

Sizing, Selection, and Installation of Pressure-relieving Devices

Part II—Installation

API STANDARD 520, PART II
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Sizing, Selection, and Installation of Pressure-relieving Devices

Part II—Installation

1 Scope

This standard covers methods of installation for pressure-relief devices (PRDs) for equipment that has a maximum allowable working pressure (MAWP) of 15 psig (1.03 barg or 103 kPAg) or greater. Pressure-relief valves (PRVs) or rupture disks (RDs) may be used independently or in combination with each other to provide the required protection against excessive pressure accumulation. As used in this standard, the term pressure-relief valve includes safety-relief valves used in either compressible or incompressible fluid service, and relief valves used in incompressible fluid service. This standard covers gas, vapor, steam, two-phase, and incompressible fluid service; it does not cover special applications that require unusual installation considerations.

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 Standard 520, *Sizing, Selection, and Installation of Pressure-relieving Devices, Part I—Sizing and Selection*

3 Terms and Definitions

The terminology for PRDs that is used in this standard is in general agreement with the definitions given in API 520, Part I.

4 PRD Location

4.1 General

There are a number of design factors that should be considered when determining the location of the PRD.

4.2 Proximity to Protected Equipment

If other factors permit, the PRD should normally be placed close to the protected equipment or system of equipment so that the pressure in the protected equipment stays within code allowable limits and to avoid PRV instability (see Section 7).

See 7.3.3 for guidance on establishing set pressure if PRD will be remote from the protected equipment.

4.3 Pressure Fluctuations

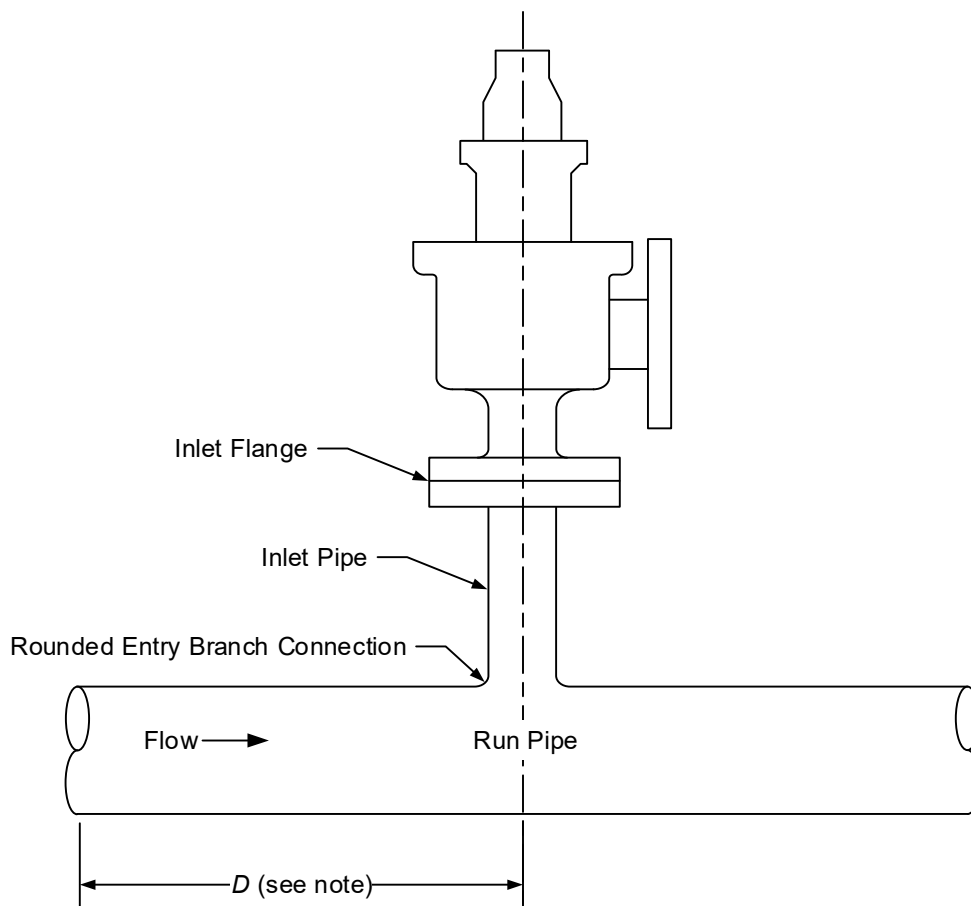
The PRD should not be located where there are pressure fluctuations large enough to result in relief valve simmering/activation or rupture disk fatigue. On installations that have pressure fluctuations that peak close to the set pressure of the PRV or burst pressure of a rupture disk, the PRD should be located farther from the source and in a more stable pressure region.

Examples of areas that may have pressure fluctuations include:

- locations close to control valves, other valves, and other appurtenances;
- locations close to orifice plates and flow nozzles;
- locations close to other fittings, such as short radius elbows;
- locations close to the discharge of positive displacement pumps or compressors.

The potential effect of pressure fluctuations on the relief device may be reduced by the following (see Figure 1):

- locating the PRD 10 or more pipe diameters from any areas as described above;
- providing a well-rounded, smooth branch connection where the relief device inlet piping joins the main piping run;
- providing a larger branch connection (relative to the size of the PRV inlet).



NOTE D is typically not less than 10 pipe diameters from any source that causes unstable flow.

Figure 1—Typical Installation Avoiding Unstable Flow Patterns at PRV Inlet

4.4 Vibration

Most vibrations that occur in piping systems are random and complex. These vibrations may cause leakage at the seat of a PRV, premature opening, or premature fatigue failure of certain valve parts or piping. Vibration in rupture disk piping may adversely affect the burst pressure and life of the rupture disk.

Detrimental effects of vibrations on the PRD can be reduced by addressing the cause of vibrations, by additional piping support, by use of either pilot-operated relief valves or soft-seated PRVs, or by providing greater PRD operating margins.

4.5 Operating Environment

When locating PRDs, consideration should be given to process conditions that could affect PRD reliability. Locating a PRD in a cleaner or cooler portion of the process may be preferable.

4.6 Free-draining

The PRD inlet and outlet piping should be free-draining (no pockets) away from the PRD. See Section 11.

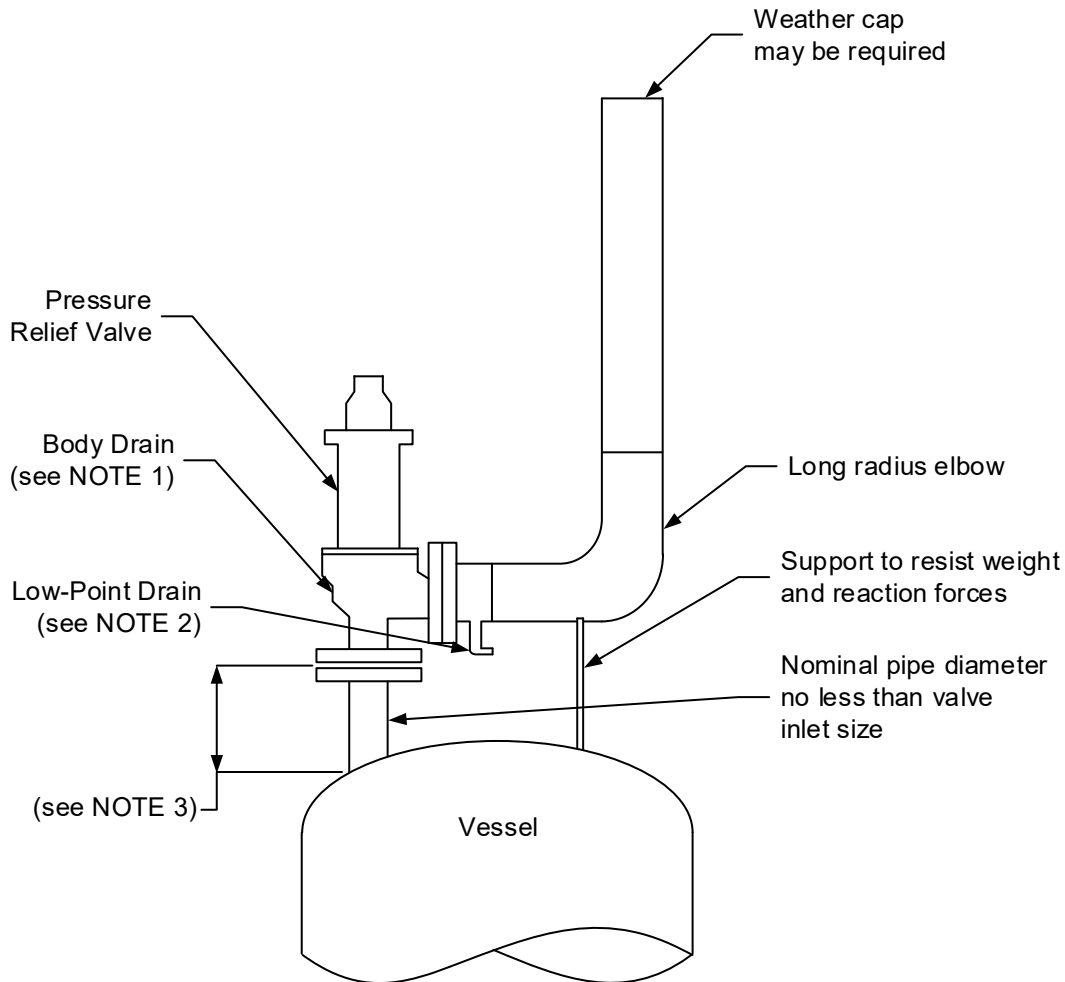
4.7 Maintainability

The PRD should be installed in a location that facilitates access and maintenance.

5 Inlet Piping Requirements

5.1 General

For general requirements for inlet piping, see Figure 2, Figure 3, Figure 4a, and Figure 4b.



NOTE 1 See Section 11 for a discussion on the use of the valve body drain.

NOTE 2 Orient low point drain—or weep hole—away from relief valve, structural steel, and operating area.

NOTE 3 See 7.3 for PRV inlet pressure drop limitations.

Figure 2—Typical Pressure-relief Valve Installation: Atmospheric (Open) Discharge

5.2 Inlet Piping Diameter Requirements

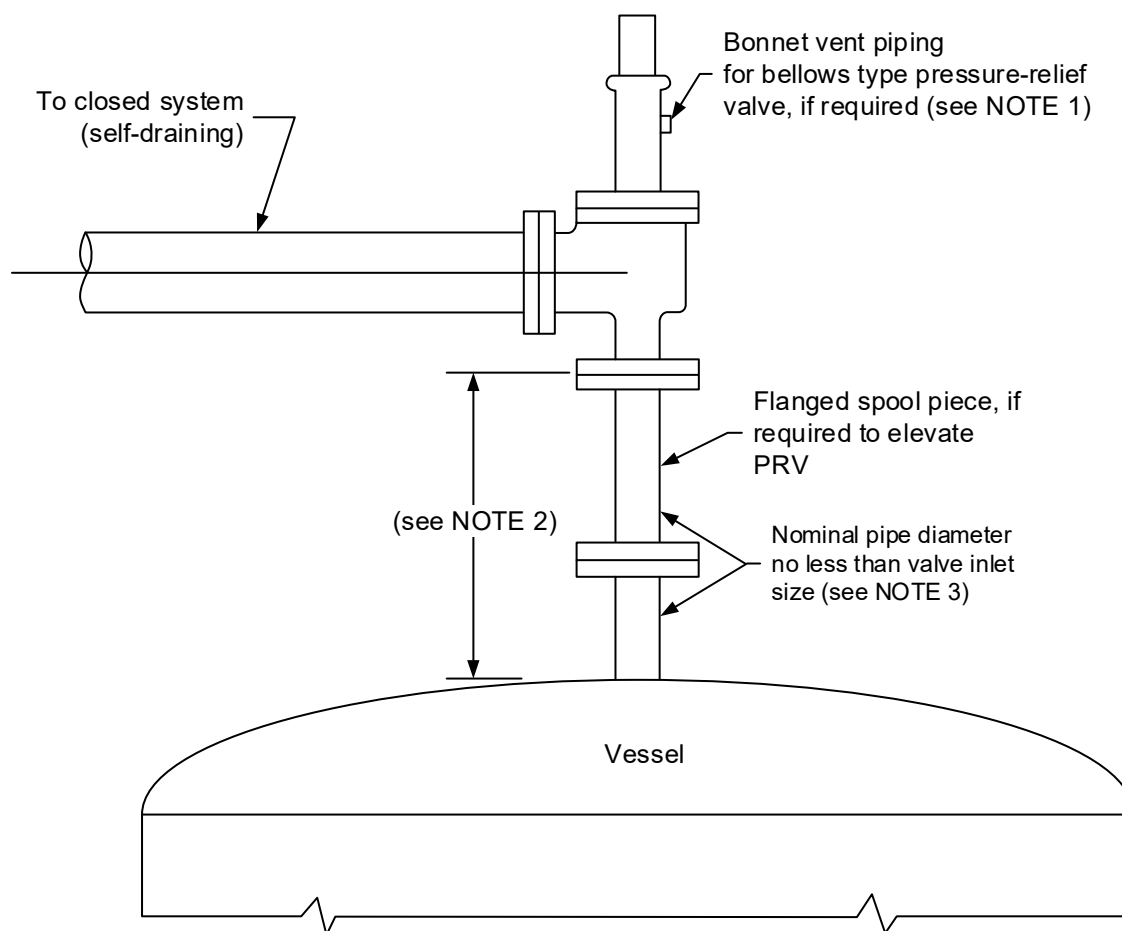
The nominal size of the inlet piping and fittings shall be the same as or larger than the nominal size of the pressure-relief valve inlet connection as shown in Figure 2 and Figure 3.

When two or more active pressure-relief valves are placed on one connection, the inlet internal cross-sectional area of this connection shall be sized to avoid restricting flow to the pressure-relief devices or made at least equal to the combined inlet areas of the in-service pressure-relief devices connected to it. The flow characteristics of this upstream system shall be such that the pressure drop will not reduce the relieving capacity below that required, or adversely affect the proper operation, of the pressure-relief valve.

5.3 Layout

The inlet piping system to PRDs should be free-draining to prevent accumulation of liquid or foreign matter in the piping.

Horizontal lines are generally regarded as self-draining. However, avoid the installation of a PRV at the end of a long horizontal inlet pipe through which there is normally no flow. Solids, such as rust or scale, may accumulate, or liquid may be trapped, creating interference with the valve's operation or requiring more frequent valve maintenance.



NOTE 1 See Section 10 for a discussion on bonnet venting.

NOTE 2 See 7.3 for PRV inlet pressure drop limitations.

NOTE 3 See 5.2 for inlet piping area requirements.

Figure 3—Typical Pressure-relief Valve Installation: Closed System Discharge

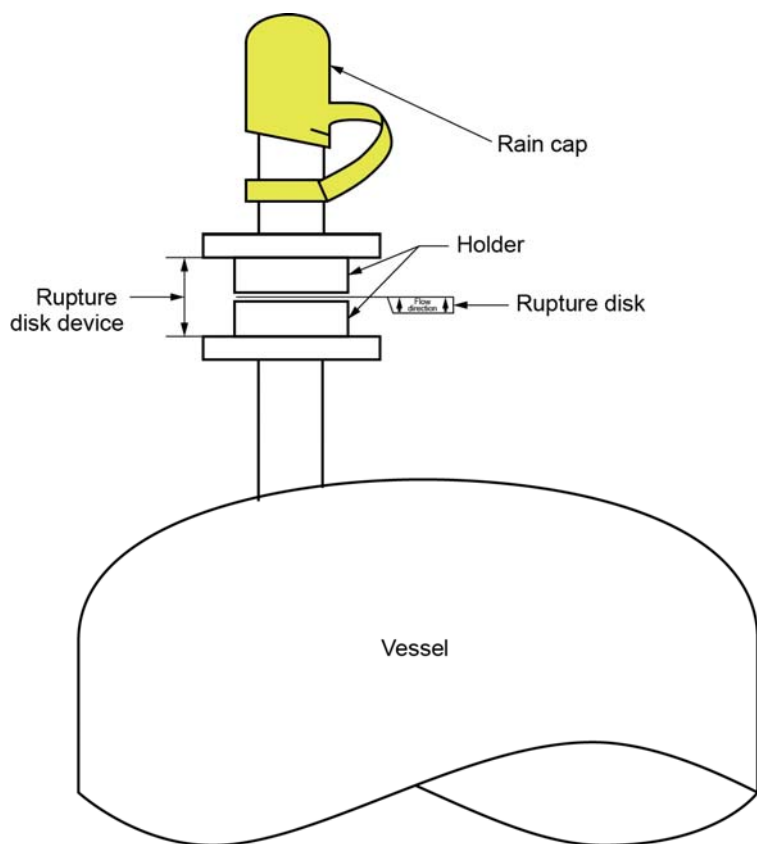


Figure 4a—Typical Rupture Disk Device Installation: Atmospheric (Open) Discharge

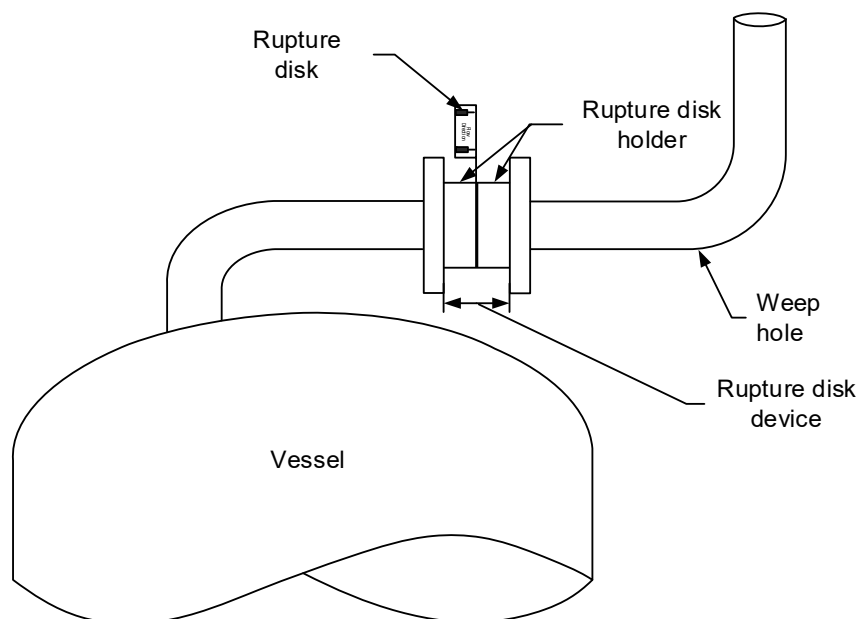


Figure 4b—Typical Rupture Disk Device Installation: Atmospheric (Open) Discharge

5.4 Isolation Valves in Inlet Piping

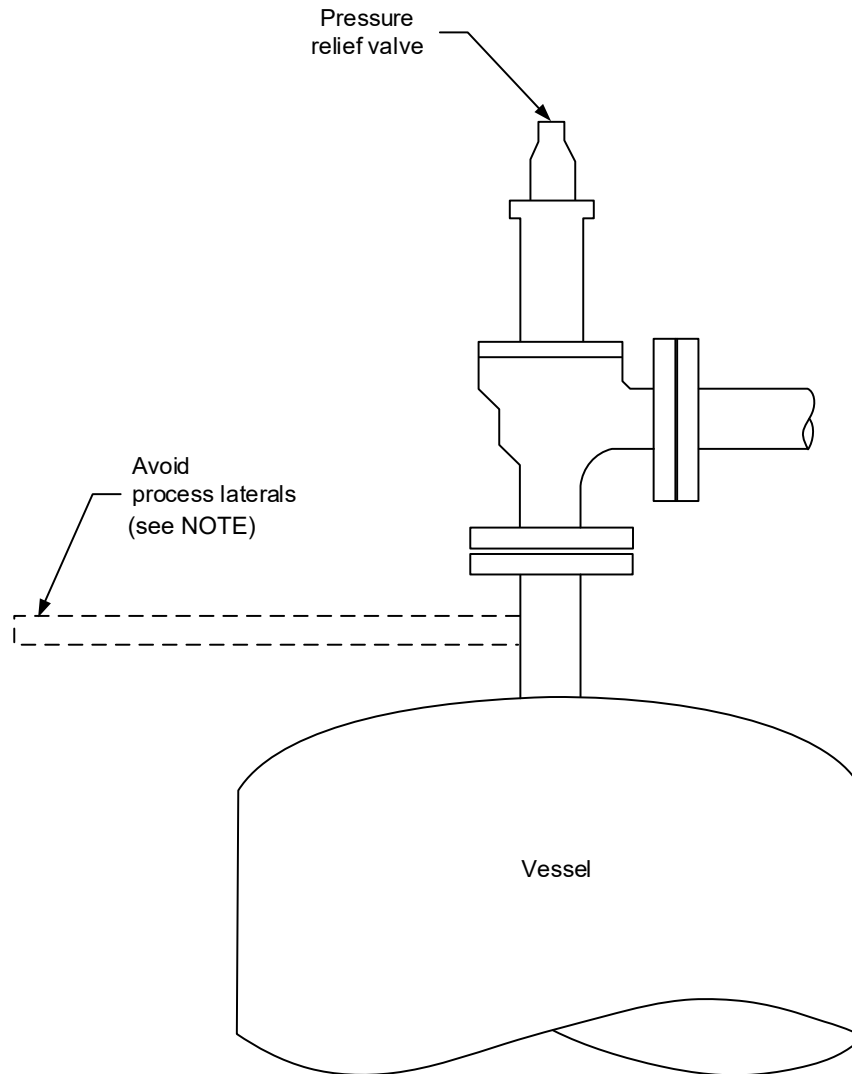
Isolation valves located in the inlet piping to PRDs shall be in accordance with the guidelines in Section 8.

5.5 Process Laterals Connected to Inlet Piping of PRVs

Process laterals should generally not be connected to the inlet piping of PRVs (see Figure 5). Exceptions should be analyzed carefully to ensure that the allowable pressure drop at the inlet of the PRV is not exceeded with simultaneous flow through the PRV and flow through the process lateral.

5.6 PRV Inlet Line Length and Pressure Loss

The length of the PRV inlet line and its pressure drop can be factors in whether the PRV will cycle, chatter, or flutter. See 7.3 for guidance.



NOTE See 5.5 for cautions related to process laterals installed on pressure-relief inlet piping.

Figure 5—Avoiding Process Laterals Connected to Pressure-relief Valve Inlet Piping

5.7 Inlet Stresses that Originate from Static Loads in the Discharge Piping

5.7.1 General

Improper design or construction of the discharge piping from a PRD can set up stresses that will be transferred to the PRD and its inlet piping. Static loads are stresses that occur during normal operation while the relief device remains closed. These stresses may cause a PRV to leak or malfunction, may change the burst pressure of a rupture disk, or may cause connected equipment flanges to leak. The PRD manufacturer should be consulted about permissible loads.

5.7.2 Thermal Stresses

Fluid flowing from the discharge of a PRD may cause a change in the temperature of the discharge piping. A change in temperature may also be caused by prolonged exposure to the sun or to heat radiated from nearby equipment. Any change in the temperature of the discharge piping will cause a change in the length of the piping and may cause stresses that will be transmitted to the PRD and its inlet piping. The PRD should be isolated from piping stresses through proper support, anchoring, or flexibility of the discharge piping.

5.7.3 Mechanical Stresses

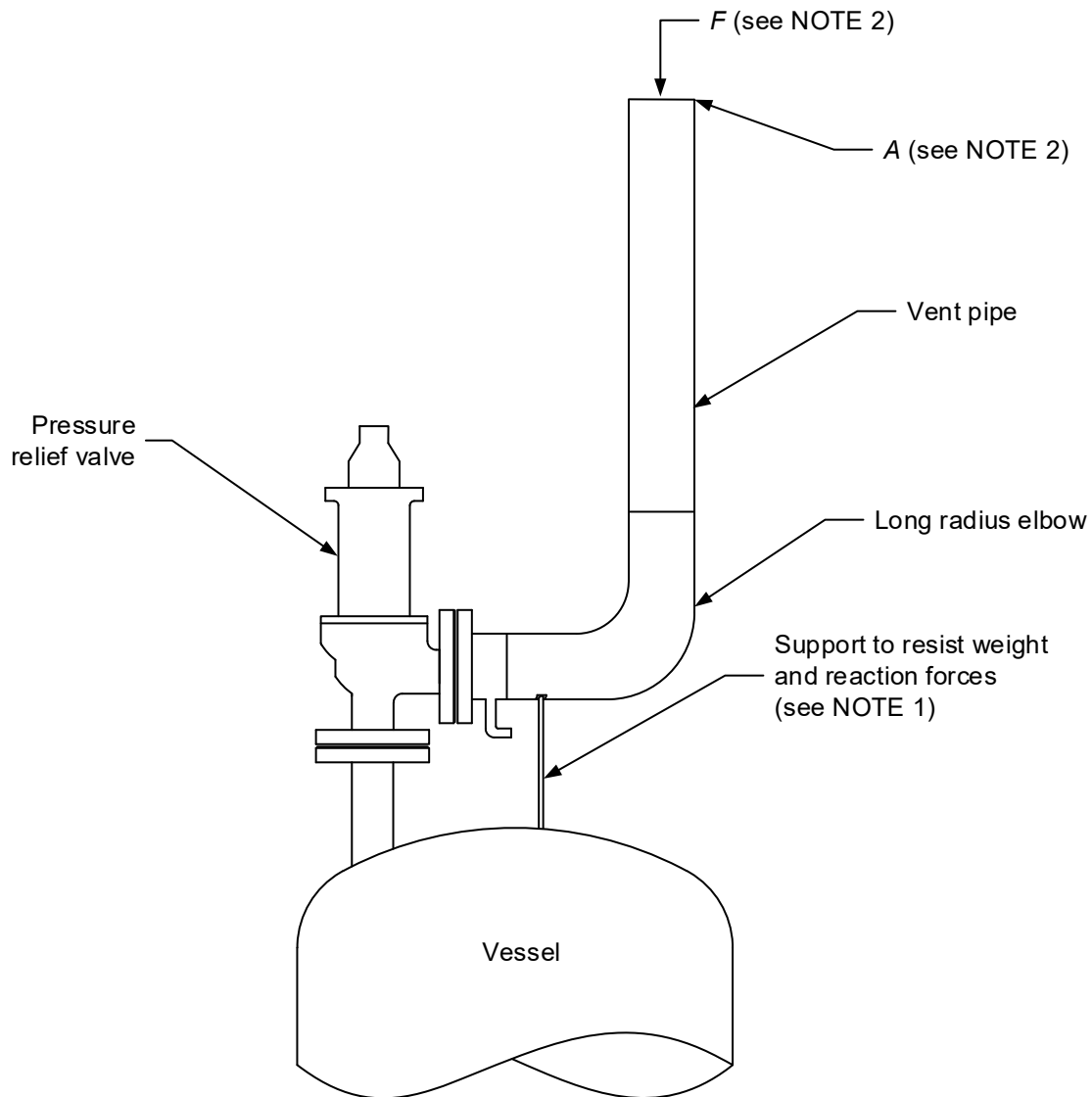
Discharge piping should be independently supported and aligned. Discharge piping that is supported by only the PRD will induce stresses in the PRD and the inlet piping. Forced alignment of the discharge piping will also induce such stresses.

5.8 Inlet Stresses that Originate from Discharge Reaction Forces

5.8.1 General

The discharge of a PRD will impose a reaction force (F) as a result of the flowing fluid (see Figure 6). This force will be transmitted into the PRD and into the mounting nozzle and adjacent supporting vessel shell unless designed otherwise. The precise magnitude of the loading and resulting stresses will depend on the reaction force and the configuration of the piping system. The user is cautioned that terminating the PRV discharge piping to any angle other than vertical with a perpendicular cut may increase the system stresses. The designer is responsible for analyzing the discharge system in compliance with the code of construction (e.g. ASME B31.3 ^[6]) to determine if the reaction forces and the associated bending moments will cause excessive stresses on any of the components in the system. A method for the design of piping systems to withstand reaction forces from PRDs is given in Appendix II of ASME B31.1 ^[5].

The magnitude of the reaction force will differ substantially depending on whether the installation is open or closed discharge. When an elbow is installed in the discharge system to direct the fluid up into a vent pipe, the location of the elbow and any supports is an important consideration in the analysis of the bending moments.



NOTE 1 The support should be located as close as possible to the centerline of the vent pipe.

NOTE 2 F = reaction force; A = cross-sectional area.

Figure 6—Typical Pressure-relief Valve Installation with Vent Pipe

5.8.2 Determining Reaction Forces in an Open Discharge System

5.8.2.1 Vapor Discharge

The following formula is based on a condition of critical steady state flow of a compressible fluid that discharges to the atmosphere through an elbow and a vertical discharge pipe. The reaction force (F) includes the effects of both momentum and static pressure; thus, for any gas, vapor, or steam:

in USC units:

$$F = \frac{W}{366} \sqrt{\frac{kT}{(k+1)M}} + (AP) \quad (1)$$

in SI units:

$$F = 129W \sqrt{\frac{kT}{(k+1)M}} + \frac{(AP)}{1000}$$

where

F is the reaction force at the point of discharge to the atmosphere, in lbf [N];

W is the flow of any gas or vapor, in lb_m/hr [kg/s];

k is the ratio of specific heats (C_p/C_v) at the outlet conditions;

C_p is the specific heat at constant pressure;

C_v is the specific heat at constant volume;

T is the stagnation temperature at the pipe outlet, in °R [K]. Note that the stagnation temperature is often not available. If this is the case, a suitable approximation is the relieving temperature. The user is cautioned that while this approximation is conservative for determination of reaction forces, the relieving temperature shall not be used for other discharge piping design aspects as this does not consider auto-refrigeration or Joule-Thompson cooling effects.

M is the molecular weight of the process fluid;

A is the area of the outlet at the point of discharge, in in.² [mm²];

P is the static pressure within the outlet pipe immediately before terminal expansion to atmosphere, in psig [kPa (gauge)].

5.8.2.2 Two-Phase Discharge

Although this paragraph provides a formula for the calculation of reaction forces for a two-phase release to atmosphere, the reader is cautioned to carefully consider the decision for atmospheric discharge. Due consideration should be given to the potential for liquid portions of the release to cause a hazardous condition. Consult API 521^[3] for additional guidance on atmospheric discharge.

The following formula can be used to determine the reaction force on inlet piping from an open discharge of a two-phase fluid. The formula assumes that the two-phase mixture is in homogeneous flow condition (no-slip).

in USC units:

$$F = \frac{W^2}{2.898 \times 10^6 A} \left[\frac{x}{\rho_g} + \frac{(1-x)}{\rho_l} \right] + (AP) \quad (2)$$

in SI units:

$$F = \frac{1 \times 10^6 \times W^2}{A} \left[\frac{x}{\rho_g} + \frac{(1-x)}{\rho_l} \right] + \frac{(AP)}{1000}$$

where

F is the reaction force at the point of discharge to the atmosphere, in lb_f [N];

W is the flow rate, in lb_m/hr [kg/s];

x is the weight fraction vapor at exit conditions;

ρ_g is the vapor density at exit conditions, in lb_m/ft³ [kg/m³];

ρ_l is the liquid density at exit conditions, in lb_m/ft³ [kg/m³];

A is the area of the outlet at the point of discharge, in in.² [mm²];

P is the static pressure within the outlet pipe immediately before terminal expansion to atmosphere, in psig [kPa (gauge)].

An example showing the reaction force calculation can be found in CCPS.^[35]

5.8.3 Determining Reaction Forces in a Closed Discharge System

PRDs that relieve under steady state flow conditions into a closed system usually do not transfer large forces and bending moments to the inlet system because changes in pressure and velocity within the closed system components are small.

Only at points of sudden expansion in the discharge piping will there be any significant inlet piping reaction forces to be calculated. Closed discharge systems, however, do not lend themselves to simplified analytical techniques. A complex time history analysis of the piping system may be required to obtain the reaction forces and associated moments that are transferred to the inlet piping system.

6 Discharge Piping

6.1 General

For general requirements for discharge piping, see Figure 2, Figure 3, Figure 6, and Figure 10.

The discharge piping installation shall provide for proper PRD performance and adequate drainage (free-draining systems are preferred; see Section 11). Consideration should be given to the type of discharge system used, the backpressure on the PRD, and the set-pressure relationship of the PRDs in the system.

Auto-refrigeration during discharge can cool the outlet of the PRD and the discharge piping to the point that brittle fracture can occur. Piping design, including material selection, shall consider the expected discharge temperature.

6.2 Safe Disposal of Relieving Fluids

For a comprehensive source of information about the safe disposal of various relieving fluids, see API 521^[3].

6.3 Backpressure Limitations and Sizing of Pipe

6.3.1 General

When discharge piping is designed, consideration should be given to the combined effect of superimposed and built-up backpressure on the operating characteristics of the PRDs. The discharge piping system should be designed so that the backpressure does not exceed an acceptable value for any PRD in the system. See API 520, Part I for limitations on backpressure.

The rated capacity corrected for the actual overpressure of a conventional spring-loaded, balanced spring-loaded, or pop-action pilot-operated PRV should typically be used to size the atmospheric vent piping or the discharge line from the PRV to the relief header. Note that the rated capacity corrected for the actual overpressure can vary depending on the overpressure scenario. Common relief header piping in closed discharge systems can be sized using the protected system's required relieving capacity (see API 521).

For a modulating pilot-operated PRV, the discharge piping can be sized using the required relieving capacity of the system that the valve is protecting.

Whenever the atmospheric vent, discharge piping, or common relief header piping is sized using the system's required relieving capacity instead of the rated capacity of the valve corrected for the actual overpressure, the backpressure should be re-checked whenever changes are made to the process that affect the required relieving capacity of the system the valve is protecting.

For pressure drop calculations, when discharging incompressible or subsonic compressible flow to either a closed reservoir or the atmosphere, the static pressure within the exit of the pipe is numerically equal to the reservoir or atmospheric pressure, respectively. When discharging sonic compressible flow, the pressure within the exit of the pipe is the calculated choking pressure.^[8] Additional information on sizing of discharge piping systems for vapor or gas service is covered in API 521^[3].

6.3.2 Thermal Relief Valves

The discharge piping from thermal relief valves designed solely to protect against liquid hydraulic expansion due to ambient heating (including solar radiation) typically does not need to be sized to meet the built-up backpressure limits provided in API 520, Part I and as discussed in 6.3.1. The reason for this is that the capacity of these PRVs is typically larger by an order of magnitude (>10 times) than the required relief rate and the flow in the discharge line never reaches a steady state flow at the capacity. See 7.3.8 for additional discussion and cautions with thermal relief valves.

Examples where outlet pressure drop calculations for thermal expansion generated by ambient heating would be considered applicable are for a long pipeline or large liquid-filled vessel, where the required flow rate due to thermal expansion approaches the rated capacity of the valve corrected for the actual overpressure. The user is cautioned that for liquids (e.g. refrigerated liquids, LPG, or LNG) where blocking in with ambient heating may lead to vaporization and possible overpressure (not thermal relief), required relief rates may be large enough to warrant outlet pressure drop calculations.

Discharge piping for thermal relief valves in applications where pressure inside the protected equipment can be generated by process heat should be sized to meet the built-up backpressure limits provided in API 520, Part I. See 7.3.8 for inlet loss criteria for thermal relief valves.

6.4 Considerations for Pilot-Operated PRVs

Superimposed backpressure that exceeds the inlet pressure of a pilot-operated PRV can cause the main valve to open, allowing reverse flow through the main valve. For example, backflow can occur if several

PRVs have their outlets manifolded into a common discharge header, and one or more of these valves is discharging while another is connected to a system with a lower inlet pressure. An accessory should be specified that would prevent such backflow.

6.5 Stresses in Discharge Piping During Release

The reaction forces and stresses that originate in the downstream piping as a result of the release of a PRD are typically not significant once flow is established and has reached steady state conditions, due to small changes in pressure and velocity within the closed system components. However, large forces may result if there are sudden pipe expansions within the system or as a result of unsteady flow conditions during the initial activation of the relief device. Additionally, large reaction forces can be created at elbows as a result of two-phase fluid flow in the slug flow regime. Mechanical loads from the initial flow from a rupture disk (both steady state and transient loads) shall be included in the mechanical installation design.^[9]

The design of flare header piping in closed discharge systems should be in accordance with ASME B31.3^[6] or other applicable piping design code. The design of flare header piping is not amenable to simplified analytical techniques; consequently, assistance by individuals knowledgeable in pipe stress analysis is recommended. A complex dynamic analysis of the system may be required. API 521^[3] gives additional guidance on the design of flare header piping.

6.6 Isolation Valves in the Discharge Piping

Isolation valves located in the discharge piping system shall be in accordance with the guidelines provided in Section 8.

6.7 Rupture Disks Installed at the Outlet of a PRV

A rupture disk device may be installed on the outlet of a PRV to protect the valve from downstream fluids. Consideration shall be given to the PRV design so that it will open at its proper pressure setting regardless of any backpressure that may accumulate between the valve and rupture disk. The pressure drop due to the rupture disk in the discharge piping should be included in the hydraulic calculations. See UG-127 of the *ASME Boiler and Pressure Vessel Code*, Section VIII^[7] for other requirements and considerations.

7 PRV Stability

7.1 General

The flow rate through a PRV can readily change with changes in inlet and/or outlet pressures. The flow through PRVs is rarely steady state since the pressure at the PRV inlet is often dynamic throughout the duration of the overpressure scenario. A PRV may experience three types of dynamic responses to variable flow conditions: cycling, flutter, and chatter.

7.1.1 PRV Cycling

Cycling is the relatively low-frequency (e.g. a few cycles per second to a few seconds per cycle) opening and closing of a relief valve. This most often occurs when the relief requirement is small when compared to the capacity of the valve. In this case, when the PRV opens, the valve may flow more than what the system can provide, causing the pressure to drop to the PRV's reseating pressure. Once the PRV is closed, the system pressure rebuilds to the PRV set pressure and the cycle repeats. Cycling frequency is a function of the upstream system's ability to keep the valve open and is much lower than the natural frequency of the valve. In general, cycling does not cause detrimental valve damage. However, the valve's ability to reseal tightly may be affected and it may cause some wear over time.

When capacity variations are frequently encountered in normal operation, one alternative is the use of multiple, smaller PRVs with staggered settings. With this arrangement, the PRV with the lowest setting will be capable of handling minor upsets, and additional PRVs will open as the capacity requirement increases.