

Inspection of Pressure-relieving Devices

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Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, Acronyms, and Abbreviations	2
3.1 Terms and Definitions	2
3.2 Acronyms and Abbreviations	6
4 Pressure-relieving Devices (PRDs)	6
4.1 General	6
4.2 Pressure-relief Valve (PRV)	6
4.3 Direct-acting PRV	7
4.4 Pilot-operated PRVs	10
4.5 Rupture Disk Devices	13
4.6 Pin-actuated Devices	22
5 Causes of Improper Performance	24
5.1 Corrosion	24
5.2 Damaged Seating Surfaces	28
5.3 Failed Springs	30
5.4 Improper Setting and Adjustment	32
5.5 Plugging and Fouling	33
5.6 Galling	35
5.7 Misapplication of Materials	35
5.8 Improper Location, History, or Identification	36
5.9 Improper Handling	36
5.10 Improper Differential Between Operating and Set Pressures	39
5.11 Improper Inlet/Outlet Piping Test Procedures	39
6 Inspection and Testing	39
6.1 Responsibilities	39
6.2 Operating History	40
6.3 Reasons for Inspection and Testing	41
6.4 Inspection Methods	41
6.5 Inspection, Testing, Maintenance, and Setting of Direct Spring-operated Safety Valves When Used on Fired Pressure Vessels	56
6.6 Inspection, Testing, Maintenance, and Setting of Pilot-operated PRVs	56
6.7 Inspection, Testing, Maintenance, and Setting of Weight-loaded Pressure and/or Vacuum Vents on Tanks	57
6.8 Inspection and Replacement of Rupture Disk Devices	58
6.9 Inspection Frequency	62
7 Records and Reports	65
7.1 General	65
7.2 The Need to Keep Records	66
7.3 Sample Record and Report System	66
Annex A (informative) Pressure-relief Valve Testing	67
Annex B (informative) Sample Record and Report Forms	70
Bibliography	76

Figures

1 Pressure/Vacuum-relief Valve	7
2 Weight-loaded Emergency Vent	8
3 Open Bonnet, Direct-acting Spring-loaded Pressure-relief Valve	8
4 Closed Bonnet, Direct-acting Spring-loaded Relief Valve	9
5 Balanced Bellows Direct-acting Spring-loaded Pressure-relief Valve	10
6 Unbalanced Piston Main Valve, Pilot-operated Pressure-relief Valve	11



7	Diaphragm Main Valve, Pilot-operated Pressure-relief Valve	12
8	Diaphragm Main Valve, Pilot-operated Pressure- and Vacuum-relief Valve	13
9	Forward-acting Conventional Rupture Disk	14
10	Forward-acting Scored Rupture Disk	15
11	Reverse-acting Knife Blade Rupture Disk	16
12	Reverse-acting Scored Rupture Disk	17
13	Graphite Rupture Disk	18
14	Rupture Disk in Union Holder	19
15	Rupture Disk in Screw-type Holder	19
16	Rupture Disk with Insert-type Holder	19
17	Insert-type Holder Installation	20
18	Conventional Domed Rupture Disk (Disk Is in an Insert-type Holder)	20
19	Piston-type Pin-actuated Device	23
20	Butterfly-type Pin-actuated Device	24
21	Acid Corrosion in Carbon Steel Bonnet Caused by Leaking Seating Surfaces	25
22	Chloride Corrosion on 18Cr-8Ni Steel Nozzle (with Machined Seating Surface)	25
23	Sulfide Corrosion on Carbon Steel Disc from Crude Oil Distillation Unit	26
24	Chloride Attack on 18Cr-8Ni Steel Disc	26
25	Pit-type Corrosion on 18Cr-8Ni Steel Bellows	27
26	Alloy 400 Rupture Disks Corroded in Sour Gas Service	27
27	Body and Bonnet Coated with Epoxy for Corrosion Protection	28
28	Seating Surface of Disc Deformed by Chattering	29
29	Seating Surface of Disc Damaged by Frequent Operation of Valve due to Excessive Cycling	30
30	Spring Failure Due to Corrosion	31
31	Spring Failure Due to Stress Corrosion	31
32	Inlet Nozzle Plugged with Coke and Catalyst After Nine Months in Reactor Vapor Line	33
33	Outlet Valve Plugged with Deposits from Other Valves in Common Discharge Header	34
34	Moving Parts of Valve Fouled with Iron Sulfide (FeS ₂)	34
35	Disc Frozen in Guide Because of Buildup of Products of Corrosion in Sour Oil Vapor Service	35
36	Improper Storage of Valves	36
37	Example of Improper Storage of Valves	37
38	Identification Tag for Pressure-relieving Device	43
39	Identification Tag for Pressure-relieving Device (Pre-2013)	43
40	Identification Tag for Pressure-relieving Device (Mandatory January 1, 2013)	44
41	Block Valves on Pressure-relief Valve Inlet and Outlet Sealed Open	48
42	Sulfur Deposits in Body of Valve	50
43	Safety Valve and Relief Valve Leak Detector	55
44	Operating Ratio Exceeded, Then Subjected to Vacuum	58
45	Operating Ratio Exceeded—Tabs Are Stretched	59
46	Disk Subjected to Corrosion	59
47	Rupture Disk Holder Subjected to Excessive Corrosion	60
48	Rupture Disk Holder Subjected to Corrosion	60
49	Rupture Disk Holder Corrosion Due to Leakage	61
50	Dent Caused by Water Freezing in Discharge Line	61
51	Rupture Disk Holder Subjected to Over-torque	62
A.1	Typical Safety Valve and Relief Valve Test Block Using Air As a Test	69
B.1	Sample Form for Recording Pressure-relieving Device Specifications	71
B.2	Sample Historical Record	72
B.3	Sample Inspection and Repair Work Order Form	73
B.4	Sample Testing Report	74
B.5	Sample In-service Report	75

Inspection of Pressure-relieving Devices

1 Scope

This recommended practice (RP) describes the inspection and repair practices for self-actuated pressure-relieving devices (PRDs) commonly used in the oil/gas and petrochemical industries. As a guide to the inspection and repair of these devices in the owner-operator's plant, it is intended to ensure their proper performance. This publication covers self-actuated devices such as direct-acting spring-loaded valves, pilot-operated pressure-relief valves (PRVs), rupture disks, pin-actuated devices, and weight-loaded pressure vacuum vents.

The recommendations in this publication are not intended to supersede requirements established by regulatory bodies. This publication excludes tank weak seams and/or sections or tank thief hatches, explosion doors, fusible plugs, control valves, pressure-regulating devices, integral rotating equipment components, other devices that either depend on an external source of power for operation or are manually operated, or devices not designed to be inspected or recertified. Inspections and tests made at manufacturers' plants, which are usually covered by codes or purchase specifications, are not covered by this publication.

This publication does not cover training requirements for personnel involved in the inspection and repair of PRDs. Those seeking these requirements should see API 510 and API 570, which give the requirements for a quality control system and specify that the repair organization maintain and document a training program ensuring that personnel are qualified.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API 510, *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*

API Standard 520 (all parts), *Sizing, Selection, and Installation of Pressure-relieving Devices*

API Standard 521, *Pressure-relieving and Depressuring Systems*

API Standard 526, *Flanged Steel Pressure-relief Valves*

API Standard 527, *Seat Tightness of Pressure Relief Valves*

API 570, *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

API Recommended Practice 580, *Elements of a Risk-Based Inspection*

API Standard 2000, *Venting Atmospheric and Low-pressure Storage Tanks*

ASME Boiler and Pressure Vessel Code (BPVC) ¹, *Section I, Rules for Construction of Power Boilers*

ASME Boiler and Pressure Vessel Code (BPVC), *Section VIII: Rules for Construction of Pressure Vessels; Division 1*

ASME Boiler and Pressure Vessel Code (BPVC), *Section XIII, Rules for Overpressure Protection*

ASME PTC 25, *Pressure Relief Devices—Performance Test Codes*

¹ ASME International, Two Park Avenue, New York, NY 10016-5990, www.asme.org.

NBBI NB-18², *Pressure Relief Device Certification*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

When used within this document, the following terms and definitions apply.

3.1.1

accumulation

The pressure increase over the maximum allowable working pressure (MAWP) of the vessel or piping system.

NOTE 1 The increase is expressed in pressure units or as a percentage of MAWP or design pressure if a MAWP has not been established.

NOTE 2 Maximum allowable accumulations are established by applicable codes for emergency, operating, and fire contingencies.

3.1.2

backpressure

The pressure that exists at the outlet of a PRD as a result of the pressure in the discharge system.

NOTE Backpressure is the sum of the superimposed and built-up backpressures.

3.1.3

blowdown

The difference between the set pressure and the closing pressure of a PRV, expressed as a percentage of the set pressure or in pressure units.

3.1.4

built-up backpressure

The increase in pressure at the outlet of a PRD that develops as a result of flow after the PRD opens.

3.1.5

burst pressure

The value of the upstream static pressure minus the value of the downstream static pressure just prior to when the rupture disk bursts.

NOTE When the downstream pressure is atmospheric, the burst pressure is the upstream static gauge pressure.

3.1.6

burst pressure tolerance

The variation around the marked burst pressure at the specified disk temperature in which a rupture disk will burst.

3.1.7

car seal

A device installed on a valve to secure it in a specified position (open or closed).

NOTE 1 The term "car seal" is refers to a plastic or metal strap clamped onto the closure mechanism to signify that the mechanism is closed and "sealed."

NOTE 2 When properly installed, the associated valve may not be operated unless the means of sealing is physically removed, thus serving as a mechanical locking element per ASME BPVC Section XIII requirements for administrative controls on a stop valve in a pressure-relief system.

² The National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229, www.nationalboard.org.

3.1.8**closing pressure**

The value of decreasing inlet static pressure at which the valve disc reestablishes contact with the seat or at which lift becomes zero.

NOTE This can be determined by seeing, feeling, or hearing.

3.1.9**cold differential test pressure****CDTP**

The pressure at which a PRV is adjusted to open on the test stand.

NOTE The cold differential test pressure (CDTP) includes corrections for the service conditions of superimposed backpressure or temperature or both.

3.1.10**design pressure**

The pressure, together with the design temperature, used to determine the minimum permissible thickness or physical characteristic of each vessel or piping component as determined by the appropriate design rules.

NOTE 1 The design pressure is selected by the owner-operator to provide a suitable margin above the most severe pressure expected during normal operation at a coincident temperature.

NOTE 2 This pressure may be used in place of the MAWP in all cases where the MAWP has not been established.

NOTE 3 The design pressure is equal to or less than the MAWP.

3.1.11**disc**

A movable component of a PRD that contains the primary pressure when it rests against the nozzle.

3.1.12**galling**

A condition whereby the interaction between two surfaces as they slide past each other results in localized welding with subsequent splitting and a further roughening of rubbing surfaces of one or both of two mating parts.

3.1.13**huddling chamber**

An annular chamber located downstream of the seat of a PRV for the purpose of assisting the valve to achieve lift.

3.1.14**lift**

The actual travel of the disc away from the closed position when a PRV is relieving.

3.1.15**lifting lever**

A device to apply an external force to the stem of a relief valve to manually operate the valve.

3.1.16**manufacturing design range**

The pressure range at which the rupture disk is marked.

NOTE 1 Manufacturing design ranges are usually catalogued by the manufacturer as a percentage of the specified burst pressure.

NOTE 2 Catalogued manufacturing ranges may be modified by agreement between the owner-operator and the manufacturer.

3.1.17**marked burst pressure**

The rupture disk burst pressure established by tests for the specified temperature and marked on the rupture disk tag by the manufacturer.

NOTE 1 The marked burst pressure may be any pressure within the manufacturing design range unless otherwise specified by the owner-operator.

NOTE 2 The marked burst pressure is applied to all the rupture disks of the same lot.

3.1.18**maximum allowable working pressure****MAWP**

The maximum gauge pressure permissible at the top of a vessel or piping system in its operating position at the designated coincident temperature specified for that pressure.

NOTE 1 The pressure is the least of the values for the internal or external pressure as determined by the vessel or piping system design rules for each element of the vessel or piping system using actual nominal thickness, exclusive of additional metal thickness allowed for corrosion and loadings other than pressure.

NOTE 2 The MAWP is the basis for the pressure setting of the PRDs that protect a vessel or piping system.

NOTE 3 The MAWP is normally greater than the design pressure but can be equal to the design pressure when the design rules are used only to calculate the minimum thickness for each element, and calculations are not made to determine the value of the MAWP.

3.1.19**non-reclosing pressure-relief device**

A PRD that remains open after operation.

NOTE A manual resetting means may be provided.

3.1.20**opening pressure**

The value of the increasing inlet static pressure at which there is a measurable lift of the disc or at which discharge of the fluid becomes continuous, as determined by seeing, feeling, or hearing.

3.1.21**overhaul**

The action to take apart and examine a component, repair if necessary, and make available for its next use in an as-repaired condition.

3.1.22**overpressure**

The pressure increase over the set pressure of the relieving device.

NOTE 1 Overpressure is expressed in pressure units or as a percentage of set pressure.

NOTE 2 Overpressure is the same as accumulation only when the relieving device is set to open at the MAWP of the vessel or piping system.

3.1.23**owner-operator**

The organization that exercises control over the operation, engineering, inspection, repair, alteration, pressure testing, and rating of the site equipment.

3.1.24**pin-actuated device**

A non-reclosing PRD actuated by static pressure and designed to function by buckling or breaking a pin that holds a piston or a plug in place.

NOTE Upon buckling or breaking of the pin, the piston or plug instantly moves to the fully open position.

3.1.25**pop pressure**

The value of increasing inlet static pressure at which the disc moves in the opening direction at a faster rate as compared with corresponding movement at higher or lower pressures.

3.1.26**qualified person**

A competent person who has met the knowledge, skill requirements, and expectations of the owner-operator.

3.1.27**set pressure**

The inlet gauge pressure at which a PRV is set to open under service conditions.

3.1.28**simmer**

The audible or visible intermittent escape of fluid between the seat and disc of a PRV that may occur at an inlet static pressure below the set pressure prior to opening/relief (pop).

3.1.29**specified burst pressure**

The burst pressure specified by the owner-operator.

NOTE 1 The marked burst pressure may be greater than or less than the specified burst pressure but shall be within the manufacturing design range.

NOTE 2 The owner-operator is cautioned to consider manufacturing design range, superimposed backpressure, and specified temperature when determining a specified burst pressure.

3.1.30**superimposed backpressure**

The static pressure that exists at the outlet of a PRD at the time the device is required to operate.

NOTE This is pressure at the PRD outlet coming from other sources and may be constant or variable.

3.1.31**telltale indicator**

An assembly installed in the space between a rupture disk and another relief device (in series) to detect or prevent the accumulation of pressure between the rupture disk and the other device.

3.1.32**trim**

The internal parts of a PRV that are exposed to the process fluid.

NOTE 1 At a minimum, "trim" refers to the nozzle and disc but may also include other components that are in contact with the process fluids (disc holder, blowdown ring, guide, spindle, etc.) or are required for proper valve performance.

NOTE 2 Trim are normally manufactured using materials that are resistant to degradation from the associated process.

3.2 Acronyms and Abbreviations

CDTP	cold differential test pressure
HF	hydrofluoric acid
MAWP	maximum allowable working pressure
NDE	nondestructive examination
P&ID	pipng and instrumentation diagram
PRD	pressure-relief device or pressure-relieving device
PRV	pressure-relief valve
PVRV	pressure- and/or vacuum-relief valves
RBI	Risk-Based Inspection

4 Pressure-relieving Devices (PRDs)

4.1 General

PRDs protect equipment and personnel by opening at predetermined pressures and preventing the adverse consequences of excessive pressures in process systems and storage equipment.

A PRD is actuated by inlet static pressure and designed to open during emergency or abnormal conditions to prevent a rise of internal fluid pressure more than a specified design value. The device may also be designed to prevent excessive internal vacuum. The device may be a PRV, a non-reclosing PRD, or a vacuum-relief valve.

Common examples include direct spring-loaded PRVs, pilot-operated PRVs, rupture disks, buckling pin devices, and weight-loaded devices.

Refer to API 520, Part I or API 2000 for more information regarding PRD design considerations.

4.2 Pressure-relief Valve (PRV)

4.2.1 General

A PRV is designed to open for the relief of excess pressure and reclose, thereby preventing further flow of fluid after normal conditions have been restored. A PRV opens when its upstream pressure reaches the opening pressure. It then allows fluid to flow until its upstream pressure falls to the closing pressure. It then closes, preventing further flow. The term “pressure-relief valve” is generic in nature, and these devices can be classified as a safety valve, relief valve, or a safety relief valve.

4.2.2 Safety Valve

A safety valve is a PRV that is actuated by the difference between its upstream and downstream pressures and characterized by rapid opening or relief (pop) action. A safety valve is normally used with compressible fluids. Safety valves are used on steam boiler drums and superheaters and are also used for general air, gas, and steam services in refinery and petrochemical plants.

When the static inlet pressure reaches the set pressure, it will increase the pressure upstream of the disc and overcome the seating force on the disc. Fluid will then enter the huddling chamber, providing additional opening force. This will cause the disc to lift and provide full opening at specified overpressure. The closing pressure will be less than the set pressure and will be reached after the blowdown phase is completed.

4.2.3 Relief Valve

A relief valve is a PRV actuated by the difference between static pressure upstream of the valve and superimposed backpressure downstream (unless pressure compensated, i.e., with bellows or balancing) and opens normally in proportion to the pressure increase over the opening pressure. A relief valve is normally used with incompressible fluids. A relief valve begins to open when the static inlet pressure reaches its set pressure. When the static inlet pressure overcomes the seating force, the disc begins to lift off the seat, allowing flow of the liquid. The value of the closing pressure is lower than the set pressure and will be reached after the blowdown phase is complete.

4.2.4 Safety Relief Valve

A safety relief valve is a PRV that may be used as either a safety or relief valve depending on the application. The trim of the safety relief valve will provide stable lifting characteristics on either compressible or incompressible media.

4.3 Direct-acting PRV

4.3.1 General

A direct-acting PRV uses a weight or compressed spring to hold the valve seat closed below the set pressure or vacuum setting of the device.

4.3.2 Weight-loaded Pressure/Vacuum-relief Valve

These devices are used in pressure and/or vacuum protection applications where operating pressures are very near atmospheric conditions. The set pressure or vacuum setting can be changed by adding or removing weights in the seating area of the valve. These devices are normally vented to atmosphere. See Figure 1. They are often used to satisfy the normal venting requirements caused by thermal inbreathing/outbreathing and product pump-in/pump-out effects.

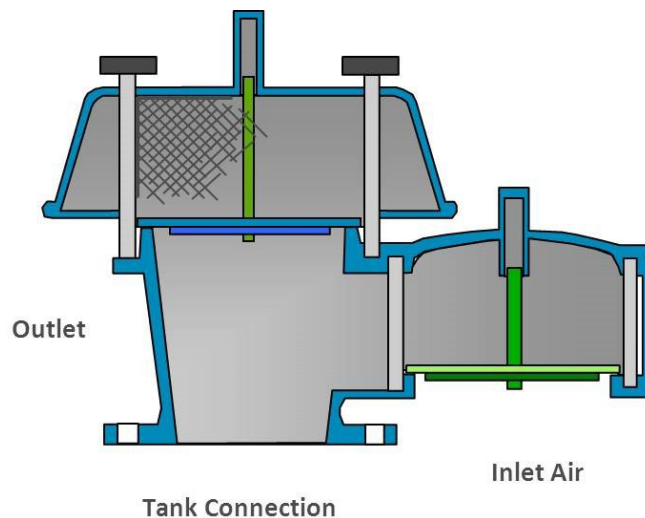


Figure 1—Pressure/Vacuum-relief Valve

There are times where additional venting requirements are needed for emergency overpressure scenarios such as external tank fire. Weight-loaded emergency vents can provide this additional capacity. These are typically hinged devices that have a hatch of sufficient weight to open at the needed set pressure. They are set higher than the normal venting devices as the hatch of the emergency vent will not reclose after opening. See Figure 2.



Figure 2—Weight-loaded Emergency Vent

4.3.3 Direct Spring-operated PRV

4.3.3.1 General

These devices use the compression of a spring to determine the set pressure. The spring may be externally visible in what is called an open bonnet valve. See Figure 3.

Warning—Open bonnet PRVs should be installed away from personnel since the exhaust of the media during a relieving cycle will be released to the ambient area via the open bonnet.

Caution—Open bonnets are limited to services that are nonhazardous, such as steam, air, and water, since the process fluid will escape through the open bonnet upon actuation of the PRV.

There are conventional and balanced types of direct spring-operating PRVs.

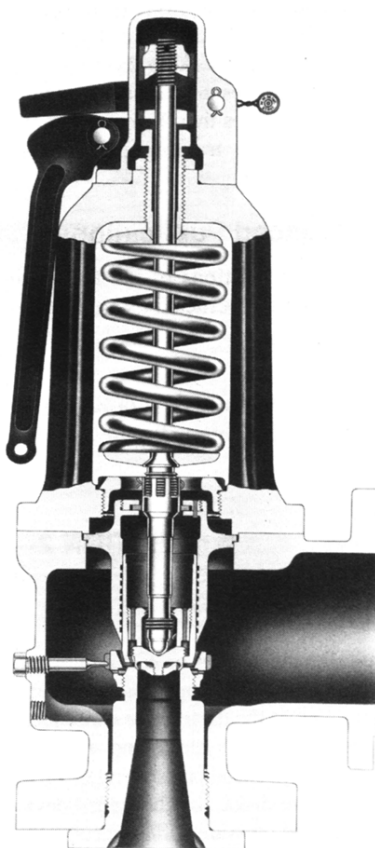


Figure 3—Open Bonnet, Direct-acting Spring-loaded Pressure-relief Valve

4.3.3.2 Conventional Direct Spring-operated PRV

A conventional valve can utilize a closed spring bonnet that will allow any backpressure to be contained within all areas of the valve downstream of the seat. This backpressure can affect the set pressure, stability, and relief capacity. Figure 4 shows a typical API 526 conventional direct spring-operated PRV.

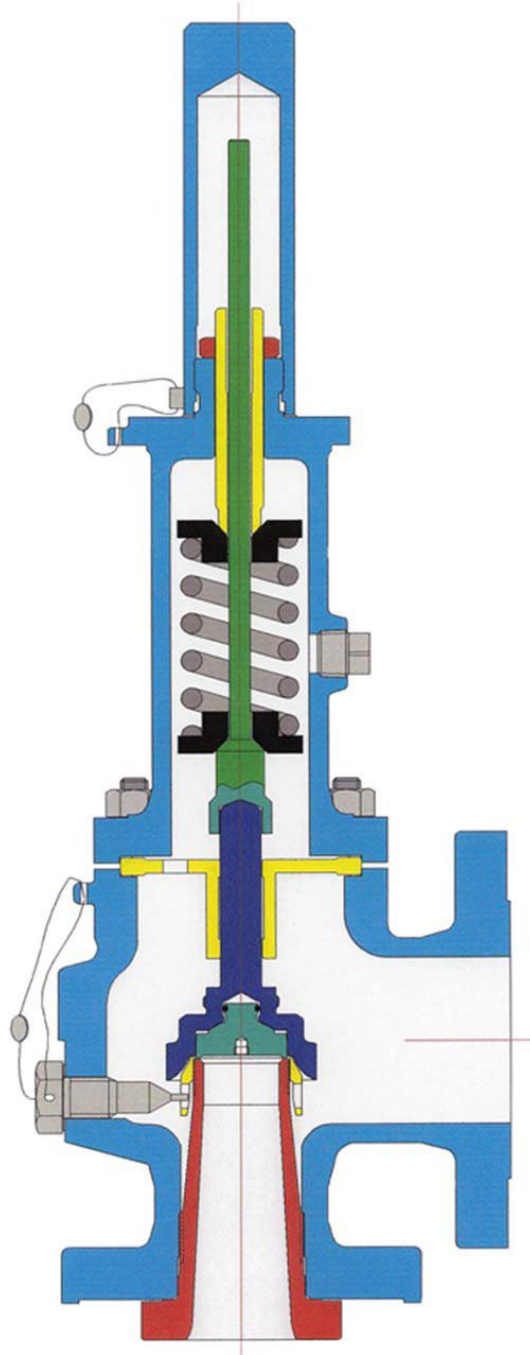


Figure 4—Closed Bonnet, Direct-acting Spring-loaded Relief Valve

4.3.3.3 Balanced Direct Spring-operated PRV

A balanced valve incorporates a bellows or other means for minimizing the effect of backpressure on the operational characteristics of the valve. A balanced valve will have a vented spring bonnet. See Figure 5. The vented bonnet allows the valve to operate without bias from the backpressure if the bellows or other balancing member should leak or otherwise fail. This vent shall always be open to atmospheric pressure. If the valve is located where atmospheric venting would present a hazard, or is not permitted by environmental regulations, the vent should be piped to a safe location that is free of backpressure that may affect the PRV opening pressure (per API 520, Part I, Section 4.2.1.2.3). Refer to API 520, Part II, Section 10 for bonnet or pilot vent piping.

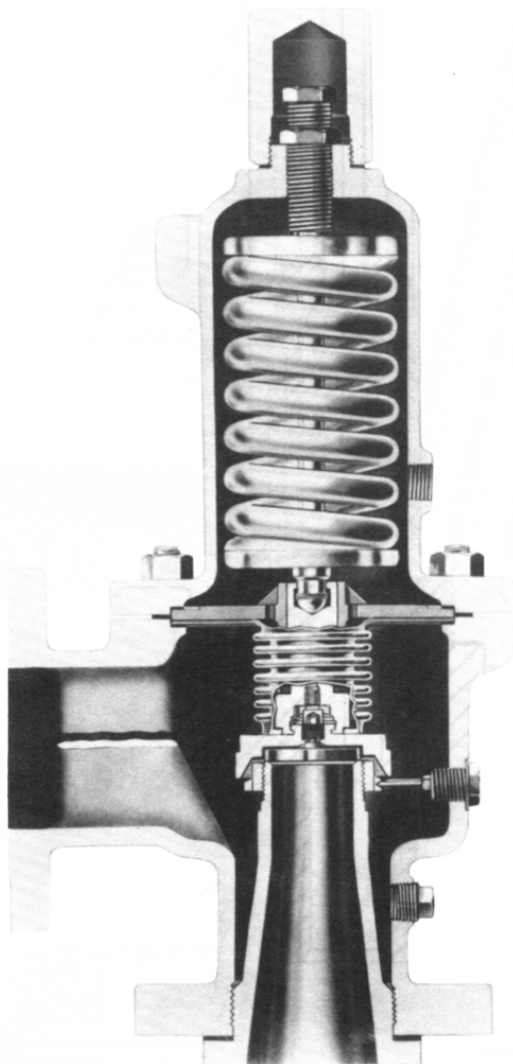


Figure 5—Balanced Bellows Direct-acting Spring-loaded Pressure-relief Valve

4.4 Pilot-operated PRVs

A pilot-operated PRV consists of a major relieving device or main valve, which is combined with and controlled by a self-actuated auxiliary PRV (pilot). Just as with direct-acting valves, the pilot-operated valve can be a safety valve (also called a snap action design), relief, or safety relief valve (also called a modulating acting design) type.

Pilot-operated PRVs are generally used:

- where a large relief area and/or high set pressures are required;
- where a low differential (operating margin) exists between the normal pressure equipment (vessel and piping) operating pressure and the set pressure of the valve;
- on large low-pressure storage tanks;
- where very short blowdown is required;
- where backpressure is very high and balanced design is required;
- where process conditions require sensing of pressure at one location and relief of fluid at another location;
- where inlet or outlet piping frictional pressure losses are high; and
- where in situ, in service, set pressure verification is desired.

The pilot is a spring-loaded valve that operates when its inlet static pressure exceeds its set pressure. This causes the main valve to open and close according to the pressure. Process pressure is either vented off by the pilot valve to open the main valve or applied to the top of the unbalanced piston (Figure 6), or diaphragm (Figures 7 and 8), of the main valve to close it. The diaphragm main valve design can also be used as a vacuum-venting device, where either the weight of the main valve disc or a pilot valve, set on vacuum, controls the opening and closing of the main valve.

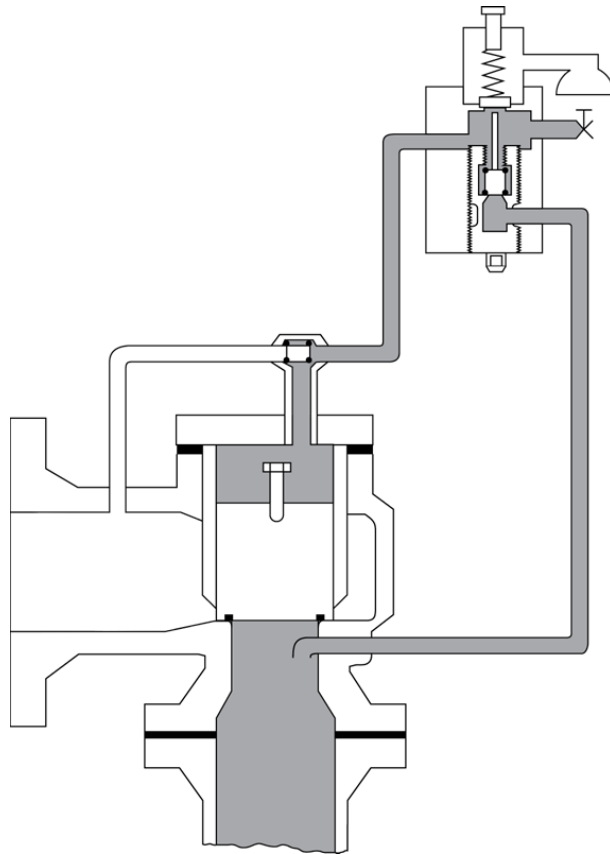


Figure 6—Unbalanced Piston Main Valve, Pilot-operated Pressure-relief Valve

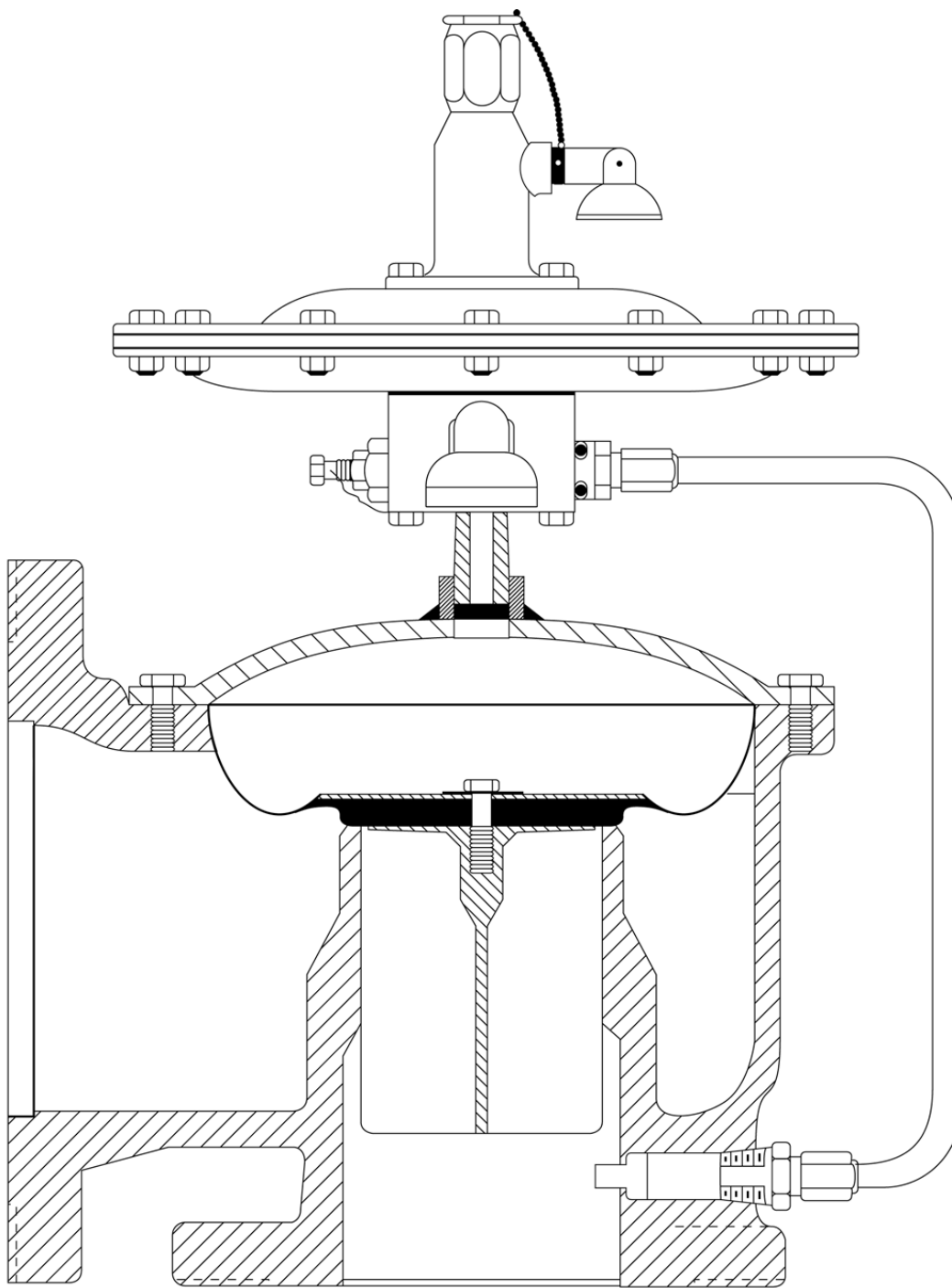


Figure 7—Diaphragm Main Valve, Pilot-operated Pressure-relief Valve



Figure 8—Diaphragm Main Valve, Pilot-operated Pressure- and Vacuum-relief Valve

4.5 Rupture Disk Devices

4.5.1 Forward-acting, Reverse-acting, and Graphite Rupture Disks

4.5.1.1 General

A rupture disk device is a non-reclosing PRD actuated by the static differential pressure between the inlet and outlet of the device and designed to function by the bursting of a rupture disk. A rupture disk device includes a rupture disk and, where applicable, a rupture disk holder.

- a) A rupture disk is a pressure-containing, pressure- and temperature-sensitive element of a rupture disk device.
- b) A rupture disk holder is the structure that encloses and clamps the rupture disk in position. Rupture disks typically require a rupture disk holder, although some disk designs can be installed between standard flanges without holders.
- c) Rupture disks are generally characterized into two groups, as follows.
 - 1) Non-fragmenting rupture disk is designed and manufactured such that on activation there will be no fragments released into the process flow. This type is often installed upstream of other piping components, such as PRVs, other types of valves, rotating and other equipment where rupture disk fragments can affect operation or cause restricted flow.
 - 2) Fragmenting rupture disk fails or activates in a manner that the device releases fragments that can inhibit action of downstream devices. They are unsuitable for installation upstream of another device.

Rupture disks may also come with corrosion-resistant liners to extend life or provide protection against deterioration in corrosive services. Service environments will dictate the type of liners selected.

There are three major rupture disk types: forward acting, reverse acting, and graphite.

4.5.1.2 Forward-acting Rupture Disks

4.5.1.2.1 General

Forward-acting, tension-loaded rupture disks are pressurized on the concave side such that the stresses in the dome are primarily tensile. Forward-acting rupture disks are designed to open by methods including tensile fracture of the dome, slitting, or scoring.

4.5.1.2.2 Forward-acting Conventional Rupture Disks

A forward-acting conventional rupture disk is a formed (domed), solid metal disk designed to burst at a rated pressure applied to the concave side. See Figure 9. This rupture disk typically has an angular seat design. The disk can be furnished with a support to prevent reverse flexing under vacuum or backpressure conditions. These disks have a random opening pattern and are considered fragmenting designs that are not suitable for installation upstream of a PRV.

4.5.1.2.3 Forward-acting Scored Rupture Disks

The forward-acting scored rupture disk is a formed (domed) disk designed to burst along score lines at a rated pressure applied to the concave side. See Figure 10. Most designs withstand vacuum conditions without a vacuum support. If backpressure conditions are present, the disk can be furnished with a support to prevent reverse flexing. Because the score lines control the opening pattern, this type of disk is generally non-fragmenting and is acceptable for installation upstream of a PRV.

4.5.1.2.4 Forward-acting Composite Rupture Disks

A forward-acting composite rupture disk is a flat or domed multi-piece construction disk. The domed composite rupture disk is designed to burst at a rated pressure applied to the concave side. Some designs are non-fragmenting and acceptable for use upstream of a PRV.

The domed composite rupture disk is available in flat seat or angular seat design. The burst pressure is controlled by the combination of slits and tabs in the top section. A metallic or nonmetallic seal member may be used under the top section to prevent corrosion. If vacuum or backpressure conditions are present, composite disks can be furnished with a support to prevent reverse flexing.

The flat composite rupture disk may be designed to burst at a rated pressure in either or both directions. A flat composite rupture disk usually comes complete with gaskets and is designed to be installed directly between companion flanges rather than within a specific rupture disk holder.



Figure 9—Forward-acting Conventional Rupture Disk

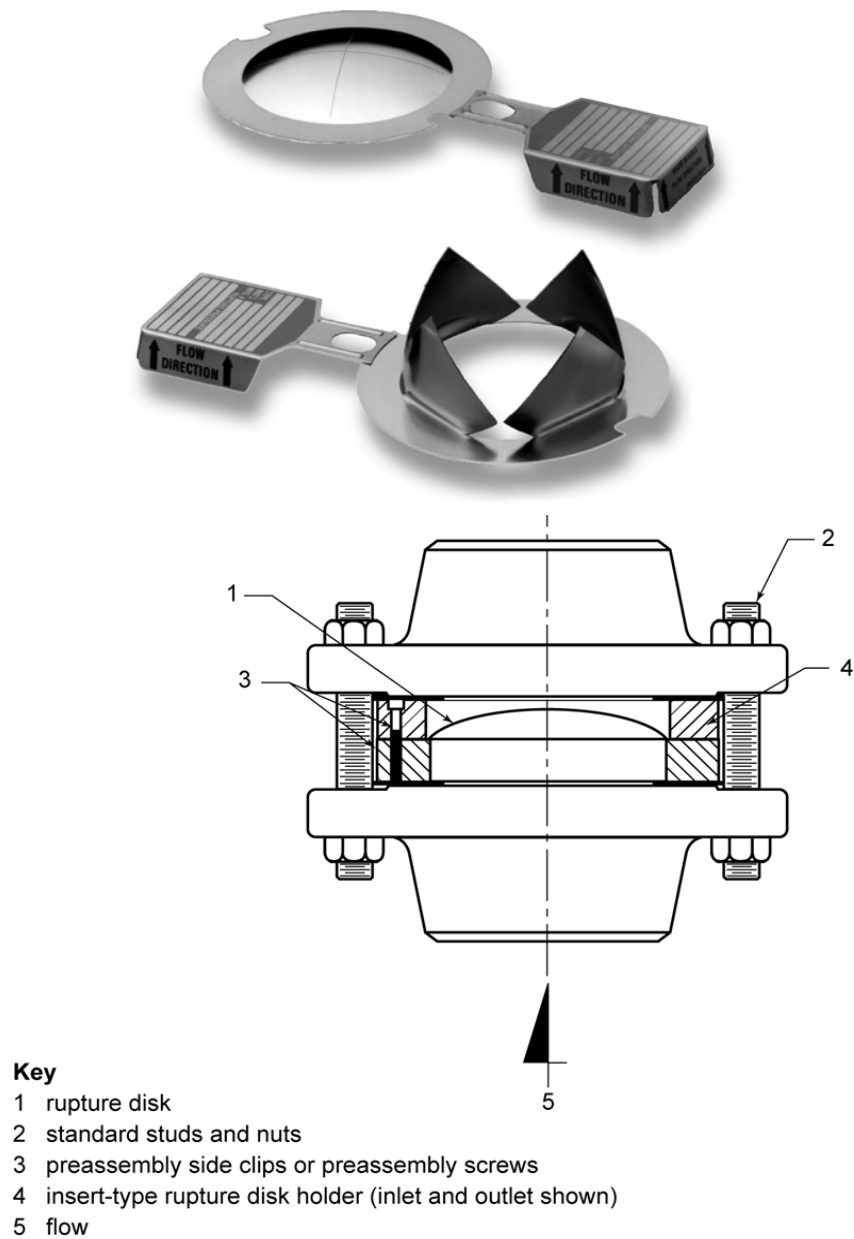


Figure 10—Forward-acting Scored Rupture Disk

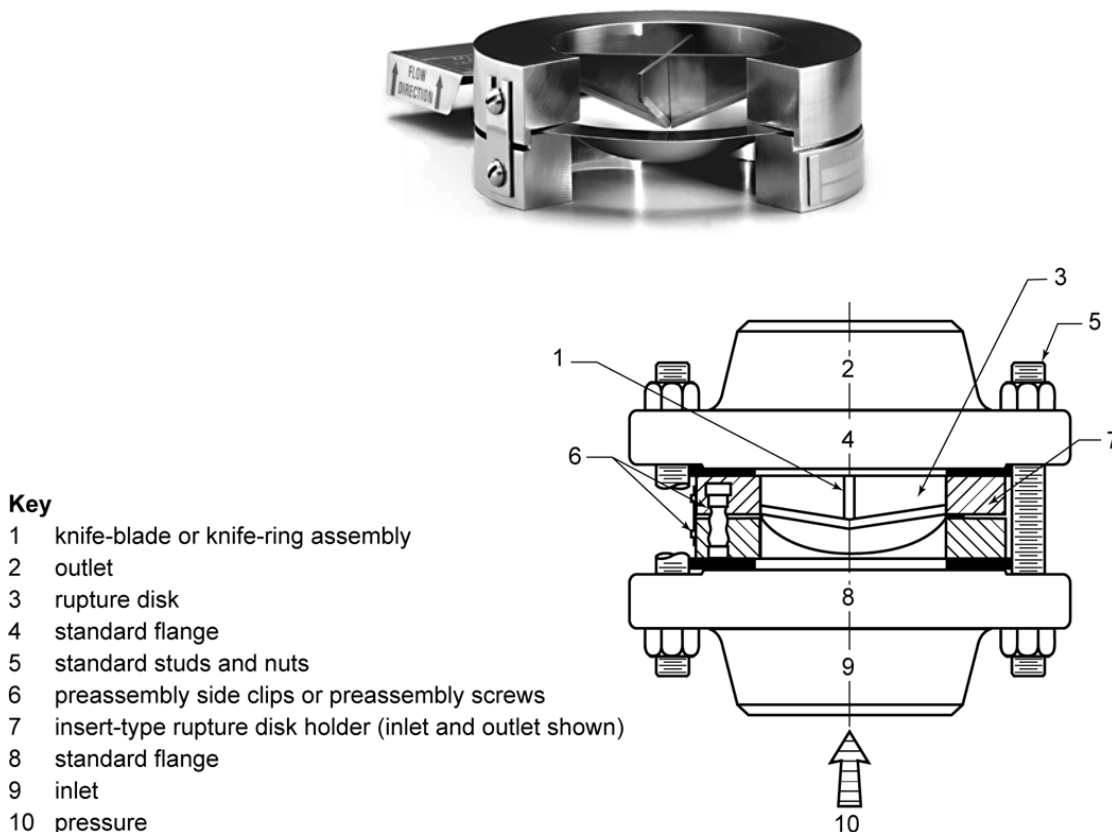


Figure 11—Reverse-acting Knife Blade Rupture Disk

4.5.1.3 Reverse-acting Rupture Disks

4.5.1.3.1 General

Reverse-acting, compression-loaded rupture disks are pressurized on the convex side such that the stresses in the dome are primarily compressive. Reverse-acting rupture disks are designed to open by such methods as shear knife blades, tooth rings, or scored lines.

4.5.1.3.2 Reverse-acting Knife Blade Rupture Disks

In a knife-blade type reverse-acting rupture disk device, the cutting edge of knife blades are positioned near the concave (i.e., downstream) side of the disk. As the bursting pressure is approached and the convex side of the disk begins to compress, the disk contacts the knife blades, which facilitate and guide the opening of the disk.

Knife blades installed in holders should be constructed of corrosion-resistant material and should be inspected periodically to ensure sufficient sharpness to open the disk. Dull or damaged knife blades will likely prevent proper opening of the disk. Personnel should be aware of safety hazards and personal injury when handling these devices. See Figure 11.

4.5.1.3.3 Reverse-acting Scored Rupture Disks

Reverse-acting rupture disks are generally designed to be non-fragmenting and are frequently installed upstream of PRVs. These disks provide satisfactory service life when operating pressures are 90 % or less of marked burst pressure (90 % operating ratio). Some types of reverse-buckling disks are designed to be exposed to pressures up to 95 % of the marked burst pressure. Consult the manufacturer for the actual

recommended operating ratio for the specific disk under consideration. Because a reverse-acting rupture disk is operated with pressure applied on the convex side, thicker disk materials may be used, thereby lessening the effects of corrosion, eliminating the need for vacuum support, and providing longer service life under pressure/vacuum cycling conditions and pressure fluctuations. See Figure 12.

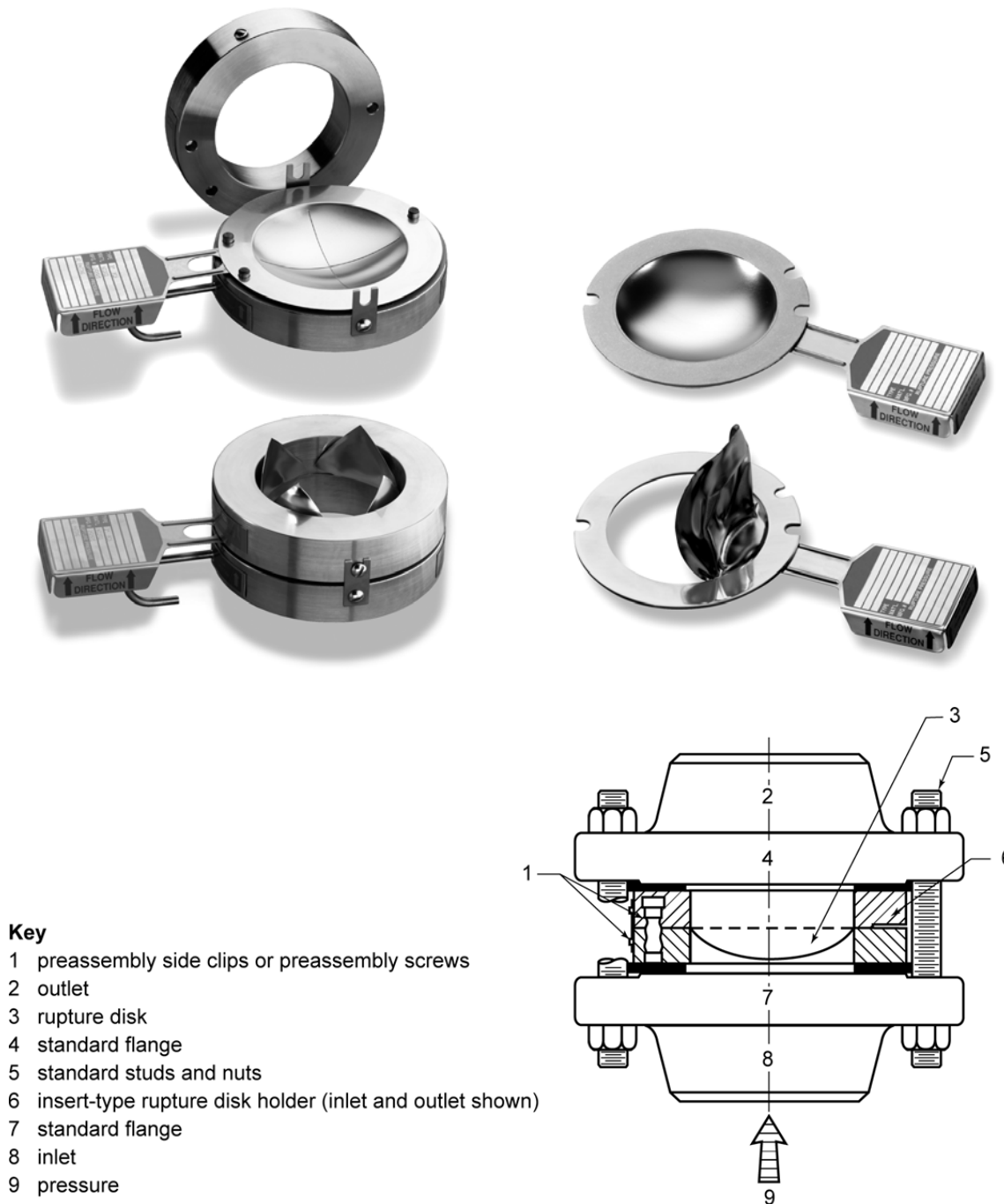


Figure 12—Reverse-acting Scored Rupture Disk

4.5.1.4 Graphite Rupture Disks

Graphite, shear-loaded rupture disks are flat and are designed to open by bending and/or shearing of the membrane.

A graphite rupture disk is manufactured from graphite impregnated with a binder material and designed to burst by bending or shearing. See Figure 13. Most graphite disks do not utilize a holder and install directly between pipe flanges. A vacuum support may be required for low-pressure disks that are subject to process vacuum. Graphite rupture disks fragment upon rupture.

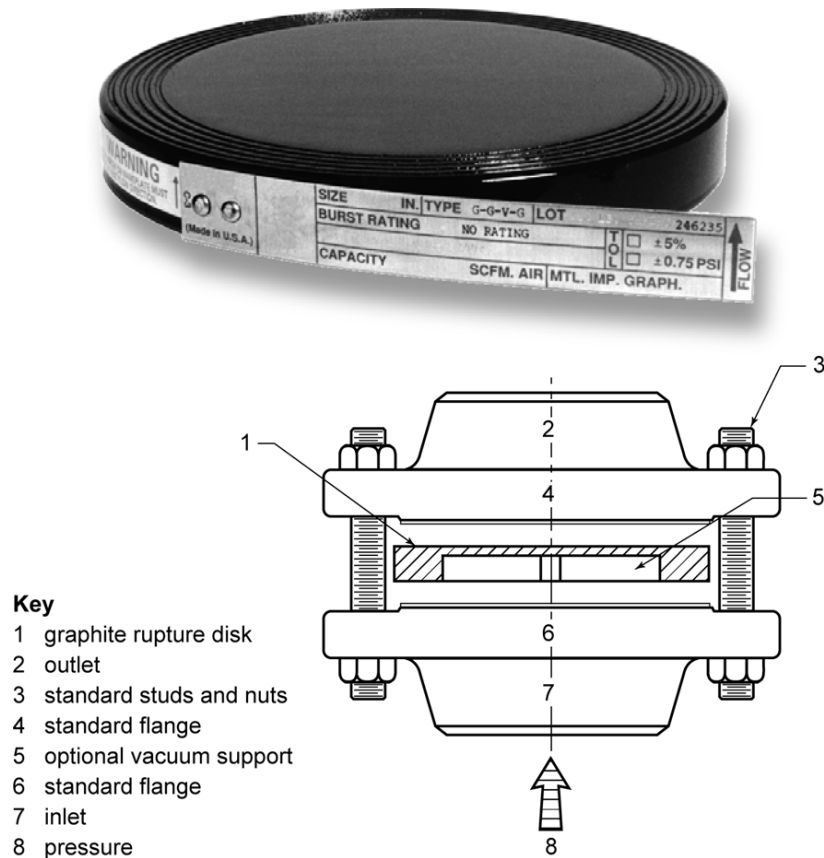


Figure 13—Graphite Rupture Disk

If vacuum or back pressure conditions are present, the disk can be furnished with a support to prevent reverse flexing. These disks have a random opening pattern and are considered fragmenting designs that are not suitable for installation upstream of a PRV. A metallic ring called armoring is often added to the outside diameter of the disk to help support uneven piping loads and minimize the potential for cracking of the outer graphite ring and blowout of process fluid.

4.5.2 Rupture Disk Holders

Rupture disk holders are used to clamp the rupture disk in place and affect a leak-tight, metal-to-metal seal. The seating area of the holders is typically unique to specific manufacturers and styles of rupture disks. There are varying designs available that present variable configurations including pre-torqued and non-pre-torqued holders plus full bolting, weld-neck, threaded connections, etc. The most common configuration is the insert type that fits between standard pipe flanges, and the outside diameter of the holder fits inside the flange studs. Rupture disk holders are available in a variety of materials and coatings. See Figures 14, 15, 16, 17, and 18.

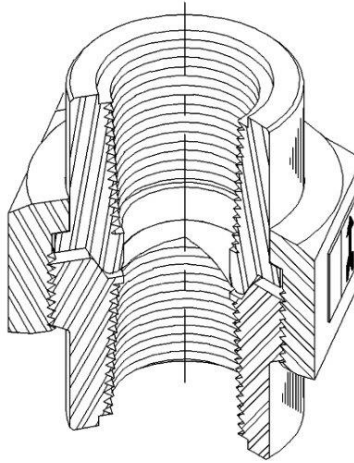


Figure 14—Rupture Disk in Union Holder

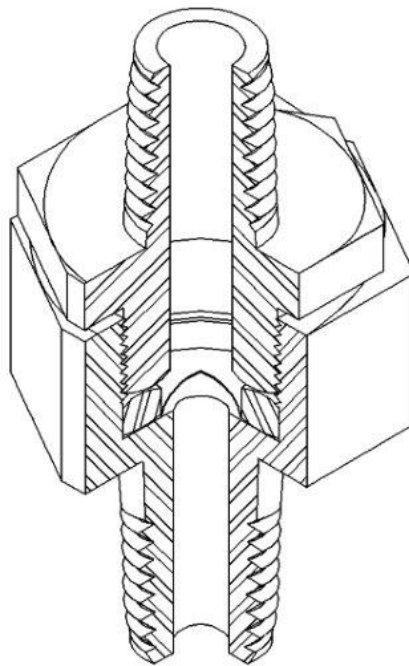


Figure 15—Rupture Disk in Screw-type Holder

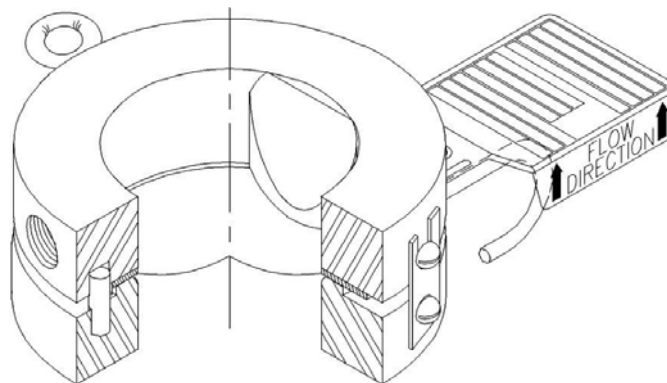


Figure 16—Rupture Disk with Insert-type Holder