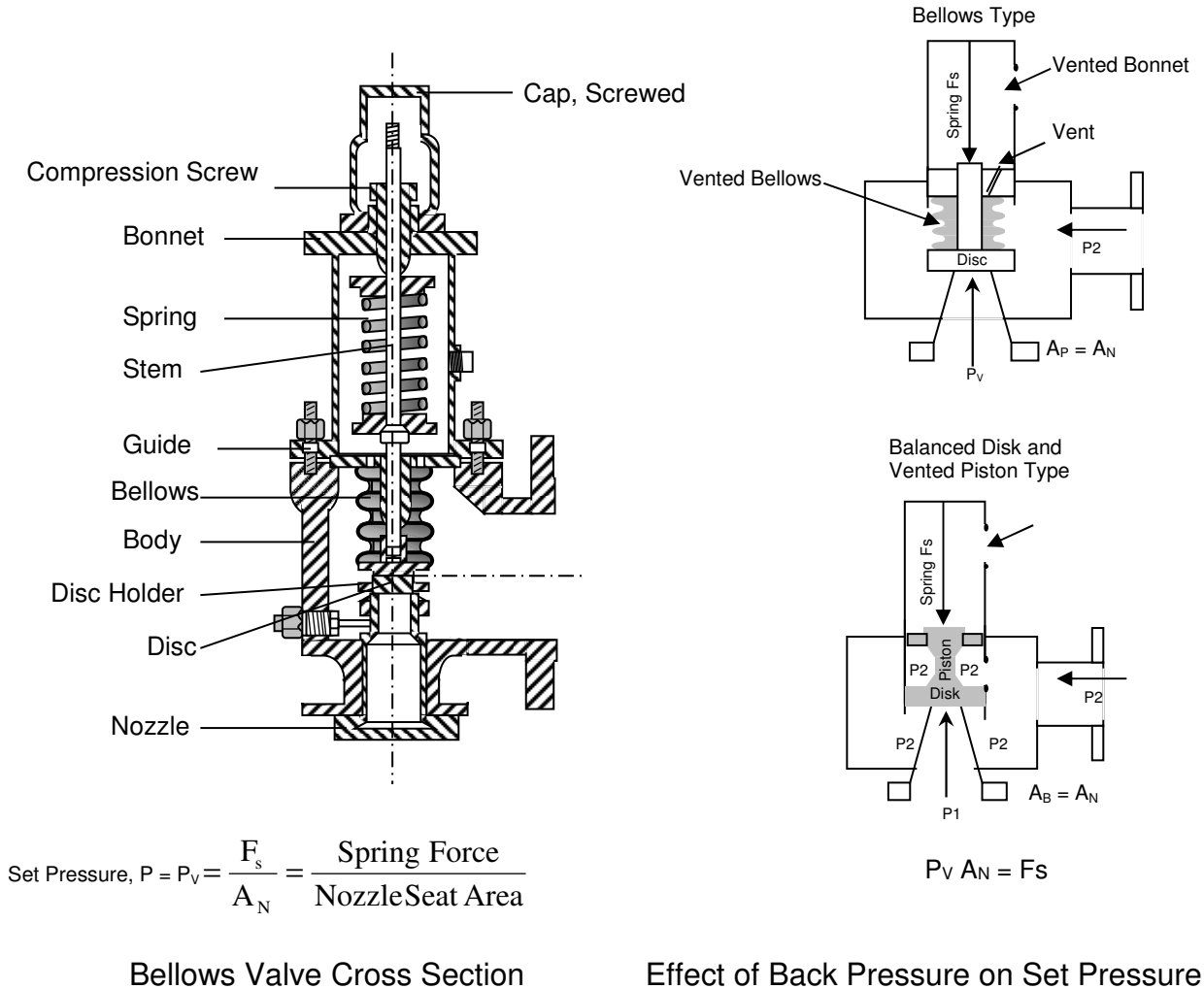


Figure 3: Balanced Pressure Relief Valve

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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 3. 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 4). 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

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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 reseal.

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

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- (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°F and the newer designs are available for a maximum inlet temperature of about 1000°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.

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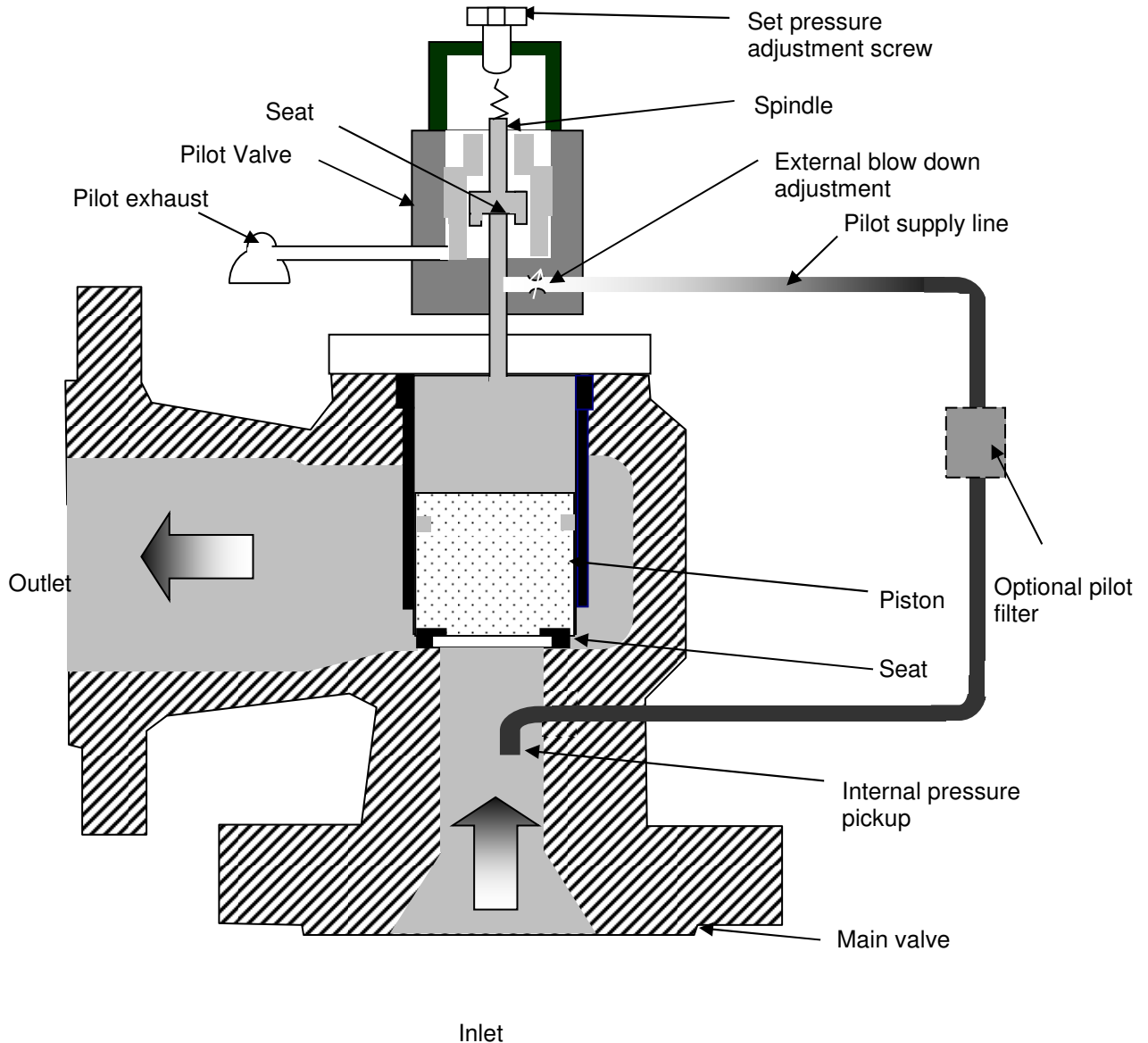


Figure 4: Pilot Operated Relief Valve

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II. Non Reclosing Pressure Relief Devices

(A) 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 5). 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 reseal; 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 pressure tolerance at the specified disk temperature shall not exceed ± 2 psi for stamped burst pressure up to and including 40 psi and $\pm 5\%$ for stamped burst pressure above 40 psi^[6].

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. The advantages and disadvantages of rupture disks show in following table.

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Table 2 : Advantages and disadvantages of rupture disks^[9]

Advantages	Disadvantages
Instaneous full opening	Non-reclosing (vent until inlet and outlet pressures equalize)
Zero leakage	Requires high margin between operating and opening pressures
Very large sizes easily and relatively economically available	Can fail by fatigue due to pulsations of pressure
Wide range of materials easily available	Burst pressure highly sensitive to temperature
Economical when exotic materials are imposed for the process	No possibility to check the burst pressure in the field
Virtually no maintenance	Requires depressurizing equipment for replacement after bursting
Full pipe bore (almost) Low pressure drop Low cost	Tolerance usually $\pm 5\%$

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 3 for the selection of the rupture disks and applications.

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Table 3: Rupture Disk Selection and Applications

Type of Rupture Disk	Applications
<p>Forward-Acting</p> <p>(a) Forward-Acting Solid Metal</p> <p>(b) Forward-Acting Scored</p> <p>(c) Forward-Acting Composite</p>	<p>(a) Operating pressure up to 70% of the marked burst pressure of the disk; not suitable for installation upstream of a pressure relief valve</p> <p>(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</p> <p>(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</p>
<p>Reverse-Acting</p> <p>(Formed solid metal disk designed to reverse and burst at a rated pressure applied on the convex side.)</p>	<p>(a) Designed to open by some methods such as shear, knife blades, knife rings, or scored lines.</p> <p>(b) Suitable for installation upstream of pressure relief valves.</p> <p>(c) Provided satisfactory service life with operating pressure 90% or less of marked burst pressure.</p>
<p>Graphite Rupture Disks</p> <p>(Machined from a bar of fine graphite that has been impregnated with a binding compound.)</p>	<p>(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.</p> <p>(b) Used for vacuum or back pressure conditions with furnished with a support to prevent reverse flexing.</p>

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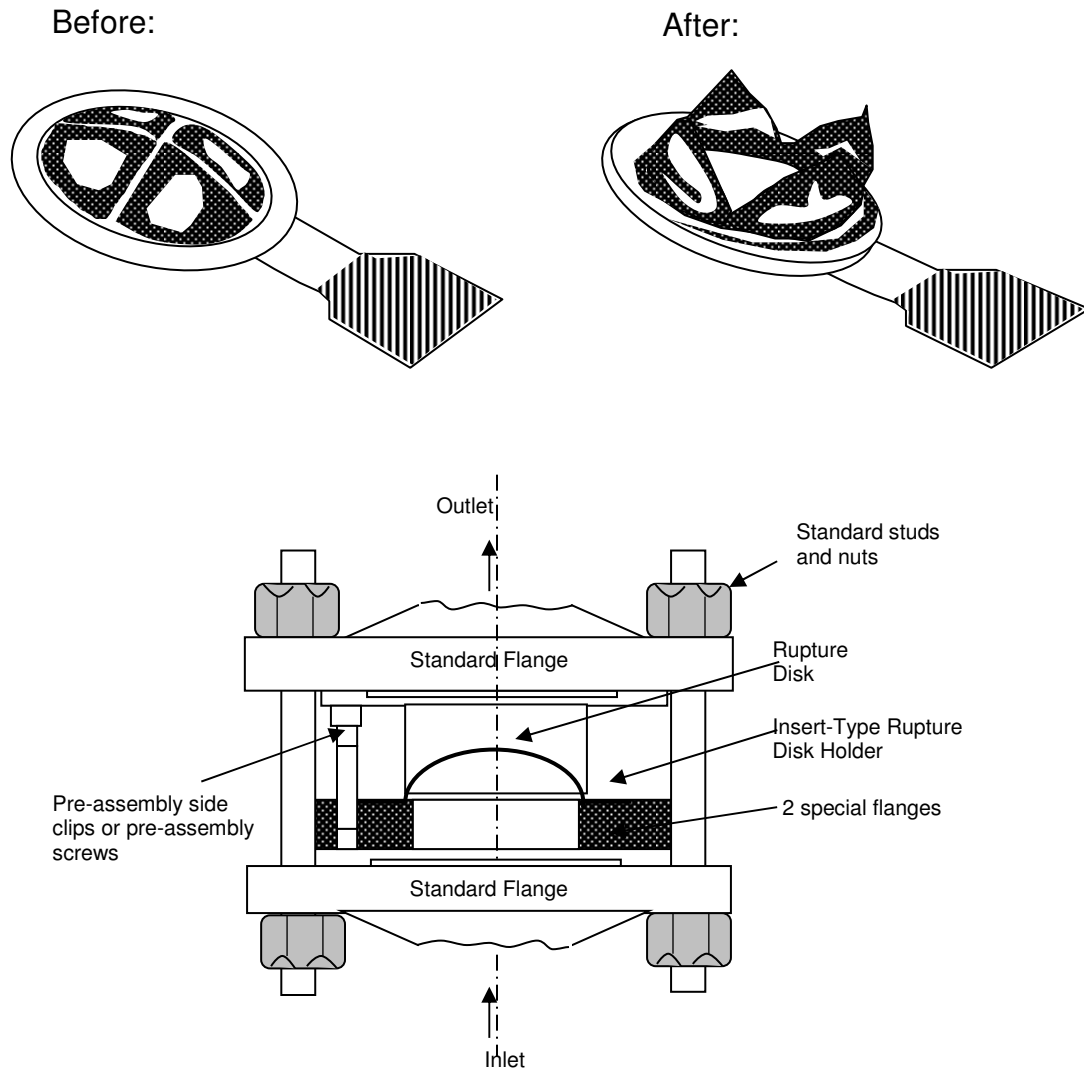


Figure 5: Forward-Acting Solid Metal Rupture Disk Assembly

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