

Pressure Relief Devices

ASME AND API CODE SIMPLIFIED

- ✓ ASME and API code requirements
- ✓ Design specifications and code calculations
- ✓ Manufacturing of pressure relief valves
- ✓ Sizing and selection of pressure relief valves and rupture disks
- ✓ Installation, operation, maintenance, inspection, and testing

Mohammad A. Malek

Pressure Relief Devices

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Pressure Relief Devices

ASME and API Code Simplified

Mohammad A. Malek, Ph.D., P.E.

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Preface

In the world of pressurized equipment, safety valves are generally known as the “last line of defense” against the risk of explosions. Even so, many accidents continue to occur throughout the world. We wonder how this can be in a world renowned for its crowning state-of-the-art technologies.

In large measure, accidents are due to the failure of safety valves to perform the function for which they were designed. It appears that safety valves, which represent one of the most essential devices within a plant, are frequently overlooked by their own industry. Personally, for me, this was unacceptable.

My past experiences, coupled with surveys into the pressure vessel industry, revealed that pressure-relieving technology was frequently an unknown territory for many of the technical personnel. Such unfamiliarity in the technological workforce of this industry was, at first, baffling. I wondered, why?

The answer turned out to be relatively simple. A comprehensive technological scope of safety valve design, production, installation, and maintenance was not available as a complete and replete resource within the scope of one textbook. One had to forage through countless volumes of books, manuals, and Web sites to get at the needed information. I decided it was time to write a book.

At this time, I am proud to present the first book ever written on the subject of pressure relief devices. This book is the definitive guide to types, design, manufacturing, installation, operation, maintenance, inspection, repair, and shop testing of all types of pressure relief devices.

After extensive research, incorporating the latest technology, I visited many Web sites, read numerous manufacturers catalogs, and consulted codebooks applicable to pressure-relieving technology. I combined my professional engineering experience with my research findings and international technology.

The book makes reference to various pressure relief device codes published by the American Society of Mechanical Engineers and the

American Petroleum Institute. I have simplified these codes for easy understanding and practical application.

I would like to express heartfelt thanks to my friends, manufacturers, suppliers, repairers, inspectors, insurance companies, jurisdictions, and numerous organizations for the valuable information and assistance they provided to me. I could not have done it without them.

The contents of this book will educate the reader on pressure relief devices. The reader is advised to exercise sound judgment in using information presented throughout the book. I will consider my work useful if the reader can apply information from this book to ensure smooth functioning of the pressure relief devices in a way that will protect human lives and property.

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Fundamentals of Pressure Relief Devices

When pressure inside a vessel such as a boiler or pressure vessel increases for some reason and excess pressure threatens to blow up the vessel, the pressure relief device protects the vessel by releasing the pressure at a predetermined set point. Pressure relief devices are used to protect pressurized equipment from exceeding the maximum allowable working pressure. Acting as the last line of defense, these mechanical devices save human lives and property.

1.1 Brief History

Safety valves have been around since the 1600s with more or less the same design concept as is used today. It is believed that Papin, a Frenchman, was the inventor of the safety valve, which he first applied in about 1682 to his digester.

Papin kept the safety valve closed by means of a lever and a movable weight. Sliding the weight along the lever kept the valve in place and regulated the steam pressure (Fig. 1.1). It is supposed that Papin was the inventor of the improvements to safety valves that were used by Glauber, a German.

Glauber contributed many scientific ideas to mechanical engineering. In his treatise on furnaces, translated into English in 1651, he described the modes by which he prevented retorts and stills from bursting from excessive pressure. He fitted a conical valve which was air-tight to its seat and loaded with a “cap of lead.” When the vapor pressure increased, it slightly raised the valve and a portion of vapor escaped. Then the valve closed itself, “being pressed down by the loaded cap,” which kept it closed.

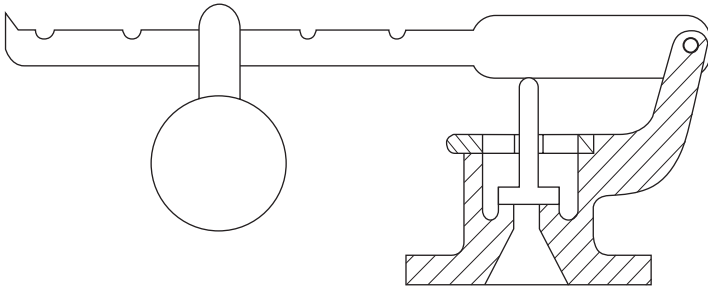


Figure 1.1 Early safety valve design.

Later this idea was followed by others. John French published the following statement about the action of such a safety valve: “Upon the top of a stubble (valve) there may be fastened some lead, that if the sprit be too strong, it will only heave up the stubble and let it fall down.” The word *steam* was unknown at that time. In these old books, words such as *vapor*, *spirit*, or *smoke* were used instead of the modern words *gas* and *steam*.

In the United States, there were 1700 boiler explosions resulting in 1300 deaths during the 5 years between 1905 and 1911. On September 15, 1911, the American Society of Mechanical Engineers (ASME) appointed a seven-member Boiler Committee to establish specifications for construction of steam boilers and other pressure vessels. In November 1914, an 18-member Advisory Committee was appointed. On December 14, 1914, the Boiler Committee and the Advisory Committee started preparation of a final draft. The first AMSE code, *Rules for Construction of Stationary Boilers and Allowable Working Pressures*, known as the 1914 Edition, was adopted in the spring of 1915.

In this first 1914 Edition, pars. 269–290 (pp. 68–75) were dedicated to safety valves for new installation of power boilers. Requirements of safety valves for boilers used exclusively for low pressure steam and hot water heating and hot water supply were covered in pars. 347–360 (pp. 83–85). All the paragraphs related to safety valves from the first boiler code are extracted in App. A.

1.2 Pressure Vessels

Pressure relief valves are used to protect pressurized systems from exceeding the design pressure. A pressurized system is a closed container designed for the containment of pressure, either external or internal. The pressure may be imposed by an external source, by the application of heat from a direct or indirect source, or any combination thereof.

There are many types of pressure vessels, but they are generally classified into two basic categories:

1. *Fired pressure vessels:* In this category, fuels are burned to produce heat, which in turn boils water to generate steam. Examples of fired pressure vessels include steam boilers, hot water boilers, hot water heaters, etc.
2. *Unfired pressure vessels:* Vessels in this category are used for storage of liquid, gas, or vapor at pressures of more than 15 psig (103 kPa). Examples of unfired pressure vessels include air tanks, heat exchangers, expansion tanks, feedwater heaters, columns, towers, drums, reactors, condensers, air coolers, oil coolers, accumulators, digesters, gas cylinders, and various pressurized systems used in industry. The word “pressure vessel” is a general term which includes all types of unfired pressure vessel.

When a substance is stored under pressure, the potential for rupture and leakage exists. Improper vessel design, operation, or maintenance increase the risk of pressure vessel failure, posing a serious safety hazard. The risk increases when vessels contain toxic or gaseous substances.

Every year, accidents occur to many pressure vessels that are in use in industry. Pressure vessels accidents can be very serious. A serious accident may not only take human lives but can damage valuable property, and can increase costs because of production downtime. Properly designed pressure relief valves with proper operation and maintenance can prevent serious accidents to pressure vessels.

1.2.1 Boiler accidents

Many boiler accidents occur throughout the world each year. There are various causes of boiler accidents, but the most common cause is the failure of a pressure relief valve. Here is an example of a catastrophic accident involving a water heater that resulted from failure of a temperature and pressure (T&P) relief valve.

Water heater explosion at Avon High School. On Thursday, May 11, 2000, at 6:05 p.m., a 5-gal electric hot water heater of Avon High School, Avon, Massachusetts, exploded (Fig. 1.2). The water heater was located in a storage room adjacent to the high school cafeteria. The catastrophic explosion caused serious damage to the cafeteria walls and surrounding area. Two custodians were working inside the cafeteria just before the accident, but no one was injured because the accident occurred after school hours.



Figure 1.2 Water heater explosion at Avon High School.

The hot water heater failed at a weakened area near the welded longitudinal lap joint. The thinned area might have been leaking slightly, resulting in abnormal conditions in the water heater. As the thinned area failed, the longitudinal seam also failed along the heat-affected zone of the weld. At one point, the temperature of the water in the vessel exceeded 212°F, flashing water into steam. The T&P relief valve (Fig. 1.3) installed on the water heater should have prevented the vessel from reaching excessive pressures and temperatures.

On testing, it was determined that the T&P relief valve failed to operate and did not prevent the temperature in the vessel from reaching 212°F. The water heater had a maximum allowable working pressure of 150 psi, but when the T&P valve was tested after the explosion, it reached a pressure of 184 psi before the test was finally stopped.

The accident report concluded that the nonfatal blast was caused by a combination of factors, namely a faulty T&P relief valve and a corroded and weakened vessel.

Boiler explosion at Ford Motor Rouge Complex. One of the largest explosions in recent years occurred at the Ford Rouge manufacturing complex on the Rouge River in Dearborn, Michigan. The explosion killed six workers and seriously injured 14 others.

On February 1, 1999, at approximately 1:00 p.m., there was an explosion in the power plant jointly owned by Ford Motor Company and Rouge Steel. The 80-year-old plant covers 1110 acres, houses six Ford manufacturing companies and Rouge Steel Company, and employs about 10,000 workers. The accident halted production at Ford's Dearborn



Figure 1.3 T&P pressure relief valve after explosion.

assembly plants, which makes Mustangs, at the five other Ford plants which supply a variety of automotive parts to most of Ford's assembly plants in North America, and at Rouge Steel Company, which produces steel for the automotive industry.

About 140 workers were employed at the power plant, which was scheduled to be replaced with a new facility in 2000. The Rouge power plant produced steam by burning a mixture of natural gas, pulverized coal, and blast furnace gas.

The investigation report concluded that the explosion was caused by a natural gas buildup in Boiler No. 6. The buildup was a result of inadequate controls for safety shutdown.

The Michigan Department of Consumer & Industry Services (CIS) concluded its 7-month investigation of this fatal explosion with an unprecedented and historic \$7 million settlement agreement with Ford Motor Company and the United Auto Workers Union (UAW). This agreement did not include the private settlement offers Ford Motor Company made to the victims and their families.

1.2.2 Pressure vessel accidents

Any pressure vessel accident, like any boiler accident, is dangerous. Most of the time a pressure vessel contains gas and liquid, which are harmful when explosion occurs.

Federal Occupational Safety and Health Administration (OSHA) statistics show that 13 people were injured in 1999, one person was killed

in 1998, three people were injured in 1997, and nine people were killed in 1996 as a result of pressure vessel accidents. An industrial survey shows that there were 1550 accidents to unfired pressure vessels in 2003, resulting in five fatalities and 22 injuries. Here is an example of a catastrophic pressure vessel accident in recent years:

Digester accident at Kaiser Alumina Plant. On Monday, July 5, 1999, at about 5:00 a.m., an explosion occurred at the Gramercy Works Alumina Plant in St. James County, Louisiana (Fig. 1.4). One hundred employees were working at the plant at the time of the explosion, which occurred in the digester area of the plant. A total of 29 persons were injured by the effects of the explosion.

A report of investigation submitted by the Mine Safety and Health Administration (MSHA) concluded that the cause of explosion was excessive pressure in several tanks in the digestion area. The plant's system of relief valves and piping failed to control the increasing vessel pressures. Further, some of the relief piping was clogged with scale, limiting the piping's ability to relieve pressure in the digestion process.



Figure 1.4 Digester system explosion in Kaiser Alumina Plant. (Courtesy Federal Mine Safety and Health Administration.)



Figure 1.5 An air receiver tank explosion.

Air tank accident. Air tanks are used in small workshops and big industrial plants for various needs of air under pressure. There have been many air tanks accidents throughout the world from time to time (Fig. 1.5).

Recently an air receiver tank of a compact air compressor unit exploded in a panel-beating workshop in the province of Victoria, Australia. The accident narrowly missed an employee but caused material damage. The reasons for failure are believed to be a non-functional safety valve and weakened metal of the tank.

A safety valve is fitted on the air tank to prevent the tank pressure from exceeding a predetermined pressure, which is design pressure in most cases. If the safety valve does not function in the event of over-pressurization inside the tank, an explosion is bound to occur.

1.3 Pressure Relief Devices

A pressure relief device is actuated by inlet static pressure and is designed to open during an emergency or abnormal conditions to prevent a rise of internal fluid pressure in excess of a specified value. The device may also be designed to prevent excessive internal vacuum.

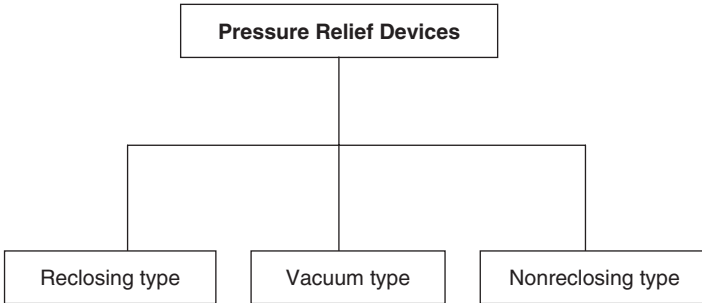


Figure 1.6 Main types of pressure relief devices.

Pressure relief devices protect a vessel against overpressure only. These devices do not protect against structural failure when the vessel is exposed to abnormal conditions such as high temperature due to fire.

The main types of pressure relief devices are: (1) reclosing-type pressure relief devices, (2) vacuum-type pressure relief devices, and (3) non-reclosing-type pressure relief devices. Figure 1.6 shows the main types of pressure relief devices.

1.4 Reclosing-Type Pressure Relief Devices

A reclosing-type pressure relief device is a pressure relief device designed to close after operation. There are many types of reclosing-type pressure relief devices. Figure 1.7 shows types of reclosing-type pressure relief devices.

1.4.1 Pressure relief valves

A pressure relief valve is a spring-loaded pressure relief device, which is designed to open to relieve excess pressure and to reclose and prevent further flow of fluid after normal conditions have been restored (Fig. 1.8). It may be used for either compressible or incompressible fluids, depending on design, adjustment, or application. Pressure relief valve is a general term, which includes safety valves, relief valves, and safety relief valves.

1.4.2 Safety valves

A safety valve is a pressure relief valve actuated by inlet static pressure and characterized by rapid opening or pop action (Fig. 1.9). Safety valves are used primarily with compressible gases and in particular for steam and air.

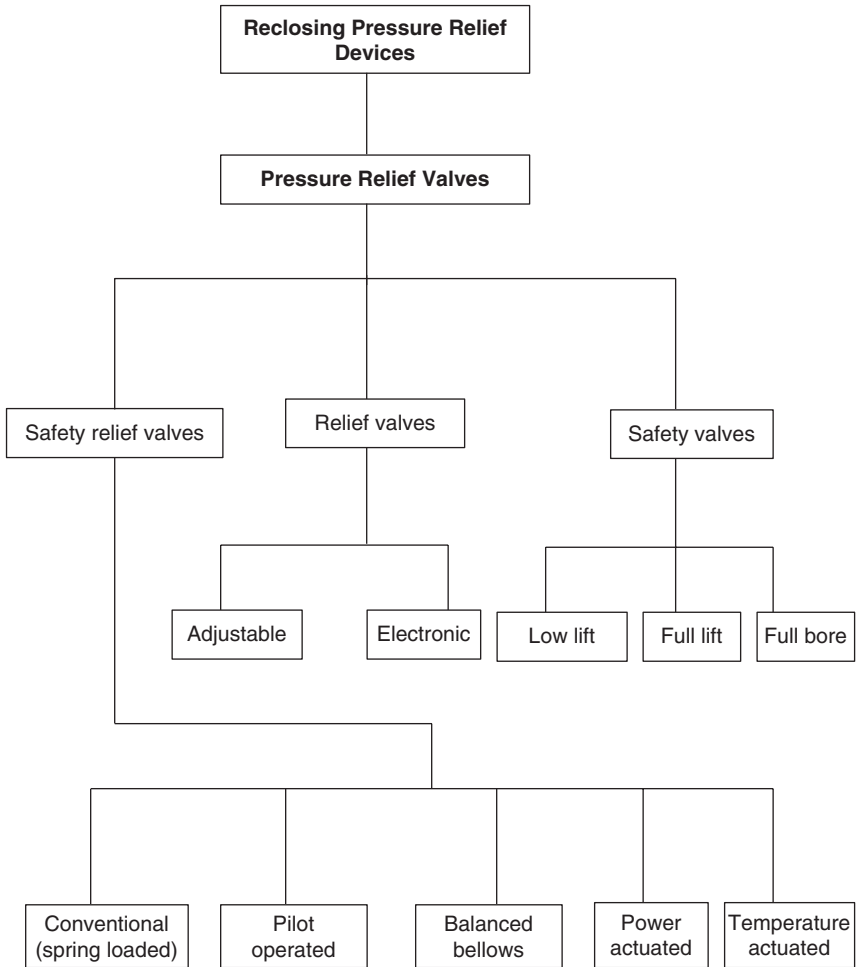


Figure 1.7 Types of reclosing pressure relief devices.

Safety valves are classified according to the lift and bore of the valves. Types of safety valves are low-lift, full-lift, and full-bore safety valves.

- *Low-lift safety valve.* A low-lift safety valve is a safety valve in which the disk lifts automatically such that the actual discharge area is determined by the position of the disk.
- *Full-lift safety valve.* A full-lift safety valve is a safety valve in which the disks lift automatically such that the actual discharge area is not determined by the position of the disk.



Figure 1.8 Pressure relief valve. (Courtesy Dresser Flow Control.)

- **Full-bore safety valve.** A full-bore safety valve is a safety valve which has no protrusions in the bore and in which the valve disk lifts to an extent sufficient for the minimum area at any section at or below the seat to become the controlling orifice.

1.4.3 Relief valves

A relief valve is a pressure relief device actuated by inlet static pressure and having a gradual lift generally proportional to the increase in pressure over opening pressure. It may be provided with an enclosed spring housing suitable for closed discharged system applications.

Relief valves are commonly used in liquid systems, especially for lower capacities and thermal expansion applications. They can also be used on pump systems as pressure overspill devices.

Adjustable relief valve. Adjustable relief valves feature convenient adjustment of the pressure setting through the outlet port. These valves



Figure 1.9 Safety valve. (Courtesy Dresser Flow Control.)

are generally available with pressure ranges up to 508 psi (35 bar), and operating temperature up to 600°F (315°C).

Adjustable relief valves are suitable for nonvented or vented inline applications in chemical, petrochemical, and high-purity gas industries.

Electronic relief valve. An electronic relief valve (ERV) is a pilot-operated relief valve which offers zero leakage. The ERV package combines a zero-leakage isolation valve with electronic controls to monitor and regulate system pressure. These valves provide protection either in a capacity-relieving function or simply in an overpressure-protection application.

An electronic relief valve system is shown in Fig. 1.10. The electronic relief valve system consists of:

1. *The valve.* Generally a metal seated ball valve is used.
2. *The actuator.* The actuator may be electric, hydraulic, or pneumatic and operated by gears.

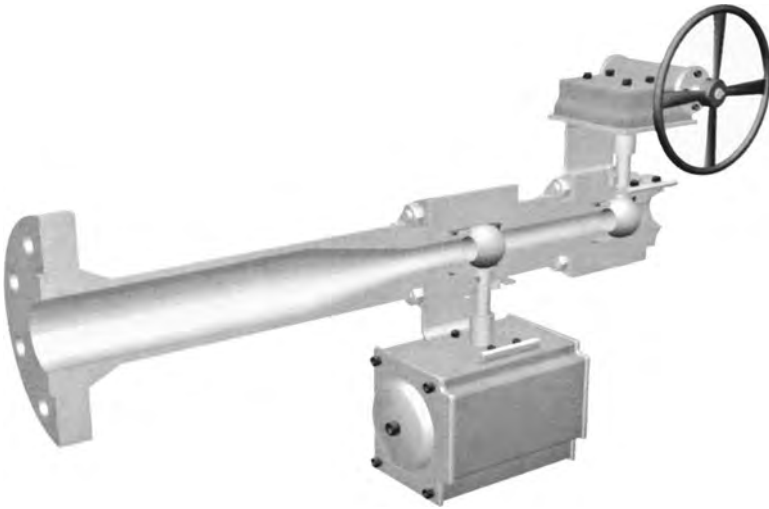


Figure 1.10 Electronic relief valve. (Courtesy Valvtechnologies, Inc.)

3. *The control system.* The ERV is supplied with or without remote controls and display. Numerous pressure ranges from zero to 5000 psi (34.5 MPa) are available. Accuracy of 1/4% is achieved for 1000- to 3000-psi and 0.1% for 5000-psi units. Standard units operate from 115 V ac or V 125 dc and control ac, dc, or pneumatic actuators.

1.4.4 Safety relief valves

A safety relief valve is a pressure relief valve characterized by rapid opening or pop action or by opening in proportion to the increase in pressure over the opening pressure, depending on the application, and which may be used either for liquid or compressible fluid.

In general, the safety relief valve performs as a safety valve when it is used in a compressible gas system. This valve opens in proportion to the overpressure when it is used in liquid systems like a relief valve.

Safety relief valves are classified as conventional, pilot operated, balanced bellows, power actuated, and temperature actuated. Details of each valve are discussed in Chap. 2.

1.5 Pressure Vacuum Relief Valves

A pressure vacuum relief valve, also known as a pressure vacuum vent valve, is an automatic or vacuum-relieving device actuated by the pressure or vacuum in the protected equipment.

Pressure vacuum relief valves are generally used to protect atmospheric and low-pressure storage tanks against a pressure large enough

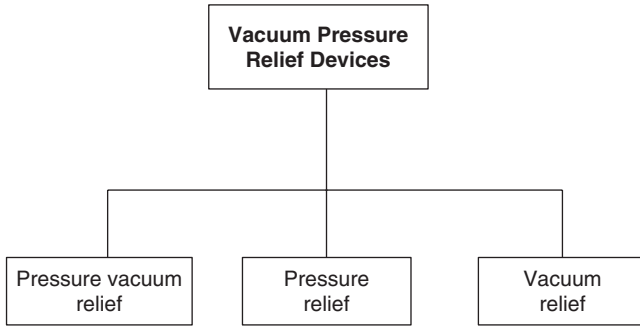


Figure 1.11 Classification of vacuum pressure relief valves.

to damage the tank. Pressure vacuum relief valves are not used for applications requiring a set pressure of more than 15 lbf/in.² (103 kPa).

Pressure vacuum relief valves are classified into three categories (Fig. 1.11): (1) pressure vacuum vent valves, (2) pressure relief valves, and (3) vacuum relief valves.

1.5.1 Pressure vacuum vent valves

The pressure vacuum vent valve or pressure vacuum relief valve design maintains a tight seal until system pressure or vacuum exceeds the set pressure of the valve. When overpressure occurs, the weighted pallet lifts, breaking the seal between the seat and pallet, allowing vapors to pass through the vacuum orifice and relieving the pressure or vacuum buildup. The valve reseals upon relief and remains sealed. A typical pressure vacuum relief valve is shown in Fig. 1.12.



Figure 1.12 Pressure vacuum vent valve. (Courtesy Enardo, Inc.)



Figure 1.13 Pressure relief valve.
(Courtesy Enardo, Inc.)

1.5.2 Pressure relief valves

This pressure relief valve design provides protection against positive overpressure, prevents air intake and evaporative loss of product, and helps to contain odorous and potentially hazardous vapors. A pressure relief valve is shown in Fig. 1.13.

Standard features include a dual-guided (top and bottom) pallet for smoother valve stroke, less flutter, and less valve wear. Generally, this valve is available in sizes 2 in (50 mm) through 12 in (300 mm).

1.5.3 Vacuum relief valves

The vacuum relief valve design provides protection against vacuum overpressure, prevents evaporative loss of product, and helps to contain odorous and potentially hazardous vapors. A vacuum relief valve is shown in Fig. 1.14.

Standard features include a dual-guided (top and bottom) pallet for smoother valve stroke, less flutter, and less valve wear. Generally, this valve is available in sizes 3 in (75 mm) through 14 in (350 mm).

1.6 Nonreclosing Pressure Relief Devices

A nonreclosing pressure relief device is a pressure relief device which remains open after operation. A manual means of resetting is usually provided.

There are many types of nonreclosing pressure relief devices. Types of nonreclosing pressure relief devices are shown in Fig. 1.15.



Figure 1.14 Vacuum relief valve.
(Courtesy Enardo, Inc.)

1.6.1 Rupture disks

A rupture disk device is a nonreclosing pressure relief device 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 (Fig. 1.16).

The combination of a rupture disk and a rupture disk holder is known as a rupture disk device. A rupture disk is a pressure-containing,

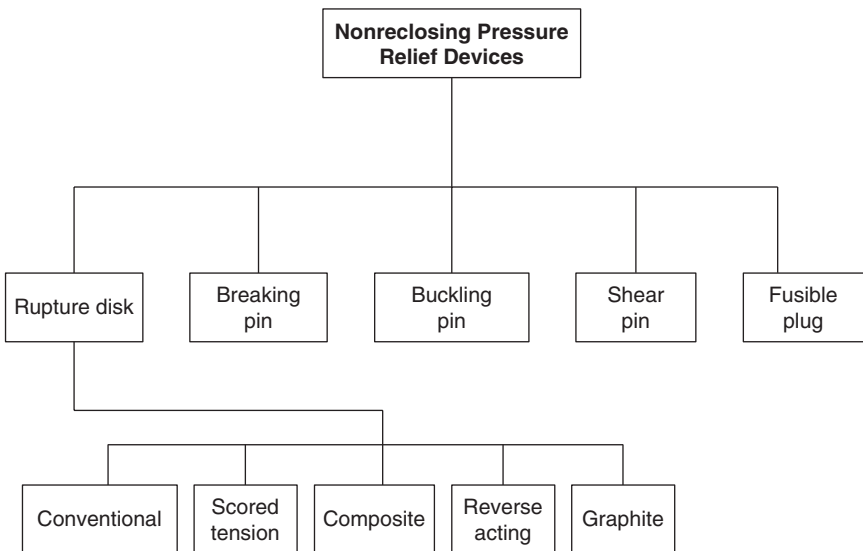


Figure 1.15 Nonreclosing pressure relief devices.



Figure 1.16 Rupture disk. (Courtesy Oseco Inc.)

pressure- and temperature-sensitive element of a rupture disk device. A rupture disk holder is the structure which encloses and clamps the rupture disk in position. A rupture disk generally requires a rupture disk holder, although disks may be designed to be installed between standard flanges without holders.

Types of rupture disks include conventional, scored tension, composite, reverse acting, graphite, and explosion. Details on each type of rupture disk are discussed in Chap. 4.

1.6.2 Breaking pin devices

A breaking pin device is a nonclosing pressure relief device actuated by inlet static pressure and designed to function by the breakage of a

load-carrying section of a pin which supports a pressure-containing member.

1.6.3 Buckling pin devices

A buckling pin device is a nonreclosing pressure relief device actuated by inlet static pressure and designed to function by the buckling of a load-carrying section of a pin which supports a pressure-containing chamber (Fig. 1.17). These devices are very stable and are suitable for applications that have both cyclic operating conditions and up to or above 90% ratio between opening pressure and set pressure.

1.6.4 Shear pin devices

A shear pin device is a nonreclosing pressure relief device actuated by inlet static pressure and designed to function by the shearing of a load-carrying pin which supports a pressure-containing member. The force of overpressure forces the pin to buckle and the valve to open. The valve can be reseated after the pressure is removed and a new pin can be

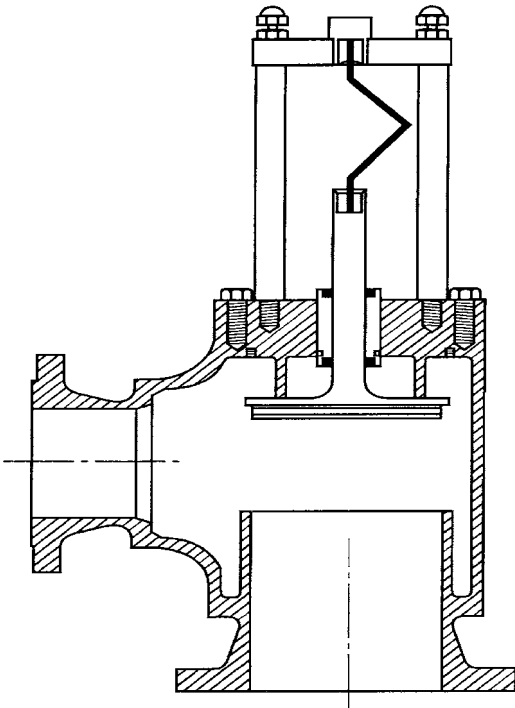


Figure 1.17 Buckling pin valve (in open condition).
(From API RP 520.)

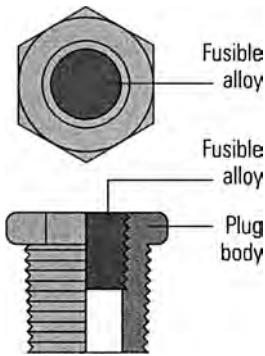


Figure 1.18 Fusible plug.

installed. These devices are usually installed on low-pressure applications and large gas distribution systems. They have limited process applications.

1.6.5 Fusible plug devices

A fusible plug device is a nonreclosing pressure relief device designed to function by the yielding or melting of a plug, which has a lower melting point than the maximum operating temperature of the system to be protected. A fusible plug is shown in Fig. 1.18.

1.7 Codes and Standards

Pressure relief devices are designed according to codes and standards. Pressure relief devices should be manufactured, installed, operated, maintained, inspected, and repaired according to the laws and rules of local jurisdictions.

1.7.1 U.S. codes

Jurisdictions such as states, counties, and major cities have laws and rules governing pressure relief devices. Most jurisdictions in the United States have adopted one or more of the following codes and standards:

- ASME Section I, Power Boilers (which covers safety valves)
- ASME Section III, Nuclear Components (which covers safety relief valves)
- ASME Section IV, Heating Boilers (which covers safety relief valves)
- ASME Section VIII, Pressure Vessels (which covers safety relief valves)
- ANSI/ASME PTC 25, Performance Test Code for Safety and Relief Valves

- API RP520 Part I, Sizing and Selection of Pressure Relieving Devices in Refineries
- API RP520 Part II, Installation of Pressure Relieving Devices in Refineries
- API RP521, Guide for Pressure Relief and De-pressurizing Systems
- API RP526, Flanged Steel Safety/Relief Valves for use in the Petroleum Industry
- API RP527, Commercial Seat Tightness of Safety/Relief Valves with Metal to Metal and Soft Seals

1.7.2 International codes

There are international codes available on pressure relief devices. Most of the developed countries have their own codes and standards for design, construction, operation, and inspection of pressure relief devices.

Codes and standards of some countries are given below.

- Canada
 - CSA B51, Boiler, Pressure Vessel, and Pressure Piping Code
 - CSA Z299.2.85, Quality Assurance Program Category 1
 - CSA Z299.3.85, Quality Assurance Program Category 2
 - CSA Z299.4.85, Quality Assurance Program Category 3
- United Kingdom
 - BS 6759 Part 1, Specification for Safety Valves for Steam and Hot Water
 - BS 6759 Part 2, Specification for Safety Valves for Compressed Air And inert gas
 - BS 6759 Part 3, Specification for Safety Valves for Process Fluids
- Germany
 - Merkblatt 22, Pressure Vessel Equipment Safety Devices against EXCESS pressure—Safety Valves
 - TRD 421, Technical Equipment for Steam Boilers Safeguards against Excessive Pressure—Safety Valves for Boilers of Groups I, III, and IV
 - TRD 721, Technical Equipment for Steam Boilers Safeguards against Excessive Pressures—Safety Valves for Steam Boilers Group
- France
 - AFNOR NFE-E-29-411 to 416, Safety and Relief Valves
 - AFNOR NFE-E-29-421, Safety and Relief Valves
- Europe
 - EN ISO 4126, Safety Devices for Protection against Excessive Pressure
 - PrEN ISO 4126-1, Safety Devices for Protection against Excessive Pressure—Part 1: Safety Valves

PrEN ISO 4126-2, Safety Devices for Protection against Excessive Pressure—Part 2: Bursting Disk Safety Devices

PrEN ISO 4126-3, Safety Devices for Protection against Excessive Pressure—Part 3: Safety Valves and Bursting Disk Safety Devices in Combination

PrEN ISO 4126-4, Safety Devices for Protection against Excessive Pressure—Part 4: Pilot-Operated Safety Valves

PrEN ISO 4126-5, Safety Devices for Protection against Excessive Pressure—Part 5: Controlled Safety Pressure Relief Systems (CSPRS)

PrEN ISO 4126-6, Safety Devices for Protection against Excessive Pressure—Part 6: Application, Selection, and Installation of Bursting Disk Safety Devices

PrEN ISO 4126-7, Safety Devices for Protection against Excessive Pressure—Part 7: Common Data

- Romania
Romanian Pressure Vessel Standard
- Russia
GOST R, Certification System
- Switzerland
Specifications 62, Safety Valves for Boilers and Pressure Vessels
- Holland
A1301, Stoomwezen Specification
- Norway
TBK, General Rules for Pressure Vessels
- Korea
KS B 6216, Spring-Loaded Safety Valves for Steam Boilers and Pressure Vessels
- Japan
JIS B 8210, Steam Boilers and Pressure Vessels—Spring-Loaded Safety Valves
- Australia
AS1271, Safety Valves, Other Valves, Liquid Level Gauges and Other Fittings for Boilers and Unfired Pressure Vessels
AS121, Unfired Pressure Vessels
AS1200, Pressure Equipment

1.8 Jurisdictional Authority

A jurisdiction is a government authority such as a municipality, county, state, province, or country. The codes and standards for pressure relief devices become mandatory only when adopted by the jurisdictions

having authority over locations where pressure relief devices are installed.

Adoption of the codes and standards is accomplished through legislative action requiring that pressure relief devices fitted on pressure vessels for use within the jurisdiction must comply with the ASME, API, or other codes. Designated officials such as chief boiler and pressure vessel inspector and his or her staff enforce the legal requirements of the jurisdictions. Legal requirements for pressure relief valves vary from jurisdiction to jurisdiction.

In some jurisdictions there are no requirements for pressure relief devices. In such cases, the owner must use good engineering practices for design, selection, installation, operation, and maintenance to avoid dangers of pressure vessel and piping explosion.

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Pressure Relief Valves

A pressure relief device is a safety device used on pressurized equipment to protect life and property when all other safety measures fail. The ASME and API codes require that all pressure vessels subject to over-pressure must be protected by a pressure-relieving device. The codes further state that:

- Liquid-filled vessels or piping subject to thermal expansion should be protected by a thermal relief device.
- Multiple vessels should be protected by a single relief device, provided there is a clear, unobstructed path to the device.
- At least one pressure relief device should be set at or below the maximum allowable working pressure (MAWP).
- Relieving pressure should not exceed MAWP (accumulation) by more than:
 - 3% for fired and unfired steam boilers
 - 10% for vessels equipped with a single pressure relief device
 - 16% for vessels equipped with multiple pressure relief devices
 - 21% for fire contingency

A pressure relief valve is a pressure relief device. Its primary purpose is to prevent pressure in the system from increasing beyond safe design limits. The secondary purpose of a pressure relief valve is to minimize damage to other system components as a result of operation of the pressure relief valve itself.

The following are advantages of pressure relief valves:

- Most reliable if properly sized and operated
- Versatile—can be used for many services

The disadvantages of pressure relief valves are:

- Relieving pressure is affected by back pressure.
- Subject to chatter if built-up back pressure is too high.

There are many types of pressure relief valves, based on design and construction. They are generally classified as safety relief valves, relief valves, and safety valves.

2.1 Safety Relief Valves

A safety relief valve is a pressure relief valve that may be used as either a safety or a relief valve, depending on the application. Safety relief valves are classified as: conventional type, pilot operated, balanced bellows, power actuated, and temperature actuated.

2.1.1 Conventional pressure relief valves

The conventional pressure relief valve is characterized by a rapid-opening pop action or by opening in a manner generally proportional to the increase in pressure over the opening pressure (Figs. 2.1 and 2.2).

The basic elements of a conventional pressure relief valve consist of:

- An inlet nozzle connected to the vessel or system to be protected
- A movable disk which controls flow through the nozzle
- A spring which controls the position of the disk

Under normal operating conditions, the pressure at the inlet is below the set pressure and the disk is seated on the nozzle, preventing flow through the nozzle.

Conventional pressure relief valves are used for applications where excessive variable or built-up back pressure is not present in the system. The operational characteristics are directly affected by changes of the back pressure on the valve.

Working principle. The working principle of a conventional spring-loaded pressure relief valve is based on the balance of force. That means the spring load is preset to equal the force exerted on the closed disk by the inlet fluid when the system pressure is at the set pressure of the valve. The disk remains seated on the nozzle in the closed position when the inlet pressure is below the set pressure. The valve opens when the inlet pressure exceeds set pressure, overcoming the spring force. The valve recloses when the inlet pressure is reduced to a level below the set pressure.

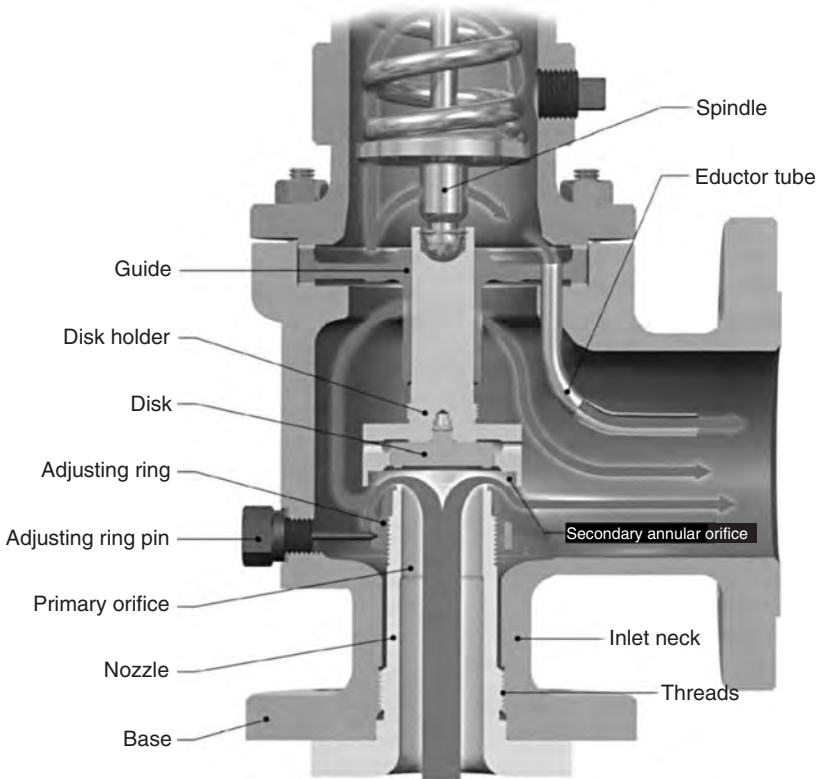


Figure 2.1 Conventional pressure relief valve. (Courtesy Dresser Flow Control.)

When the pressure relief valve is closed during normal operation (Fig. 2.3A), the vessel pressure acting against the disk surface A is resisted by the spring force. When the vessel pressure approaches the set pressure, the seating force between the disk and the nozzle approaches zero.

When vessel pressure slightly exceeds the set pressure, fluid will move past the seating surfaces into the huddling chamber B. During this operation, pressure is built up in the huddling chamber (Fig. 2.3B) as a result of restricted flow between the disk holder and adjusting ring. The controlled pressure buildup in the huddling chamber will overcome the spring force, causing the disk to lift and the valve to pop open.

Additional pressure buildup occurs at C, causing the disk to lift substantially at pop (Fig. 2.3C). This is the result of sudden flow increase and the restriction to flow through another annular orifice formed between the inner edge of the disk holder skirt and the outside diameter of the adjusting ring.

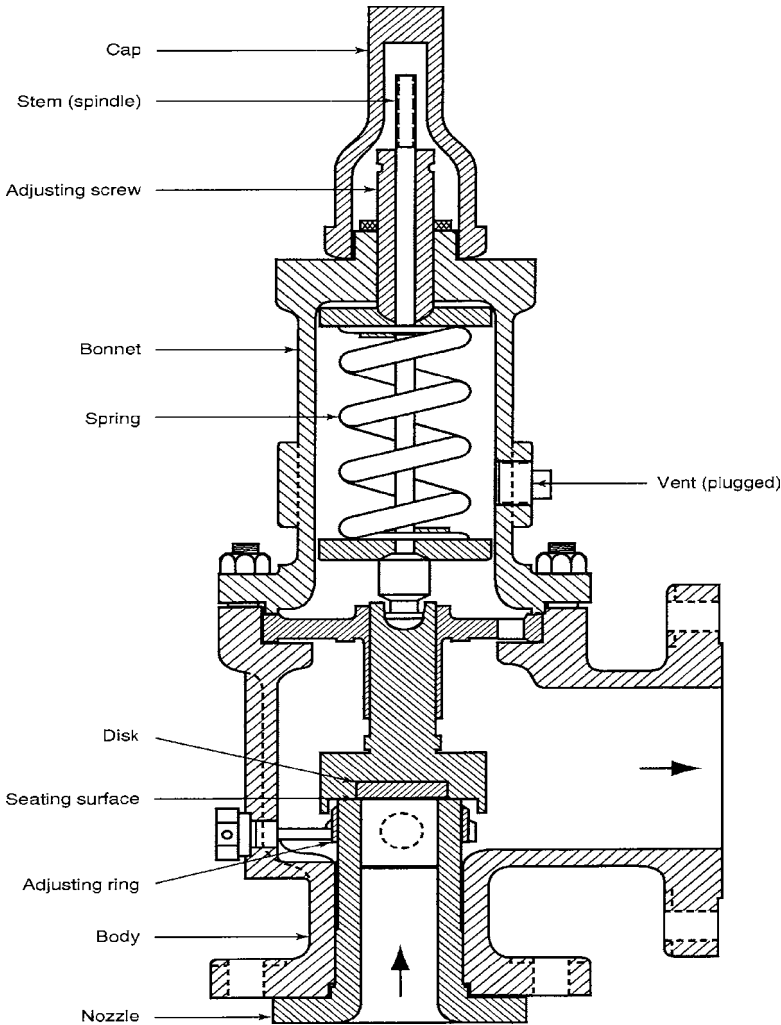


Figure 2.2 Sectional view of a conventional pressure relief valve. (From API RP 520.)

The pressure relief valve closes when the inlet pressure has dropped considerably below the set pressure, allowing the spring force to overcome the summation of forces at A, B, and C. The pressure at which the valve reseats is called the closing pressure. The difference between the set pressure and the closing pressure is called blowdown.

During operation, the disk travels as pressure is built-up (Fig. 2.4). The disk travels from the set pressure A to the maximum relieving pressure B during overpressure, and to the closing pressure C during blowdown.

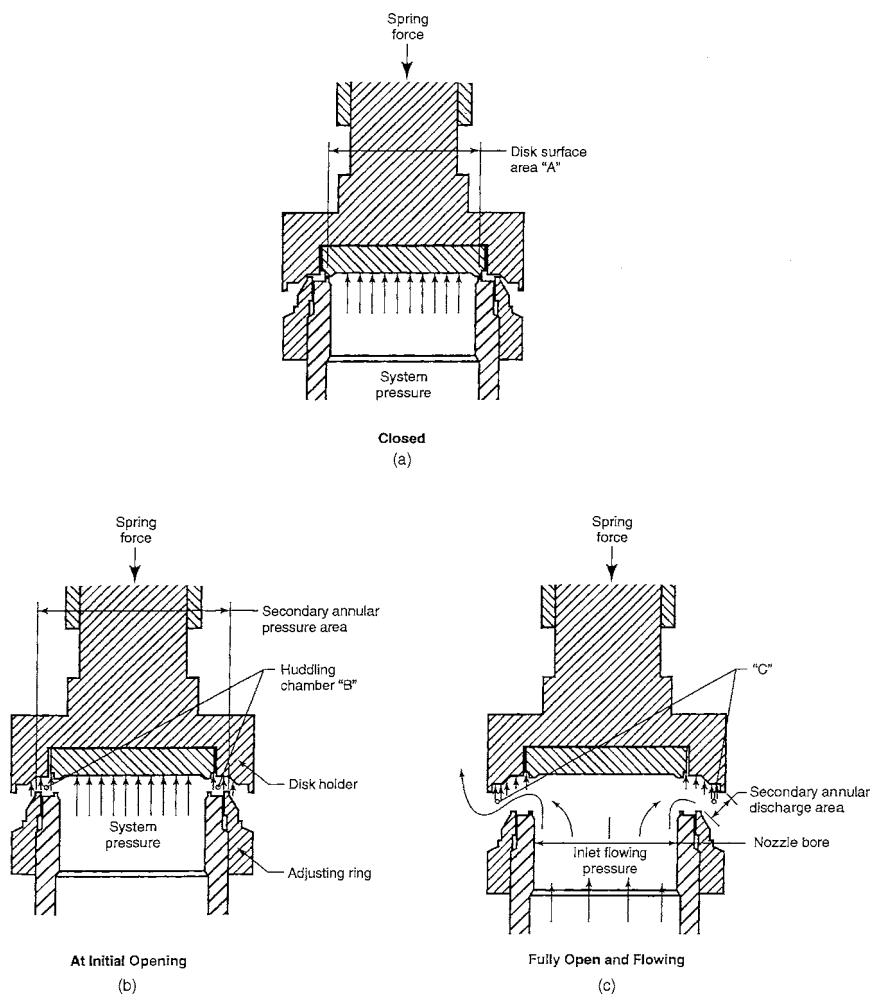


Figure 2.3 Conventional pressure relief valve operating principle. (From API RP 520.)

Types of valves. Seat leakage is an important consideration in the design of a conventional pressure relief valve. Seat leakage may result in continuous loss of system fluid and may cause progressive damage to the valve seating surfaces. Based on the seating material, conventional pressure relief valves are classified as: metal seated valves and soft seated valves.

Conventional metal seated valves. Metal-to-metal seats, commonly made from stainless steel, are normally used for high temperature such as steam.

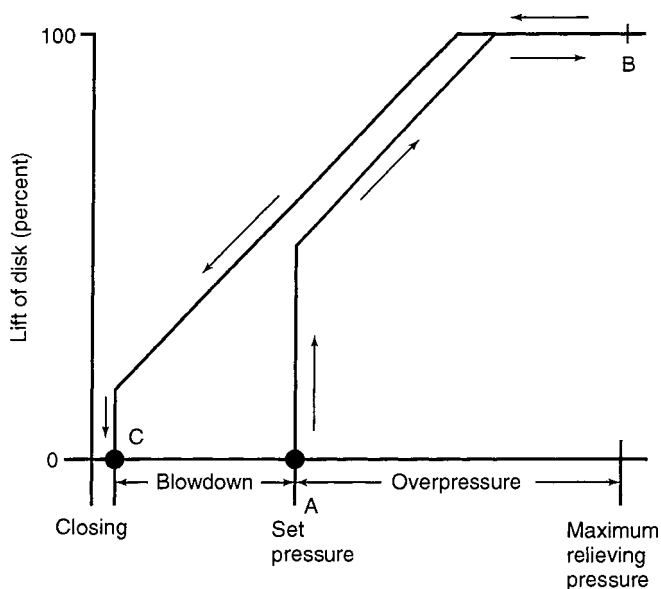


Figure 2.4 Lift of disk versus vessel pressure. (From API RP 520.)

The following are advantages of conventional metal-seated pressure relief valves:

- Lowest cost (in smaller sizes and lower pressures)
- Wide chemical compatibility
- High temperature capability
- Standard center-to-face dimensions (API 526).
- General acceptance for most applications

The following are disadvantages of conventional metal-seated pressure relief valves:

- Seat leakage, resulting in lost product and unacceptable emissions, causing environmental pollution.
- Simmer and blowdown adjustment is a compromise, which may result in intolerable leakage, and product loss.
- Vulnerable to effects of inlet pressure losses.
- Sensitive to effects of back pressure (set pressure and capacity).
- Generally not able to obtain accurate, in-place set-pressure verification.

Conventional soft seated valves. As alternative to metal, resilient disks can be fixed to either or both the seating surfaces where tighter shut-off is required, specially for gas or liquid applications. These inserts may be made from a number of different materials, but Viton, nitrile or EPDM are the most common. Soft seal inserts are not recommended for steam use.

The conventional soft seated pressure relief valve has the following advantages:

- Good seat tightness before relieving
- Good reseal tightness after relieving
- Good cycle life and maintained tightness
- Low maintenance costs

The conventional soft seated valve has the following disadvantages:

- Temperature is limited to seat material used.
- Chemically limited according to soft goods used.
- Vulnerable to effects of inlet pressure losses.

2.1.2 Pilot-operated pressure relief valves

A pilot-operated pressure relief valve is a pressure relief valve in which the major relieving device is combined with and is controlled by a self-actuated auxiliary pressure relief valve (Fig. 2.5).

The primary difference between a pilot-operated pressure relief valve and a spring-loaded pressure relief valve is that the pilot-operated valve uses process pressure to keep the valve closed instead of a spring. A pilot is used to sense process pressure and to pressurize or vent the dome pressure chamber which controls the valve opening or closing.

A pilot-operated pressure relief valve consists of the main valve, a floating unbalanced piston assembly, and an external pilot. The pilot controls the pressure on the top side of the main-valve unbalanced moving chamber. A resilient seat is normally attached to the lower end of this member.

- At pressures below set, the pressure on opposite sides of the moving members is equal.
- When the set pressure is reached, the pilot opens, depressurizes the cavity on the top side and the unbalanced member moves upward, causing the main valve to relieve.
- When the process pressure decreases to a predetermined pressure, the pilot closes, the cavity above the piston is depressurized, and the main valve closes.



Figure 2.5 Pilot-operated pressure relief valve. (Courtesy Farris Engineering.)

Advantages of the pilot-operated pressure relief valve are as follows:

- The pilot-operated valve's set pressure is not affected by back pressure. The pilot control valve, isolated from the influence of downstream pressure, controls the main valve's opening and closing.
- The pilot-operated valve operates bubble tight at higher operating pressure-to-set pressure ratios, allowing operators to run very close to the vessel's maximum allowable working pressure.
- As the system pressure increases, the force holding the disk in closed position increases. This allows the system operating pressure to be increased to values within 5% of set pressure without danger of increased seat leakage in the main valve.
- Reduced cost of the larger size valves. The large spring and associated envelope is replaced by a small pilot, thus reducing the mass and cost of the valve.
- Less susceptibility to chatter.

Pilot-operated pressure relief valves have the following disadvantages:

- Pilot is susceptible to plugging.
- Potential for back flow.

- Vapor condensation and liquid accumulation above the piston may cause problems.
- Limited chemical and high-temperature use by “O-ring” seals.

Working principle. The working principle can be described for three positions (Fig. 2.6): Closed valve position, relieving cycle, and reclosing cycle.

Closed valve position. As the system approaches set pressure, the pressure pickup transmits the pressure from the inlet of the main valve

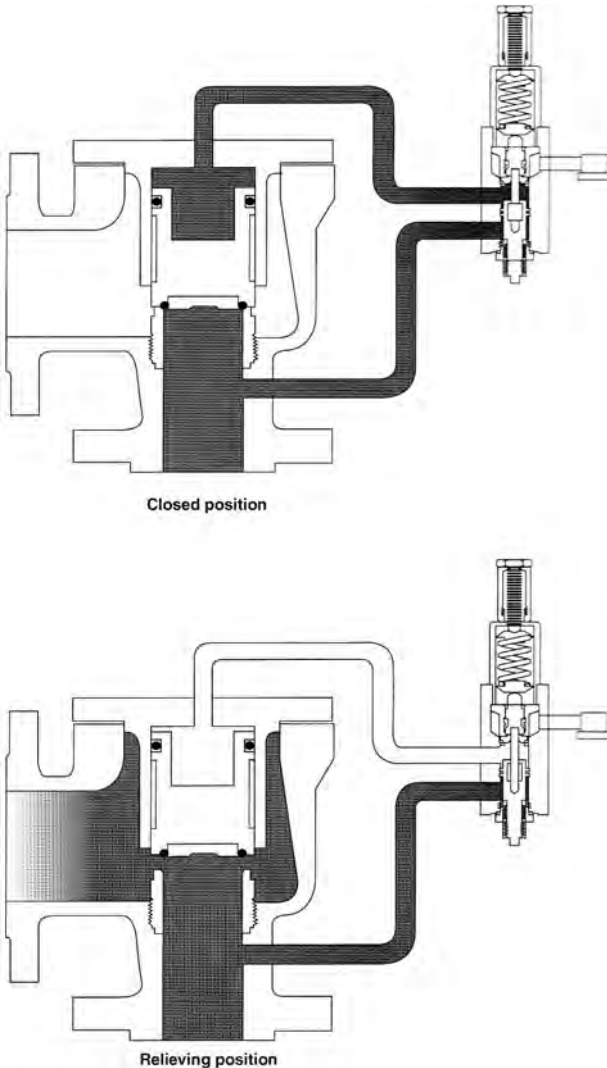


Figure 2.6 Pilot-operated safety valve operation. (Courtesy Farris Engineering.)

through the pilot control and into the dome of the main valve. This pressure acts on the top of the piston in the dome, holding the piston firmly against the seat on the nozzle of the main valve.

Relieving cycle. When the inlet pressure overcomes the spring force in the pilot valve, the pilot valve lifts. As the seat assembly in the pilot control begins to lift, it seals off the flow of pressure to both the vent and the main valve dome. At that time, the pressure in the dome is released through the pilot vent. As the pressure in the dome has been released, the system pressure acting on the bottom of the piston lifts the piston and relieves system overpressure.

Reclosing cycle. When the system pressure blows down, the spring force in the pilot valve overcomes the force of the system acting on the pilot control seat assembly. The pilot control redirects system pressure back into the main valve dome, closing the main valve. Of course, blow-down can be adjusted by raising and lowering the blowdown adjuster position in the pilot valve.

Types of valves. There are two general types of pilot-operated pressure relief valves: piston and diaphragm.

Piston-type pilot-operated pressure relief valve. This type of valve (Fig. 2.7) uses a piston for the unbalanced moving member. A sliding O-ring or

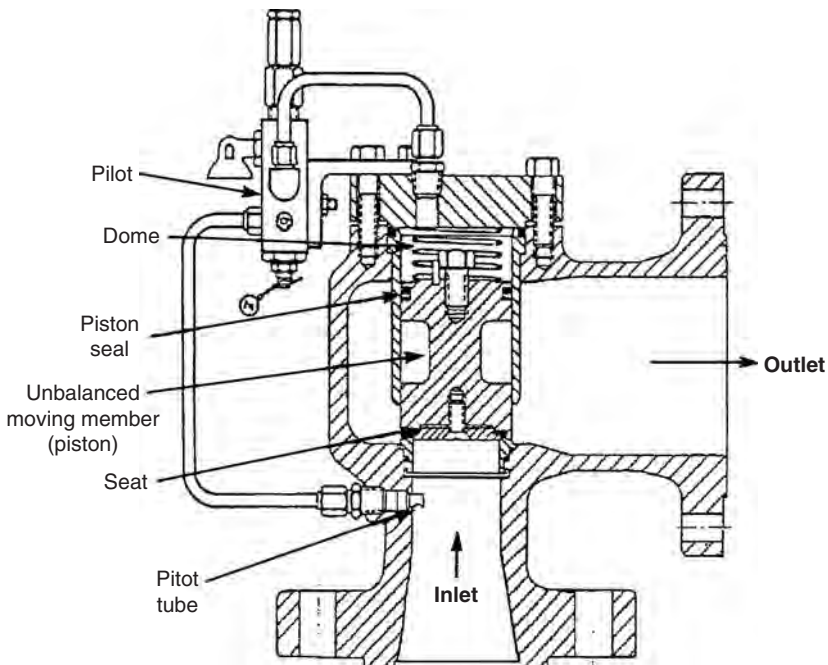


Figure 2.7 Piston-type pilot-operated pressure relief valve.

spring-loaded plastic seal is used to obtain a pressure seal for the dome activity. The piston-type valve is used for pressures from 5 to 10,000 psig, and occasionally for even higher pressures.

Diaphragm-type pilot-operated pressure relief valve. This type of valve (Fig. 2.8) is similar to the piston type except that a flexible diaphragm is used to obtain a pressure seal for the dome volume instead of a piston and sliding piston seal. This is done to eliminate sliding friction and permit valve operation at much lower pressures than would be possible with a sliding seal. The diaphragm-type valve can be used for pressures from 3-in water column (0.108 psig) to 50 psig.

Types of pilots. The pilot that operates the main valve can be classified based on (1) action and (2) flow.

Based on action. Based on action, the pilot may be classified as a pop-action or a modulating-action pilot.

Pop-action pilot. The pop-action pilot (Fig. 2.9) causes the main valve to lift fully at set pressure without overpressure. Typical relationship

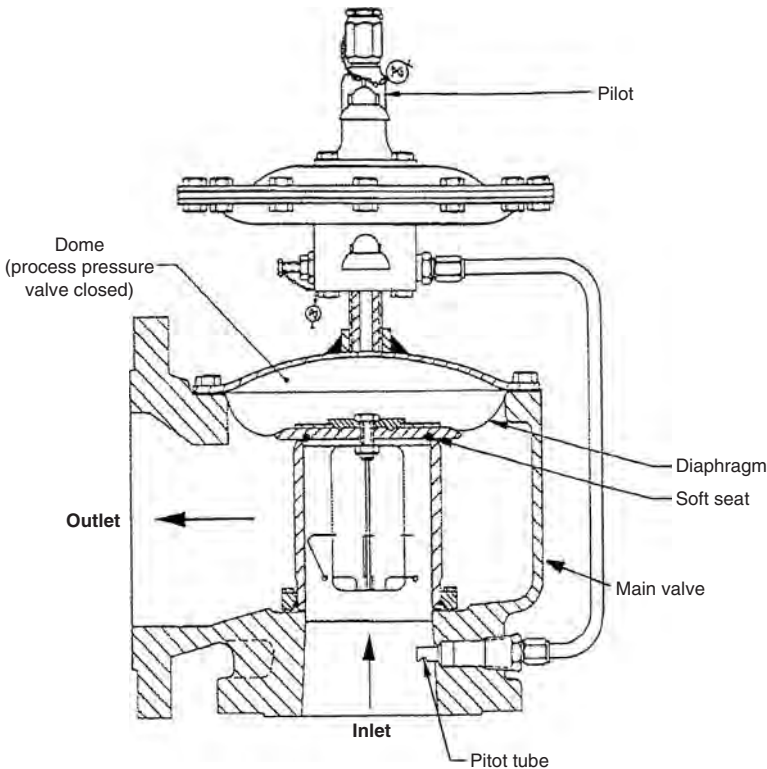


Figure 2.8 Diaphragm-type pilot-operated pressure relief valve.

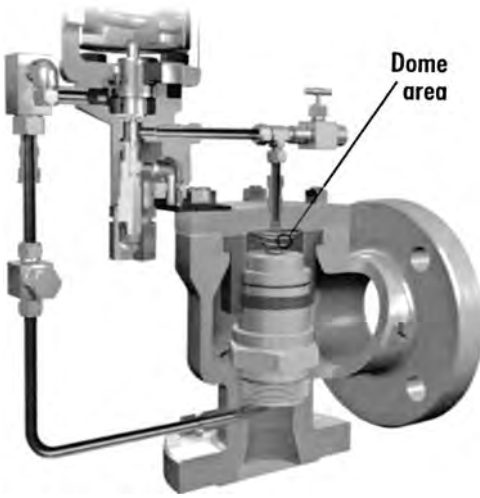


Figure 2.9 Pop-action pilot valve.
(Courtesy Dresser Flow Control.)

between lift of disk or piston and vessel pressure in a pop-action pilot-operated pressure relief valve is shown in Fig. 2.10.

Modulating-action pilot valve. The modulating pilot (Fig. 2.11) opens the main valve only enough to satisfy the required relieving capacity. Typical relationship between lift disk or piston and vessel

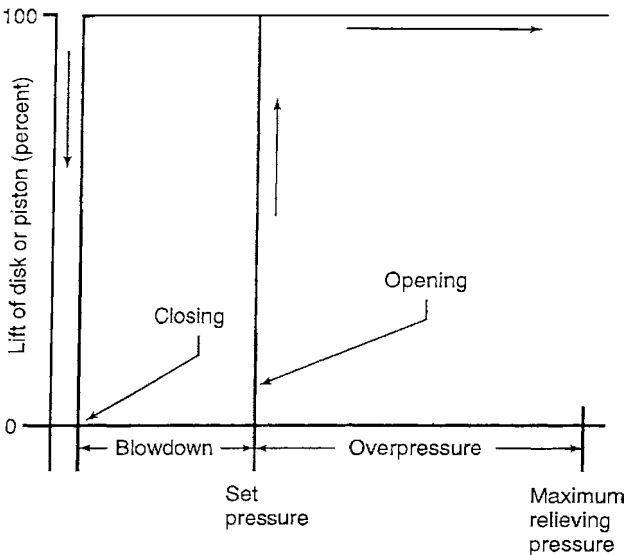


Figure 2.10 Typical relationship between lift of disk and vessel pressure in a pop-action pilot-operated pressure relief valve.
(From API RP 520.)

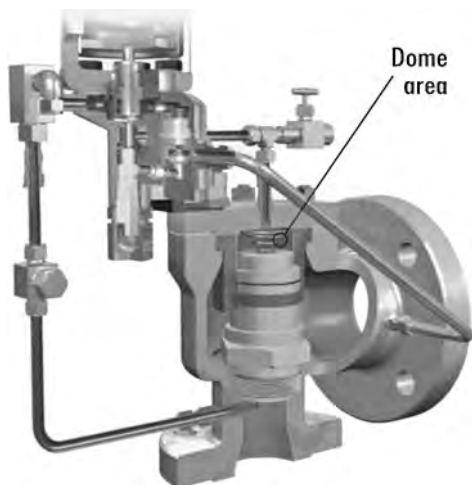


Figure 2.11 Modulating-action pilot valve. (Courtesy Dresser Flow Control.)

pressure in modulating-action pilot-operated pressure relief valve is shown in Fig. 2.12.

Based on flow. Based on flow, the pilot may be classified as flowing or nonflowing type.

Flowing-type pilot. The flowing type allows process fluid to flow continuously through the pilot when the main valve is open (Fig. 2.13).

Nonflowing-type pilot. The nonflowing-type pilot does not allow process fluid to flow continuously when the main valve is open (Fig. 2.14). This type of pilot is generally recommended for services to reduce the possibility of hydrate formation (icing) or solids in the landing fluid affecting the pilot's performance.

Options and accessories. The following options and accessories are available for pilot-operated pressure relief valves.

Manual blowdown valve. A manual blowdown valve is available for relieving the pilot-operated safety relief valve. The blowdown valve is ported directly to the main valve dome area so that the fluid in the dome is vented when blowdown is actuated, thus allowing the main valve to open.

Field test connection. A field test connection of size $\frac{1}{4}$ in FNTF is provided on pilot-operated valves. The connection allows the stroking of the valve with an auxiliary fluid such as air or nitrogen. The internal check valve isolates the inlet fluid from the test fluid and at the same

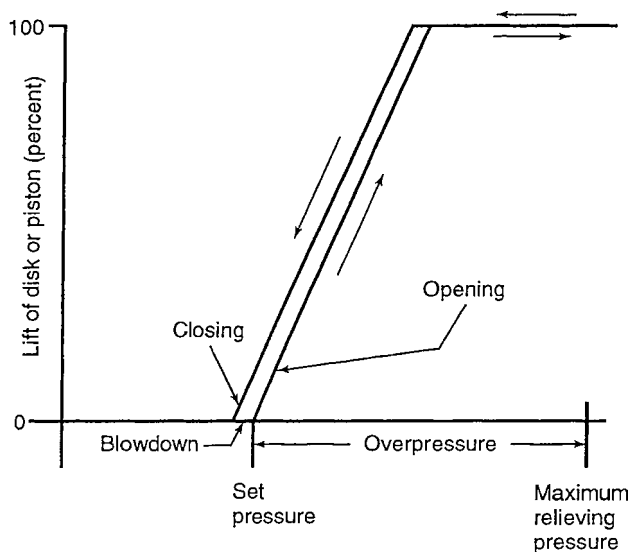


Figure 2.12 Typical relationship between lift of disk and pressure vessel in a modulating-action pilot-operated pressure relief valve. (From API RP 520.)

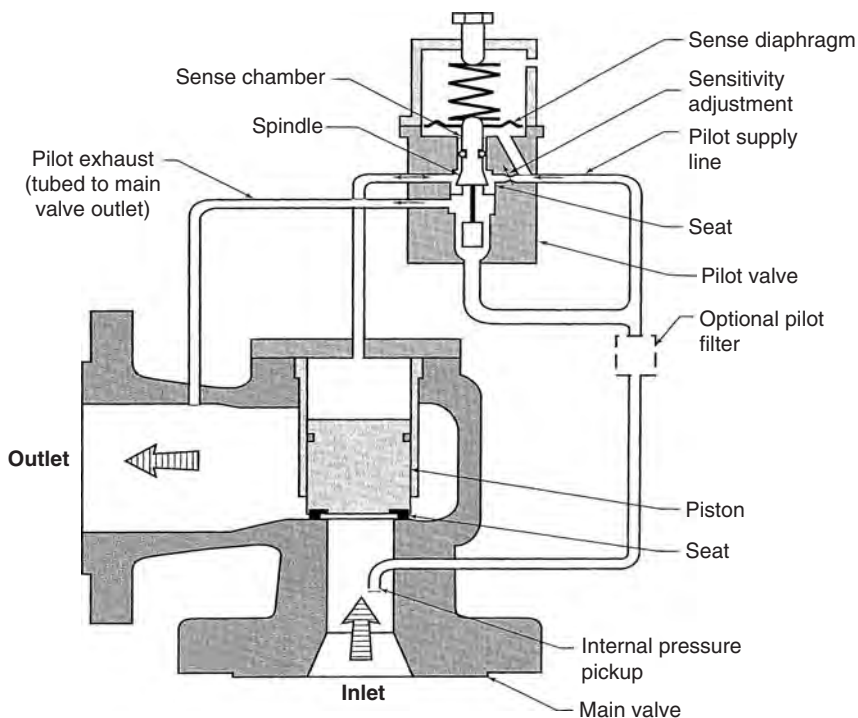


Figure 2.13 Modulating-flowing-type pilot-operated pressure relief valve. (From API RP 520.)

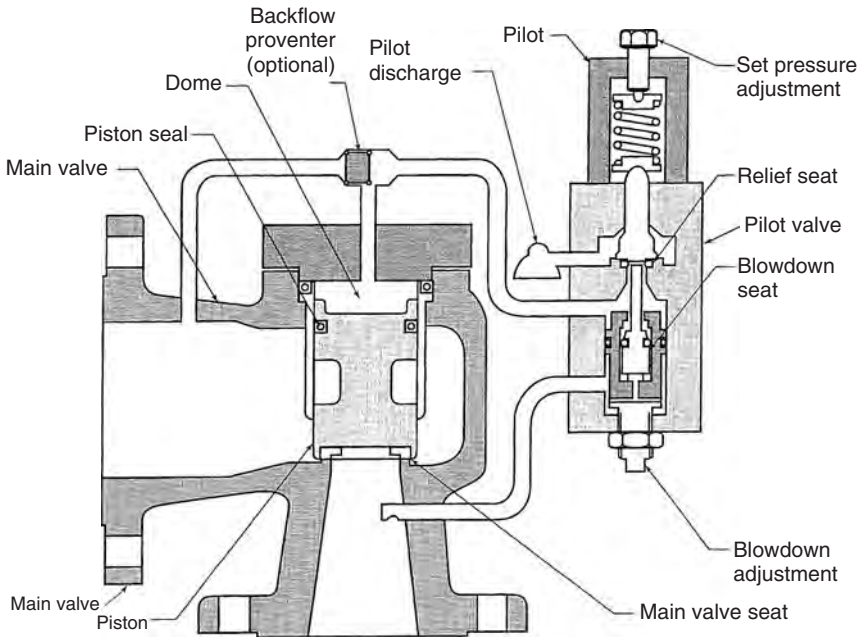


Figure 2.14 Pop-action nonflowing-type pilot-operated pressure relief valve. (From API RP 520.)

time allows the valve to open normally in case of system pressurization during a field test.

Filter. A filter is used for dirty applications and installed in the pilot sensing line. A standard filter for steam service has a 316 stainless steel body, Teflon seals, and a 40-to 50-micron stainless steel filter element.

Backflow preventer. If a pilot-operated safety relief valve is not vented directly to atmosphere, a back pressure may build up in the discharge line. This is especially true if several valves manifold into a common discharge header. If the discharge line pressure exceeds the valve inlet pressure, it can cause the piston to lift and allow reverse flow through the main valve. A backflow preventer is used to eliminate this situation.

Pilot valve tester. A pilot valve tester is available as an option for the modulating and pop-action pilot valves. The valve test indicator measures the set pressure of the pilot, while maintaining pressure on the main valve dome area. This allows only the pilot to actuate. The pilot valve tester shown in Fig. 2.15 is available for remote or local testing.

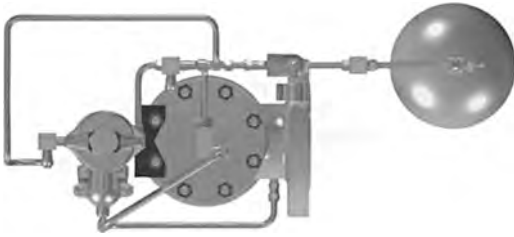


Figure 2.15 Pilot valve tester. (Courtesy Dresser Flow Control.)

Pressure differential switch. An electrical pressure differential switch is available which may be wired to a control room or some other location. The switch provides a signal that indicates when the main valve is opening. An option is also available to provide a pneumatic signal instead of an electrical differential switch to indicate when the main valve opens.

Remote sensing. The pilot inlet may be piped to a location remote from the main valve. The customer may want to pipe the inlet sensing line to some location other than where the main valve is located and where the pressure will be relieved.

2.1.3 Balanced bellows pressure relief valves

A balanced pressure relief valve is a spring-loaded safety valve which incorporates a bellows or other means of balancing the valve disk to minimize the effects of back pressure on the performance characteristics of the valve (Fig. 2.16). The term *balanced* means the set pressure of the valve is not affected by back pressure. Balanced pressure relief valves should be selected where the built-up back pressure is too high for a conventional relief valve.

Back pressure which occurs in the downstream system while the valve is closed is called superimposed back pressure. This back pressure is the result of the valve outlet being connected to a pressurized system or may be caused by other pressure relief valves venting to a common header. Compensation for superimposed back pressure is provided by reducing the spring force. The force of the spring plus back pressure acting on the disk should be equal to the force of the inlet pressure acting to open the disk.

When superimposed back pressure is variable, a balanced pressure relief valve is recommended. The bellows are designed with an effective pressure area equal to the seat area of the disk. The bonnet is vented to ensure that the pressure area of the bellows will always be exposed

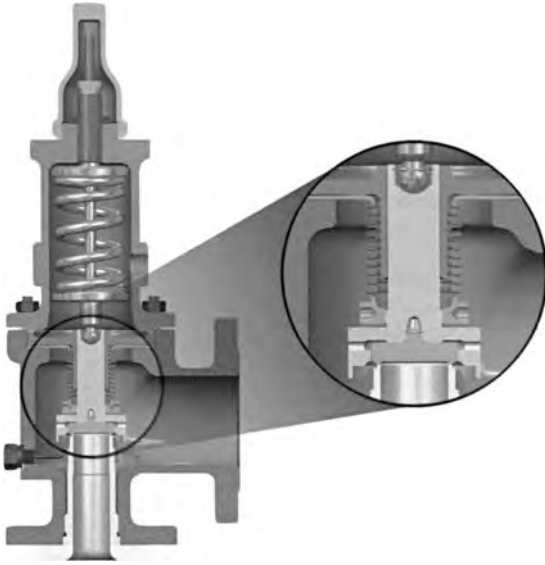


Figure 2.16 Balanced bellows pressure relief valve.
(Courtesy Dresser Flow Control.)

to atmospheric pressure and to provide a telltale sign if the bellows begin to leak. Variations in back pressure will have no effect on set pressure. However, back pressure may affect flow.

Back pressure which occurs after the valve is open and flowing is called dynamic or built-up back pressure. This type of back pressure is caused by fluid flowing from the pressure relief valve from downstream piping system. Built-up back pressure does not affect the valve opening pressure, but has an effect on valve lift and flow. On applications of 10% overpressure, balanced bellows designs are recommended when built-up back pressure is expected to exceed 10% of the cold differential test pressure (CDTP).

The bellows offset the effects of variable back pressure, and seals process fluid from escaping to atmosphere and isolate the spring, bonnet, and guiding surfaces from contacting process fluid.

The advantages of balanced bellows, metal-seated pressure relief valves are as follows:

- Relieving pressure is not affected by back pressure.
- Can handle higher built-up back pressure.
- Protects spring from corrosion.
- Protected guiding surfaces and spring.
- Good chemical and high-temperature capabilities.

The following are disadvantages:

- Bellows are subjected to fatigue/rupture.
- May release flammables/toxics to atmosphere.
- Require separate venting systems.
- Seat leakage, resulting in unacceptable emissions, causing loss of product and environmental pollution.
- Simmer or blowdown may be unacceptable.
- High maintenance costs.
- Vulnerable to effects of inlet pressure losses.
- Generally not able to obtain accurate, in-place set-pressure verification.

Working principle. The working principle of a balanced bellows pressure relief valve is similar to that of a conventional spring-loaded safety valve. The main difference is that the area downstream of the seat disk is enclosed within a protective pressure barrier to balance against back pressure. Figure 2.16 shows the seat disk enclosed by the bellows.

When the bellows is installed on a conventional spring-loaded safety valve, the eductor tube is removed. Conventional valves can be easily converted to a bellows design or vice versa through the use of retrofit kits.

The balanced bellows pressure relief valve works by the same principle as the conventional pressure relief valve, as described in Sec. 2.1.1.

Types of valves. Balanced pressure relief valves are classified into two categories: balanced bellows type and balanced bellows with auxiliary balancing piston.

Balanced bellows type. This valve is the same as the conventional pressure relief valve design except that a bellows has been added (Fig. 2.17). The bellows is added to the spring-loaded pressure relief valve for the following purposes:

- Back pressure entering the valve through the valve outlet is excessive or variable. A bellows is required if back pressure fluctuates within +10% of a nominal value. If a built-up back pressure exceeds 10% of the set pressure or cold differential set pressure, a bellows should be used.
- If the process fluid is slurry, highly viscous, or a type of fluid that enters the critical clearances between guides/disk holder, protect that area with a bellows.
- If the process fluid is corrosive to the upper works of the valve, isolate the bonnet chamber by using a bellows.

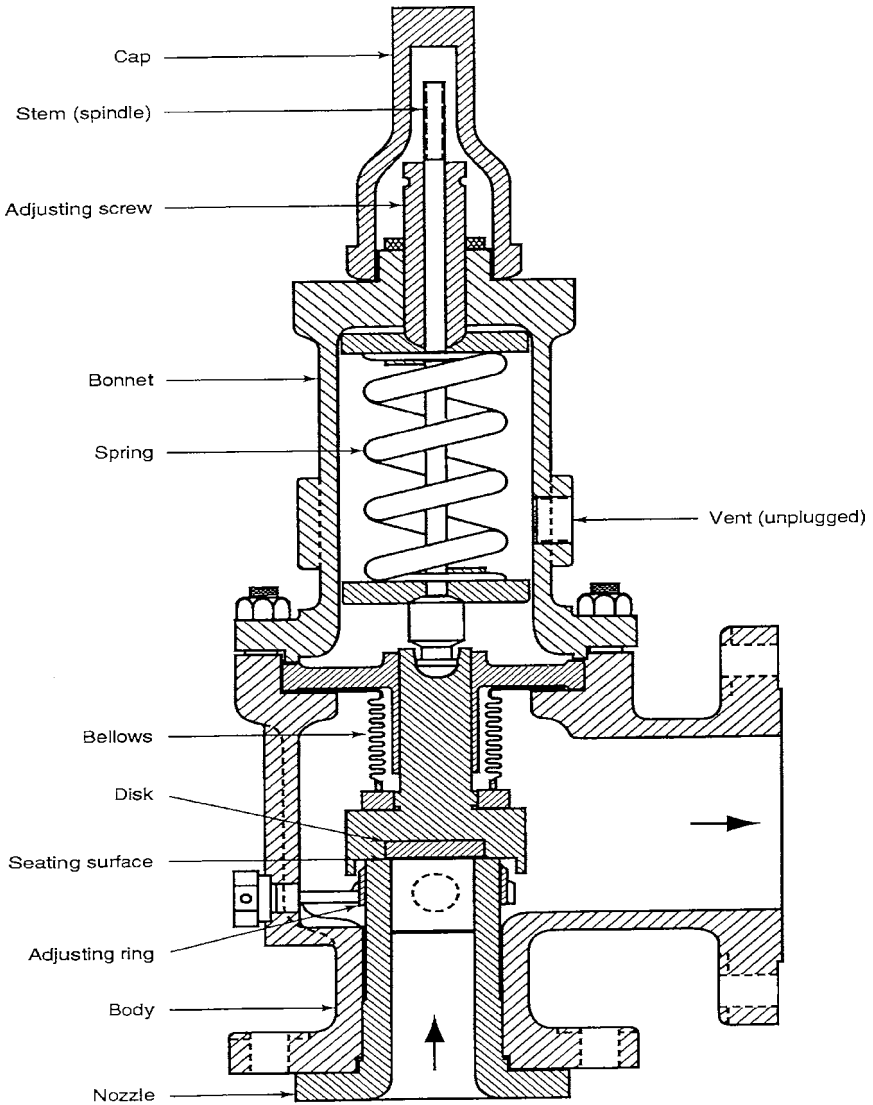


Figure 2.17 Balanced bellows pressure relief valve. (From API RP 520.)

Balanced bellows with auxiliary balancing piston. The balanced bellows seals the body and fluid stream from the bonnet and working parts. The auxiliary balancing piston assures proper valve performance by compensating for back pressure in case of bellows failure (Fig. 2.18). The use of an auxiliary balanced piston is recommended when:

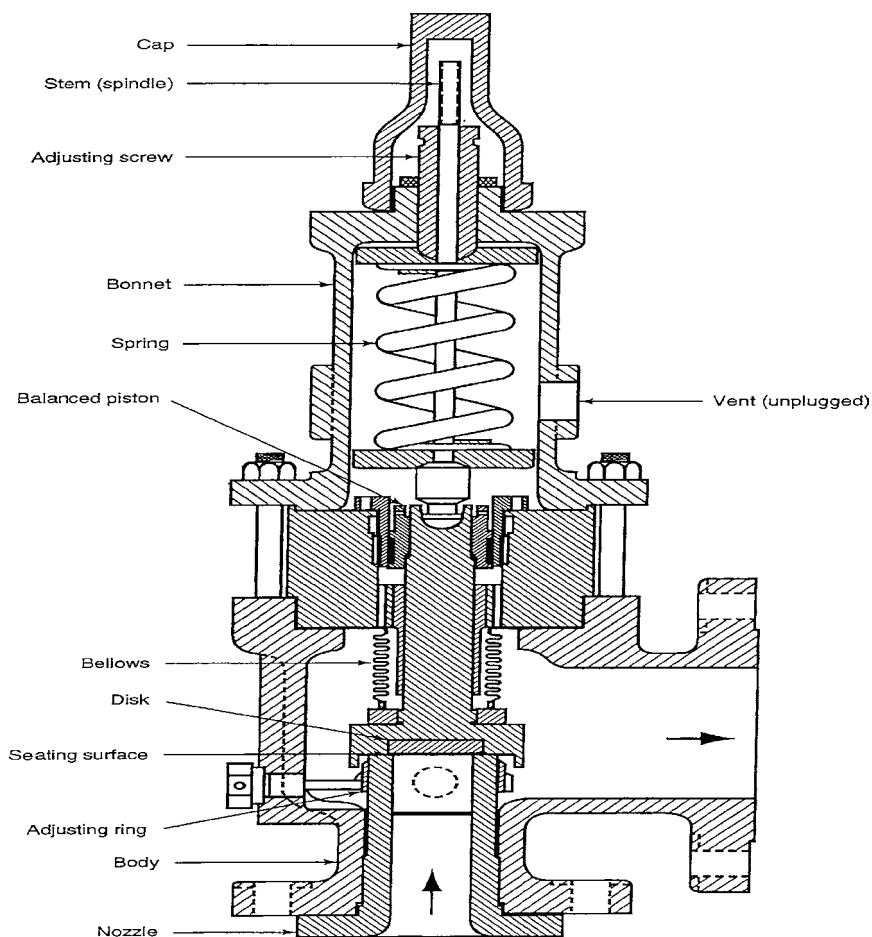


Figure 2.18 Balanced bellows pressure relief valve with an auxiliary balanced piston.
(From API RP 520.)

- Back pressure, either constant or variable, exists.
- Excessive pressure is built up in the bonnet as a result of pressure buildup in the bonnet venting piping.
- Resultant buildup of pressure in the bonnet would cause a dangerous condition.

2.1.4 Power-actuated pressure relief valves

A power-actuated pressure relief valve is a pressure relief valve in which the major relieving device is combined with and controlled by a device requiring an external source of energy.

The power-actuated pressure relief valve is one whose movement to open or close is fully controlled by a source of power such as electricity, air, steam, or water (hydraulic). The valve may discharge to atmosphere or to a container at lower pressure. The discharge capacity may be affected by downstream conditions, and such effects should be taken into account.

If the power-actuated pressure relieving valves act in response to other control signals, the control impulse to prevent overpressure should be responsive only to pressure and should override any other control function.

Power-actuated valves are used mostly for forced-flow steam generators with no fixed steam or waterline. These valves are also used in nuclear power plants.

2.1.5 Temperature-actuated pressure relief valves

A temperature-actuated pressure relief valve is a pressure relief valve which may be actuated by external or internal temperature or by pressure on the inlet side (Fig. 2.19). It is also called a T&P safety relief valve.

The thermal sensing elements for this valve should be so designed and constructed that they will not fail in any manner which could obstruct flow passages or reduce capacities of the valve when elements are subjected to saturated steam temperature corresponding to capacity test pressure. T&P safety relief valves incorporating these elements should comply with a nationally recognized standard such as ANSI Z21.22, Relief Valves for Hot Water Supply Systems.

Working principle. A temperature-actuated pressure relief valve is designed for dual purposes. First, the T&P valve prevents temperature



Figure 2.19 T&P relief valve.
(Courtesy Conbraco Industries, Inc.)

within a vessel from rising above a specified limit (generally 210°F). Second, the T&P valve also prevents pressure in the vessel from rising above a specified value. The valve incorporates two primary controlling elements, a spring and a thermal probe.

The spring provides a force acting down on the disk, keeping it closed until the pressure in the vessel overcomes the spring force, then opening the valve and allowing fluid to escape from inside the vessel. When pressure is reduced as a result of this discharge, the spring causes the valve to close and permits normal operation of the system.

On the other hand, the thermal probe senses water temperature in the vessel, and when this temperature reaches or exceeds a specified temperature, a pen or plunger within the probe pushes upward against the disk and causes it to open. The thermal probe accomplishes this by a waxlike substance within the probe which undergoes a phase transformation as a result of increasing temperature and expands when doing so. This expansion causes the pen to push upward, discharging fluid from the vessel. When fluid is discharged as a result of the probe operation, a cooler supply of fluid enters into the vessel, reducing overall temperature in the vessel to within an acceptable limit. At this point, the pen in the thermal probe retracts and permits the spring to cause the valve disk to reclose.

2.2 Relief Valves

A relief valve is a spring-loaded pressure relief valve actuated by the static pressure upstream of the valve (Fig. 2.20). The valve opens normally in proportion to the pressure increase over the opening pressure. A relief valve is generally used for liquid service.

Liquid-service valves do not pop in the same manner as vapor-service valves, as the expansive forces produced by the vapor are not present in liquid flow. Liquid-service valves depend on reactive forces to achieve lift. Relief valves designed for liquid service have been developed which achieve full lift, stable operation, and rated capacity at 10% overpressure.

When the valve is closed, the forces acting on the valve disk are the as those applied by vapor until a force balance is reached and the net force holding the seat closed approaches zero. From this point on, the force relationship is different.

Working principle. At initial opening, the escaping liquid forms a very thin sheet of fluid (Fig. 2.21A), expanding radically between the seating surfaces. The liquid strikes the reaction surface of the disk holder and is deflected downward, creating a reactive (turbine) force tending to

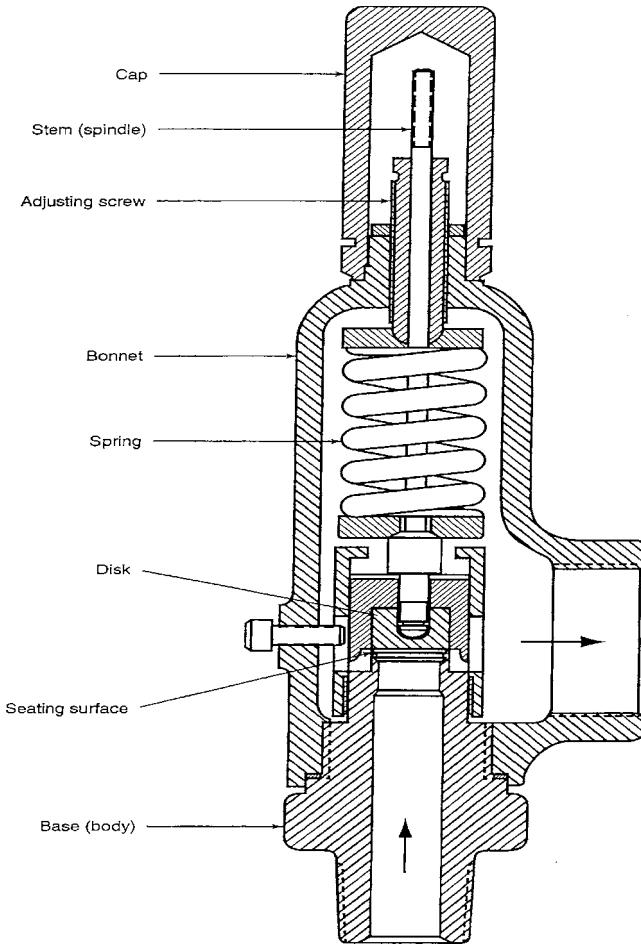


Figure 2.20 Relief valve. (From API RP 520.)

move the disk and holder upward. These forces build slowly during the first 2–4% of overpressure.

As the flow increases, the velocity head of the liquid moving through the nozzle increases. These momentum forces, combined with the reactive forces of radially discharging liquid as it is deflected downward from the reaction surface (Fig. 2.21B), are enough to cause the valve to go into lift. Typically the valve surges suddenly at 50–100% lift at 2–6% overpressure. As the overpressure increases, these forces continue to grow, driving the valve into full lift. Liquid-service valves, capacity certified by ASME, are required to reach full rated capacity at 10% or less overpressure.

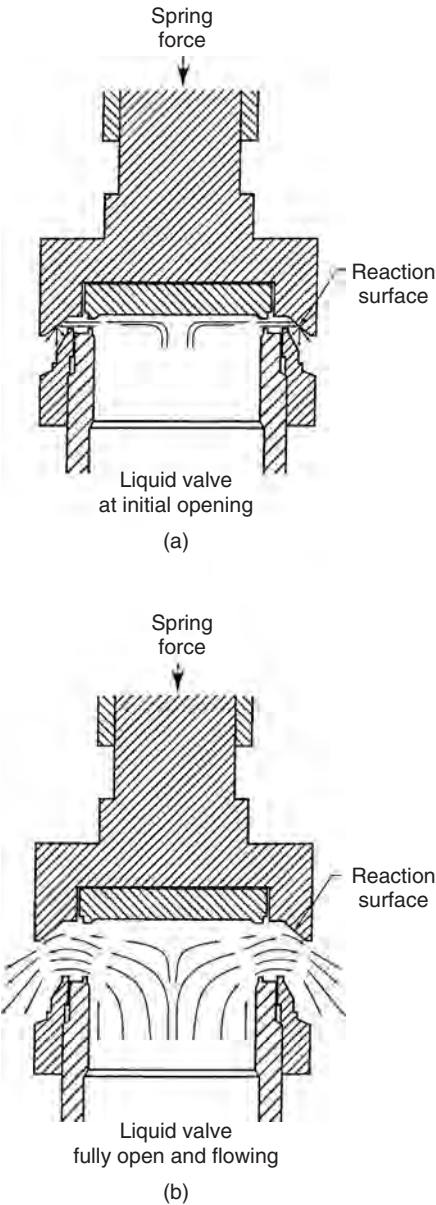


Figure 2.21 Working principle of a relief valve. (From *API RP 520*.)

2.3 Safety Valves

A safety valve is a direct spring-loaded pressure relief valve that is actuated by the static pressure upstream of the valve and is characterized by rapid opening or pop action. Details about safety valves are discussed in Chap. 3.

2.4 Major Components

- *Adjusting ring.* A ring assembled to the nozzle or guide of a direct spring valve, used to control the opening characteristics and/or the reseal pressure.
- *Adjusting screw.* A screw used to adjust the set pressure or the reseal pressure of a reclosing pressure relief valve.
- *Balanced bellows.* A bellows designed so that the effective area of the bellow is equivalent to that of the valve seat, thereby canceling out the additive effect of back pressure.
- *Body.* A pressure retaining or containing member of a pressure relief device that supports the parts of the valve assembly and has provision(s) for connecting to the primary and/or secondary pressure source(s).
- *Bonnet.* A component of a direct spring valve or of a pilot in a pilot-operated valve that supports the spring. It may or may not be pressure containing.
- *Cap.* A component used to restrict access and/or protect the adjustment screw in a reclosing pressure relief device. It may or may not be a pressure containing part.
- *Disk.* A moveable component of a pressure relief device that contains the primary pressure when it rests against the nozzle.
- *Disk holder.* A moveable component in a pressure relief device that contains the disk.
- *Guide.* A component in a direct spring or pilot operated pressure relief device used to control the lateral movement of the disk or disk holder.
- *Huddling chamber.* The annular pressure chamber located beyond the valve seat for the purpose of generating a popping characteristic.
- *Lifting device (lever).* A device to open a pressure relief valve manually, by the application of external force to lessen the spring loading which holds the valve closed. Lifting devices can be open levers or packed levers (fully enclosed design).
- *Nozzle.* The pressure-containing element which constitutes the inlet flow passage and includes the fixed portion of the seat closure. Nozzles can be divided into two types:
 - *Full nozzle.* A single member extending from the face of the inlet flange to the valve seat.
 - *Semi-nozzle.* The lower part of the inlet throat is formed by the body casting and the upper part is valve seat threaded or welded into the valve body.
- *Orifice.* A computed area of flow for use in flow formulas to determine the capacity of a pressure relief valve.

- *Pilot.* The pressure or vacuum sensing component of a pilot operated pressure relief valve that controls the opening and closing of the main relieving valve.
- *Piston.* The moving element in the main relieving valve of a pilot operated piston type pressure relief valve which contains the seat that forms the primary pressure containment zone when in contact with the nozzle.
- *Seat.* The pressure-sealing surfaces of the fixed and moving pressure containing components.
- *Spring.* The element in a pressure relief valve that provides the force to keep the disk on the nozzle.
- *Stem.* A part whose axial orientation is parallel to the travel of the disk. It may be used in one or more of the following functions:
 - (a) assist in alignment,
 - (b) guide disk travel, and
 - (c) transfer of internal or external forces to the seats
- *Trim.* Internal parts, especially the seat (nozzle) and disk.

2.5 Accessories

- *Lifting mechanisms.* Lifting mechanisms are used to open the pressure relief valve when the pressure under the valve disk is lower than the set pressure. These mechanisms are available in three basic types: plain lever, packed lever, and air-operated devices.
 - *Plain lever.* The plain lever assembly is not pressure tight and should not be used where back pressure is present or where the escape of vapor around the lever assembly is undesirable.
 - *Packed lever.* This lifting lever assembly is packed around the lever shaft so that leakage does not occur around the upper part of the valve when the valve is open or when back pressure is present.
 - *Air-operated lifting device.* The air-operated lifting device uses an air cylinder to obtain lifting power to open the valve from a remote control station (Fig. 2.22). Regulated air, not exceeding 100 psig, is required for operation of the lifting device.
- *Bolted cap.* Standard pressure relief valves are available with bolted caps in addition to the screwed caps.
- *Cap with gag.* The gag is used to hold the pressure relief valve closed while equipment is being subjected to an operational hydrostatic test (Fig. 2.23). This is the only purpose for which the gag is intended, and it can be accomplished by pulling the gag hand tight. The gag should never be left in the valve during operation of the equipment.

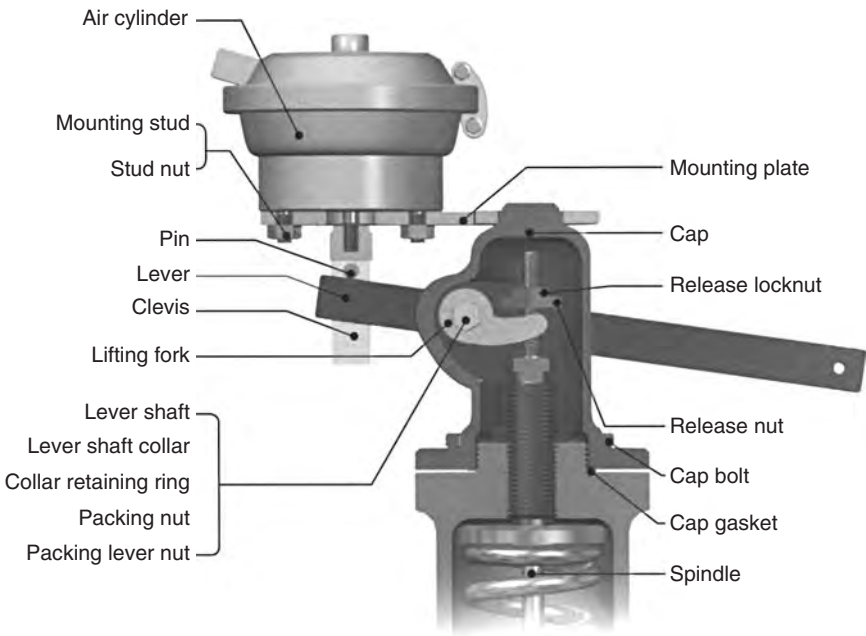


Figure 2.22 Air lifting device. (Courtesy Dresser Flow Control.)



Figure 2.23 Cap with gag. (Courtesy Dresser Flow Control.)

- *Test plugs.* Test plugs are used for hydrostatic testing of the vessel. The test plugs are installed at the pressure relief valve openings. The plugs are available in pipe I.D. sizes from 0.93 to 8.53 in for pressures up to 14,000 psi (960 bar).
- *Valve position indicators.* Generally, a valve position indicator is a microswitch apparatus used for remote indication of the opening of a pressure relief valve. It is designed to activate warning devices such as control panel lights or auditory indicators.
- *Bolt-on jacket.* Bolt-on jackets on relief valves are used in many different process service applications. Viscous materials that freeze in relief valve nozzles create hazardous conditions. Process pipe jacketing may not provide sufficient heat to the area in and around the relief valve seat. During pressure surge, solid materials may stick in and around the seating area, resulting in the valve not functioning and reseating properly. The bolt-on jacket (Fig. 2.24) is a two-piece aluminum casting with a steel pressure chamber embedded in the aluminum jacket casting. The pressure chamber is fabricated of pressure vessel-quality materials for various heating fluids and service temperatures. The jacket casting conducts heat from the pressure chamber and distributes it evenly over the outer surface of the relief valve. Standard service ratings for the jackets are 150 psig and 500°F.

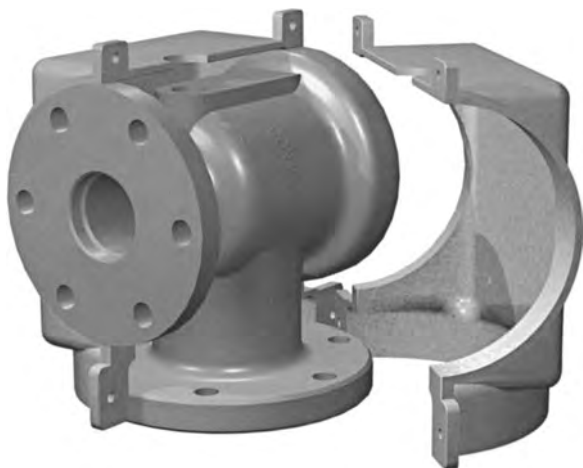


Figure 2.24 A typical bolt-on jacket. (Courtesy Dresser Flow Control.)

2.6 Specifications

2.6.1 How to order a conventional pressure relief valve

Figure 2.25 shows a specification sheet that can be used when ordering conventional pressure relief valves.

2.6.2 Specification sheets

- *Spring-loaded pressure relief valve.* A specification sheet for a spring-loaded pressure relief valve is shown in App. B.
- *Pilot-operated pressure relief valve.* A specification sheet for a pilot-operated pressure relief valve is shown in App. C.

Page _____ of _____	
Requisition No. _____ Job No. _____ Date _____ Revised _____ By _____	
General 1. Item Number: 2. Tag Number: 3. Service, Line or Equipment No: 4. Number Required: Basis of Selection 5. Code: ☐ ASME Sec. III ☐ ASME Sec. VIII ☐ OTHER Specify: 6. ☐ Fire ☐ OTHER Specify: 7. Rupture Disk: ☐ YES ☐ NO Valve Design 8. Type: Safety Relief 9. Design: ☐ Metal Seat ☐ Resilient Seat ☐ API 527 Seat Tightness ☐ OTHER Specify: Connections 10. Flanged Inlet Size: Rating: Facing: Outlet Size: Rating: Facing: 11. Threaded Inlet ☐ MNPT ☐ FNPT Outlet ☐ MNPT ☐ FNPT 12. ☐ OTHER Specify:	Materials 13. Base: 14. Bonnet: 15. Guide/Rings: 16. Seat Material: Metal: Resilient: 17. Spring: 18. Comply with NACE MRO 175 ☐ YES ☐ NO 19. OTHER Specify: 20. Cap and Lever Selection ☐ Screwed Cap (Standard) ☐ Bolted Cap ☐ Plain Lever ☐ Packed Lever ☐ Gag 21. ☐ OTHER Specify: Service Conditions 22. Fluid and State: 23. Required Capacity per Valve & Units: 24. Molecular Weight or Specific gravity: 25. Viscosity at Flowing Temperature & Units: 26. Operating Pressure & Units: 27. Blowdown: ☐ Standard ☐ Other 28. Latent Heat of Vaporization & Units: 29. Operating Temperature & Units: 30. Relieving Temperature & Units: 31. Built-up Back Pressure & Units: 32. Superimposed Back Pressure & Units: 33. Cold Differential Test Pressure & Units: 34. Allowable Overpressure in Percent or Units: 35. Compressibility Factor, Z: 36. Ratio of Specific Heats: Sizing and selection 37. Calculated Orifice Area (square inches): 38. Selected Orifice Area (square inches): 39. Orifice Designation (letter): 40. Manufacturer: 41. Model Number: 42. Vendor Calculations Required: ☐ YES ☐ NO

Figure 2.25 Information required for ordering pressure relief valves. (Courtesy Dresser Flow Control.)

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Safety Valves

The principal device used to prevent overpressure in steam plants is the safety valve. The safety valve operates by releasing a volume of fluid from within the plant when a predetermined maximum pressure is reached, thereby reducing the excess pressure in a safe manner. As the safety valve is the only remaining mechanical device to prevent catastrophic failure under overpressure conditions, it is most important that any such device is capable of operating at all times and under all possible conditions.

Safety valves are installed wherever the maximum allowable working pressure (MAWP) of a system or pressure-containing vessel is likely to be exceeded. Safety valves are typically used for boiler overpressure protection and other applications such as downstream of pressure-reducing controls. Although their primary role is for safety, safety valves are also used in process operations to prevent product damage due to excess pressure.

A wide range of different safety valves is available for many different applications and performance criteria. Furthermore, various designs are required to meet the numerous national standards that govern the use of safety valves.

3.1 Working Principle

A safety valve is a pressure relief valve, and its working principle is similar to that of a conventional pressure relief valve. A safety valve is actuated by inlet static pressure and characterized by rapid opening or pop action. A sectional view of a safety valve is shown in Fig. 3.1.

Lifting. When the inlet static pressure rises above the set pressure, the valve begins to lift off its seat. As soon as the spring starts to compress, the spring force increases. That means the pressure is required

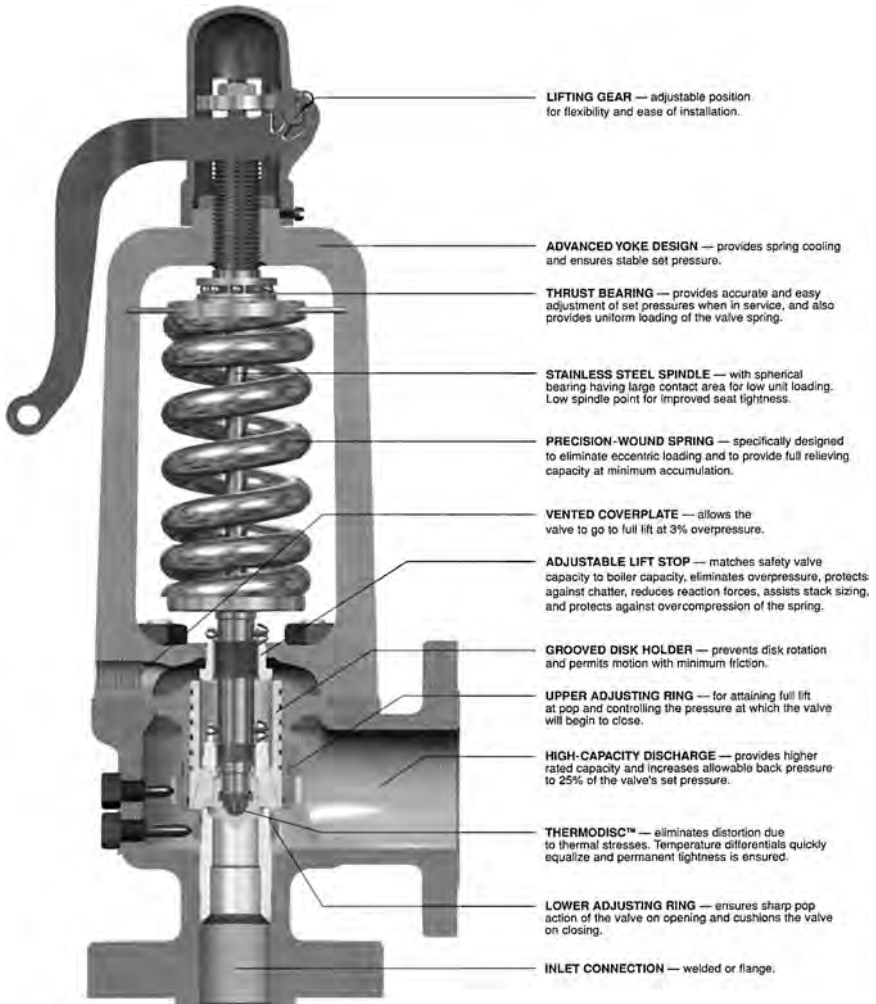


Figure 3.1 Sectional view of a safety valve. (From Dresser Flow Control.)

to continue to rise before any further lift can occur and for significant flow through the valve. The additional pressure rise required before the safety valve discharges at its rated capacity is called the overpressure. The overpressure for compressible fluid is normally between 3% and 10%.

In order to accomplish full opening from this small overpressure, the valve has to be designed for rapid opening. This is done by placing a skirt or hood around the valve. The volume contained within this skirt is known as the huddling chamber.

As lift begins and fluid enters the chamber, a larger area of the skirt is exposed to the fluid pressure. The magnitude of the lifting force F is proportional to the product of the pressure P and the area exposed to the fluid A . That means, $F = P \times A$.

The opening force increases with the magnitude of the lifting force. The incremental increase in opening force overcompensates for the increase in spring force, causing rapid opening. At the same time, the skirt reverses the direction of flow, which provides a reaction force, further enhancing the lift. The combined effects allow the valve to achieve its designed lift with a relatively small percentage overpressure. The relationship between pressure and lift for a typical safety valve is shown in Fig. 3.2.

Reseating. Once the safety valve has discharged fluid, it is required to close. Since the larger area of the valve is still exposed to fluid, the valve will not close until the pressure has dropped below its original set pressure. The difference between the set pressure and this reseating pressure is known as the blowdown, and it is usually expressed as a percentage of the set pressure. The blowdown is usually less than 10% for compressible fluids.

The valve is designed in such a manner that it offers both rapid opening and relatively small blowdown, so that as soon as a potentially hazardous situation is reached, any overpressure is relieved, but excessive quantities of fluid are prevented from being discharged. It is necessary to ensure that the system pressure is reduced to prevent immediate reopening.

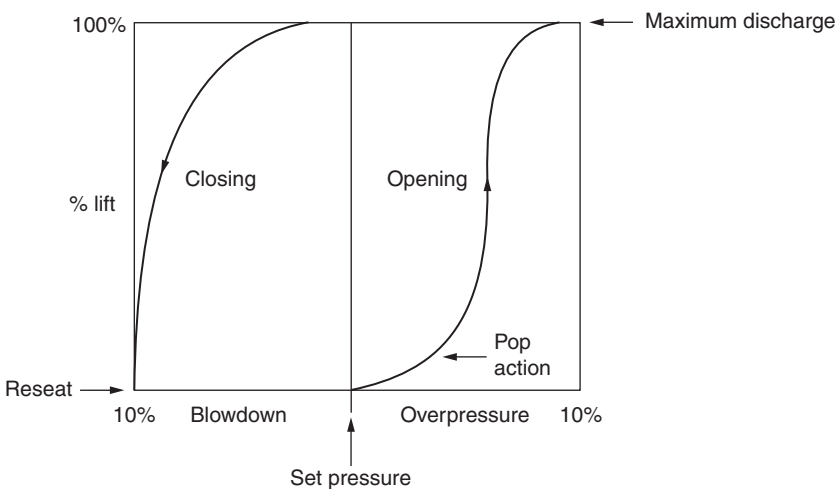


Figure 3.2 Relationship between pressure and lift for a safety valve.

The blowdown rings on the safety valves are used to make fine adjustments to the overpressure and blowdown values. The upper adjusting ring is usually factory set and if it is adjusted, this takes out the manufacturing tolerances which affect geometry of the huddling chamber. The lower adjusting ring is also factory set but can be adjusted under certain conditions. When the lower adjusting ring is adjusted to its top position, the valve pops rapidly, minimizing the overpressure, and requires a greater blowdown before the valve reseats. When the lower adjusting ring is adjusted to its lower position, a greater overpressure is required before the valve is fully open and the blowdown value is reduced.

3.2 Classification of Safety Valves

Many types of safety valves are used in modern applications. These safety valves are classified based on:

- Actuation
- Lift
- Seat design
- Lever
- Bonnet

3.2.1 Classification based on actuation

Based on type of actuation, safety valves are classified as dead-weight safety valves and pop-action safety valves.

Dead-weight safety valves. Although dead-weight safety valves have in general been superseded by spring-loaded safety valves, the dead weight variety (Fig. 3.3) is still sometimes used for low-pressure applications. The closing force of this safety valve is provided by a weight rather than a spring. As the closing force is provided by a weight, it remains constant and once the set pressure is reached, the safety valve opens fully.

Pop action safety valves. The pop-action safety valve is the standard or conventional safety valve. It is actuated by inlet static pressure and characterized by rapid opening or pop action. This type of safety valve is a simple, basic spring-loaded, and self-acting device that provides overpressure protection (Fig. 3.4).

The basic elements of the design consist of a right-angle-pattern valve body with the valve inlet connection, or nozzle, mounted on the pressure-containing system. The outlet connection may be screwed or flanged for

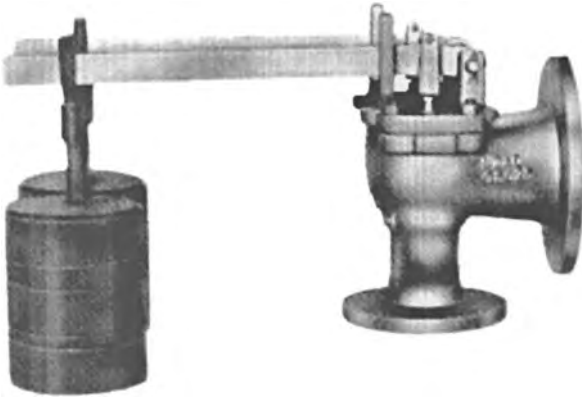


Figure 3.3 Dead-weight safety valve. (*Courtesy Seetru Limited, U.K.*)



Figure 3.4 Pop-action safety valve. (*Courtesy Conbraco Industries, Inc.*)

connection to a pipe discharge system. In some applications, such as compressed air systems, the safety valve does not have an outlet connection and the air is vented directly to the atmosphere.

The valve is held against the nozzle seat by the spring, which is housed in an open or closed spring housing arrangement (bonnet) mounted on the top of the body. The disks in rapid-opening (pop-type) safety valves are surrounded by a huddling chamber, which helps to produce the rapid-opening characteristic.

The closing force on the valve is provided by a spring, typically made from carbon steel. The amount of compression on the spring is usually adjustable, using the spring adjuster, to change the pressure at which the valve is lifted off its seat.

3.2.2 Classification based on lift

Safety valves may be classified based on lift. The term *lift* refers to the amount of travel the valve undergoes as it moves from its closed position to the position required to produce the certified discharge capacity.

Safety valves may be classified as full lift, high lift, and low lift based on the amount of lift, which affects the discharge capacity of the valve.

Full-lift safety valves. A full-lift safety valve is a safety valve in which the valve lifts sufficiently so that the curtain area no longer influences the discharge area. This occurs when the valve lifts a distance of at least a quarter of the bore diameter. That is, the discharge area, and therefore the capacity of the valve, is determined by the bore area.

Full-lift safety valves are considered the best choice for general steam applications.

High-lift safety valves. A high-lift safety valve is a safety valve in which the valve lifts a distance of at least $1/12$ th of the bore diameter. This means that the curtain area, and ultimately the position of the valve, determine the discharge area. The discharge capacity of a high-lift valve is significantly lower than that of a full-lift valve. For a given discharge capacity, a full-lift valve has smaller size than a corresponding high-lift valve.

High-lift safety valves are used on compressible fluids, where their action is more proportional.

Low-lift safety valves. A low-lift safety valve is a safety valve in which the valve lifts a distance of $1/24$ th of the bore diameter. The discharge area is determined by the position of the valve. Since the valve has a small lift, the capacity of a low-lift safety valve is much lower than that of full- or high-lift valves.

3.2.3 Classification based on seat design

Based on seat design, safety valves are classified as soft-seat safety valves and metal-seat safety valves.

Soft-seat safety valves. Resilient disks can be fixed to either or both of the seating surfaces where tighter shut-off is required, typically for gas or liquid applications (Fig. 3.5a). These inserts are made from a number of different materials, but Viton, nitrile, or EPDM are the most common. Soft seal inserts are not recommended for steam use. Seating materials and their applications are shown in Table 3.1.

Metal-seat safety valves. Metal-to-metal seats, commonly made from stainless steel, are normally used for high-temperature applications such as steam. Stellite is used for wear resistance in tough applications. A view of metal seat design is shown in Fig. 3.5b.

3.2.4 Classification based on type of lever

Safety valves are generally fitted with a lever, which enables the valve to be lifted manually in order to ensure that it is operational at pressures in excess of 75% of set pressure. This is usually done as part of a routine safety check, or during maintenance to prevent seizing.

Based on the type of lever, safety valves may be classified as open-lever or packed-lever design.

Open-lever type. An open lever is the standard lever for most safety valves. It is typically used in applications such as steam or air, where a small leakage of fluid to the atmosphere is acceptable. A typical open lever is shown in Fig. 3.6a.

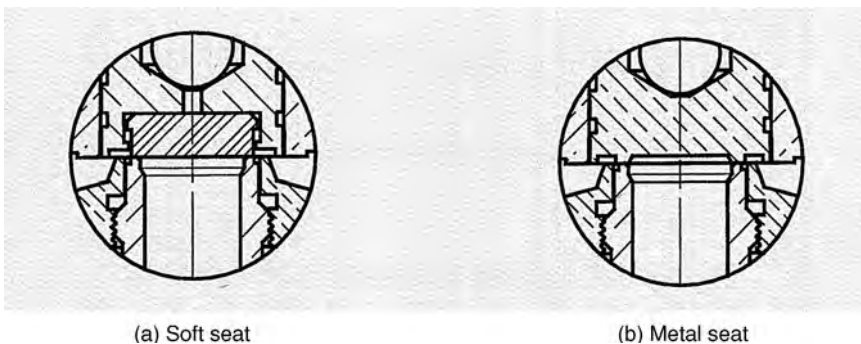


Figure 3.5 Safety valve seats.

TABLE 3.1 Materials for Soft Safety Valve Seats

Material	Applications
EPDM	Water
Viton	High-temperature gas
Nitrile	Air and oil

Packed-lever type. If fluid cannot be permitted to escape, a packed-lever safety valve is used. This type uses a packed gland seal to ensure that the fluid is contained within the cap. A packed lever is shown in Fig. 3.6b.

3.2.5 Classification based on bonnet design

Process fluid enters the bonnet (spring housing) if bellows or diaphragm sealing is not used. The amount of fluid depends on the particular design of the safety valve. Based on the design of the bonnet, safety valves are classified as open-bonnet or closed-bonnet type.

Open-bonnet type. An open bonnet is used if discharge of fluid to the atmosphere is permitted. This has advantage when the safety valve is used in high-temperature fluid or boiler applications, because high temperature can cool the spring. However, an open bonnet exposes the spring and internals to environmental conditions that can lead to corrosion of the spring. An open bonnet is shown in Fig. 3.7a.

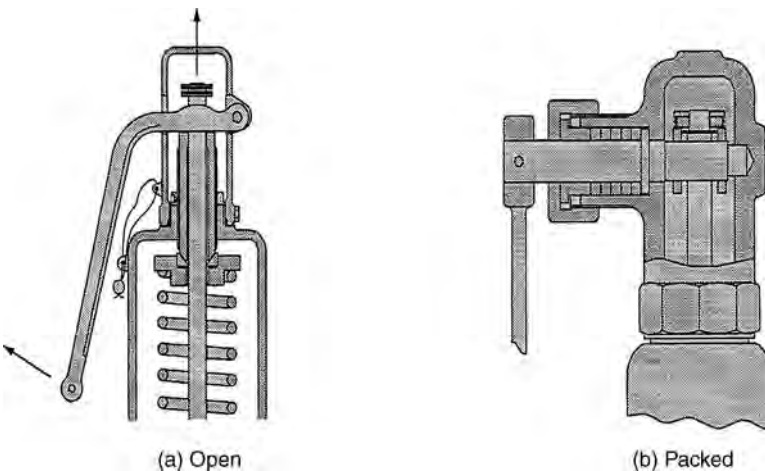


Figure 3.6 Lever types. (Courtesy Spirax Sarco, U.K.)

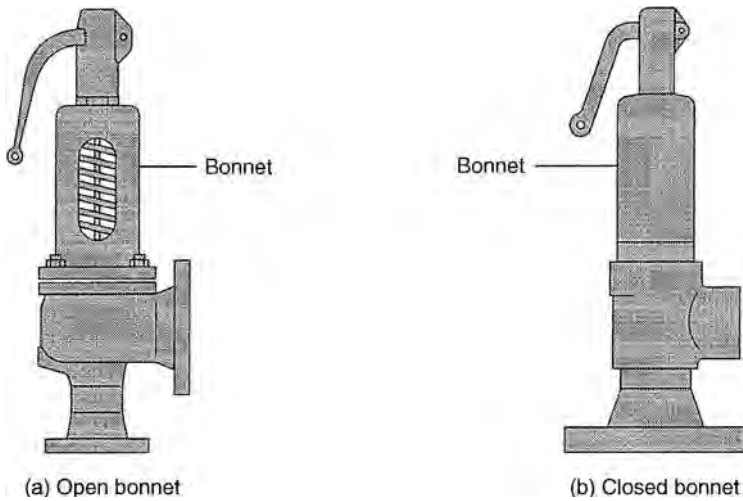


Figure 3.7 Types of bonnets. (Courtesy Spirax Sarco, U.K.)

Closed-bonnet type. It is necessary to use a closed bonnet if fluid is not permitted to discharge to the atmosphere. The closed-bonnet safety valve is used for small screwed safety valves. It is becoming increasingly common to use closed-bonnet safety valves, particularly for steam, discharge of which can be hazardous to personnel. A closed bonnet is shown in Fig. 3.7b.

3.3 Major Components

- *Approach channel.* The passage through which the fluid must pass to reach the operating parts of a safety valve.
- *Discharge channel.* The passage through which the fluid must pass between the operating parts of a safety valve and its outlet.
- *Disk.* A moveable component of a safety valve that contains the primary pressure when it rests against the nozzle.
- *Huddling chamber.* The annular pressure chamber located beyond the valve seat for the purpose of generating a popping characteristic.
- *Lifting lever.* A device to open a safety valve manually, by the application of external force to lessen the spring loading which holds the valve closed.
- *Nozzle.* A pressure-containing element which constitutes the inlet flow passage and includes the fixed portion of the seat enclosure.

- *Seat.* The pressure-sealing surfaces of the fixed and moving pressure containing components.
- *Spring.* The element in a safety valve that provides the force to keep the disk on the nozzle.

3.4 Accessories

Test gag. The purpose of the test gag is to hold the safety valve closed while the equipment is being subjected to a hydrostatic test. However, care should be exercised not to tighten the gag screw excessively, so as to avoid damage to the spindle and/or seat. The test gag should never be left in the valve during the operation of the equipment. It should be removed each time after hydrostatic test.

Hydraulic lift assist device. Some safety valve designs can be tested for opening pressure while the boiler is operating at reduced pressures. The valves are tested after the hydraulic lift assist device is installed to augment the steam lifting force. This device eliminates the need for raising the system pressure above the operating level to check opening pressure (set pressure) of the valve for opening.

The lift assist device does not allow the valve to go into full lift nor does it provide data concerning blowdown. Lift assist should be used only with valves designed for such devices, to develop a preliminary setting for new valves or when there is uncertainty that the valve set pressure complies with the nameplate data.

3.5 Safety Valve Locations

In order to ensure that the maximum allowable accumulation pressure of any system or vessel protected by a safety valve is never exceeded, careful consideration of the safety valve's position in the system has to be made. As there is a wide range of applications, every application needs to be designed separately.

It is practical to fit safety valves close to the steam inlet of any vessel. The following may be used as general guidelines for positioning safety valves:

1. A separate safety valve may be fitted on the inlet of each downstream vessel, when the pressure-reducing valve supplies several such vessels.
2. If supplying one vessel, which has MAWP pressure less than the pressure-reducing valve supply pressure, the vessel should be fitted with a safety valve, preferably close-coupled to its steam inlet connection.
3. If a pressure-reducing valve is supplying more than one vessel and the MAWP of any item is less than the pressure-reducing valve supply

pressure, either the pressure-reducing station should be fitted with a safety valve at the lowest possible MAWP of the connected vessel, or each item of the affected vessel should be fitted with a safety valve.

4. The safety valve should be located so that pressure cannot accumulate in the vessel via another route, such as from a separate steam line or a bypass line.
5. Any pressure vessel should be protected from overpressure in case of fire. Special consideration should be given in each case for protecting vessels under fire conditions.
6. Exothermic applications should be fitted with a safety valve close-coupled to the vessel steam inlet or the body direct.
7. Safety valves may be fitted as warning devices. These are not required to relieve fault loads, but to warn of pressures increasing above normal working pressures for operational reasons only. In these cases, safety valves should be set at the warning pressure and need only to be of minimum size. If there is any danger of exceeding maximum allowable working pressure, the system should be protected by additional safety valves in the regular way.

In order to illustrate the importance of the positioning of a safety valve, two examples are given below.

3.5.1 Pressure-reducing station

A common application for a safety valve is to protect process equipment supplied from a pressure-reducing station. Two possible arrangements are shown in Fig. 3.8.

The safety valve can be installed within the pressure-reducing station itself, before the downstream stop valve, as shown in Fig. 3.8a. Alternatively, the safety valve may be installed farther downstream, nearer the equipment, as shown in Fig. 3.8b.

Installation of the safety valve before the downstream stop valve has the following advantages:

- The safety valve can be tested in-line by shutting down the downstream stop valve without pressurizing the downstream equipment.
- When testing is performed in-line, the safety valve does not have to be removed from its location.
- When setting the safety valve under no-load conditions, the operation of the safety valve can be observed.
- Any additional take-offs downstream are protected. Only equipment with lower MAWP requires additional protection.

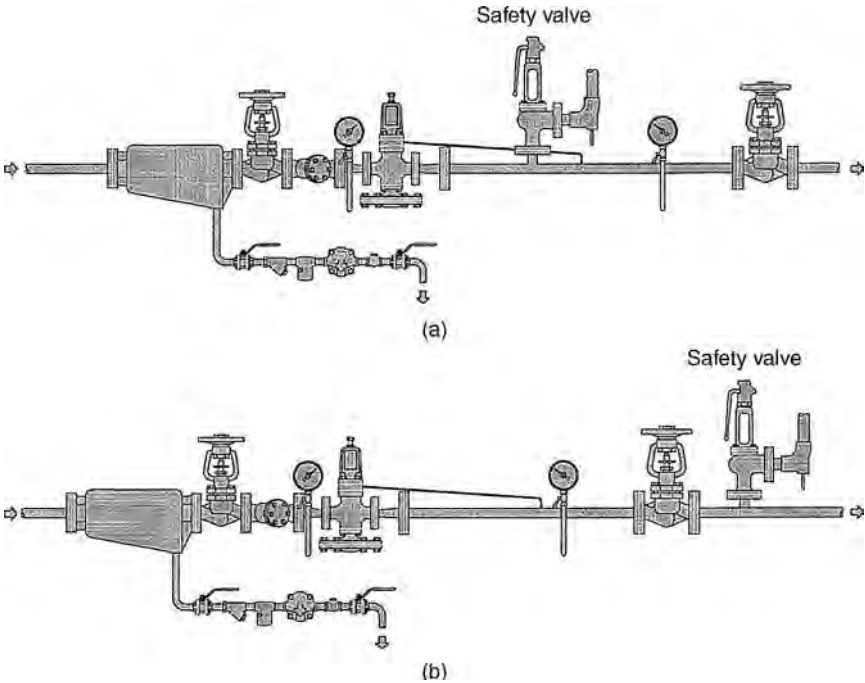


Figure 3.8 Positioning of a safety valve in a pressure-reducing station. (Courtesy Spirax Sarco, U.K.)

3.5.2 Pharmaceutical factory with jacketed pans

A pharmaceutical factory has three jacketed pans on the same production floor. All the pans are rated with the same MAWP. There are two possible positionings of the safety valve(s), as shown in Figs. 3.9 and 3.10.

One solution is to install a safety valve on the inlet to each pan (Fig. 3.9). In this case, each safety valve has to be sized to pass the entire load.

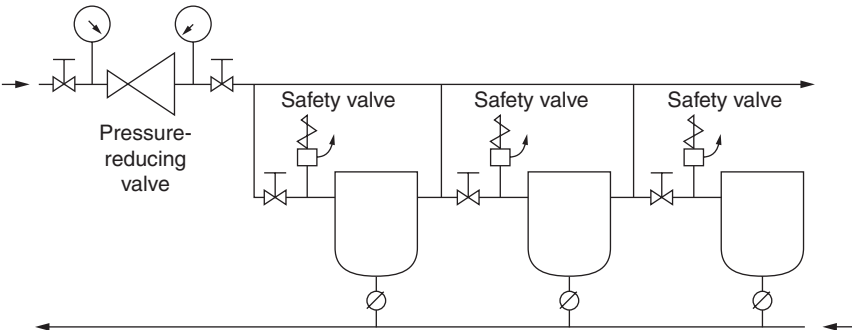


Figure 3.9 Protection of pans using individual safety valves.

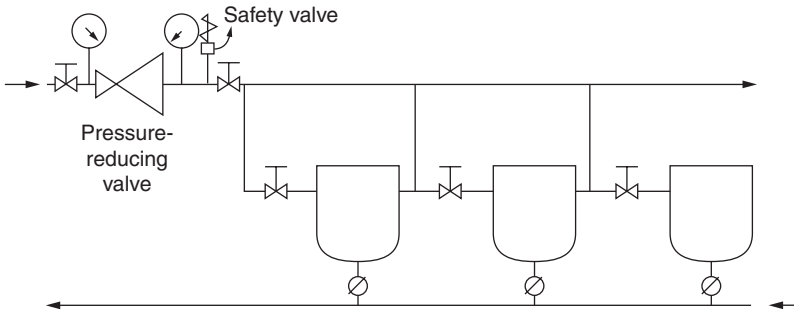


Figure 3.10 Protection of pans using a single safety valve.

As all the pans are rated to the same maximum allowable working pressure, it is possible to install a single safety valve after the pressure-reducing valve (Fig. 3.10).

Suppose a shell-and-tube heat exchanger with a MAWP lower than the pans is added to the system (Fig. 3.11). It is necessary to install an additional safety valve. This safety valve should be set to an appropriate lower set pressure and sized to pass the fault flow through the temperature-control valve.

3.6 Specifications

Safety valves should be specified correctly in order to meet the process requirements. To properly process your order and avoid delay, the following information is required as a minimum: quantity, inlet and outlet size, inlet and outlet flange class and facing, materials of construction, set pressure, maximum inlet temperature, allowable overpressure, fluid and fluid state, backpressure, required capacity, accessories, and code requirements.

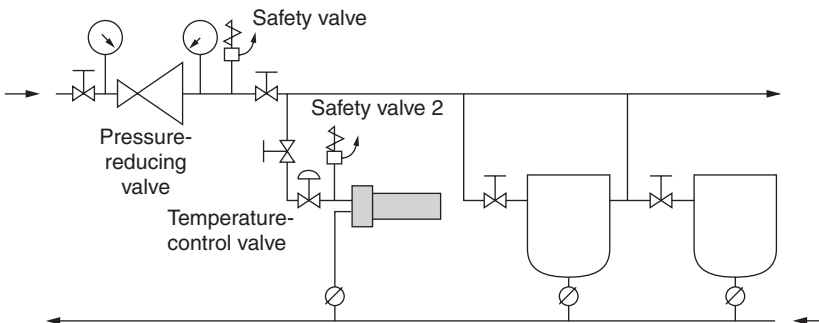


Figure 3.11 Arrangement showing additional vessel in the system.

If an exact replacement valve is required, the valve type, size, and serial number should be specified, to assure proper dimensions and material to be supplied. If a specific valve has become obsolete, a proper recommendation of the current equivalent should be made.

3.6.1 Specification sheet

The following technical information is required when ordering a safety valve:

1. Type of Application

- (a) Boiler Drum
- (b) Superheater
- (c) Reheater
- (d) Other _____ (identify)

2. Applicable ASME Code

- (a) Section I – Power Boiler
- (b) Section VIII – Pressure Vessels
 - Single Valve System _____
 - Multiple Valve System _____

3. System Parameters

(For drum, superheater, or reheater)

- (a) Design Pressure _____ psig
- (b) Design Temperature _____ °F
- (c) Operating Pressure _____ psig
- (d) Operating Temperature _____ °F

4. Valve Specifications

- (a) Valve Set Pressure _____ psig
- (b) Allowable Overpressure on Valve _____ %
- (c) Relieving Capacity _____ lb/hr
- (d) Butt weld Valves
 - Inlet Size _____
 - Inlet Specifications _____
 - Outlet Size & Flange Rating _____
- (e) Flanged Valves
 - Inlet Size & Flange Rating _____
 - Outlet Size & Flange Rating _____
- (f) Other Type Connections Other Than
 - Butt weld or Flange _____
- (g) Special Codes or Standards _____

5. Valve Supplemental Data

- (a) Gag Required _____
- (b) Weathershield Required _____
- (c) Hydrostatic Test Plug Required _____

- (d) Special Cleaning _____
- (e) Special Boxing _____
- (f) Export Boxing _____
- (g) Special Panting _____

3.6.2 Specifying a safety valve

Following are some typical specifications for a safety valve:

Number of valves	1
Valve inlet size (MNPT)	1½ in
Set pressure	100 psig
Operating pressure	80 psig
Operating temperature	325°F
Relieving temperature	339°F
Design temperature	400°F
Built-up back pressure	5 psig
Allowable overpressure	3%
Orifice size	J
Required capacity	6500 lb/hr
Service	Steam
ASME boiler and PV code	Section I
Trim	Stainless
Accessories	Gag
Customer drawings	For approval

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Rupture Disks

A rupture disk is a nonreclosing precision relief device designed to rupture at a predetermined pressure and temperature. Rupture disks are used where instantaneous and full opening of a pressure relief device is required. These devices are used to protect vessels, piping, and other pressurized systems from excessive pressure and/or vacuum.

Rupture disks may be used where “zero” leakage is required of a pressure relief device. These devices provide overprotection to a system which may be subject to excessive pressure by malfunction of mechanical equipment, runaway chemical reaction, and external or internal fires.

A rupture disk has no moving parts, and is a simple, reliable, and faster-acting device than other pressure relief devices. Rupture disks react quickly to relieve some types of pressure spikes.

Rupture disks have the following advantages when compared with pressure relief valves:

- Reduced emissions—no simmering or leakage before bursting
- Provide both overpressure protection and depressuring
- Protect against rapid pressure rise caused by heat-exchanger tube ruptures
- Less expensive way to provide corrosion resistance
- Provide secondary protection for lower-probability contingencies requiring large relief areas
- Fewer tendencies to foul or plug
- Absolute tightness when disk is intact
- Available in exotic materials
- Minimum space required

Rupture disks may not be suitable for some applications. The following are disadvantages of rupture disks when compared with pressure relief valves:

- Don't reclose after relief
- Require periodic replacement
- Burst pressure cannot be tested
- Greater sensitivity to mechanical damage
- Greater sensitivity to temperature
- Relatively wide burst pressure tolerances
- Can burst prematurely in the presence of pressure pulsations

4.1 Brief History

Prior to the 1930s, rupture disks consisted of flat metal membranes. Their use was very limited, as the devices did not have predictable bursting pressure. Rupture disks were not used widely because of their limited service life.

In the 1930s, rupture disks consisted of a flat sheet of metal, generally copper, clamped between a pair of piping flanges. However, operating pressure caused bulging and stretching of the metal, resulting in premature failure between 30% and 50% of the disk rating. Later on, prebulged disks made of Monel, Inconel, and stainless steel were developed that could be operated at 70% of their rated pressure.

The use of prebulged disks with relief valves created the problem of fragmentation resulting in occasional blockage of the valve. The introduction of composite-type rupture disks in the 1950s helped reduce this problem. Composite-type disks can be operated at up to 80% of their rated pressure.

Scored rupture disks were introduced in the 1960s. These designs are nonfragmenting and permit operation up to 90% of their rated pressure.

The first reverse-acting rupture disk with knife blades was introduced in the mid-1960. Its advantages were a predictable opening pattern and generally nonfragmenting characteristics. In the mid- to late 1970s, a modified, reverse knife blade was introduced. This blade configuration has a "swooped" edge which provides enhanced performance characteristics.

There have been considerable improvement in design over the years. Nowadays, rupture disks of many varieties are available.

4.2 Working Principle

A standard rupture disk is a solid metal, differential pressure relief device with an instantaneous, full-opening, and nonreclosing design (Fig. 4.1). A rupture disk assembly comprises mainly two parts:

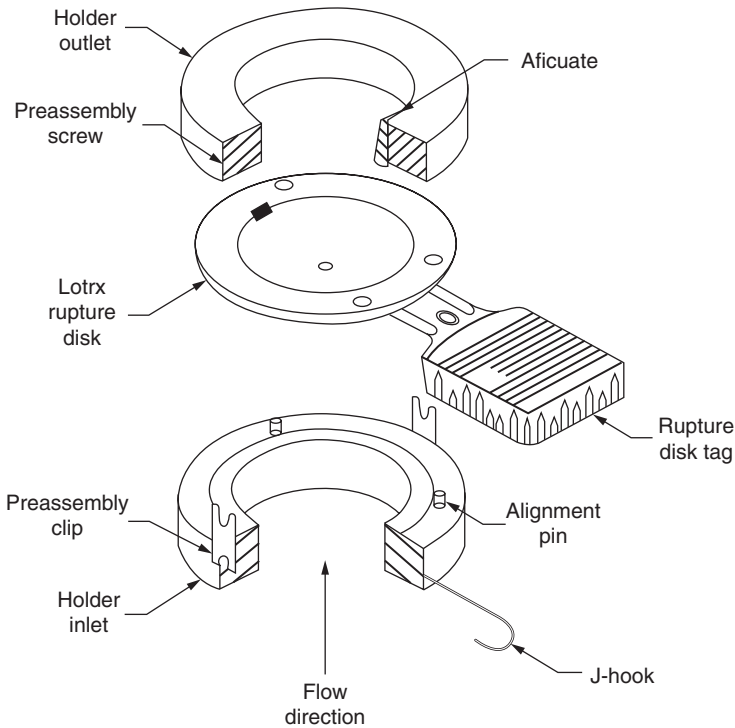


Figure 4.1 A standard rupture disk.

1. A rupture disk, which is a thin metal diaphragm bulged to a spherical shape, providing both a consistent burst pressure within a predictable tolerance and an extended service life; and
2. A rupture disk holder, which is a flanged structure designed to hold the rupture disk in position.

The rupture disk is oriented in a system with the process fluid against the concave side of the disk (Fig. 4.2). The disk may have a flat seat (Fig. 4.2a) or a 30° angle seat (Fig. 4.2b). As the pressure of process fluid increases beyond the allowable operating pressure, the rupture disk starts to grow. This growth will continue as the pressure increases, until the tensile strength of the material is reached and rupture occurs.

4.3 Application of Rupture Disks

Rupture disks may be used for the following purposes: (1) primary relief, (2) secondary relief, and (3) in series with a relief valve.

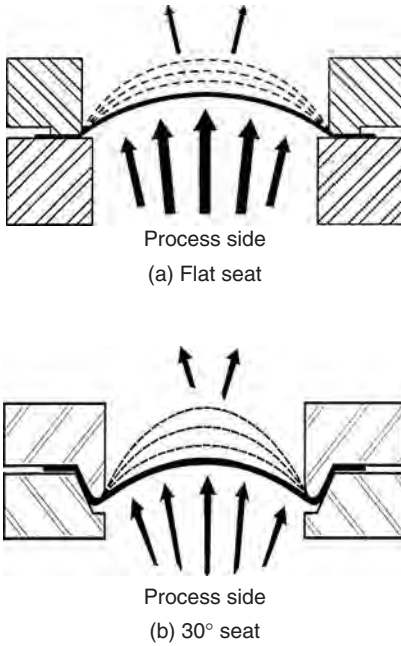


Figure 4.2 Rupture disks and holders.

4.3.1 Primary relief

The rupture disk may be used for primary relief (Fig. 4.3). In such a case, the rupture disk is the only device utilized for pressure relief. The advantages of using rupture disks as primary devices are that they are leak-tight and have instantaneous response time, minimum pressure drop, low cost, high reliability, and minimum maintenance.

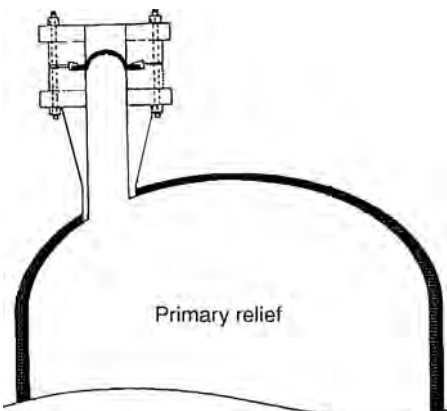


Figure 4.3 Primary relief application. (Courtesy Fike Corporation.)

4.3.2 Secondary relief

A rupture disk may be used as a secondary device (Fig. 4.4) providing backup vent to a primary relief device. The purpose of this secondary device is to provide additional protection for an event that would exceed the capacity of the primary relief device.

4.3.3 Combination relief

The rupture disk is installed upstream of the pressure relief valve when it is used in series (Fig. 4.5). The disk protects the valve from process fluid that can corrode or prevent relief valve operation. The space between the rupture disk and the pressure relief valve should have a pressure gauge, try cock, free vent, or telltale indicator. This arrangement is provided to eliminate the possibility of, or facilitate the detection of, a back-pressure build up.

The ASME Pressure Vessel Code permits the use of a rupture disk device at both a pressure relief valve inlet and outlet. The combination of rupture disks and pressure relief valves is becoming more common in oil, chemical, and petrochemical plants.

The following are advantages of rupture disks when used in combination with pressure relief valves:

- Zero process leakage to the atmosphere.
- Allows pressure relief valves to be tested in place.

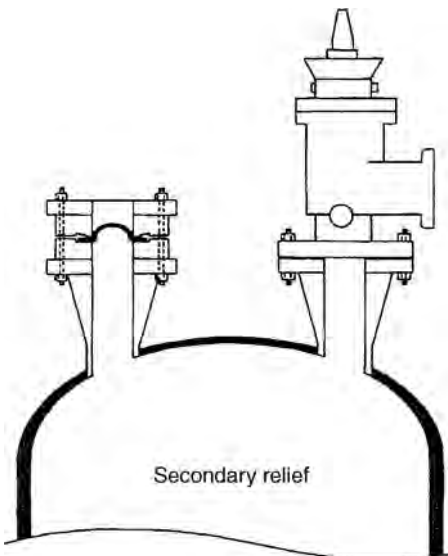


Figure 4.4 Secondary relief application. (Courtesy Fike Corporation.)

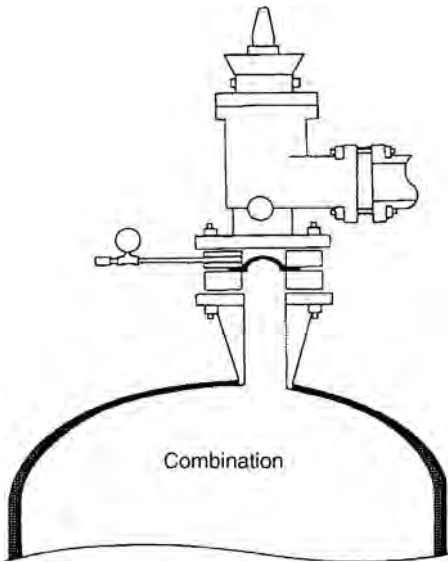


Figure 4.5 Combination relief application. (Courtesy Fike Corporation.)

- Life of valve is extended.
- Longer periods between major overhauls.
- Less expensive valve materials can be used.

4.4 Types of Rupture Disks

There are two basic designs of rupture disks: forward acting rupture disk which fails in tension, and reverse acting rupture disk which fails in compression. All rupture disks are classified based on either of the designs.

4.4.1 Conventional rupture disks

A conventional domed rupture disk (Fig. 4.6) is a prebulged solid metal disk designed to burst when it is overpressured on the concave side. The domed rupture disk fragments upon burst.

The conventional-type rupture disk with a flat or angular seat provides satisfactory service if the operating pressure is 70% or less of the rated burst pressure and when limited pressure cycling and temperature changes are present. If the disk is subjected to vacuum or back pressure, the disk should be designed for vacuum support to prevent reverse flexing or implosion.

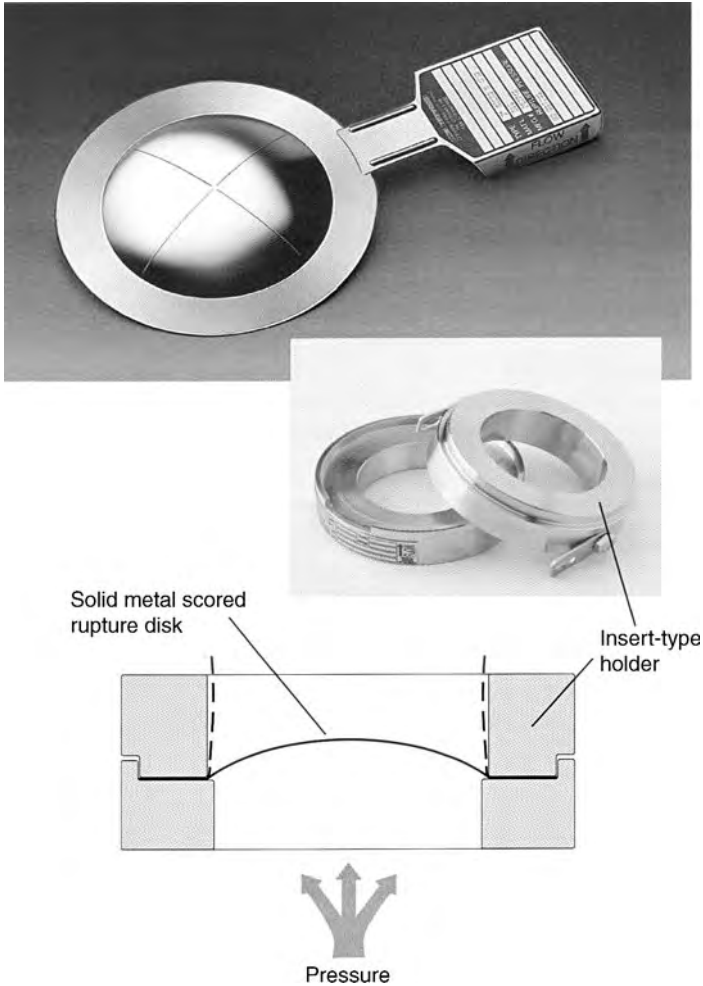


Figure 4.6 Forward-acting rupture disk. (Courtesy Zook USA.)

The main features of conventional tension-loaded rupture disks are:

- Broad range of applications for gas and liquids
- A tendency to fragment
- May need vacuum support
- Subject to early failures if operating pressure exceeds 70% of burst pressure
- Available in various sizes, burst pressures, temperatures, and materials

4.4.2 Scored tension-loaded rupture disks

A scored tension-loaded rupture disk is designed to open along scored lines (Fig. 4.7) This type of disk allows a close ratio (about 85%) of operating pressure to disk burst pressure. Because the score lines control the opening pattern, this type of disk is generally nonfragmenting.

The main features of the scored tension loaded rupture disks are:

- Nonfragmenting.
- Vacuum support is not required.
- Broad range of applications.
- Can operate to 85% of burst pressure.
- Available in various sizes, burst pressures, and materials.

4.4.3 Composite rupture disks

A composite rupture disk (Fig. 4.8) is a flat or domed metallic or non-metallic multipiece construction disk. The domed construction disk is designed to burst when it is overpressured on the concave side. The flat composite disk is designed to burst when it is over pressured on the side designed by the manufacturer.

The advantages and disadvantages of composite rupture disks are similar to those of conventional tension-loaded rupture disks. Moreover, the composite disks allow use of corrosion-resistant materials in lower-pressure service and smaller sizes than solid metal discs.

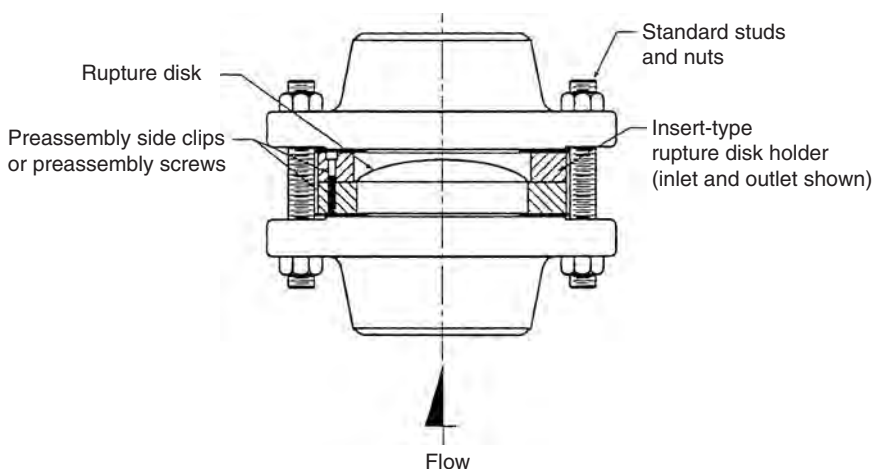


Figure 4.7 Scored tension-loaded rupture disk. (From API RP 520.)

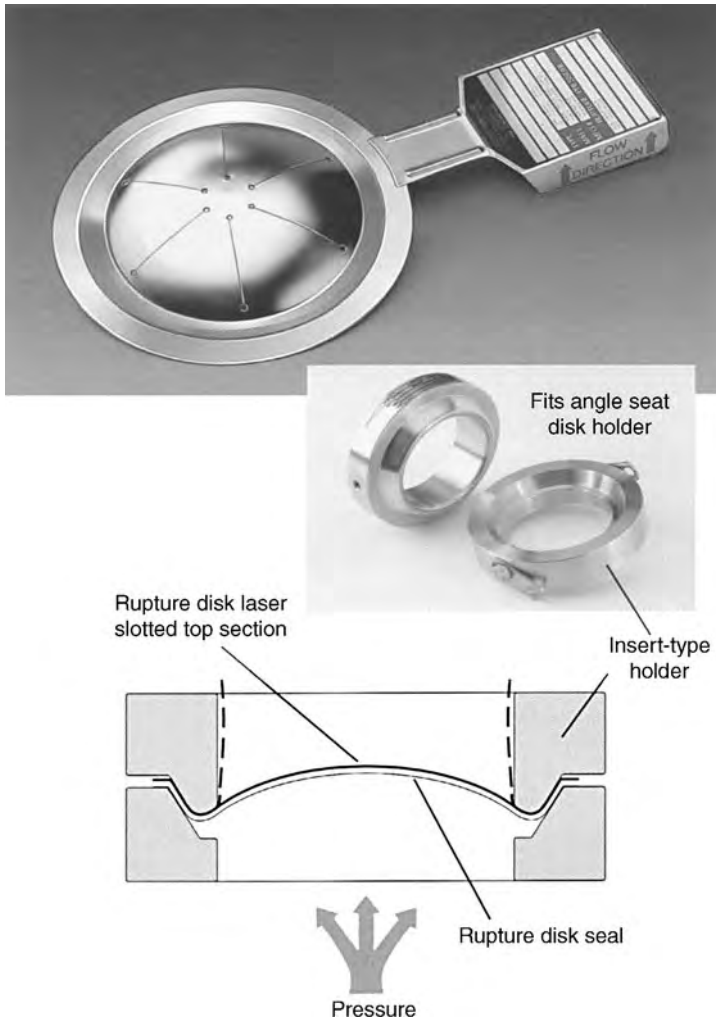


Figure 4.8 Composite rupture disk. (Courtesy Zook USA.)

4.4.4 Reverse-acting rupture disks

A reverse-acting rupture disk (Fig. 4.9) is a domed solid metal disk designed to burst when it is overpressured on the convex side. As the burst pressure rating is reached, the compression loading on the rupture disk causes it to reverse, snapping through the neutral position and causing it to open by a predetermined scoring pattern or knife-blade penetration. Reverse-acting rupture disks are designed to open by various methods, such as shears, knife blades, knife rings, or scored lines.

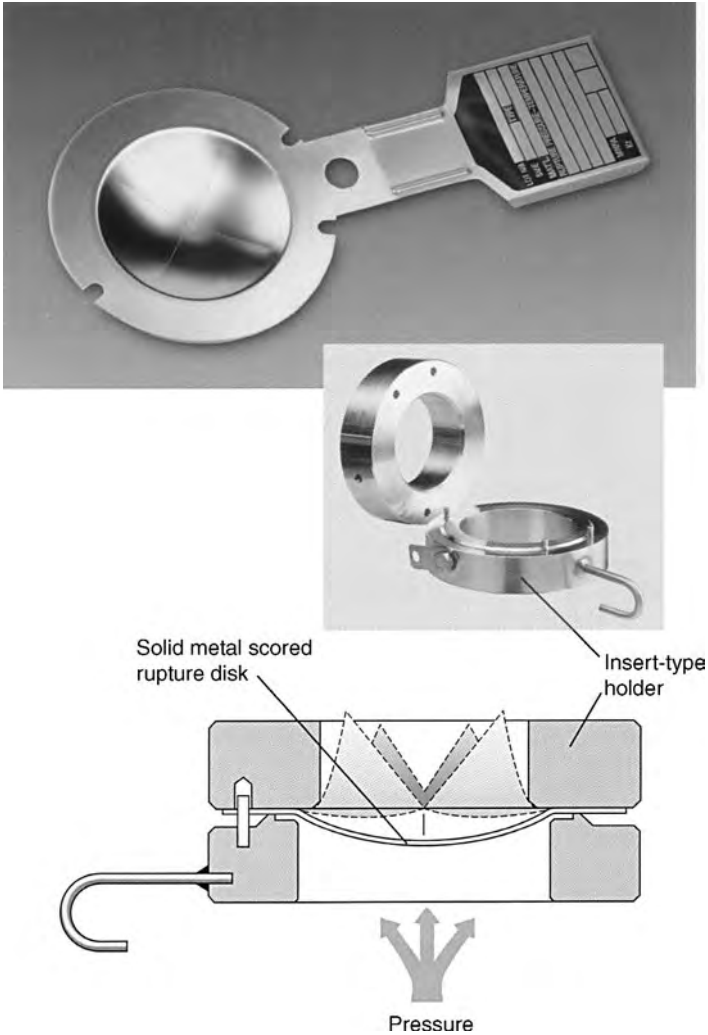


Figure 4.9 Reverse-acting rupture disk. (Courtesy Zook USA.)

Reverse-acting rupture disks have the following advantages over tension-type rupture disks:

- Zero manufacturing range, allowing disk to operate to 90% of its stamped burst pressure
- Full vacuum capability without the need for an additional support member
- Longer service life under cyclic or pulsating conditions

- Constructed using thicker materials providing greater resistance to corrosion
- Available in wide ranges of sizes, materials, pressures, and temperatures

4.4.5 Graphite rupture disks

A graphite rupture disk (Fig. 4.10) is manufactured from graphite impregnated with a binder material and is designed to burst by bending or shearing. Graphite rupture disks are resistant to most acids, alkalis, and organic solvents.

Graphite rupture disks have the following advantages:

- Offer ultralow rated pressure settings
- Eliminate back-pressure effects on overpressure devices in common vent lines
- Solve sourcing and cost problems for disks used with highly corrosive fluids
- Easy to install and maintain, because disks are tamper-proof, have no springs or moving parts, and mount directly between standard flanges without special holders
- Prevent relief valves from fouling and leaking

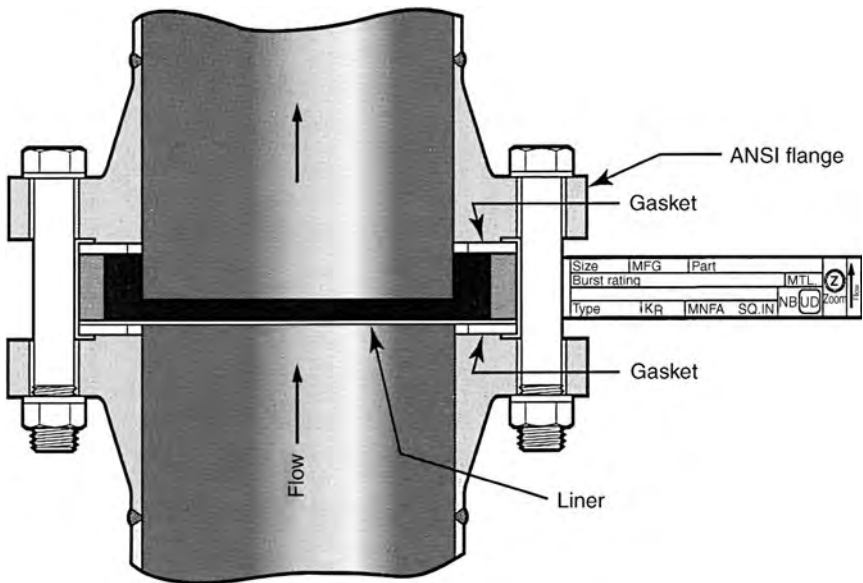


Figure 4.10 Graphite disk—duplex type. (Courtesy Zook USA.)

Graphite rupture disks are further classified as mono-type, duplex-type, inverted-type, and two-way-type disks.

4.5 Major Components

- *Rupture disk.* A pressure-containing, pressure- and temperature-sensitive element of a rupture disk device. (Fig. 4.11)
- *Disk holder.* The structure which encloses and clamps the rupture disk in position. Some disks are designed to be installed between standard flanges without holders (Fig. 4.12).
- *Gasket.* Used with graphite disks for sealing (Fig. 4.13).

4.6 Accessories

Burst sensors. When connected to an electrical alarm, a burst sensor is used to alert the operator when a rupture disk bursts. When excessive pressure causes a pressure relief valve to open, it also destroys the rupture disk under the valve. This leaves the pressure relief valve vulnerable to chemical attack. Once bursting of the disk is known, an operator can take immediate action to protect the pressure relief valve from further damage.

When a rupture disk bursts, flow pulls one end of the burst sensor's conductor out of its retaining slot and opens the electrical circuit. The sensor can be reset by reinserting the conductor into the retaining slot.



Figure 4.11 Rupture disk. (Courtesy Oseco Inc.)



Figure 4.12 Rupture disk holders. (Courtesy Oseco Inc.)

A burst sensor is shown in Fig. 4.14. The burst sensor is reusable and available in sizes 1 in (25 mm) through 24 in (600 mm). The operating limit for the sensor is maximum 700°F.

Alarm monitors. An alarm monitor is a surface-mounted two-channel monitor designed to remotely detect the condition of two rupture disks in service. When used in conjunction with a burst sensor, it immediately alerts the operator of a ruptured disk. A rupture disk monitor is shown in Fig. 4.15.



Figure 4.13 Gaskets for graphite disks. (Courtesy Zook USA.)

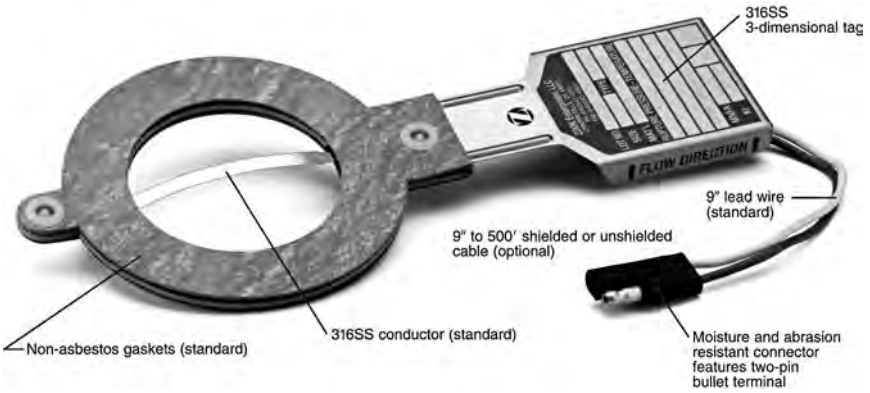


Figure 4.14 Burst sensor. (Courtesy Zook USA.)

The alarm system uses a normally closed electrical circuit. When the disk ruptures, it breaks the circuit, triggering the alarm. Specifications of a typical monitor are given below:

- Intrinsically safe sensing signal level: 6 V dc @ 7.5 mA max
- Operating voltage: 115/230 V ac @ 50/60 Hz; 12 V dc
- Monitor sensing level: Open 200 Ω or greater
- Output relay contacts: one normally open and one normally closed for each channel rated 3 A, 120 V ac (resistive)
- Operating temperature: +15 to +140°F

Heat shields. Heat shields are installed upstream of the rupture disk in high-process-temperature applications to reduce the temperature at the rupture disk.



Figure 4.15 Rupture disk monitor. (Courtesy Zook USA.)

Baffle plates. Baffle plates are used to deflect process discharge away from personnel and equipment. These are effective when rupture disks are venting to atmosphere.

4.7 Specifications

No single type of rupture disk can meet all the numerous applications of industry. Rupture disks should be specified properly in order to meet the application requirements. To properly process your order and avoid delay, the following information is required as a minimum: type, size, operating conditions, service, material, tagging, seat type, holders, and alarm system.

4.7.1 How to specify a rupture disk

Following is an example of a specification for a rupture disk.

Type	Forward-acting solid metal rupture disk
Size	4 in (100 mm) diameter
Operating conditions:	
Pressure	70% of rated burst pressure
Temperature	1000°F (538°C)
Burst pressure	1500 psig @ 72°F (103 bar @ 22°C)
Service	Liquid
Material	Hastelloy C
Tagging	Three-dimensional stainless steel flow tag attached to rupture disk
Holder	Insert type
Alarm system	Compatible alarm system

4.7.2 Specification sheet

A specification sheet for a rupture disk is shown in App. D.

4.8 Rupture Pin Relief Valves

A rupture pin relief valve is a nonreclosing device, similar to a rupture disk. In a rupture pin device a piston is held in the closed position with a buckling pin which fails at a set pressure according to Euler's law. An O-ring on the piston is used to make a bubble-tight seal.

Rupture pin relief valves find applications where rupture disks are required to be replaced for frequent failures. Replacing rupture disks with rupture pin relief valves allow running slightly closer to design pressure, possibly resulting in a capacity increase. Higher accuracy of rupture pins at less than 40 psig (2.7 bar) gives significant advantage over rupture disks. When it is installed under a pressure relief valve, the rupture pin relief valve can be reset without removing the pressure relief valve.

4.8.1 Comparison of rupture pins and rupture disks

Rupture pin relief valves have distinct advantages over rupture disks. The following are advantages:

- Not subject to premature failure due to fatigue.
- Suitable for any type of liquid service.
- Available as balanced or unbalanced device.
- Suitable for operating closer to its set point.
- Set point is insensitive to operating temperature.
- Suitable for operating as low as 0.1 psig (0.007 bar).
- Resetting after release usually requires no breaking of flanges.
- Replacement pins are one-third to one-quarter the cost of replacement disks.

The following are considered disadvantages of using rupture pin relief valves instead of rupture disks:

- The elastomer O-ring seal limits the maximum operating temperature to about 450°F (230°C).
- Initial cost of installation is greater than for a rupture disk:
 - Twice as costly for 2-in carbon steel
 - Up to seven times as costly for 8-in stainless steel

4.9 Buckling Pin Relief Valves

A buckling pin relief valve is an inline relief device which provides quick and simple reset without removing the valve from the piping system. This nonreclosing pressure relief device offers practical technology for the protection of many applications in refinery, petrochemical, and other processing industries. A buckling pin relief valve is shown in Fig. 4.16.

The buckling pin relief valve has three primary components: a rotating disk, a flanged body, and an external enclosure and mechanism.

- *Rotating disk.* A rotating disk normally closes the flow path and turns 90° in response to an overpressure/underpressure condition. The rotating disk is constructed from metal and has a hollow design.
- *Flanged body.* A flanged body contains the rotating disk, holding it in place using shaft connections which are sealed within the body and pass through bearings to permit free rotation of the disk within the body.

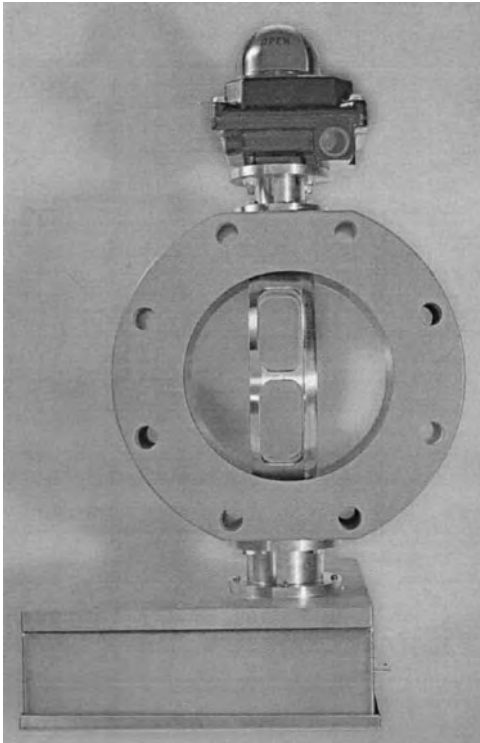


Figure 4.16 Buckling pin relief valve. (Courtesy BS & B Safety Systems, L.L.C.)

- *External enclosure and mechanism.* The external enclosure and mechanism provides set-pressure control for the valve. The mechanism is designed to resist the turning moment of the disk shaft during normal service pressure conditions.

The buckling pin technology provides an accurate and reliable means of calibrating a pressure relief device. When an axial load is applied to a straight cylindrical pin, it buckles at a specific load according to Euler's law.

The main features of the buckling pin relief valve are:

- Simple inline installation.
- Maximum relieving capacity.
- Easy external resetting.
- Set pressure remains unaffected by cycling/pulsating pressure.
- Set pressure remains unaffected by valve orientation.
- Buckling pin is totally protected within a rugged enclosure.
- Individual pins are supplied as a buckling pin cartridge.

TABLE 4.1 Buckling Pin Relief Valves

Size		Set pressure			
		Minimum		Maximum	
		psig	barg	psig	barg
1	25	40	2.76	276	18.96
1½	40	10	0.69	275	18.96
2	50	5	0.34	720	49.64
3–6	80–150	5	0.34	720	18.96
8–16	200–400	3	0.21	275	18.96
18–24	450–600	1	0.70	150	10.34

4.9.1 Valve characteristics

The design of the buckling pin relief valve is based on the offset-shaft butterfly valve concept. The offset of the shaft results in a turning moment being generated about the valve shaft when a pressure differential is applied across the device. A buckling pin mounted externally to the process normally resists this turning moment. By calibrating the pin to collapse at a load coincident with that resulting from the shaft torque at a predetermined differential pressure, the valve provides accurate pressure relief.

Size and set pressure. Buckling pin relief valves are available in a variety of sizes and set-pressure capabilities. These valves are suitable for applications that are compatible with ANSI and DIN flange specifications. Table 4.1 shows standard size and set pressure capability of buckling pin relief valve.

Set pressure certification and tolerance. The buckling pin relief valve is certified in accordance with the ASME Boiler and Pressure Code. The valve is certified with a single set-pressure tolerance as shown in the Table 4.2.

Operating pressure ratio. The buckling pin relief valve can be operated at up to 95% of minimum set pressure. This is called operating ratio. This ratio can be further increased by special testing.

TABLE 4.2 Buckling Pin Relief Valve Tolerances

Pressure	Tolerance
Over 40 psi (2.76 bar)	±5% standard
1–40 psi (0.07–2.76 bar)	±1.14 bar/2 psi standard
Over 20 psi (1.38 bar)	±5% upon request

RUPTURE/BUCKLING PIN TECHNOLOGY Customer specifications and application sheet for a quotation			
Date _____		Fax No: _____	
Customer _____		Phone No: _____	
From _____		Project: _____	
Application description: _____			
Angle Body _____		In-line Body _____	
		Quarter turn valve _____ Ball _____ Butterfly _____	
Service Conditions:			
1. Maximum operating pressure: _____ PSIG (or provide other units) 2. Desired set pressure: _____ PSIG (or provide other units) 3. Fluid type/state: _____ 4. Temperature: Maximum: _____ Operating: _____ Degrees F (or provide other units) 5. Backpressure: Constant: _____ Variable: _____ PSIG (or provide other units) 6. Allowable overpressure: _____ % (10% standard) 7. Molecular weight: _____ 8. Specific gravity: _____ 9. Viscosity at flowing temperature: _____ CP 10. Compressibility: _____ 11. Ratio of specific heats: _____ 12. Relieving capacity required: _____ (Provide unit of measure)			
Connections:			
13. Size NPT _____		Inlet: _____ Outlet: _____	
14. Class flange _____		Inlet: _____ Outlet: _____	
15. Other: _____			
Materials: Of Construction:		Standard Options of Materials: Body: C/S, low temperature C/S or SS. Seat: Stainless steel. Piston: SS with 17-4 SS stem. Bushing: Aluminum bronze or SS. Seals: Viton, Buna or EDPM or other. (list) Pins: Four come with valve.	
16. Body: _____			
17. Seat: _____			
18. Piston: _____			
19. Gland bushing: _____			
20. Seals: _____			
21. Pin material 304 SS: _____		Inconel: _____ Inco: _____	
Options:			
22. Proximity switch: _____		27. Fire safe _____	
23. Pin storage at valve: _____		28. Remote operating _____	
24. 100% NDE: _____		29. Downstream pressure balancing _____	
25. Special Paint: _____		30. POCO Pin System for multiple set points _____	
26. Spare pins (qty): _____			

Figure 4.17 Customer specification sheet. (Courtesy Rupture/Buckling Pin Technology.)

4.9.2 Specifications

A manufacturer requires detailed technical information to supply buckling pin relief valves. A customer specification sheet for Rupture/Buckling Pin Technology is shown in Fig. 4.17.

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Materials

Materials for construction of pressure relief valves and their major parts are listed in American Society of Mechanical Code Section II—Materials. This Code has four parts:

Part A—Ferrous Material Specifications

Part B—Nonferrous Material Specifications

Part C—Specifications for Welding Rods, Electrodes, and Filler Metals

Part D—Properties

Materials for minor components are either listed in ASME Section II or in ASTM specifications, or are controlled by the manufacturer according to a specification equivalent to an ASTM standard. In the latter case, the manufacturer is responsible for ensuring that the allowable stresses at design temperature meet the requirements of ASME Section II, Part D, Appendix I—Nonmandatory Basis for Establishing Stress values in Tables 1A and 1B.

5.1 Pressure Relief Valves

During operation, the pressure parts that are wetted by the process fluid are the inlet nozzle and the disk. For most applications, all other components are made from standard materials. Special materials are required for the following applications:

- Cryogenic applications
- Corrosive fluids
- Where contamination of discharged fluid is not allowed

- When the valve discharges into a manifold which contains corrosive fluid discharged by another valve

It is important that moving parts such as spindle and guides are constructed from the materials that are not easily degraded or corroded. As seats and disks are constantly in contact with the fluid, they should be able to resist the effects of erosion and corrosion. Austenitic stainless steel is commonly used for seats and disks; sometimes they are “satellite faced” for increased durability. Nozzles, disks, and seats that will be exposed to corrosive fluids are constructed from special alloys such as Monel or Hastelloy.

The spring is a very critical component of any pressure relief valve and should provide reliable service. Standard pressure relief valves typically use carbon steel for applications at moderate temperatures. Tungsten steel is used for higher-temperature but noncorrosive applications. Stainless steel is used for corrosive or clean steam applications. Special materials such as Monel, Hastelloy, and Inconel are used for sour-gas and high-temperature applications.

The major pressure-retaining components of pressure relief valves are generally constructed from the following materials: bronze, cast iron, cast steel, austenitic steel, Monel, Inconel, and Hastelloy.

5.1.1 Materials

Materials of construction are specified in the construction codes for pressure relief valves. Generally the following materials are used for construction: copper alloys, cast iron, cast steels, austenitic stainless steels, and nickel alloys.

Copper alloys. There are several copper alloy systems, which include brasses, bronzes, and cupronickels. These are single-phase alloys of copper used for corrosion resistance.

Brasses are wrought alloys of copper and zinc. The zinc content varies from 5% to 50% Zn. Some wrought brasses may contain additions of tin and other elements. Brasses consist of three groups: alpha and beta brass, tin brass, and leaded brass.

Commercial bronze, C22000, is an alpha brass with 10% Zn. Manganese bronzes are high-strength beta brass containing 55–60% Cu and 38–42% Zn. Tin bronzes are wrought and cast alloys of copper and tin. Silicon bronzes are wrought and cast alloys of copper with 1–5% Si and additions of manganese, iron, and zinc.

Cupronickels (copper-nickels) are wrought and cast alloys of copper containing up to 30% Ni, plus minor additions of chromium, tin, beryllium,

or iron. Cupronickels have moderate strength and better corrosion resistance than copper alloys.

Normally, bronze is used for small screwed pressure relief valves for general duty on steam, air, and hot water applications up to 150 psig (15 bar). A bronze safety valve for steam, air, and gas service is shown in Fig. 5.1. This rugged safety valve features a top-guided design and patented “soft seal” for reduced seat leakage. This safety valve is recommended for use on small- to medium-sized steam boilers, sterilizers and distillers, air compressors and air receivers, pressure vessels, and pressure piping systems.

Cast irons. Cast irons are characterized by high carbon content. The very low carbon content in steels is dissolved in the structure, whereas a surplus of carbon exists in the cast irons. This surplus carbon is found as graphite stringers in a matrix of metal crystals.

Two types of cast iron are commonly used in refineries: ferritic and austenitic. In ferritic irons, graphite is found in a matrix of ferrite and cementite. Gray cast iron is an example of ferritic iron. In the austenitic irons, graphite is found in a matrix of austenite. Some of the alloy cast irons such as Ni-Resist are austenitic.



Figure 5.1 Bronze safety valve. (Courtesy Conbraco Industries, Inc.)

Cast iron is used extensively for ASME-type valves. Its use is typically limited to 247 psig (17 barg). A cast iron relief valve for liquid service is shown in Fig. 5.2. This type of valve is extra heavy and is constructed with a bolted bonnet to permit easy inspection and servicing without having to remove it from the system. This relief valve is recommended for fire pump service.

Cast steels. Casting is the process of pouring molten metal into a mold of a predetermined shape and allowing the metal to solidify. Castings are made in various finished forms and then fabricated to the final shape by machining and joining.

Cast steel is commonly used on high-pressure valves up to 580 psig (40 barg). Process valves are usually made from a cast steel body with an austenitic full nozzle type of construction.

Austenitic stainless steels. Austenitic stainless steel is a widely used family of stainless steels, and has excellent corrosion resistance, weldability, high-temperature strength, and low-temperature toughness. Austenitic stainless steel is used for extremely high-pressure applications, and



Figure 5.2 Cast iron relief valve.
(Courtesy Kunkle Valve.)

pressure-containing components may be forged or machined from solid. This type of material is used in food, pharmaceutical, and clean steam applications.

The austenitic stainless steels contain more than 12% chromium and 6% or more nickel to stabilize the austenite. Typical austenitic stainless steels are 18 chromium–8 nickel steel, such as ANSI Types 301, 302, 303, 304, 316, 321, and 347. Typical 25 chromium–12 nickel is ANSI Type 309, and 25 chromium–20 nickel is ANSI Type 310.

Nickel alloys. The main alloying elements for nickel are copper, iron, molybdenum, chromium, and cobalt. Nickel alloys have unique properties such as very low thermal expansion, wear resistance, corrosion resistance, and heat resistance. The following nickel alloys are used for pressure relief valve construction:

- *Alloy 20.* Alloy 20, composed of 20% chromium and 29% nickel, is usually used for resistance to chemical attack.
- *Inconel 600 and Incoloy 800.* Inconel 600 (15 Cr–76 Ni) and Incoloy 800 (21 Cr–32 Ni) is commonly used for high-temperature strength purposes.
- *Inconel X.* Inconel X is a nickel alloy which is used in a heat-treated condition for increased strength.
- *Inconel X750.* Inconel X750 contains 73% nickel, 15.5% chromium, 7% iron, and 2.5% titanium.
- *Monel.* Alloy 400 is widely known as Monel or Monel 400. Monel contains 66% nickel, 32% copper, and additions of iron and manganese. Monel is used for low-temperature corrosion resistance.
- *Monel K.* Alloy 400 is made precipitation hardenable by addition of a small amount of aluminum or titanium. Monel K (Alloy K-500) is such a material.
- *Nickel 200/201.* This is used for construction of rupture disk in corrosion and heat resistance application.
- *Hastelloy.* Hastelloy is used in industries mostly for its excellent corrosion resistance at moderate temperatures and also because it has good high-temperature strength properties as a result of its high molybdenum content.
- *Hastelloy C.* This nickel-base superalloy contains 51% nickel, 22% chromium, 13.5% molybdenum, 5.5% iron, and 4% tungsten.
- *Hastelloy C-276.* This is used for construction of disk and disk holder of rupture disk in corrosive services.
- *Hastelloy X.* Hastelloy X contains 47% nickel, 22% chromium, 18.5% iron, and 9% molybdenum.

5.1.2 Bill of materials

Bills of materials for various pressure relief valves (PRVs) are shown in the figures and tables listed below:

Type of PRV	Figure no.	Table no.
Conventional pressure relief valve	5.3	5.1
Pilot-operated pressure relief valve	5.4	5.2
Pilot control valve	5.5	5.3
Bellows-type pressure relief valve	5.6	5.4
Safety valve	5.7	5.5

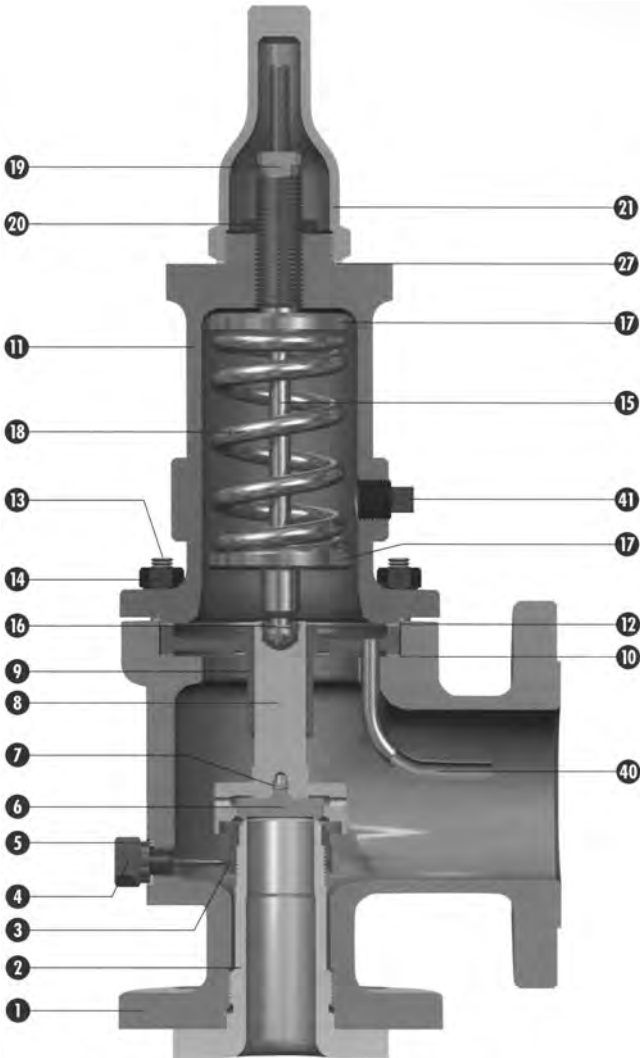


Figure 5.3 Pressure relief valve—spring loaded. (Courtesy Dresser Flow Control.)

TABLE 5.1 Bill of Materials for a Conventional Pressure Relief Valve

Part no.	Description	Material
1	Base	SA216—WCC carbon steel
2	Nozzle	316 SS
3	Adjusting ring	316 SS
4	Adjusting ring pin	316 SS
5	Adjusting ring pin gasket	Soft iron
6	Disk	316 SS
7	Disk retainer ring	Inconel X750
8	Disk holder	316 SS
9	Guide	316 SS
10	Guide gasket	Soft iron
11	Bonnet	SA216—WCC carbon steel
12	Bonnet gasket	Soft iron
13	Base stud	B7 alloy steel
14	Base stud nut	2H carbon steel
15	Spindle	410 SS
16	Spindle retainer	Inconel X750
17	Spring washer	Carbon steel
18	Spring (−75 to +800°F)	Alloy steel
	Spring (+801 to +1000°F)	Inconel X750 or tungsten
19	Adjusting screw	416 SS
20	Adjusting screw locknut	416 SS
21	Screwed cap	Carbon steel
27	Cap gasket	Soft iron
40	Eductor tube	304 SS
41	Vent pipe plug	Carbon steel

TABLE 5.2 Bill of Materials for a Standard Pilot-Operated Relief Valve—Main Valve

Part no.	Description	Material
1	Body	SA216—WCB carbon steel
2	Nozzle	316 SS
3	Piston	316 SS
4	Seat retainer	316 SS
5	Guide/cover	316 SS
6	Retainer screw	316 SS
7	Preload spring	316 SS
8	Body stud	A193—B7 alloy steel
9	Hex nut (body)	A194—2H alloy steel
10	Pressure pickup	316 SS
11	Male elbow (2)	316 SS
12	Seat seal	Viton
13	Nozzle seal	Viton
14	Piston seal	Viton
15	Guide seal	Viton
16	Tubing	316 SS
17	Male connector	316 SS
18	Pilot control	316 SS

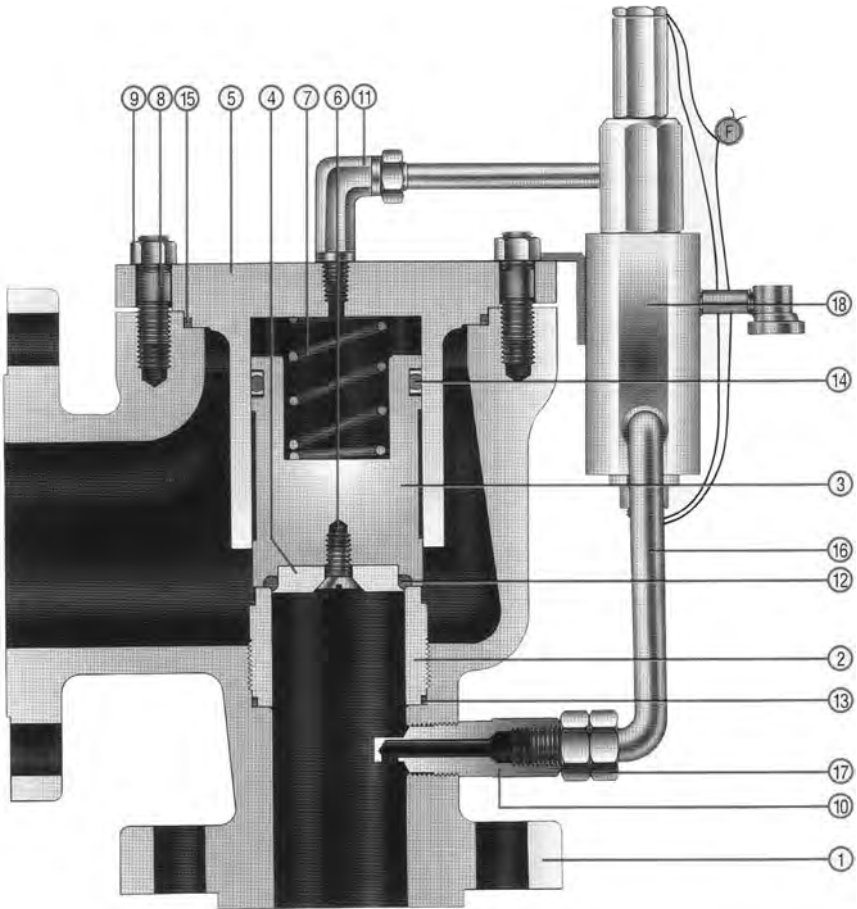


Figure 5.4 Pilot-operated pressure relief valve—main valve. (Courtesy Farris Engineering.)

5.1.3 Material selection

Selection of materials is made based on the type of fluid, and process application. Requirements of materials for sour gas service, hydrofluoric acid service, corrosive service, and process fluid services are given below. In addition, materials for O-ring are also listed.

Material requirements for sour gas services. Material requirements of NACE Standard MR-01-75 are used for handling sour gas if total operating pressure is 65 psia or greater and if the partial pressure of H_2S in the gas is 0.05 psia or greater. Typical materials for conventional valves are shown in Table 5.6.

Material requirements for hydrofluoric acid services. Monel Alloy 400, in the stress-relieved condition for critical components, is used by industry to meet the demands of extremely corrosive hydrofluoric acid (HF) services. Typical materials for conventional valves for HF service are given in Table 5.7.

Material requirements for corrosive services. Material requirements for conventional valves for corrosive services are shown in Table 5.8.

Material requirements for process fluid services. Material requirements for conventional valves for use in process fluid services at low temperature and at high temperature are shown in Table 5.9.

O-ring selection. Materials for O-rings are listed in Table 5.10.

TABLE 5.3 Bill of Materials for a Pilot Control Valve

Part no.	Description	Material
1	Body	316 SS
2	Bonnet	316 SS
3	Cap	316 SS
4	Spring adjusting screw	316 SS
5	Upper spring button	316 SS
6	Spring	316 SS
7	Lower spring button	316 SS
8	Disk	316 SS
9	Jam nut	18-8 Steel
10	Guide	316 SS
11	Upper seat seal	Viton
12	Upper seat	316 SS
13	Static seal, body	Viton
14	Blowdown relay	316 SS
15	Lower seat	316 SS
16	Retainer, lower seat seal	316 SS
17	Lower seat seal	Viton
18	Static seal adjuster	Viton
19	Blowdown adjuster	316 SS
20	Static seal filter	Viton
21	Filter	300 series SS
22	Filter housing	316 SS
23	Poppet	316 SS
24	Adjuster cap seal	Viton
25	Blowdown adjuster cap	316 SS
26	Thread seal	Teflon
27	Blowdown adjuster locknut	18-8 SS
28	Bug vent housing	Commercial=grade steel
29	Wire seal	SS wire/lead seal

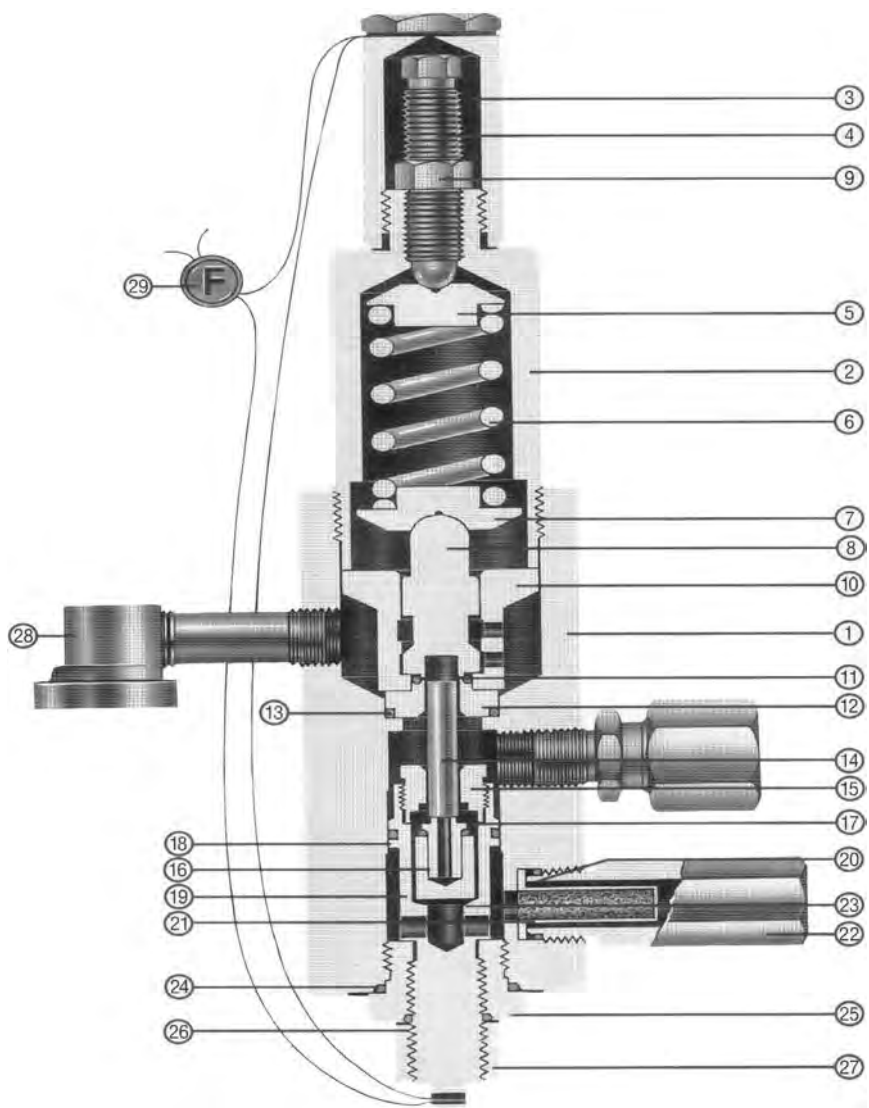


Figure 5.5 Pilot control valve. (Courtesy Farris Engineering.)

TABLE 5.4 Bill of Materials for a Standard Bellows-Type Pressure Relief

Part no.	Description	Material
1	Base	SA216—WCC carbon steel
2	Nozzle	316 SS
3	Adjusting ring	316 SS
4	Adjusting ring pin	316 SS
5	Adjusting ring pin gasket	Soft iron
6	Disk	316 SS
7	Disk retainer ring	Inconel X750
8	Disk holder	316 SS
9	Guide	316 SS
10	Guide gasket	Soft iron
11	Bonnet	SA216—WCC carbon steel
12	Bonnet gasket	Soft iron
13	Base stud	B7 alloy steel
14	Base stud nut	2H carbon steel
15	Spindle	410 SS
16	Spindle retainer	Inconel X750
17	Spring washer	Carbon steel
18	Spring (−75 to +800°F)	Alloy steel
	Spring (+801 to 1000°F)	Inconel X750 or tungsten
19	Adjusting screw	416 SS
20	Adjusting screw locknut	416 SS
21	Screwed cap	Carbon steel
27	Cap gasket	Soft iron
40	Bellows assembly:	
	Bellows	Inconel 625
	Bellows ring & bellows flange	316L SS
41	Bellows gasket	Soft iron

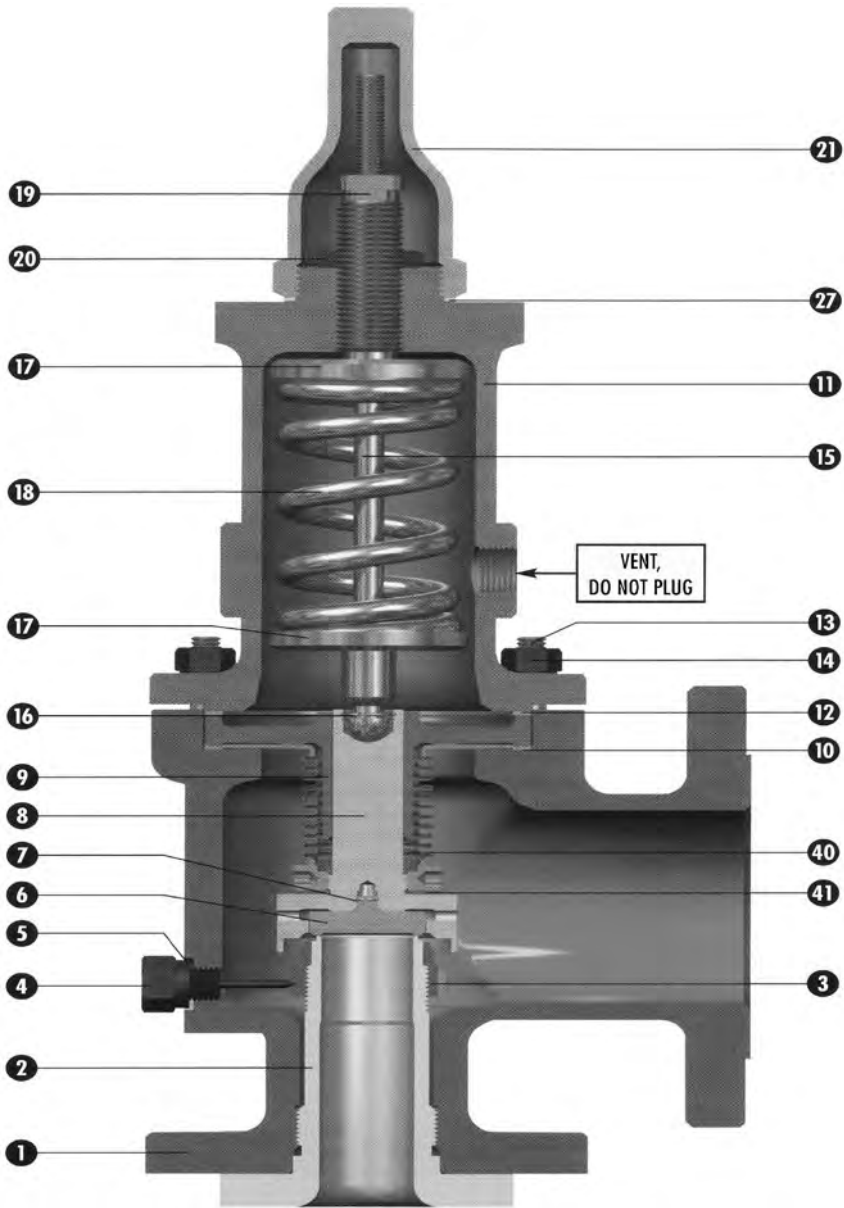


Figure 5.6 Pressure relief valve—bellows type. (Courtesy Dresser Flow Control.)

TABLE 5.5 Bill of Materials for a Standard Spring-Loaded Safety Valve

Part no.	Description	Material
1	Body:	
	Flanged	SA217—WC6 carbon steel
	Buttweld	SA217—WC6 carbon steel
2	Yoke	SA216—WCC carbon steel
3	Disk holder	Monel
4	Guide	Monel
5	Upper adjusting ring	Stainless steel
6	Lower adjusting ring	Stainless steel
7	Spring	Alloy steel
8	Seat bushing	Stainless steel
9	Disk	Inconel
10	Disk collar	Stainless steel
11	Lift stop	Stainless steel
12	Spindle	Stainless steel
13	Compression screw	Silicone brass
14	Upper adjusting ring pin	Stainless steel
15	Lower adjusting ring pin	Stainless steel
16	Thrust bearing	Steel
17	Compression screw:	
	Adopter	Stainless steel
18	Spring washer	Carbon steel
19	Lifting gear	Malleable iron
20	Studs	B7 alloy steel
21	Nuts	2H steel

TABLE 5.6 Typical Materials for Conventional Valves for Sour Gas Services

Component	Material
Base	SA216—217 WC6 alloy steel
Nozzle	316 SS
Disk	316 SS
Adjusting ring	316 SS
Adjusting ring pin	316 SS
Disk holder	316 SS
Guide	316 SS
Spindle	316 SS
Spindle retainer	Inconel X750
Bonnet	SA216—WCC carbon steel
Base stud	B7 alloy steel
Base stud nut	2H carbon steel
Spring	Inconel X750
Spring washer	316 SS
Adjusting screw locknut	316 SS

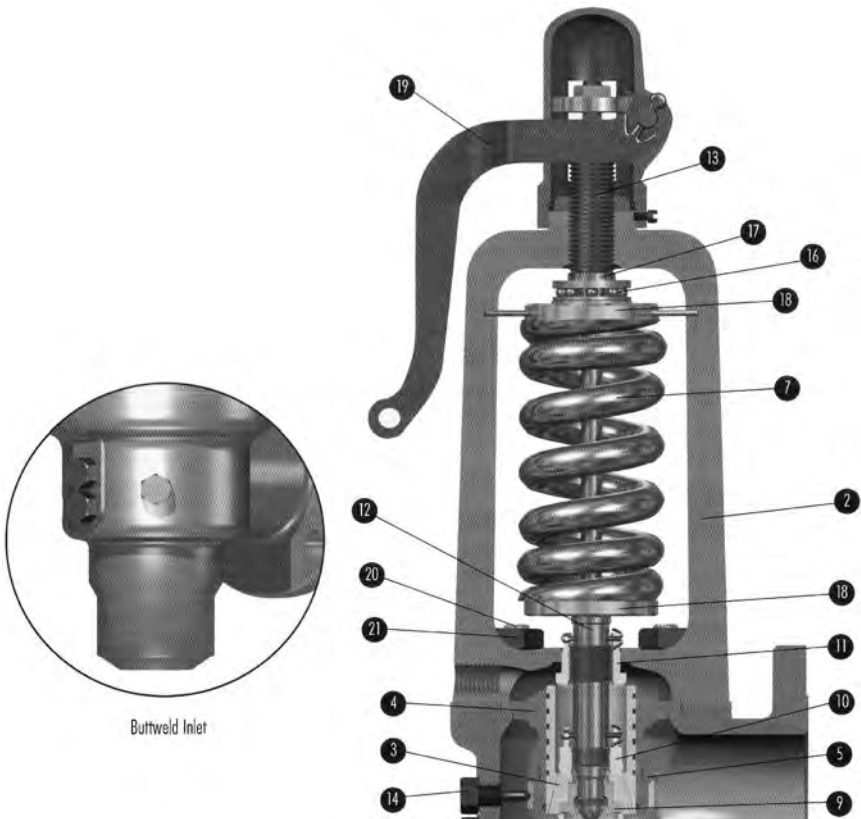


Figure 5.7 Safety valve—spring loaded. (Courtesy Dresser Flow Control.)

TABLE 5.7 Typical Materials for Conventional Valves for Hydrofluoric Acid Services

Component	Material
Base	SA216 WCC (radiographed)
Nozzle	Monel 400 (stress relieved)
Adjusting ring	Monel 400
Adjusting ring pin	Monel 400
Adj. ring pin gasket	Monel 400
Disk	Monel 400 (stress relieved)
Disk retainer	Inconel X750
O-ring	Viton A (litharge cured)
O-ring retainer	Monel 400 (stress relieved)
Retainer lock screw	Monel 400
Disk holder	Monel 400 (stress relieved)
Guide	Monel 400
Guide gasket	Monel 400
Bonnet	SA216—WCC Carbon Steel
Bonnet gasket	Monel 400
Base stud	K Monel
Base stud nut	K Monel
Spindle retainer	Inconel X750
Spring (−20 to +800°F)	Carbon steel (nickel plated)
Spring washer	Carbon steel
Adjusting screw	Monel 400
Adjusting screw locknut	Monel 400
Cap	Carbon steel
Cap gasket	Monel 400
Limit washer	Monel 400

5.2 Rupture Disks

During operation, the pressure parts that are wetted by the process fluid are disk, and disk holder. Materials used for pressure relief valves may be used for rupture disk construction if the application is similar. Special materials such as Monel, Hastelloy, and Inconel are used for corrosive and high-temperature applications.

5.2.1 Bill of materials

A bill of materials for a rupture disk (Fig. 5.8) is shown in Table 5.11.

5.2.2 Material selection

Selection of materials is made based on the type of fluid, and conditions of application.

Material selection recommendations for use with various fluids are listed in Table 5.12.

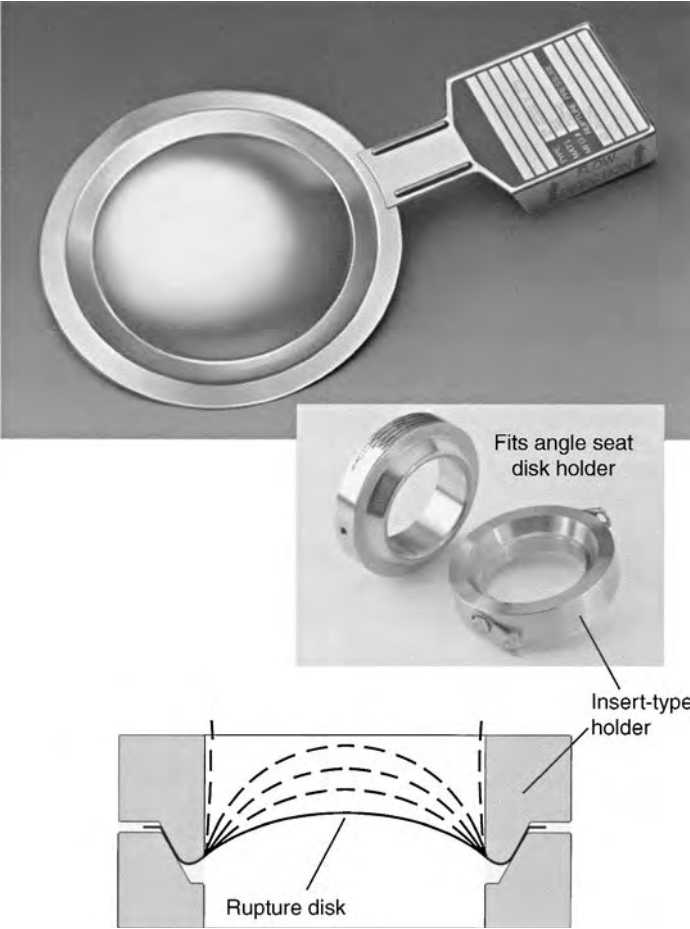


Figure 5.8 Forward-acting metal rupture disk. (Courtesy Zook USA.)

TABLE 5.8 Material Requirements for Conventional Valves for Corrosive Services

Components	Alloy 20 material	Hastelloy material
Nozzle	Alloy 20	Hastelloy C
Disk	Alloy 20	Hastelloy C
Disk retainer	Inconel X750	Inconel X750
Disk holder	Alloy 20	Hastelloy C
Adjusting ring	Alloy 20	Hastelloy C
Adjusting ring pin	Alloy 20	Hastelloy C
Spindle retainer	Inconel X750	Inconel X750
Adjusting ring pin gasket	Monel	Monel
Guide basket	Monel	Monel
Base, bonnet, cap	Carbon steel	Carbon steel
Base studs	B7 alloy steel	B7 alloy steel
Base stud nuts	2H carbon steel	2H carbon steel
Guide	Alloy 20	Hastelloy C
Spindle	Alloy 20	Hastelloy C
Adjusting screw	Alloy 20	Hastelloy C
Adjusting screw locknut	Alloy 20	Hastelloy C
Spring	Alloy steel	Alloy steel
Spring washers	Carbon steel	Carbon steel
Eductor tube	304 SS	304 SS
Bonnet gasket	Monel	Monel
Cap gasket	Monel	Monel

TABLE 5.9 Material Requirements for Conventional Valves for Process Fluid Services

Component	Low temperature, –21 to –75°F (–29 to –59°C)	High temperature, +1001 to +1200°F (+538 to +649°C)
Nozzle	316 SS	316 SS
Disk	316 SS	316 SS
Disk retainer	Inconel X750	Inconel X750
Disk holder	316 SS	316 SS glide-alloy treated
Adjusting ring	316 SS	316 SS
Adjusting ring pin	316 SS	316 SS
Spindle retainer	Inconel X750	Inconel X750
Cap gasket	Monel	Monel
Adjusting ring pin gasket	Monel	Monel
Guide gasket	Monel	Monel
Base	316 SS	316 SS
Bonnet	Carbon steel	316 SS
Cap	Carbon steel	Carbon steel
Base studs	Gr. B8M	Gr. B8M
Base stud nuts	Gr. G8M	Gr. B8M
Guide	316 SS	316 SS
Spindle	410 SS	410 SS
Adjusting screw	416 SS	416 SS
Adjusting screw nut	416 SS	416 SS
Spring	Alloy steel	Inconel X750 or tungsten
Spring washers	316 SS	Carbon steel
Eductor tube	304 SS	304 SS
Bonnet gasket	Monel	Monel

TABLE 5.10 O-Ring Material Options

Material	Durometer	Temp. limits	
		(°F)	(°C)
Nitrile	50	−45 to +225	−43 to +107
	90	−40 to +350	−40 to +177
Ethylene/propylene	75	−70 to +250	−57 to +121
	90	−70 to +500	−57 to +260
Fluorocarbon	50	−15 to +400	−26 to +204
	90	−15 to +400	−26 to +204
Neoprene	50	−45 to +300	−43 to +149
	70	−45 to +300	−43 to +149
Silicone	50	−65 to +437	−53 to +225
	70	−65 to +437	−53 to +225
Teflon	—	−300 to +500	−184 to +260
Kalrez	65	−40 to +500	−40 to +260
	82	−42 to +550	−41 to +288

TABLE 5.11 Bill of Materials for Rupture Disks

Part name	Material
Disk	Inconel 600, Monel 400, 316 SS
	Hastelloy C-276, Nickel 200
	Tantalum
	Aluminum, silver, graphite
Disk holder	Nickel, Monel 400
	Inconel 600, Hastelloy C-276
	Carbon steel, 316 SS, 304 SS
Tag	Stainless steel
Gasket	Viton, EPDM, PTFE Teflon
	Neoprene, silicone, non-asbestos

TABLE 5.12 Material Selection Choices for Fluids*

Fluid	Hastelloy	316SS	Inconel	Monel
Acetic acid	X	X	XX	XX
Acetylene	X	X	X	XX
Aluminum chloride	X	XXX	XXX	XX
Ammonium hydroxide	XX	X	X	NR
Bromine (free)	XXX	XXX	XX	XXX
Calcium chlorate	XX	X	XX	XX
Calcium hydroxide	X	X	X	XX
Calcium hypochlorite	X	X	XX	NR
Carbon dioxide	X	X	X	X
Chlorine (free)	X	XXX	X	XXX
Chromic acid (plating)	XXX	XX	XXX	NR
Fluorine (free)	X	XXX	X	XXX
Hydrofluoric acid	XX	XXX	XXX	X
Iodine (free)	X	XXX	X	X
Kerosene	X	X	X	X
Nitric acid	X	X	NR	NR
Oxalic acid	XX	XX	XX	XX
Oxygen	X	X	X	X
Potassium chlorate	XX	X	X	NR
Potassium hydroxide	XX	X	X	X
Sodium chloride	X	X	X	X
Sodium hydroxide	XXX	X	X	X
Sodium hypochlorite	X	XX	XXX	NR
Sulfur dioxide	X	X	XX	XXX
Sulfuric acid	XX	XXX	XX	NR

*Key: X = good; XX = fair; XXX = poor; NR = not recommended.

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Design

The spring-loaded pressure relief valve (PRV) is referred to as a “standard” or “conventional” pressure relief valve. This standard pressure relief valve is a simple and self-acting device, which provides overpressure protection.

The basic elements of design of a standard pressure relief valve consist of a right-angle-pattern valve body with the valve inlet connection or nozzle mounted on the pressure-containing side of the vessel. The outlet connection may be screwed or flanged for connection to a pipe that is discharged to a suitable safe location. A pressure relief safety valve design is shown in Fig. 6.1.

In a spring-loaded valve, the pressure force required to lift the seat disk is the preload of the spring, which is equal to the pressure under the disk times the seat sealing area, plus the force required to compress the spring as the valve opens. This compression force is equal to the spring rate times the lift of the seat disk, and must be generated during the allowable pressure.

A design feature applied to further compress the spring and achieve lift is the addition of a “skirt” to the seat disk, as shown in Fig. 6.2. The skirt redirects the flow downward as it discharges through the nozzle, resulting in a change in momentum. The fluid also expands and acts over a larger area. Both the momentum change and expansion significantly increase the force available to compress the spring.

In order to achieve a significant lift, a ring is added around the valve nozzle and positioned to form a huddling chamber with the disk skirt (Fig. 6.2). The ring is generally called a blowdown ring, and its function is important for controlling the valve opening.

If the blowdown ring is adjusted up, the forces required to lift the seat disk off the nozzle occur at pressure very close to the set pressure. With the

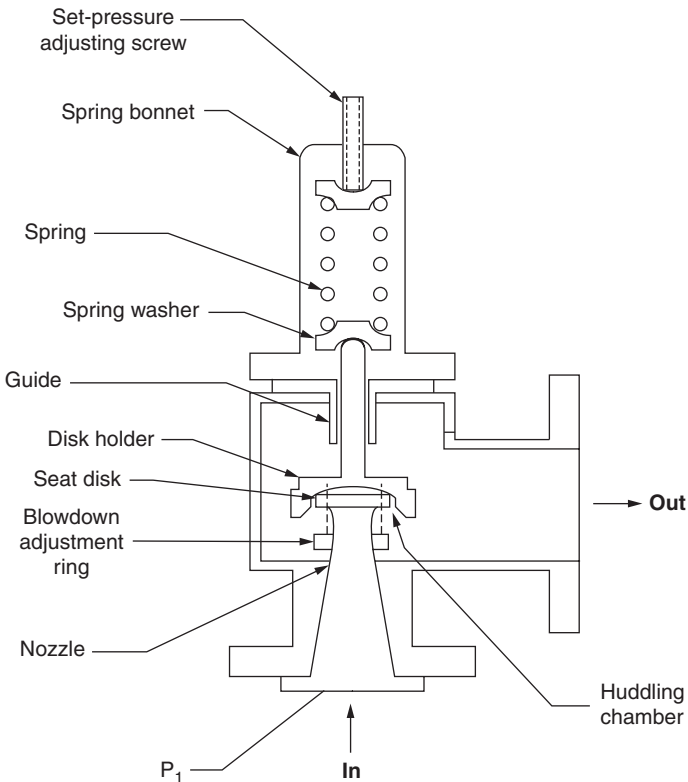


Figure 6.1 A conventional direct spring-operated PRV. (Courtesy Tyco Valves and Controls.)

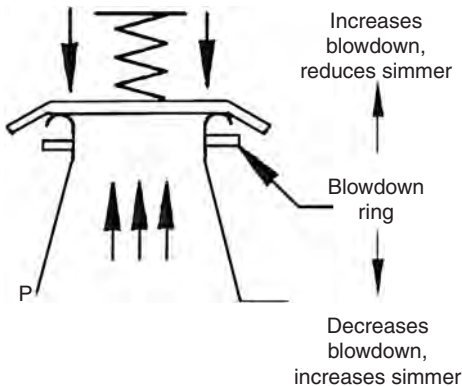


Figure 6.2 Pressure relief valve with blowdown ring. (Courtesy Tyco Valves and Controls.)

ring in this up position, the blowdown is long, as the pressure between the seat disk skirt and the ring remains high. This prevents the seat disk from losing lift until pressure under the disk falls to a much lower value. When the ring is adjusted down, the forces required to lift the seat disk off the nozzle do not occur until the pressure under the seat disk is considerably higher. With the ring in this position, the blowdown is short, as the pressure between the disk holder skirt and ring quickly decreases when the lift of the seat disk is decreased.

An enclosure or body encloses the nozzle and seat disk. This body protects the working internals and safe disposal of the discharge through the valve. Body pressure, which is generated during flow conditions, should be controlled to ensure reliable and safe operation of the pressure relief valve.

6.1 Fundamentals of Design

Consideration should be given on the fundamental principles while designing pressure relief valves. A designer should apply the basic principles relating to disk lift, back pressure, bonnet, nozzle, and other factors such as coefficient of discharge.

6.1.1 Seat disk lift

A seat disk lift characteristic (seat disk lift versus set pressure) of a conventional pressure relief valve is shown in Fig. 6.3. The valve is on the threshold of opening when the upward force produced by the product of the process pressure acting on the seat disk sealing area equals the downward force of the spring.

To obtain rated capacity, the seat disk should lift an amount equal to at least 30% of the nozzle bore diameter.

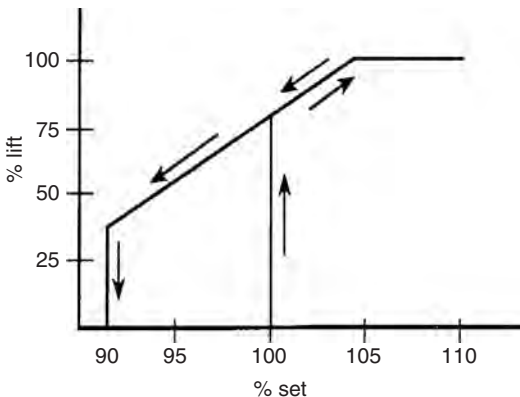


Figure 6.3 Valve seat disk lift characteristics.

6.1.2 Back pressure

Pressure existing at the outlet of a pressure relief valve is defined as back pressure. The back pressure may affect the operation of the pressure relief valve regardless of the type of installation. Effects due to back pressure are variations in opening pressure, reduction in flow capacity, instability, or a combination of all three.

It is critical to balance the forces in a conventional pressure relief valve. The lifting forces may be disturbed by any change in pressure within the valve body downstream of the disk holder and huddling chamber. The relationship between back pressure and capacity of a typical conventional pressure relief valve is shown in Fig. 6.4.

Types of back pressure. There are two types of back pressure: superimposed back pressure and built-up back pressure.

Superimposed back pressure. Superimposed back pressure is defined as the back pressure which is present at the outlet of a pressure relief valve when it is required to operate. The superimposed back pressure is mostly variable, because of the changing conditions in the discharge system.

Built-up back pressure. Built-up back pressure is defined as the back pressure which develops in the discharge system after the pressure relief valve opens. This type of back pressure occurs due to pressure drop in the discharge system as a result of flow from the pressure relief valve.

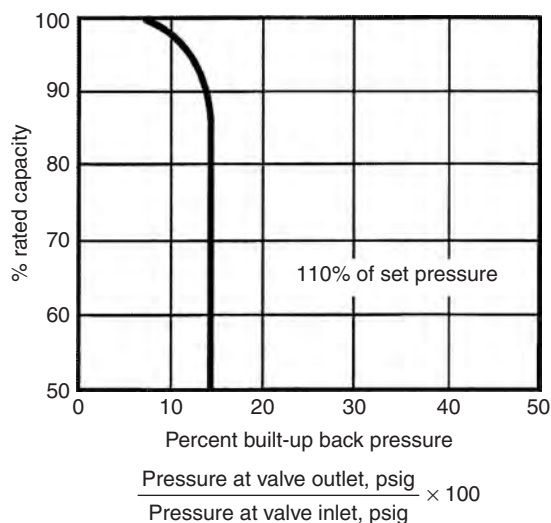


Figure 6.4 Back pressure characteristics of a PRV.

The magnitude of the built-up back pressure should be evaluated for all systems, regardless of the outlet piping configuration.

In a conventional pressure relief valve, superimposed back pressure will affect the opening characteristic and set valve, but the combined back pressure will alter the blowdown characteristic and reset value.

Effect of back pressure on set pressure. In both the above cases, if a significant superimposed back pressure exists, its effects on the set pressure need to be considered when designing a pressure relief valve system. Superimposed back pressure will increase the set pressure on a one-for-one basis. For example, if the set pressure is 100 psig and a back pressure of 10 psig is superimposed on the valve outlet, the set pressure will increase to 110 psig.

Once the valve starts to open, the effects of built-up back pressure also have to be taken into consideration. For a conventional pressure relief valve with the bonnet vented to the discharge side of the valve (Fig. 6.5), the effect of built-up back pressure may be determined by Eq. 6.2. Once the valve starts to open, the inlet pressure is the sum of the set pressure P_S and the overpressure P_O :

$$(P_S + P_O)A_N = F_S + P_B A_N \quad (6.1)$$

$$P_S A_N = F_S + A_N (P_B - P_O)$$

where P_S = set pressure of pressure relief valve
 P_O = overpressure

Therefore, if the back pressure is greater than the overpressure, the valve will tend to close, reducing the flow. This can lead to instability

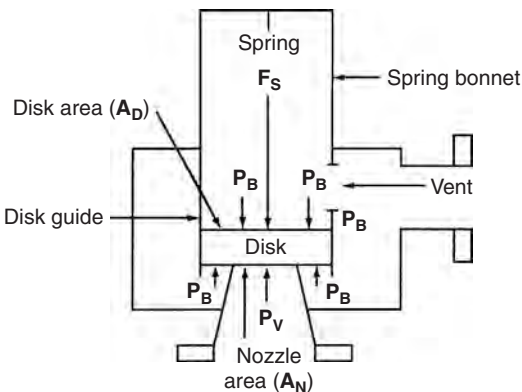


Figure 6.5 PRV with bonnet vented to the valve discharge.

within the system and can result in flutter or chatter of the valve. In a conventional pressure relief valve, if there is an excessive built-up pressure, the valve will not perform as expected.

According to the API 520 Recommended Practice Guidelines:

- A conventional pressure relief valve should typically not be used where the built-up back pressure is greater than 10% of the set pressure at 10% overpressure.
- A higher maximum allowable built-up back pressure may be used for overpressure greater than 10%.

6.1.3 Bonnet

In a conventional pressure relief valve, the bonnet may be vented to the discharge side of the valve or open to the atmosphere.

Bonnet vented to the discharge side. Figure 6.5 shows a schematic diagram of a pressure relief valve with the bonnet vented to the discharge side of the valve. By considering the forces acting on the disk (with area A_D), it is seen that the required opening force (equivalent to the product of inlet pressure P_V and the nozzle area A_N) is the sum of the spring force F_S and the force due to back pressure P_B acting on the top and bottom of the disk. The required opening force is

$$\begin{aligned} P_V A_N &= F_S + P_B A_D - P_B (A_D - A_N) \\ P_V A_N &= F_S + P_B A_N \end{aligned} \quad (6.2)$$

where P_V = fluid inlet pressure

A_N = nozzle area

F_S = spring force

P_B = back pressure

A_D = disk area

Therefore, any superimposed back pressure will tend to increase the closing force, and the inlet pressure required to lift the disk will be greater.

Bonnet vented to the atmosphere. Figure 6.6 shows a schematic diagram of a pressure relief valve with the bonnet vented to the atmosphere. In this case, the required opening force is

$$P_V A_N = F_S - P_B (A_D - A_N) \quad (6.3)$$

Therefore, the superimposed back pressure acts with the vessel pressure to overcome the spring force, and the opening pressure will be less than expected.

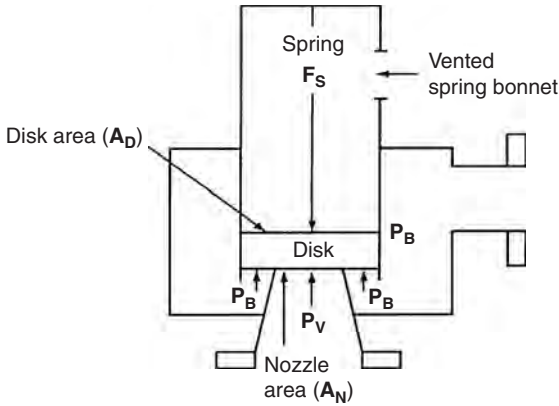


Figure 6.6 PRV with bonnet vented to the atmosphere.

6.1.4 Valve nozzle

The inlet tract is the only part of the valve, other than the disk, that is exposed to the fluid during normal operation, unless the valve is discharging. The valve inlet design can be either a full-nozzle or a semi-nozzle type.

Full nozzle. In a full-nozzle design the entire “wetted” inlet tract formed is from one piece. Full nozzles are usually used in pressure relief valves designed for high-pressure applications, especially for corrosive fluids. A full-nozzle valve is shown in Fig. 6.7.

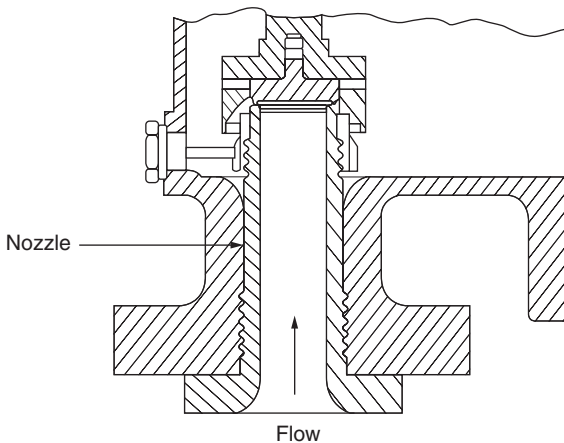


Figure 6.7 Full nozzle.

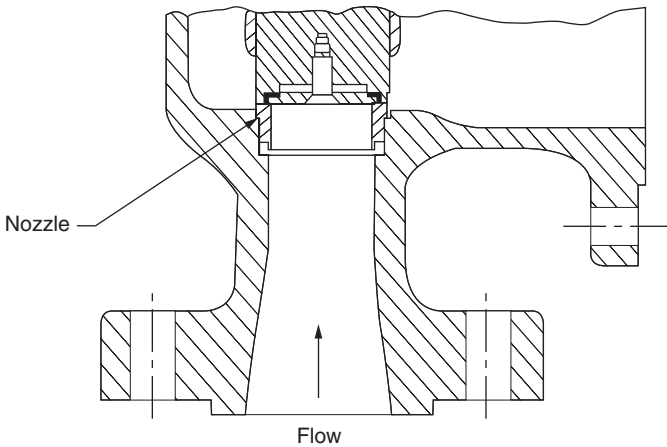


Figure 6.8 Seminozzle.

Seminozzle. A seminozzle design consists of a seat ring fitted into the body. The top of the seat ring forms the seat of the pressure relief valve. The seat may be easily replaced without replacing the complete inlet. A seminozzle valve is shown in Fig. 6.8.

Under normal operating conditions, the disk is held against the nozzle seat by the spring, which is housed in an open or closed spring housing arrangement (or bonnet) mounted on the top of the valve body. A shroud, disk holder, or huddling chamber surrounds the disk, which helps to produce rapid opening. The closing force on the disk is provided by a spring. The amount of compression on the spring is usually adjustable. Adjusting the spring may alter the pressure at which the disk is lifted off its seat.

6.2 Design Factors

Standard design of pressure relief valves generally governs the three dimensions that relate to the discharge capacity of the pressure relief valve. These are flow area, curtain area, and discharge area.

6.2.1 Flow area

Flow area is the minimum cross-sectional area between the inlet and the seat, at its narrowest point. The diameter of the flow area is the dimension d shown in Fig. 6.9. The equation for flow area is

$$\text{Flow area} = \frac{\pi d^2}{4}$$

If the flow area determines capacity, the valve is known as a full-lift valve. A full-lift valve has a greater capacity than a low-lift or high-lift valve.

6.2.2 Curtain area

Curtain area is the area of the cylindrical or conical discharge opening between the seating surfaces created by the lift of the disk above the seat. The diameter of the curtain area is d_1 as shown in Fig. 6.9. The equation for curtain area is

$$\text{Curtain area} = \pi d_1 L$$

6.2.3 Discharge area

Discharge area is the lesser of the curtain or flow area that determines the flow through the valve.

6.2.4 Other design factors

Nozzle area. The nozzle area is the minimum cross-sectional flow area of a nozzle. The nozzle area is also referred to as nozzle throat area, throat area, or bore area.

Inlet size. The inlet size is the nominal pipe size (NPS) of the valve at the inlet connection, unless otherwise designated.

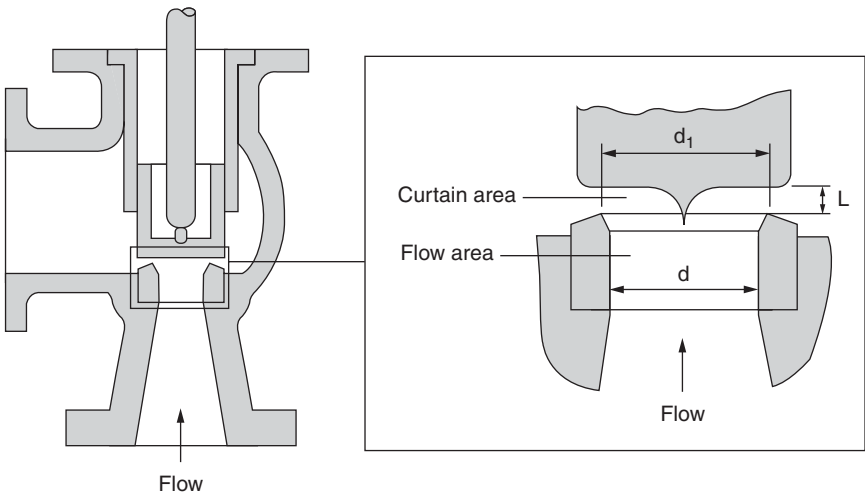


Figure 6.9 Standard defined areas of a PRV. (Courtesy Spirax Sarco, U.K.)

Discharge size. The discharge size is the nominal pipe size (NPS) of the valve at the discharge connection, unless otherwise designated.

Lift. The lift is the actual travel of the disk from the closed position when a valve is relieving.

Coefficient of discharge. The coefficient of discharge is the ratio of the mass flow rate in a valve to that of an ideal nozzle. It is used for calculation of flow through a pressure relief device. There are two types of coefficient of discharge:

1. *The effective coefficient of discharge.* The effective coefficient of discharge is a nominal value used with an effective discharge area to calculate the minimum required relieving capacity of a pressure relief valve.
2. *The rated coefficient of discharge.* The rated coefficient of discharge is determined in accordance with the applicable code or regulation and is used with the actual discharge area for calculation of the rated flow capacity of a pressure relief valve.

6.3 Pressure Requirements

A pressure-level relationship for pressure relief valves according to API 520 Recommended Practice is shown in Fig. 6.10. The features are:

- The figure conforms with the requirements of ASME Sec. VIII—Unfired Pressure Vessel Code for maximum allowable working pressure (MAWP) greater than 30 psi.
- The pressure conditions shown are for pressure relief valves installed on a pressure vessel.
- Allowable set-pressure tolerances will be in accordance with the applicable codes.
- The MAWP is equal to or greater than the design pressure for a coincident design temperature.
- The operating pressure may be higher or lower than 90 psi.
- Appendix M of Sec. VIII, Division I, should be referred to for guidance on blowdown and pressure differentials.

6.3.1 System pressures

Maximum operating pressure. Maximum operating pressure is the maximum pressure expected during system operation.

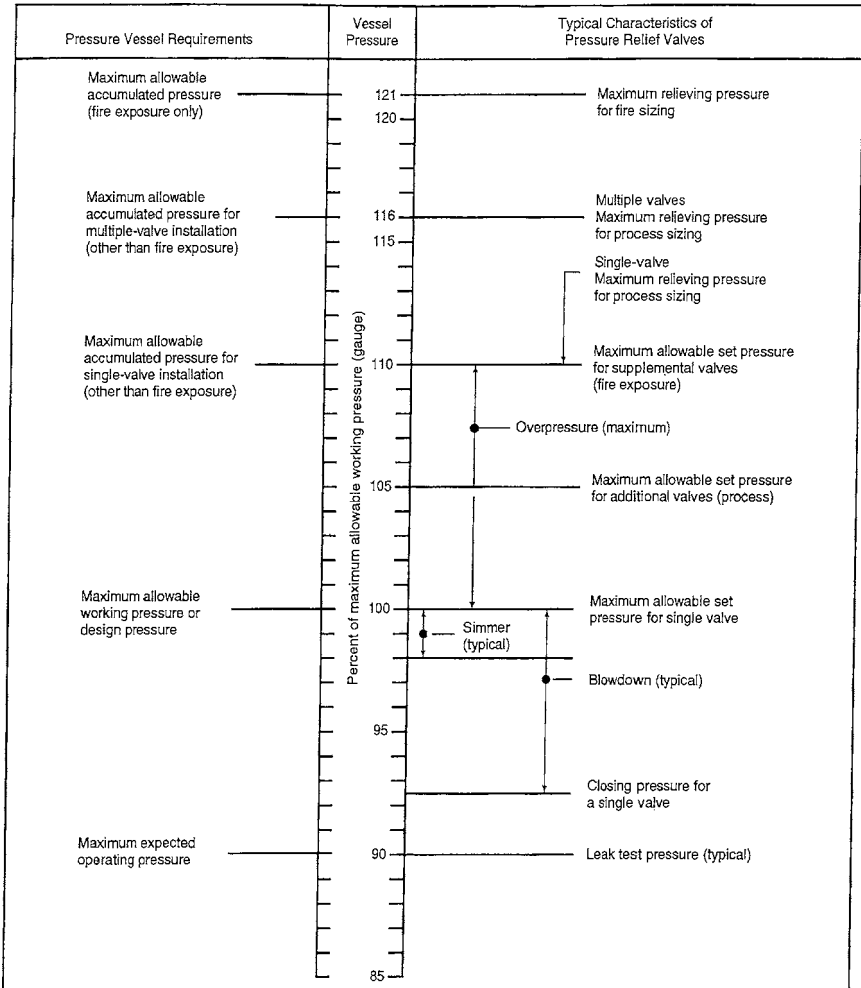


Figure 6.10 Pressure-level relationships for PRV. (From API RP 520.)

Maximum allowable working pressure (MAWP). Maximum allowable working pressure is the maximum gauge pressure permissible at the top of a completed vessel. The MAWP is the basis for the pressure setting of the pressure relief devices that protect the vessel.

Accumulated pressure. Accumulated pressure is the pressure increase over the MAWP of the vessel during discharge through the pressure relief device, expressed in pressure units or as a percentage. Maximum allowable accumulation pressures are established by applicable codes for operating and fire contingencies.

Rated relieving capacity. Rated relieving capacity is the measured relieving capacity permitted by the applicable code or regulation to be used as a basis for the application of a pressure relief device.

Stamped capacity. Stamped capacity is the rated relieving capacity that appears on the device nameplate. The stamped capacity is based on the set pressure or burst pressure plus the allowable overpressure for compressible fluids and the differential pressure for incompressible fluids.

6.3.2 Relieving device pressures

Set pressure. Set pressure is the inlet gauge pressure at which the pressure relief valve is set to open under service conditions.

Blowdown. Blowdown is the difference between the set pressure and the closing pressure of a pressure relief valve, expressed as a percentage of the set pressure or in pressure units.

Overpressure. Overpressure is the pressure increase over the set pressure of the relieving device, expressed in pressure units or as a percentage. It is the same accumulation when the relieving device is set at the MAWP of the vessel and there are no inlet pipe losses to the relieving device.

Opening pressure. Opening pressure is the value of increasing inlet static pressure at which there is a measurable lift of the disk or at which discharge of the fluid becomes continuous.

Closing pressure. Closing pressure is the value of decreasing inlet static pressure at which the valve disk reestablishes contact with the seat or at which lift becomes zero.

Simmer. Simmer is the audible or visible escape of compressible fluid between the seat and the disk at an inlet static pressure below the set pressure and at no measurable capacity.

Leak-test pressure. Leak-test pressure is the specified inlet static pressure at which a seat leak test is performed.

6.4 Design Considerations

The main purpose of designing a pressure relief valve is to prevent pressure in the system being protected from increasing beyond safe design limits. The other purpose of a pressure relief valve is to minimize damage to other system components due to operation of the PRV itself.

The following design features should be considered when designing a pressure relief valve:

- Leakage at system operating pressure is within acceptable standards of performance.
- Opens at specified set pressure, within tolerance.
- Relieves the process products in a controlled manner.
- Closes at specified reseal pressure.
- Easy to maintain, adjust, and verify settings.
- Cost-effective maintenance with minimal downtime and spare parts investment.

Mechanical loads for both the closed and open (full discharge) positions should be considered in concurrence with the service conditions. The pressure relief valves have extended structures and these structures are necessary to maintain pressure integrity.

Earthquake loadings for the piping system or vessel nozzle should be considered. An analysis may be performed based on static forces resulting from equivalent earthquake acceleration acting as the center of gravity of the extended masses. Classical bending and direct stress equations may be used for such an analysis.

6.5 Design of Parts

Parts of the pressure relief valves are designed in accordance with the code requirements of the American Society of Mechanical Engineers (AMSE) and American Petroleum Institute (API). A designer should conform that all the parts meet the code requirements so that complete pressure relief valves can be stamped with code symbols.

6.5.1 Body

The design of the valve body should take into consideration the inlet flange connection, the outer flange connection, and the body structural configuration. The bonnet design should follow the body design if the outlet flange is an extension of the bonnet.

6.5.2 Bonnet

A bonnet is a component used on a direct spring valve or on a pilot in a pilot-operated valve that supports the spring. The bonnet may or may not contain pressure.

6.5.3 Nozzle

A nozzle is a primary pressure containing component in a pressure relief valve that forms a part of the inlet flow passage.

6.5.4 Disk

A disk is a movable component of a pressure relief valve that contains the primary pressure when it rests against the nozzle.

6.5.5 Spindle

A spindle is a part whose axial orientation is parallel to the travel of the disk. The spindle may be used for the following applications:

- Assist in alignment
- Guide disk travel, and
- Transfer of internal or external forces to the seats.

6.5.6 Adjusting ring

An adjusting ring is a ring assembled to the nozzle or guide of a direct spring valve used to control the opening characteristics or the reseal pressure.

6.5.7 Adjusting screw

An adjusting screw is a screw used to adjust the set pressure or the reset pressure of a pressure relief valve.

6.5.8 Huddling chamber

A huddling chamber is the annular pressure chamber between the nozzle exit and the disk or disk holder which produces the lifting force to obtain a pop action.

6.5.9 Spring

A spring is the element in a pressure relief valve that provides the force to keep the disk on the nozzle. The valve spring is designed in such a way that the full-lift spring compression should not be greater than 80% of the nominal solid deflection. The permanent set of the spring should not exceed 0.5% of the free height.

The permanent set of the spring is defined as the difference between the free height measured a minimum of 10 min after the spring has been compressed solid three additional times after presetting at room temperature.

6.6 Testing and Marking

Each pressure relief valve to which code symbol stamp is to be applied should be tested by the manufacturer or assembler. Once construction is completed, the valves should be tested and marked according to the code.

6.6.1 Hydrostatic Test

Hydrostatic testing should be performed after assembly of the valve in accordance with the provision of the code. The primary pressure parts should be tested at a pressure of at least 1.5 times the design pressure of the parts. The secondary pressure zones of each closed bonnet valve should be tested with air or other gas at a pressure of at least 30 psi. The test results should no show any visible sign of leakage.

6.6.2 Marking

The valves shall be marked according to the requirements of the code. A manufacturer or assembler is required to mark pressure relief valves in such a way that the marking will not be obliterated in service.

The following data, as a minimum, should be marked on the pressure relief valves: name or an acceptable abbreviation of the manufacturer, manufacturer's design or type number, set pressure (psig), blowdown (psi), certified capacity (SCFM or lb/min), lift of the valve (in.), year built, and code symbol stamp.

6.7 Rupture Disks

Rupture disks are nonreclosing pressure relief devices designed to provide virtually instantaneous unrestricted pressure relief to a closed system at a predetermined pressure and coincident temperature.

Rupture disks can be specified for pressure relief requirements of systems with gas, vapor, or liquid. Also, rupture disks designs are available for highly viscous fluids. The rupture disk for liquid service should be carefully designed to ensure that design of the disk is suitable for liquid service.

The rupture disk is also a temperature-sensitive relief device. Burst pressure may vary significantly with the temperature of the rupture disk device. As the temperature at the disk increases, the burst pressure usually decreases. For this reason, the rupture disk should be designed for the pressure and temperature at the disk is expected to burst.

6.7.1 Basic design

There are three main basic designs of rupture disks: (1) forward acting, tension loaded; (2) reverse acting, compression loaded; and (3) graphite, shear loaded.

Forward-acting rupture disks. Forward-acting rupture disks are designed to fail in tension (Fig. 6.11). When pressure applied to the concave side reaches the point at which severe localized thinning of metal occurs, the

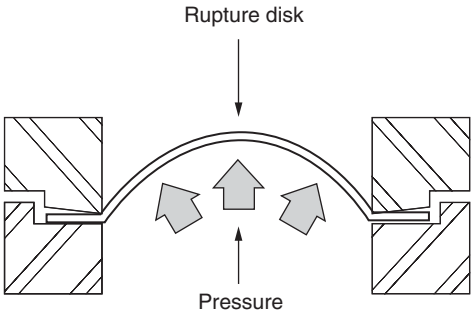


Figure 6.11 Forward-acting (tension-loaded) rupture disk.

disks will rupture. Forward-acting rupture disks are produced in conventional, composite, and scored designs.

Reverse-acting rupture disks. Reverse-acting rupture disks are designed to fail when the disk is in compression (Fig. 6.12). Pressure is applied to the convex side until the disk “reverse buckles.” Once reversal pressure is reached, the crown of the disk snaps through the center of the holder and can either be cut open by a knife blade or other cutting device, or opened along score lines, allowing pressure to be relieved. Reverse-acting disks are produced with either knife blades or scored designs.

Graphite rupture disks. Graphite rupture disks are designed to fail when the disk is in shear. These disks are typically machined from a bar of fine graphite that has been impregnated with a binding compound. The disk operates on a pressure differential across the center diaphragm or web portion of the disk. Graphite rupture disks provide good service life when the operating ratio is 80%. If the disk is designed for vacuum or back-pressure conditions, the disk has to be furnished with a support to prevent reverse flexing.

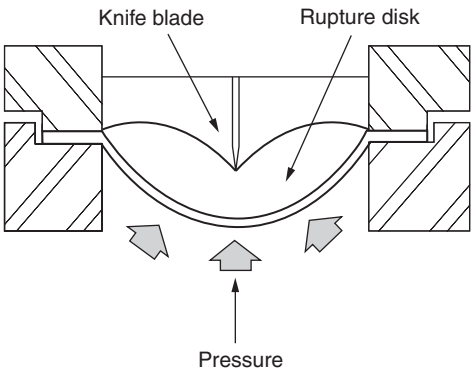


Figure 6.12 Reverse-acting (compression loaded) rupture disk.

6.7.2 operating ratios

The operating ratio is defined as the relationship between the operating pressure and the stamped burst pressure of the rupture disk. The operating ratio is generally expressed as a percentage:

$$\text{Operating ratio} = \frac{P_O}{P_B} \times 100$$

where P_O = operating pressure
 P_B = burst pressure

Regardless of the design, rupture disks give greater service life when the operating pressure is considerably less than the burst pressure. In general, good service life can be expected if operating pressures do not exceed the following:

- 70% of stamped burst pressure for conventional prebulged rupture disk designs
- 80% of stamped burst pressure for composite-design rupture disks
- 80–90% of stamped burst pressure for forward-acting scored design rupture disks
- Up to 90% of stamped burst pressure for reverse-acting design rupture disks

6.7.3 Pressure-level relationship

A pressure-level relationship for rupture disk devices according to API 520 Recommended Practice is shown in Fig. 6.13. The features are:

- The figure conforms to the requirements of ASME Sec. VIII—Unfired Pressure Vessels for MAWPs greater than 30 psi.
- The pressure conditions shown are for rupture disk devices installed on a pressure vessel.
- The margin between the maximum allowable working pressure and the operating pressure should be considered in the selection of a rupture disk.
- The allowable burst-pressure tolerance will be in accordance with the applicable code.
- The operating pressure may be higher or lower than 90 psi, depending on the rupture disk design.
- The marked burst pressure of the rupture disk may be any pressure at or below the maximum allowable marked burst pressure.

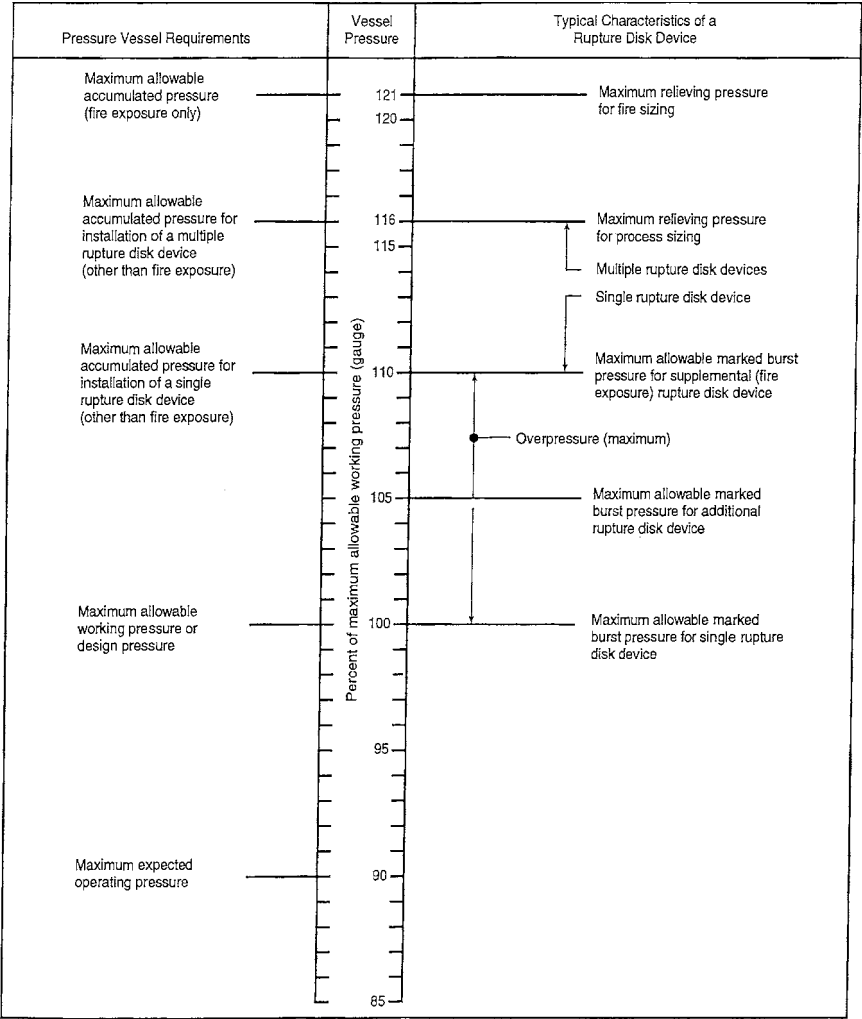


Figure 6.13 Pressure-level relationships for rupture disks. (From API RP 520.)

6.7.4 Certified K_R and MNFA

The ASME Code Sec. VIII—Division 1 requires that any product carrying the UD stamp shall be flow tested at an ASME-approved test laboratory in the presence of an ASME-designated observer. Results of the flow testing such as certified flow resistance factor (K_R) and minimum net flow area (MNFA) are stamped on the disk nameplate.

Certified K_R . The loss coefficient K is the minor losses in a piping system due to elbows, tees, fittings, valves, reducers, etc. In other

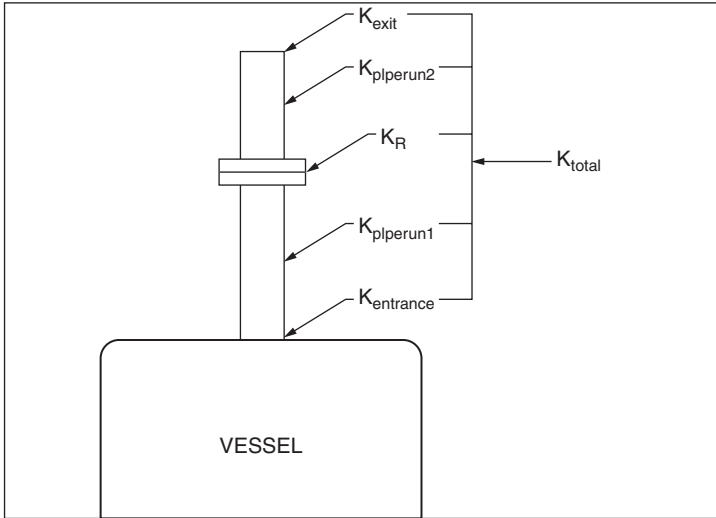


Figure 6.14 Rupture disk discharging directly to atmosphere.

words, K is the pressure loss expressed in terms of the number of velocity heads.

For the piping system shown in Fig. 6.14, K is defined as

$$K_{total} = K_{entrance} + K_{piperun1} + K_R + K_{piperun2} + K_{exit}$$

The value of K can be calculated if all the parameters are known. The easiest way to find K_R is on the rupture disk nameplate itself. Most manufacturers provide K_R tables by model number in their rupture disk catalogs. API RP 521 prescribes 1.5 for K_R , regardless of disk design.

Minimum net flow area. The minimum net flow area (MNFA) is used in relieving-capacity calculations as defined in ASME Sec. VIII—Division 1, “coefficient of discharge” method. This method is used when the disk discharges directly to atmosphere and is installed within eight pipe diameters of the vessel and within five pipe diameters of the outlet of the discharge piping (Fig. 6.14).

The MFNA is the area A of the equation. A coefficient of discharge K_D of 0.62 is assumed. It is important to note that the coefficient of discharge K_D is a different dimensionless parameter than K_R .

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Manufacturing

Pressure relieving devices in the United States are manufactured in accordance with the rules of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. The manufacturer is responsible for design, construction, quality control, and capacity certification. A pressure relief device can be marked with the ASME Code symbol stamp only if all the requirements of the ASME Code are met.

Following are the ASME Code symbols for pressure relief devices:

- V**—safety valve for power boilers
- HV**—safety relief valve for heating boilers
- NV**—safety relief valve for nuclear components
- TV**—safety relief valve for transport tanks
- UV**—safety relief valve for pressure vessels
- UD**—rupture disks
- TD**—rupture disks for transport tanks

In foreign countries, pressure relieving devices are manufactured according to the Code adopted by the respective countries. The manufacturer is responsible for design, construction, quality control, and capacity certification. Generally, the jurisdictional authority of a country or inspection companies authorized by that jurisdiction provide inspection services during construction.

7.1 Manufacture of Pressure Relief Valves

Pressure relief valves are manufactured by manufacturers or assemblers, who must hold an ASME certification to use Code symbol stamps.

A manufacturer is defined as a person or organization that is responsible for design, material selection, capacity certification, manufacturer of all component parts, assembly, testing, sealing, and shipping of pressure relieving valves as required by various sections of the ASME Boiler and Pressure Vessel Code.

An assembler is defined as a person or organization that purchases or receives from a manufacturer the necessary components or valves and assemblies, adjusts, tests, seals, and ships pressure relieving valves certified in accordance with the ASME Boiler and Pressure Vessel Code at a geographic location other than that of the manufacturer and using facilities other than those used by the manufacturer.

A manufacturer is required to establish a quality control system for manufacturing pressure relief valves. The manufacturer has to demonstrate to the ASME designee that the manufacturing, production, and test facilities and quality control procedures as described in the quality control system ensure close performance between the production samples and the valves submitted for capacity certification. An ASME designee can inspect the manufacturing, assembly, and test operations at any time.

A Certificate of Authorization to apply ASME Code symbol stamps (see Fig. 7.1 for the **V** symbol stamp and Fig. 7.2 for the **UV** symbol stamp), if granted by the ASME, remains valid for 3 years from the date it is initially issued. This Certificate of Authorization may be extended for 3-year periods if the following tests are completed satisfactorily within 6 months before expiry date:

1. Two sample production pressure relief valves of a size and capacity selected by an ASME designee.
2. An ASME designee observes the operational and capacity tests at an ASME-accepted laboratory.

An assembler can apply the ASME Code symbol for the use of unmodified parts as per instructions of the valve manufacturer. The assembler is permitted to convert original finished parts by machining to other finished parts, provided that:

1. Conversions are done according to either drawings or written instructions or both, furnished by the manufacturer.
2. The assembler's quality system is accepted by a representative from an ASME-designated organization.



CERTIFICATE OF AUTHORIZATION

This certificate accredits the named company as authorized to use the indicated symbol of the American Society of Mechanical Engineers (ASME) for the scope of activity shown below in accordance with the applicable rules of the ASME Boiler and Pressure Vessel Code. The use of the Code symbol and the authority granted by this Certificate of Authorization are subject to the provisions of the agreement set forth in the application. Any construction stamped with this symbol shall have been built strictly in accordance with the provisions of the ASME Boiler and Pressure Vessel Code.

COMPANY:

**AMERICAN VALVE & PUMP
140 BRANNEN ROAD
LAKELAND, FLORIDA 33813**

SCOPE:

**ASSEMBLY OF SAFETY VALVES FOR POWER BOILERS AT THE ABOVE
LOCATION (THIS AUTHORIZATION DOES NOT COVER WELDING OR BRAZING)**

**AUTHORIZED: AUGUST 14, 2002
EXPIRES: AUGUST 14, 2005
CERTIFICATE NUMBER: 27,407**

**CHAIRMAN OF THE BOILER
AND PRESSURE VESSEL COMMITTEE**

DIRECTOR, ACCREDITATION AND CERTIFICATION



Figure 7.1 Certificate of Authorization for V symbol. (Courtesy ASME International.)

3. The assembler demonstrates to the manufacturer the ability to perform conversions.
4. The manufacturer reviews the assembler's system and machining capabilities at least once a year.

7.1.1 Test laboratories

A test laboratory is a facility where pressure relieving devices are tested for capacity certification. Such a test laboratory is approved by the ASME.



CERTIFICATE OF AUTHORIZATION

This certificate accredits the named company as authorized to use the indicated symbol of the American Society of Mechanical Engineers (ASME) for the scope of activity shown below in accordance with the applicable rules of the ASME Boiler and Pressure Vessel Code. The use of the Code symbol and the authority granted by this Certificate of Authorization are subject to the provisions of the agreement set forth in the application. Any construction stamped with this symbol shall have been built strictly in accordance with the provisions of the ASME Boiler and Pressure Vessel Code.

COMPANY:

**MEC-TRIC CONTROL COMPANY
4110 MONROE ROAD
CHARLOTTE, NORTH CAROLINA 28205**

SCOPE:

**MANUFACTURE OF PRESSURE VESSEL PRESSURE RELIEF VALVES AND
ASSEMBLY OF PRESSURE VESSEL PRESSURE RELIEF VALVES AT THE
ABOVE LOCATION ONLY (THIS AUTHORIZATION DOES NOT COVER WELDING
OR BRAZING)**

AUTHORIZED: **APRIL 17, 2002**
EXPIRES: **AUGUST 6, 2005**
CERTIFICATE NUMBER: **24,999**

CHAIRMAN OF THE BOILER
AND PRESSURE VESSEL COMMITTEE



DIRECTOR, ACCREDITATION AND CERTIFICATION

Figure 7.2 Certificate of Authorization for **UV** symbol. (Courtesy ASME International.)

The arrangement of test equipment in a test laboratory is shown in Fig. 7.3.

Any organization interested in applying to set-up a test laboratory can apply to the ASME using a prescribed form, which is shown in App. E. Once a Certification of Acceptance is issued, the test laboratory



Figure 7.3 Flow test laboratory. (Courtesy Continental Disk Corporation.)

can conduct capacity certification tests. A Certificate of Acceptance (Fig. 7.4) remains valid for 5 years from the date it is issued. This Certificate of Acceptance may be renewed every 5 years if ASME rules are followed.

The rules for ASME acceptance of test laboratories and authorized observers for conducting capacity certifications are given in App. A-310 of ASME Sec. I—Power Boilers. A list of ASME accredited testing laboratories is shown in App. F.

An Authorized Observer is an ASME-designated person who supervises capacity certification tests only at testing facilities specified by ASME. An ASME designee reviews and evaluates the experience of persons interested in becoming authorized observers, and makes recommendation to the Society.

The manufacturer and authorized observers sign the capacity test data reports after completion of test on each valve design and size. The capacity test reports, with drawings for valve construction, are submitted to the ASME designee for review and acceptance.

7.1.2 Capacity certification

A valve manufacturer is required to have the relieving capacity of valves certified before applying ASME Code symbol stamps to any pressure relieving devices. The valve capacity is certified by a testing laboratory accredited by the ASME. A sample copy of the valve certificate published by the National Board Valve Testing Laboratory is shown in Fig. 7.5.

The manufacturer and authorized observers sign the capacity test data reports after completion of tests on each valve design and size. The capacity test reports, with drawings for valve construction, are submitted to the ASME designee for review and acceptance.



CERTIFICATE OF
ACCEPTANCE

This is to accept the named Testing Laboratory for conducting capacity certification tests of pressure relief devices in accordance with the applicable rules of the American Society of Mechanical Engineers Boiler & Pressure Vessel Code. The acceptance granted by this certificate is subject to the provisions of the agreement set forth in the application.

TESTING
LABORATORY

FIKE CORPORATION
704 SOUTH 10TH STREET
BLUE SPRINGS, MO 64013

TESTING
MEDIUM

NITROGEN

ACCEPTED

AUGUST 28, 2001

EXPIRES

AUGUST 28, 2005

CERTIFICATE NUMBER

PRD-023

Alan B. ...

DIRECTOR, ACCREDITATION AND CERTIFICATION

Figure 7.4 Certificate of Acceptance for a test laboratory. (Courtesy ASME International.)

Capacity certification tests are conducted at a pressure not exceeding set pressure by 3% or 2 psi (7 kPa), whichever is greater. The valves are adjusted so that blowdown does not exceed 4% of the set pressure. The tests are conducted by using dry saturated steam of 98% minimum quality, and 20°F (11°C) maximum superheat.

CONBRACO INDUSTRIES, INC. (CNB) Matthews, North Carolina

VALVE SERIES OR CAT. NO. - 18-402, 18-402X (T&P Valve)
 NB Capacity Certification Number - M11271
 CAPACITY TESTS - Sec. IV at National Board on April 16, 1975
 METHOD OF ESTABLISHING RELIEVING CAPACITY - Slope
 5.05
 TEST MEDIUM - Steam
 CERTIFIED MEDIUM - Saturated Water
 Set Pressure Definition - 40 cm³/min.

Inlet Size 3/4 in. M Seat Dia. 0.468 in.		Outlet Size 3/4 in. F	
Set Pressure PSIG	Sec. IV #/Hr Steam		
125	450		
180	450		

VALVE SERIES OR CAT. NO. - 19 Series
 NB Capacity Certification Number - M11282
 CAPACITY TESTS - Sec. I at National Board on March 27, 1990
 METHOD OF ESTABLISHING RELIEVING CAPACITY - Coefficient
 0.826 (918 x .9)
 TEST MEDIUM - Steam
 CERTIFIED MEDIUMS - Steam, Air and Gas
 Set Pressure Definition - Pop
 Blowdown - Adjustable

Inlet Size 1/2, 3/4 in. Orifice Dia. 0.405 in.		Minimum Lift 0.101 in. Flow Area 0.129 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	165	171	61
30	250	262	93
50	363	383	136
250	1494	1590	564
300	N/A	N/A	673

Inlet Size 3/4, 1 in. Orifice Dia. 0.541 in.		Minimum Lift 0.135 in. Flow Area 0.230 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	295	305	108
30	446	467	166
50	647	681	242
250	2660	2832	1007
300	N/A	N/A	1200

Inlet Size 1, 1-1/4 in. Orifice Dia. 0.676 in.		Minimum Lift 0.169 in. Flow Area 0.359 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	460	476	169
30	695	726	259
50	1010	1063	378
250	4153	4420	1573
300	N/A	N/A	1874

Inlet Size 1, 1-1/4, 1-1/2 in. Orifice Dia. 0.866 in.		Minimum Lift 0.217 in. Flow Area 0.589 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	755	781	277
30	1141	1195	425
50	1658	1745	621
250	6815	7253	2581
300	N/A	N/A	3074

Inlet Size 1-1/2, 2 in. Orifice Dia. 1.082 in.		Minimum Lift 0.271 in. Flow Area 0.918 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	1178	1218	433
30	1780	1864	664
50	2587	2722	968
250	10639	11317	4027
300	N/A	N/A	4796

Inlet Size 2, 2-1/2 in. Orifice Dia. 1.386 in.		Minimum Lift 0.347 in. Flow Area 1.509 sq. in.	
Set Pressure PSIG	Sec. I #/Hr Steam	Sec. VIII #/Hr Steam	Sec. VIII SCFM Air
15	1934	1999	711
30	2924	3082	1090
50	4246	4467	1590
250	17457	18570	6608
300	N/A	N/A	7876

Figure 7.5 Capacity certification report. (Courtesy National Board.)

New tests are performed if changes are made in the design of the valve in such a manner that affects the flow path, lift, or performance characteristics of the valve.

Three methods, (1) the three-valve method, (2) the slope method, and (3) the coefficient of discharge method, are permitted for capacity certification. Relieving capacity of a safety valve or safety relief valve may be determined by using any one of these methods.

Three-valve method. In the three-valve method, a set of three valves for each combination of size, design, and pressure setting is tested. On test, the capacity should stay within the range of $\pm 5\%$ of the average capacity. If the test fails for one valve, it is required to be replaced with two valves. Now a new average capacity of four valves is calculated, and tested again. If the test result for a valve fails to fall within $\pm 5\%$ of the new average, that valve design is rejected.

The rated relieving capacity for each combination of design, size, and test pressure is required to be 90% of the average capacity.

Slope method. In the slope method, a set of four valves for each combination of pipe size and orifice size is tested. The valves are set at pressures covering the range of pressures for which the valves will be used or the range of pressures available at the testing laboratory. The capacities are determined according to the following.

The slope W/P of the measured capacity versus the flow pressure for each test is calculated on average:

$$\text{Slope} = \frac{W}{P} = \frac{\text{measured capacity}}{\text{absolute flow rating pressure, psia}}$$

The values obtained from the testing are required to stay within $\pm 5\%$ of the average value:

$$\text{Minimum slope} = 0.95 \times \text{average slope}$$

$$\text{Maximum slope} = 1.05 \times \text{average slope}$$

The Authorized Observer is required to witness testing of additional valves at the rate of two for each valve if the values from the testing do not fall within the above minimum and maximum slope values.

Rated relieving capacity must not exceed 90% of the average slope times the absolute accumulation pressure:

$$\text{Rated slope} = 0.90 \times \text{average slope}$$

The stamped capacity $\leq$ rated slope $(1.03 \times \text{set pressure} + 14.7)$ or $(\text{set pressure} + 2 \text{ psi} + 14.7)$, whichever is greater.

Coefficient of discharge method. In the coefficient of discharge method, a coefficient of discharge, K , is established for a specific valve design. The manufacturer is required to submit at least three valves for each of three different sizes, a total of nine valves, for testing. Each valve is set at a different pressure covering the range of pressure for which the valves will be used or the range of pressures available at the test laboratory. The test

is performed on each valve to determine its lift, popping, and blowdown pressures, and actual relieving capacity. A coefficient, K_D , is established for each valve:

$$\text{Individual coefficient of discharge, } K_D = \frac{\text{actual flow}}{\text{theoretical flow}}$$

The actual flow is determined by the test, whereas the theoretical flow, W_T , is calculated by the following formulas:

(a) For 45° seat:

$$W_T = 51.5 \times \pi DLP \times 0.707$$

(b) For flat seat:

$$W_T = 51.5 \times \pi DLP$$

(c) For nozzle:

$$W_T = 51.5AP$$

where W_T = theoretical flow, lb/hr (kg/hr)

A = nozzle throat area, in² (m²)

P = (1.03 × set pressure + 14.7), psia, or (set pressure + 2 + 14.7) psia, whichever is greater

L = lift pressure at P , in (mm)

D = seat diameter, in (mm)

The coefficient of design K is calculated by multiplying the average of K_D of the nine tests by 0.90. All nine K_D must fall within ±5% of the average coefficient. If any valve fails to meet this requirement, the Authorized Observer is required to witness two additional valves as replacements for each valve that failed, with a limit of four additional valves. If the new valves fail to meet the requirement of new average value, that particular valve design is rejected.

The rated relieving capacity is determined by the following formula:

$$W \leq W_T \times K$$

where W = rated relieving capacity, lb/hr

W_T = theoretical flow, lb/hr

K = coefficient of discharge

The value of W is multiplied by the following correction factor for valves with pressure range from 1500 to 3200 psig:

$$\text{Correction factor} = \frac{0.1906P - 1000}{0.2292P - 1061}$$

For power-actuated pressure relief valves, one valve of each combination of inlet pipe size and orifice size used with that inlet pipe size is tested. The valve capacity is tested at four different pressures available at the testing laboratory, and the test result is plotted as capacity versus absolute flow test pressure. A line is drawn through these four points, and all points must stay within $\pm 5\%$ in capacity value and must pass through 0–0. A slope of the line dW/dP is determined and applies to the following equation for calculating capacity in the supercritical region at elevated pressures:

$$W = 1135.8 \frac{0.90}{51.45} \times \frac{dW}{dP} \sqrt{\frac{P}{v}}$$

where W = capacity, lb of steam/hr (kg/hr)

P = absolute inlet pressure, psia (kPa)

v = inlet specific volume, ft^3/lb (m^3/kg)

dW/dP = rate of change of measured capacity

After obtaining capacity certification, the power-actuated pressure relief valves are marked with the above computed capacity.

7.1.3 Capacity certification in combination with rupture disks

The pressure relief valve manufacturer or the rupture disk manufacturer should submit for tests the smallest rupture disk device size with the equivalent size of pressure relief valve of the combination device. The pressure relief valve to be tested should have the largest orifice in that particular size inlet.

Capacity certification tests should be conducted with saturated steam, air, or natural gas. Corrections should be made for moisture content of the steam if saturated steam is used. Test should be performed according to the following guidelines:

1. The test should represent the minimum burst pressure of the rupture disk device. The marked burst pressure should be between 90% and 100% of the marked set pressure of the valve.

2. The following test procedures should be used:
 - One pressure relief valve should be tested for capacity like an individual valve, without rupture disk, at a pressure 10% or 3 psi (20.6 kPa), whichever is greater, above the valve set pressure.
 - The rupture disk device should then be installed at the inlet of the pressure relief valve and the disk burst to operate the valve. The capacity test should be performed on the combination at 10% or 3 psi (20.6 kPa), whichever is greater, above the valve set pressure.
3. The tests should be repeated with two additional rupture disks of the same rating, for a total of three rupture disks with the single pressure relief valve. The test result should fall within a range of 10% of the above capacity in three tests. If the test fails, the rupture disk device should be retested to determine causes of discrepancies.
4. A combination capacity factor is determined from the results of the tests. The combination capacity factor is the ratio of the average capacity determined by the combination tests to the capacity determined on the individual valve. This factor applies only to combinations of the same design of pressure relief valve and the same design of rupture disk device as tested.
5. The test laboratory submits the test results to the ASME-designated organization for acceptance of the combination capacity factor.

7.1.4 Testing by manufacturers

The manufacturer or assembler is required to test every valve with steam to ensure its popping point, blowdown, and pressure-containing integrity. The test may be conducted at a location where test fixtures and test drums of adequate size and capacity are available to observe the set pressure stamped on the valve. Alternatively, the valve may be tested on the boiler, by raising the pressure to demonstrate the popping pressure and blowdown.

The pressure relief valves are tested at 1.5 times the design pressure of the parts, which are cast and welded. This test is required for valves exceeding 1 in (DN 25) inlet size or 300 psig (2070 kPa) set pressure. The test result should not show any leakage.

Pressure relief valves with closed bonnets, designed for a closed system, are required to be tested with a minimum of 30 psig (207 kPa) air or other gas. The test should not show any leakage.

A seat tightness test is required at maximum operating pressure, and the test result should no sign of leakage. The time for testing the valve should be sufficient to ensure that the performance is satisfactory. The manufacturer or assembler is required to have a program for documentation of application, calibration, and maintenance of all test gauges.

7.1.5 Inspection and stamping

A Certified Individual (CI) provides oversight to assure that the safety valves and safety relief valves are manufactured and stamped in accordance with the requirements of the ASME Code.

A Certified Individual is an employee of the manufacturer or assembler. The CI is qualified and certified by the manufacturer or assembler. The CI should have knowledge and experience in the requirements of application of ASME Code symbol stamps, the manufacturer's quality program, and special training on oversight, record maintenance, and the Certificate of Conformance. The following are the duties of a CI:

1. Verifying that each valve for which an ASME Code symbol is applied has a valid capacity certification.
2. Reviewing documentation for each lot of items that requirements of the Code have been met.
3. Signing the Certificate of Conformance on ASME Form P-8, for valves manufactured in accordance with Sec. I of the Code.

Each pressure relief valve designed, fabricated, or assembled by a Certificate of Authorization holder should be stamped with the appropriate ASME Code symbols.

The manufacturer or assembler should mark each safety valve with the required data, either on the valve or on a nameplate attached securely to the valve. The Code symbol **V** should be stamped on the valve or on the nameplate. The marking should include the following data:

1. Name of the manufacturer or assembler
2. Manufacturer's design or type
3. Nominal pipe size of the valve inlet, in (mm)
4. Set pressure, psi (kPa)
5. Blowdown, psi (kPa)
6. Capacity, lb/hr (kg/h)
7. Lift of the valve, in (mm)
8. Year built
9. Code **V** symbol stamp
10. Serial number

A nameplate indicating the above information is shown in Fig. 7.6.

① Manufacturer's name or trademark

② Manufacturer's design or type number

③ Size of valve in inches seat diameter

④ Popping pressure setting

⑤ Blowdown in pounds per square inch

⑥ Capacity in pounds per hour

⑦ Lift of the valve in inches

⑧ Year built or code mark

⑨ ASME symbol

⑩ Serial number

TELEDYNE FARRIS ENGINEERING PALISADES PARK NJ USA PAT NO 2517858 AND PATENIS PENDING			
NB			
Type A 584FA			
Size and orifice 1 1/2		Set press 98	PSIG
Cap. " 3% Overpress.	1927		LBS/HR SAT. Steam
Blowdown 4			PSIG
Cap Lift 206			Inches
Serial 3915-S1	Year 1985		

Figure 7.6 Safety valve nameplate data.

7.1.6 Manufacturer's data reports

A Certificate of Conformance for a pressure relief valve is a certificate similar to Manufacturer's Data Reports for boilers. The Certificate of Conformance, Form P-8 (Fig. 7.7), is completed by the manufacturer or assembler and signed by the CI. If multiple duplicate pressure relief valves are identical and manufactured in the same lot, they may be recorded as a single entry.

The manufacturer or assembler is required to retain Certificates of Conformance for a minimum period of 5 years.

7.2 Manufacture of Rupture Disks

Rupture disks are manufactured by either a manufacturer or an organization, which must hold an ASME certification to use Code symbol stamps.

A manufacturer is required to demonstrate to the satisfaction of a representative of an ASME-designated organization that its manufacturing, production, testing facilities and quality control procedures are in accordance with the performance of random production samples and the performance of those devices submitted for certification. An ASME

FORM P-8 MANUFACTURER'S OR ASSEMBLER'S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES

As Required by the Provisions of the ASME Code Rules, Section I

1. Manufactured (or assembled) by _____ ① _____

2. Table of Code symbol stamped items:

[illegible]

3. Remarks _____ (14)

CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted above, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the pressure relief valves conform with the requirements of Section I of the ASME Boiler and Pressure Vessel Code.

V Certificate of Authorization No. 15 Expires 16

Date _____⁽¹⁷⁾ Signed _____⁽¹⁸⁾ Name _____⁽¹⁹⁾
 (Responsible Representative) (Manufacturer or Assembler)

Figure 7.7 Certificate of Conformance. (From ASME Section I.)

designee can inspect the manufacturing, assembly, and test operations at any time.

A Certification of Authorization to apply the ASME Code symbol **UD** (Fig. 7.8), if granted by the ASME, remains valid for 5 years from the date it is issued. This Certificate of Authorization may be extended for another 5-year period if the following tests are successfully completed within 6 months before expiration:

1. Two production sample rupture disk devices of a size and capacity within the capability of an ASME-accepted laboratory are selected by a representative of an ASME-designated organization.



CERTIFICATE OF AUTHORIZATION

This certificate accredits the named company as authorized to use the indicated symbol of the American Society of Mechanical Engineers (ASME) for the scope of activity shown below in accordance with the applicable rules of the ASME Boiler and Pressure Vessel Code. The use of the Code symbol and the authority granted by this Certificate of Authorization are subject to the provisions of the agreement set forth in the application. Any construction stamped with this symbol shall have been built strictly in accordance with the provisions of the ASME Boiler and Pressure Vessel Code.

COMPANY:

**CONTINENTAL DISC CORPORATION
3160 WEST HEARTLAND DRIVE
LIBERTY, MISSOURI 64068-3385**

SCOPE:

**MANUFACTURE OF PRESSURE VESSEL PRESSURE RELIEF DEVICES AT THE
ABOVE LOCATION ONLY**

AUTHORIZED: JANUARY 21, 2004

EXPIRES: MARCH 13, 2007

CERTIFICATE NUMBER: 30,165

Chairman of The Boiler
And Pressure Vessel Committee

Director, Accreditation and Certification



Figure 7.8 Certificate of Authorization for rupture disk. (Courtesy ASME International.)

2. Burst and flow tests are conducted in the presence of a representative of an ASME-designated organization at an authorized test laboratory. The manufacturer should be notified of the time of the test and may have representatives present to witness the test.

3. If any device fails to meet or exceed the performance (burst pressure, minimum net flow area, and flow resistance) requirements, the test can be repeated at the rate of two replacement devices for each device that failed.
4. If any replacement device fails to meet the performance requirements, the authorization to use the Code symbol for that particular device may be revoked by the ASME within 60 days of the authorization. The manufacturer must demonstrate the cause of such failure and the action taken within this period.

7.2.1 Manufacturing ranges

ASME Code Sec. VIII—Division I requires that the marked burst pressure of a disk (also referred to as set pressure) should not exceed the maximum allowable working pressure (MAWP) of a pressure vessel when the disk is used as the primary or sole relief valve.

A customer may request to rupture the disk at a specified pressure. This pressure is called requested burst or rupture pressure. As the burst pressure of a disk is affected by temperature, the burst temperature should also be specified. The requested burst pressure is generally a function of the equipment or system design pressure. Applicable codes and operating conditions should be considered when deciding requested burst pressure.

The marked burst pressure always varies from the requested burst pressure. The amount of this variation is controlled by the manufacturing range for the disk. A manufacturing range is permitted because it is not practical to manufacture rupture disks to an exact value. The range of burst pressure depends on the type of disk, a typical range being +10% to -5% for standard and composite-type disks. The total manufacturing range is always on the minus side for scored rupture disks.

The marked burst pressure is normally determined by bursting at least two disks at the required temperature during the manufacturing process and determining the rupture disk rating. This burst pressure may be anywhere within the specified manufacturing range. The requested burst pressure should be specified in such a way that the upper end of the manufacturing ranges does not exceed the MAWP of the vessel or system.

7.2.2 Rupture tolerances

The ASME Code, Sec. VIII—Division I, also specifies rupture tolerances. This tolerance is $\pm 5\%$ for pressure exceeding 40 psig, or ± 2 psig for pressure up to 40 psig. The manufacturer is required to guarantee that the burst pressure of all rupture disks in a given lot is within this

tolerance from the marked burst pressure for compliance with the ASME Code requirements.

If the marked burst pressure is at or near the maximum of the manufacturing range due to the allowed ruptured tolerance, the actual burst pressure may exceed the MAWP. This situation is permissible under the ASME Code.

7.2.3 Capacity certification

The manufacturer is required to have the relieving capacity of the rupture disk devices certified before stamping with Code symbol stamp **UD**. The types of capacity certification are described below.

Individual rupture disks. The capacity certification for an individual rupture disk by the National Board is shown in Fig. 7.9.

Capacity of pressure relief valves in combination with a rupture disk device at the inlet. The pressure relief valve manufacturer or the rupture disk manufacturer submits for tests the smallest rupture disk device size with the equivalent size of pressure relief valve of the combination device. The pressure relief valve to be tested should have the largest orifice in that particular size inlet.

Capacity certification tests should be conducted with saturated steam, air, or natural gas. Corrections should be made for moisture content of the steam if saturated steam is used.

The test laboratory submits the test results to an ASME-designated organization for acceptance of the combination capacity factor.

Optional testing of rupture disk devices and pressure relief valves. A valve manufacturer or a rupture disk manufacturer may conduct tests according to UG-132 using the next two larger sizes of the rupture disk device and pressure relief valve to determine a combination capacity factor applicable to larger sizes. If established and certified, the combination capacity factor may be used for all larger sizes of the combination. The combination factor cannot be greater than 1.

If desired, additional tests may be conducted at higher pressures to establish a maximum combination capacity factor for use at all higher pressures. However, the combination factor cannot be greater than 1.

Capacity of breaking pin devices in combination with pressure relief valves. Beaking pin devices in combination with pressure relief valves should be tested in accordance with UG-131(d) or UG-131(e) as a combination. Capacity and Code symbol stamping should be based on the capacity established in accordance with these paragraphs.

BS&B SAFETY SYSTEMS, INC., Tulsa, Oklahoma
(with Anderson, Greenwood & Co., Stafford, Texas)

Disk Type Number: S90 Heads: S90-7R or SRB-7RS
Approved in accordance with Section VIII on February 21, 1978
Valve Type: 123/223/323/423/623/923

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	150	Inconel, Teflon	.96
2"	73	Nickel	.96
2"	73	Nickel, Teflon	.96
6"	38	Nickel	.96
6"	41.5	Monel, Teflon	.96

(with IMI Bailey Birkett Ltd., Manchester, England)

Disk Type Number: JRS Heads: SRB-7RS
Approved in accordance with Section VIII on October 20, 1983
Valve Type: WB-400

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	98.5	316 SS	.993

Disk Type Number: S-90 Heads: S-90-7R or SRB-7RS
Approved in accordance with Section VIII on October 21, 1983
Valve Type: WB-400

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	148	Nickel	.994

Disk Type Number: JRS Heads: SRB-7RS
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JB

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	76	Stainless	.993

Disk Type Number: JRS Heads: SRB-7RS
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JO

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	76	Stainless	.998

Disk Type Number: S90 Heads: S90-7R or SRB-7RS
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JB

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	126	Nickel	.955
2"	75	Nickel	.994

Disk Type Number: S90 Heads: S90-7R or SRB-7RS
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JO

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	126	Nickel	.959
2"	75	Nickel	.995

Disk Type Number: SVI Heads: SVI
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JB

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1-1/2"	125	Nickel	.950
2"	90	Nickel	.960

Disk Type Number: SVI Heads: SVI
Approved in accordance with Section VIII on January 7, 1983
Valve Type: JO

Minimum Size	Minimum Set Pressure, PSIG	Combination Material	Capacity Factor
1-1/2"	125	Nickel	.956
2"	90	Nickel	.967

(with Crosby Valve & Gage, Wrentham, Massachusetts)

Disk Type Number: GFN Heads: NF-7R
Approved in accordance with Section VIII on September 19, 1980
Valve Type: JB

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
2"	90	Nickel	.974

Disk Type Number: JRS Heads: SRB-7RS
Approved in accordance with Section VIII on July 23, 1981
Valve Type: JOS/JBS

Minimum Size	Minimum Set Pressure, PSIG	Material	Combination Capacity Factor
1"	60	316 SS	.993

Figure 7.9 Capacity certification for a rupture disk. (Courtesy National Board.)

7.2.4 Production testing

The manufacturer should test each rupture disk device to which an ASME Code symbol stamp is to be applied. In addition, the manufacturer must have a documented program for the application, calibration, and maintenance of gauges and instruments used during the tests.

As a minimum, the manufacturer must conduct the following production tests:

1. The pressure parts of each rupture disk holder exceeding NPS 1 (DN 25) inlet size or 300 psi (2070 kPa) design pressure should be tested at a pressure of minimum 1.5 times the design pressure of the parts. There should not be any visible sign of leakage.
2. Sample rupture disks, selected from each lot of rupture disks, should be made from the same material and size as those used in service. Each lot of rupture disks should be tested by one of the following methods:
 - (a) A minimum of two sample rupture disks from each of rupture disks should be burst at the specified temperature.
 - (b) A minimum of four sample rupture disks, not less than 50% from each lot, should be burst at four different temperatures over the applicable temperature range for which the disks will be used. This data should be used to create a curve of burst pressure versus temperature for the lot of disks. The value of burst pressure should be derived from the curve for a specified temperature.
 - (c) A minimum of four sample rupture disks of prebulged solid metal disks or graphite disks, using one size of disk from each lot of material, should be burst at four different temperatures covering the applicable temperature range. These data should be used for creating a curve of percent change of burst pressures versus temperature for the lot of the material.
 - (d) A minimum of two disks from each lot of disks, made from this lot of material and of the same size, should be burst at the ambient temperature to establish the room-temperature rating of the lot of disks. The percent change should be used to establish the burst pressure at the specified disk temperature for the lot of disks.

7.2.5 Marking

The manufacturer or assembler should mark each rupture disk with data as required by the ASME Code. The data should be marked in such a way that the marking will not be wiped out in service over a period of time.

The rupture disk marking may be placed on the flange of the disk or on a metal tag. The marking should include the following:

1. Name or identifying trademark of the manufacturer
2. Manufacturer's design or type number
3. Lot number
4. Disk material
5. Size [NPS (DN) of rupture disk holder]

6. Marked burst pressure, psi (kPa)
7. Specified disk temperature, °F (°C)
8. Minimum net flow area, in² (mm²)
9. Certified flow resistance (as applicable):
 - (a) K_{RG} for rupture disk certified on air or gases; or
 - (b) K_{RL} for rupture disk certified on liquid; or
 - (c) K_{RGL} for rupture disk certified on air or gases, and liquid
10. ASME Code symbol as shown in Fig. 7.10.
11. Year built; alternatively, a coding may be marked on the rupture disk so that the disk manufacturer can identify the year the disk was assembled and tested.

It is required that items 1, 2, and 5 above and flow direction also be marked on the rupture disk holder.

7.2.6 Manufacturer's data reports

Each rupture disk to which Code symbol **UD** will be applied must be fabricated or assembled by a manufacturer or assembler holding a valid Certificate of Authorization from the ASME. A Certified Individual is required to provide oversight during fabrication of the rupture disks.

The data for each use of the Code symbol shall be documented on Form UD-1 Manufacturer's or Assembler's Certificate of Conformance for Rupture Disk Devices, shown in Fig. 7.11.

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Sizing and Selection

A pressure relief device should be sized in such a manner that the pressure within the protected system cannot exceed the maximum allowable accumulated pressure (MAAP). This means that a pressure relief device should be sized so as to enable it to pass the required amount of fluid at the required pressure under all possible fault conditions. Once the type of relief device has been established, along with its set pressure and its position in the system, the discharge capacity of the device has to be calculated. The required orifice area and nominal size can be determined if the discharge capacity is known.

Pressure relief devices should be selected by engineers who have complete knowledge of the pressure relieving requirements of the system to be protected and the environmental conditions. Selection should not be made based on arbitrarily assumed conditions or incomplete information. Nowadays computer assisted programs are available for sizing and selection of pressure relief devices.

8.1 Pressure Relief Valves

Sizing of pressure relief valves involves calculating the required effective area for the specific valve that will flow the required volume of system fluid at anticipated relieving conditions.

Pressure relief valves are sized either by calculation or by selection from a capacity chart according to the valve type and process fluid. The capacity chart is available in the manufacturer's product catalog and sizing is self-explanatory. Generally, ASME and API formulas are used for sizing calculations.

Alternatively, Windows-based sizing programs for pressure relief valves can be used with the Windows operating systems. This program

includes multi-lingual capability, the ability to save files in a standard Windows format, and the ability to print to any printer configured for the Windows system. The printout options for each valve selection include a datasheet, a drawing showing dimensions, weight, materials, the API designation, and a calculation sheet showing the applicable formula used in the area and capacity calculation. Each selected valve is completely configured to match the order entry, and name-plate designation. The program also includes the capabilities of copying tag numbers, editing the selected valve options, and resizing tag numbers.

This computer program is written based on the latest editions of ASME and API Codes. The program includes the checks for ASME Section VIII – Division 1 compliance, ASME B16.34 pressure temperature limits, API pressure and temperature limits, O-ring and bellows requirements, spring chart limitations, and steam chart correlations. The output includes noise and reaction force calculation, outlines dimensional drawing (installation dimensions), bill of materials for valve component parts, and detailed valve selection criteria.

8.1.1 Valve sizes

Valve sizes are usually selected on the basis of orifice areas. The American Petroleum Institute (API) and the American Society of Mechanical Engineers (ASME) have devised standard equations that are used to size an orifice once the required relieving capacity has been determined. Once the required orifice has been determined then a standard size orifice is selected from a list of standard orifice sizes available from manufacturers.

The orifice areas are listed in API Standard 526. Valve manufacturers generally list their valves by inlet size, API letter designation for nozzle area, and outlet size. Manufacturers also provide ASME standard orifice sizes.

Table 8.1 shows the API and ASME letter designations for valves and their orifice areas.

The user can pick either API or ASME standard orifice sizes. Also, the user must pick orifice coefficients used to determine the required orifice. These orifice coefficients represent deviations from perfect discharge due to friction, viscosity, system backpressure, and multiple relief devices used in combination. For a perfect discharge, all coefficients would be one.

The actual ASME orifice size for a selected orifice is actually the same orifice as the API, although they show two different sizes. ASME gives the actual orifice size whereas API gives the “effective” orifice size.

TABLE 8.1 Standard Letter Designations for Orifice Areas

Orifice letter designation	API		ASME	
	Orifice in ²	Orifice cm ²	Orifice in ²	Orifice cm ²
D	0.110	0.71	0.1279	0.83
E	0.196	1.26	0.2279	1.47
F	0.307	1.98	0.3568	2.30
G	0.503	3.24	0.5849	3.77
H	0.785	5.06	0.9127	5.89
J	1.287	8.30	1.496	9.65
K	1.838	11.85	2.138	13.79
L	2.853	18.40	3.317	21.40
M	3.600	23.23	4.186	27.00
N	4.340	28.00	5.047	32.56
P	6.380	41.16	7.417	47.85
Q	11.050	71.29	12.85	82.90
R	16.000	103.22	18.60	120.00
T	26.000	167.74	28.62	184.64

The default K_d for ASME is 90% of the default K_d for API. For selection purpose, the default K_d is 0.95 for API and 0.855 for ASME. The difference is $0.95 \times 0.9 = 0.855$. When you look at the Table 8.1, the difference between the ASME and the API is always approximately 0.855.

As an example for M orifice, the API size is 3.6 and the ASME size is 4.186. This is because, $4.186 \times 0.855 = 3.58$, which is rounded off to 3.6. This is true for every orifice size to move from API to ASME except for the T orifice, which is a special case.

The selection of the standard orifice is based on API and ASME standard orifices. Table 8.2 shows pressure relief valve inlet and outlet connection sizes for various standard orifices.

Example 8.1: Valve Listing What would be the listing of a pressure relief valve with inlet size 2 in, outlet size 3 in, with orifice D.

Solution The valve listing would be 2D3.

8.1.2 Required sizing data

In order to select the proper pressure relief valve for process application, necessary information should be provided. Details of the fluid and conditions are especially important. The following is a list of sizing data which should be provided to properly size and select a pressure relief valve:

A. Fluid properties

Fluid and state

Molecular weight

TABLE 8.2 Relief Valve Inlet × Outlet Sizes

Letter	Outlet pressure 150 lbs			Outlet pressure 300 lbs		
	Inlet pressure rating as stated below					
	150 lb	300 lb	600 lb	900 lb	1500 lb	2500 lb
	Flange size	Flange size	Flange size	Flange size	Flange size	Flange size
D	1" × 2"	1" × 2"	1" × 2"	1½" × 2"	1½" × 2"	1½" × 3"
E	1" × 2"	1" × 2"	1" × 2"	1½" × 2"	1½" × 2"	1½" × 3"
F	1½" × 2"	1½" × 2"	1½" × 2"	1½" × 3"	1½" × 3"	1½" × 3"
G	1½" × 3"	1½" × 3"	1½" × 3"	1½" × 3"	2" × 3"	2" × 3"
H	1½" × 3"	1½" × 3"	1½" × 3"	2" × 3"	2" × 3"	
J	2" × 3"	2" × 3"	3" × 4"	3" × 4"	3" × 4"	
K	3" × 4"	3" × 4"	3" × 4"	3" × 6"	3" × 6"	
L	3" × 4"	3" × 4"	4" × 6"	4" × 6"		
M	4" × 6"	4" × 6"	4" × 6"			
N	4" × 6"	4" × 6"	4" × 6"			
P	4" × 6"	4" × 6"	4" × 6"			
Q	6" × 8"	6" × 8"	6" × 8"			
R	6" × 8"	6" × 8"	6" × 10"			
T	8" × 10"	8" × 10"				

- Viscosity
- Specific gravity
 - Liquid (referred to water)
 - Gas (referred to air)
- Ratio of specific heats (*k*)
- Compressibility factor (*z*)

B. Operating conditions

- Maximum operating pressure (psig)
- Maximum operating temperature (°F)
- Maximum allowable working pressure (psig)

C. Relieving conditions

- Required relieving capacity
 - Gas or vapor (lb/hr)
 - Gas or vapor (scfm)
 - Liquid (gpm)
- Set pressure (psig)
- Allowable overpressure (%)
- Superimposed back pressure (psig)

(Specify constant or variable)
 Built-up back pressure (psig)
 Relieving temperature (°F)

8.1.3 API sizing

API RP 520 has established the rules for sizing of pressure relief valves. This recommended practice has addressed only flanged spring-loaded and pilot-operated safety valves with a D-T orifice. Valves smaller or larger than those with D-T orifices are not addressed by API RP 520.

The rules and equations of API RP 520 are intended for the estimation of pressure relief device requirements only. Manufacturers may have their own criteria, such as for discharge coefficients and correction factors, that are different from those listed in API RP 520. Final selection of a pressure relief device is made by using the manufacturer's specific parameters, which are based on actual testing.

It is practice to size and select pressure relief valves as per API RP 526 for gas, vapor, and steam service using the API RP 520 K_d value of 0.975 and the effective areas of API RP 526. Although the API K_d values exceed the ASME-certified K values, the ASME-certified areas exceed the effective areas of API RP 526, with the product of ASME-certified K and area exceeding the product of API RP 520 K_d and API RP 526 effective areas.

The value of K is established at the time valves are certified by the ASME and are published for all ASME-certified valves in "Pressure Relief Device Certifications" by the National Board.

Pressure relief valves are selected on the basis of their ability to meet an expected relieving condition and flowing a sufficient amount of fluid to prevent excessive pressure increase. The following steps are used for sizing pressure relief valves:

Step 1. Establish a set pressure at which the valve is to operate. This set pressure is determined based on the pressure limit of the system and the applicable code.

Step 2. Determine the size of the valve orifice.

Step 3. Select a valve size that will flow the required relieving capacity when set at the pressure determined in step 1.

Step 4. Add accessories and options.

Sizing by calculation of the orifice area from a known required capacity is given in API Standard API-520, Part 1—Sizing and Selection of Pressure Relief Devices.

8.1.4 Sizing for vapors and gases

Sizing for vapors and gases can be calculated by either capacity weight or volume. The formulas used are based on the perfect gas laws, which assume that a gas neither gains nor loses heat (adiabatic) and the energy of expansion is converted into kinetic energy. Some gases deviate from the perfect gases, especially when approaching saturation. Various correction factors such as gas constant C , compressibility factor Z , etc., are used to correct for these deviations.

The sizing formulas for vapors or gases fall into two categories based on the flowing pressure with respect to the discharge pressure. These categories are: critical and subcritical.

Critical flow. If a compressible gas is expanded across a nozzle, or an orifice, its velocity and specific volume increase with decreasing downstream pressure. For a given set of upstream conditions, the mass flow rate through a nozzle increases until a limiting velocity is reached in the nozzle. The limiting velocity is the velocity of sound in the flowing fluid at that location. The flow rate corresponding to the limiting velocity is called the critical flow rate.

The critical flow pressure ratio in absolute units is estimated by using the ideal gas relationship in the following equation:

$$\frac{P_{cf}}{P_1} = \left(\frac{2}{K+1} \right)^{k/(k-1)}$$

where P_{cf} = critical flow nozzle pressure, psia

P_1 = upstream relieving pressure, psia

K = ratio of specific heats for any ideal gas

If the pressure downstream of the nozzle is less than or equal to the critical flow pressure P_{cf} , then critical flow will occur.

Sizing for critical flow of vapor and gas services. Pressure relief devices that operate at critical flow conditions are sized according to Eqs. 8.1 and 8.2, below. Each equation is used to calculate the effective discharge area A required to obtain a required flow rate through a pressure relief device. A pressure relief valve that has an effective discharge area equal to or greater than the calculated area A is then selected for the application from API RP 526.

Balanced pressure relief valves may be sized using Eqs. 8.1 and 8.2. The back-pressure correction factor, K_b , for this application should be obtained from the manufacturer.

The formula used for calculating orifice area based on volumetric flow rate is

$$A = \frac{V\sqrt{MTZ}}{6.32CKP_1K_b} \quad (8.1)$$

The formula used for calculating orifice area based on mass flow rate is

$$A = \frac{W\sqrt{TZ}}{CKP_1\sqrt{MK_b}} \quad (8.2)$$

where A = valve orifice area, in²

V = flow capacity (scfm)

W = flow capacity (lb/hr)

M = molecular weight of flowing medium

T = inlet temperature, absolute (°F + 460)

Z = compressibility factor; use $Z = 1.0$ if value is unknown

C = gas constant based on ratio of specific heats at standard conditions

K = ASME coefficient of discharge = 0.975

P_1 = Inlet pressure (psia) during flow

Set pressure (psig) – inlet pressure drop (psig) +
overpressure (psig) + local atmospheric

K_b = capacity correction factor due to back pressure; use $K_b = 1.0$
for atmospheric back pressure

Notes

1. The following equation is used to convert flow capacity from scfm to lb/hr:

$$W = \frac{MV}{6.32}$$

2. The molecular weight (M) of the flowing media can be determined from the specific gravity:

$$M = 29G$$

where G = specific gravity of medium referenced to 1.00 for air at
60°F and 14.7 psig

3. The compressibility factor (Z) can be calculated by the following equation:

$$Z = \left(\frac{1}{F_{pv}} \right)^2$$

A chart for Z for hydrocarbon gas is shown in Fig. 8.1.

4. A gas constant C is based on the ratio of specific heats $K = C_p/C_v$ at standard conditions and is usually given in manufacturers' catalogs. Table 8.3 lists some typical gas properties.
5. The gas constant C from Table 8.3 can be used, or C may be calculated using the following equation:

$$C = 520 \sqrt{k \left(\frac{2}{k+1} \right)^{(k+1)/(k-1)}}$$

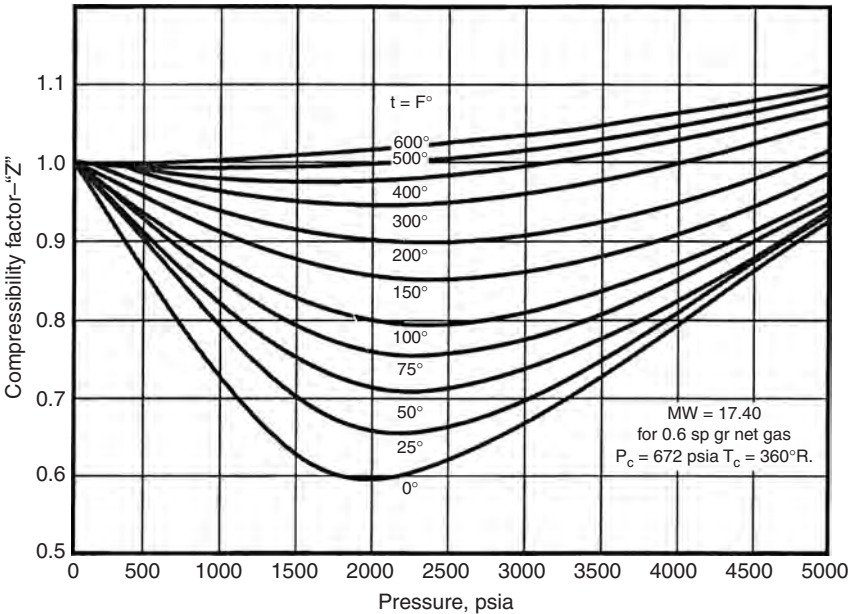


Figure 8.1 Compressibility of hydrocarbon gas.

TABLE 8.3 Properties of Gases

Gas	Molecular weight	<i>C</i> factor	Specific heat ratio <i>k</i>
Acetylene	26	343	1.26
Air	29	356	1.40
Ammonia	17	348	1.31
Argon	40	378	1.67
Benzene	78	329	1.12
Butadiene	54	329	1.12
Carbon dioxide	44	345	1.28
Carbon monoxide	28	356	1.40
Ethane	30	336	1.19
Ethylene	28	341	1.24
Freon 22	86	335	1.18
Helium	4	377	1.66
Hexane	86	322	1.06
Hydrogen	2	357	1.41
Hydrogen sulfide	34	349	1.32
Methane	16	348	1.31
Methyl mercaptan	48	337	1.20
<i>n</i> -Butane	58	326	1.09
Natural gas	18.9	344	1.27
Nitrogen	28	356	1.40
Oxygen	32	356	1.40
Pentane	72	323	1.07
Propane	44	330	1.13
Propylene	42	332	1.15
Steam	18	348	1.31
Sulfur dioxide	64	346	1.29

NOTE: Use *C* = 315 when gas or vapor is unknown.

The value of *C* may also be calculated from Fig. 8.2 if the value of *k* is known. The ratio of specific heat *k* varies with pressure and temperature.

Critical flow of steam. Pressure relief devices in steam service that operate at critical flow conditions are sized using Eq. 8.3. The formula for calculating orifice area for critical flow of steam vapor is

$$A = \frac{W}{51.5KK_{SH}K_pP_1} \quad (8.3)$$

where *A* = orifice area, in²

W = flow capacity, lb/hr

K = ASME coefficient of discharge

K_{SH} = superheat correction factor

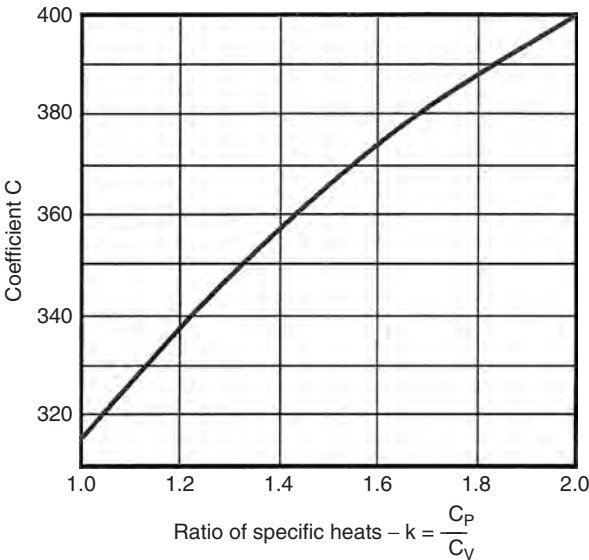


Figure 8.2 Gas constant, C.

K_p = correction factor for pressure above 1500 psig
 P_1 = inlet pressure during flow (psia) (Set – inlet pressure loss + overpressure + local atmospheric)

Notes

- 1. The superheat factor K_{SH} corrects for the flow rate of steam above the saturation temperature. $K_{SH} = 1.0$ for saturation temperature. For temperatures less than saturation temperature, K_{SH} is less than 1.00. Appendix B shows a list of superheat correction factors.
- 2. The high-pressure correction factor K_p corrects for the increase in flow rate above 1500 psig. It is dependent only on the absolute inlet pressure. Figure 8.3 illustrates a curve showing this correction factor.

Example 8.2: Sizing—Sonic Flow What orifice area is required to protect a process vessel from overpressure due to an upstream control valve failure, if the maximum capacity of the control valve is 126,000 scfm? The maximum allowable working pressure of the vessel is 1000 psig.

Solution

Required capacity	126,000 scfm
MAWP	1000 psig
Molecular weight of gas	18.9

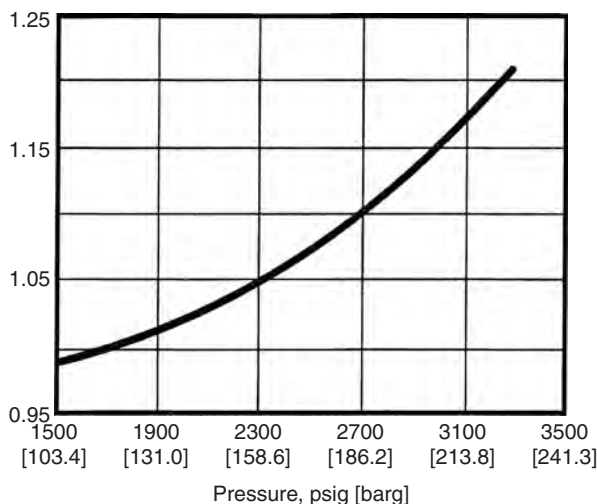


Figure 8.3 High-pressure correction factor.

Gas temperature	60°F
Compressibility factor	1.00 (assumed)
Gas constant	344
PRV coefficient	0.975
Inlet piping pressure loss	15%
Built-up back pressure	150 psig
Capacity correction factor K_b	1.0 (from manufacturer's catalog)

Using MAWP as the set pressure for the pressure relief valve, the equation is

$$A = \frac{V\sqrt{MTZ}}{6.32CKP_1K_b}$$

$$A = \frac{126,000\sqrt{(18.9)(460 + 60)(1.00)}}{6.32(344)(0.975)[(1000 - 150 + 100 + 14.7)](1.00)}$$

$$A = 6.11 \text{ in}^2$$

The next larger orifice area is an API "P" orifice. Therefore, either a balanced bellows spring PRV or a pilot-operated PRV in a 4P6 size would be the proper selection. The choice of a conventional PRV is out of question, as the back pressure is >10%.

Subcritical flow. When the ratio of back pressure to inlet pressure exceeds the critical pressure ratio P_{cf}/P_1 , the flow through the pressure relief

device is subcritical. Equations 8.4 and 8.5 may be used to calculate the required effective discharge area for a conventional pressure relief valve that has its spring setting adjusted to compensate for superimposed back pressure. Equations 8.4 and 8.5 may also be used for sizing a pilot-operated relief valve. The formula for calculating orifice area based on volumetric flow rate is

$$A = \frac{V\sqrt{MTZ}}{4645K_{vc}P_1F} \quad (8.4)$$

The formula for calculating orifice area based on mass flow rate is

$$A = \frac{W\sqrt{TZ}}{735K_{vc}P_1F\sqrt{M}} \quad (8.5)$$

where the flow correction factor F is

$$F = \sqrt{\frac{k}{k-1}} \left[\left(\frac{P_2}{P_1} \right)^{2/k} - \left(\frac{P_2}{P_1} \right)^{(k+1)/k} \right]$$

Example 8.3: Sizing—Subsonic Flow What orifice area would be required to protect a refrigerated liquefied natural gas (LNG) storage tank from overpressure due to vapor generated by failure of the boil-off compressor?

The calculated blow-off rate is 25,000 scfm. The MAWP of the vessel is 1.50 psig.

Given

MAWP	1.5 psig
Molecular weight of gas	18.9
Gas temperature	−260°F
Compressibility factor (assumed)	1.0
Ratio of specific heats	1.27
Inlet piping pressure loss	0%
Discharge piping	None

Solution The equation is

$$A = \frac{V\sqrt{MTZ}}{4645K_{vc}P_1F}$$

where $V = 25,000$ scfm

$$M = 18.9$$

$$T = (-260 + 460) = 200^\circ\text{R}$$

$$Z = 1.00$$

$$P_1 = (1.50 + 0.15 + 14.7) = 16.35 \text{ psia}$$

$$P_2 = 14.7 \text{ psia}$$

$$K_{VC} = 0.676 @ P_2/P_1 = 0.899 \text{ (from manufacturer's catalog)}$$

$$k = 1.27$$

$$F = \sqrt{\frac{k}{k-1}} \left[\left(\frac{P_2}{P_1} \right)^{2/k} - \left(\frac{P_2}{P_1} \right)^{(k+1)/k} \right]$$

$$F = \sqrt{\frac{1.27}{0.27}} \left[\left(\frac{14.7}{16.35} \right)^{2/1.27} - \left(\frac{14.7}{16.35} \right)^{2.27/1.27} \right]$$

$$A = \frac{25,000 \sqrt{(18.9)(200)(1.0)}}{4645(0.676)(16.35)(0.2984)}$$

$$A = 100.33 \text{ in}^2$$

An overpressure of 10% was used. Section 6.0 of API 620 specifies the maximum pressure to be limited to 110% of MAWP. The set pressure was selected to be the same as the MAWP.

8.1.5 Sizing for liquids

In accordance with ASME Sec. VIII, Division 1 rules, capacity certification should be obtained for pressure relief valves designed for liquid service. The capacity certification includes testing to determine the rated coefficient of discharge for the liquid relief valves at 10% overpressure. The formula for calculating orifice area based on volumetric flow rate is

$$A = \frac{Q\sqrt{G}}{38KK_wK_v\sqrt{P_1 - P_2}} \quad (8.6)$$

where A = valve orifice area, in^2 (mm^2)

Q = flow rate (U.S. gal/min)

G = specific gravity of liquid at flowing temperature referenced to water = 1.00 at 70°F

- K = ASME coefficient of discharge on liquid
 K_w = back pressure correction factor for direct spring-loaded valves due to reduced lift (for all other valves, $K_w = 1.00$)
 K_v = viscosity correction factor
 P_1 = inlet pressure during flow = set pressure – inlet pressure loss + allowable overpressure (psig)
 P_2 = back pressure during flow (psig)

Notes

1. K_w factor: The K_w correction factor can be obtained from the valve manufacturer. Figure 8.4 is a typical graph for a balanced direct spring-loaded valve in liquid service.

The set pressure always varies with back pressure for unbalanced valves. The set pressure is not affected by back pressure for balanced valves. In unbalanced direct spring-loaded valves, K_w equals 1.00. For pilot-operated relief valves, K_w is always equal to 1.00 since lift is not affected by back pressure.

2. When a relief valve is sized for viscous liquid service, it is first sized as if it were for a nonviscous liquid by using K_v factor = 1.00. For a viscous liquid (above 100 Saybolt universal seconds), a preliminary required discharged area, A , is determined by using $K_v = 1.00$. From

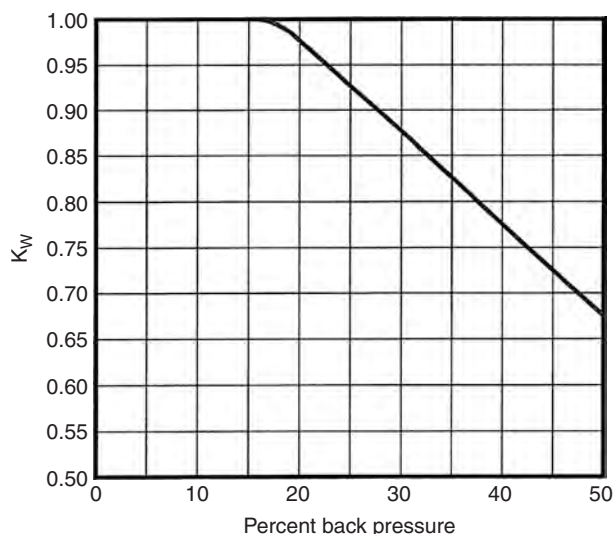


Figure 8.4 K_w for balanced bellows spring valves on liquids.

API RP 526, the next orifice size larger than A should be used in determining the Reynolds number, R , from the following equation:

$$R = \frac{2800GQ}{\mu\sqrt{A'}} \quad (8.7)$$

where R = Reynolds number

A' = next larger valve orifice area, in² (mm²)

G = specific gravity of liquid

Q = required capacity in U.S. gal/min (liters/min)

U = viscosity at the flowing temperatures, in Saybolt universal seconds, SSU

μ = absolute viscosity at flowing temperature, in cP

If R is known, the viscosity correction factor K_v can be determined from Fig. 8.5. Then K_v is applied to Eq. 8.6 to correct the preliminary required discharge area. If the corrected area is less than the next larger orifice area, chosen to calculate the Reynolds number, the

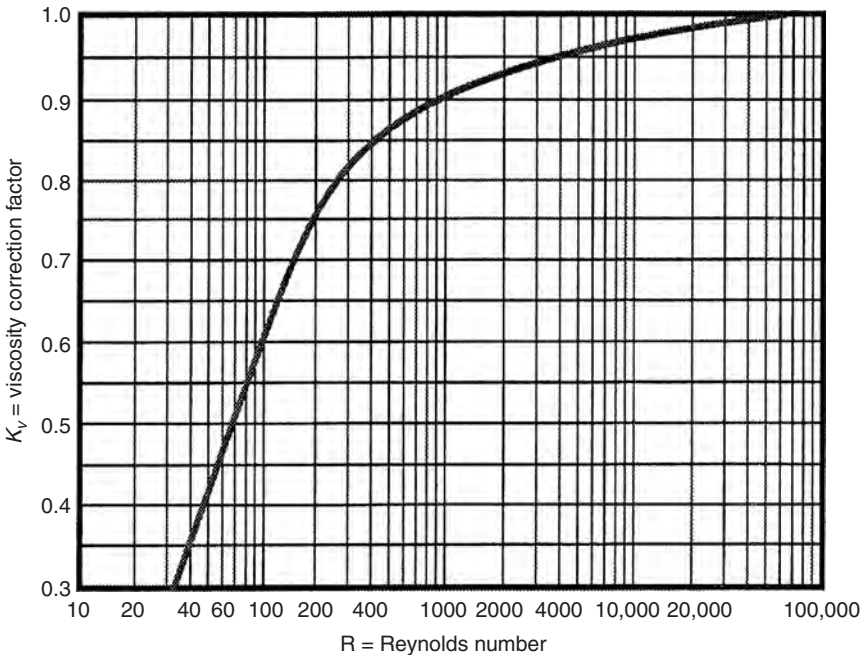


Figure 8.5 Viscosity correction factor.

chosen orifice is adequate. If the corrected area exceeds the chosen standard orifice area, the above calculation should be repeated using the next larger standard orifice size.

Example 8.4: Sizing—Liquid Flow What orifice area is required to protect a lubrication oil system from overpressure if the pump capacity is 150 gal/min?

The maximum allowable working pressure of the system is 4000 psi. The pressure relief valve discharges into a closed header. An ASME UV valve has been used.

Given

MAWP	1440 psi
Specific gravity of oil	0.75
PRV coefficient	0.74
Required flow rate	150 U.S. gal/min
Built-up back pressure	100 psig
Viscosity of oil	2000 SSU
Inlet pressure losses	3%

A full-nozzle, spring PRV is required.

Solution The required equation is

$$A = \frac{Q\sqrt{G}}{38KK_WK_V\sqrt{P_1 - P_2}}$$

where $Q = 150$

$$G = 0.75$$

$$K = 0.74$$

$$K_W = 1.00$$

$$P_1 = 1440 - 43 + 144 = 1541 \text{ psig}$$

$$P_2 = 100$$

Assume that $K_V = 1.00$. Then

$$A = \frac{150\sqrt{0.75}}{38(0.74)(1.00)(1.00)\sqrt{1541 - 100}}$$

$$A = 0.122 \text{ in}^2$$

To correct for viscosity, the next larger orifice available for the valve type chosen is used to calculate the Reynolds number. The next larger orifice is 0.196 in^2 .

Therefore,

$$R = \frac{12,700Q}{U\sqrt{A'}}$$

$$R = \frac{12,700(150)}{2000\sqrt{0.196}} = 2151$$

$R = 2151$; therefore, $K_V = 0.94$. The corrected area A is

$$A = \frac{0.122}{0.94} = 0.130 \text{ in}^2$$

As the corrected area of 0.130 in^2 is smaller than the next larger orifice, the 0.196-in^2 orifice is adequate to handle the flow.

8.1.6 Sizing for air

The formula for calculating orifice area for volumetric air flow rate is determined using

$$A = \frac{60Q(0.0763)\sqrt{TZ}}{356KP_1(5.3824)K_b} \quad (8.8)$$

where Q = scfm flow rate at 14.7 psia and 60°F .

Example 8.5: Sizing—Air What valve orifice size is needed for the following application of air?

Fluid	Air
Required flow rate	15,000 ft^3/min
Set pressure	200 psi
Overpressure	16%
Back pressure	Atmospheric
Inlet relieving temperature	150°F

Given

$$Q = 15,000 \text{ ft}^3/\text{min}$$

$$T = 150 + 460 = 610^\circ\text{R}$$

$$Z = \text{compressibility factor, use } z = 1.0$$

$$P_1 = 200 + 32 + 14.7 = 246.7 \text{ psia}$$

$$K = 0.975$$

$K_b = 1.0$ for atmospheric back pressure

$M = 28.97$

Solution The minimum required effective discharge area A is

$$A = \frac{60Q(0.0763)\sqrt{T}\sqrt{Z}}{356KP_1(5.3824)K_b}$$

$$A = \frac{(60)(15,000)(0.0763)\sqrt{(610)(1)}}{(356)(0.975)(246.7)(5.3824)(1.0)}$$

$$A = 3.68 \text{ in}^2$$

Therefore, a valve of “N” orifice with an effective area of 4.34 in² is selected for this application.

8.1.7 Sizing multiple valves

An installation may require one or more pressure relief valves as per ASME Sec. VIII, Division 1, and API RP 520. The application requires the pressure relief valve(s) to provide overpressure protection caused by non-fire- and fire-related situations. Set pressure and overpressure requirements vary with the type of installation.

The overpressure is the difference between the accumulation of the system and the set pressure of the pressure relief valve. The flow pressure P_1 is set equal to the system accumulation pressure to determine the valve orifice area.

Single-valve installations. When only one valve is required for system overpressure protection, the following situations are considered:

1. Overpressure due to non-fire-exposure event:

- (a) The set pressure is equal to or less than the MAWP of the system.
- (b) The accumulation of the system should not exceed the larger of 3 psi or 10% above the MAWP:

$$P_1 = \text{MAWP} + 3 + 14.7 \quad \text{MAWP 15–30 psig}$$

$$P_1 = 1.1(\text{MAWP}) + 14.7 \quad \text{MAWP} > 30 \text{ psig}$$

2. Overpressure due to fire-exposure event:

- (a) The set pressure is equal to or less than the MAWP of the system.
- (b) The accumulation should not exceed 21% above MAWP:

$$P_1 = 1.21(\text{MAWP}) + 14.7 \quad \text{MAWP} > 15 \text{ psig}$$

Multiple-valve installations. When more than one valve is required for system overprotection, the following situations are considered:

1. Overpressure due to non-fire-exposure event:

- (a) The set pressure of one valve should be less than or equal to the MAWP of the system. The set pressure of the remaining valve(s) should not exceed 1.05 times the MAWP.
- (b) The accumulation of the system should not exceed the larger of 4 psi or 16% above the MAWP:

$$P_1 = \text{MAWP} + 4 + 14.7 \quad \text{MAWP 15–25 psig}$$

$$P_1 = 1.16(\text{MAWP}) + 14.7 \quad \text{MAWP} > 25 \text{ psig}$$

2. Overpressure due to fire-exposure event:

- (a) The set pressure of at least one valve should be equal to or less than the MAWP of the system. The set pressure of the remaining valve(s) should not exceed 1.10 times the MAWP.
- (b) The accumulation of the system should not exceed 21% above MAWP:

$$P_1 = 1.21(\text{MAWP}) + 14.7 \quad \text{MAWP} > 15 \text{ psig}$$

Example 8.6: Sizing—Multiple-Valve Installation What orifice areas would be required for the following multiple-valve application?

Fluid	Natural gas
MAWP	6000 lb/hr
Set pressure	210 psig
Overpressure	16%
Back pressure	Atmospheric
Inlet relieving temperature	120°F
Molecular weight	19.0

Given

$$W = 6000 \text{ lb/hr}$$

$$T = 120 + 460 = 580^\circ\text{R}$$

$$Z = \text{compressibility factor, use } Z = 1.0$$

$$P_1 = (210)(1.16) + 14.7 = 258.3 \text{ psia}$$

$$C = 344 \text{ (from Table 8.3)}$$

$$K = 0.975$$

K_b = capacity correction factor due to back pressure, use $K_b = 1.0$ for atmospheric back pressure
 $M = 19.0$

Solution The minimum required effective discharge area A is

$$A = \frac{W\sqrt{TZ}}{CKP_1K_b\sqrt{M}}$$
$$A = \frac{(6000)\sqrt{(580)(1)}}{(344)(0.975)(258.3)(1)\sqrt{19}}$$
$$A = 0.382 \text{ in}^2$$

Therefore, two “E” orifice valves with a total area of 0.392 in² are required to meet the required flow for this multiple-valve application. The effective area of each “E” orifice valve is 0.196 in². One valve should be set at MAWP = 210 psig and one should be set at 105% of MAWP or 220.5 psig.

8.1.8 Saturated-water valve sizing

ASME Code Sec. VIII, Division 1, App. 11 provides specific rules for determining valve-relieving orifice areas required for saturated-water service. However, the valve has to be continuously subjected to saturated water for these rules to apply. If, after initial relief the flow changes to quality steam, the valve should be treated as per dry saturated steam.

The rules apply to those safety valves that have a nozzle type construction (throat-to-inlet-area ratio of 0.25–0.80 with a continuously contoured change) and have exhibited a coefficient K_d in excess of 0.90.

Figure 8.6 is used to determine the saturated-water capacity of a valve rated under UG-131 of Sec. VIII, Division 1. Enter the graph at the set pressure, move vertically upward to the saturated-water line, and read the relieving capacity horizontally. This capacity is a theoretical, isentropic value determined by assuming equilibrium flow and calculated values for critical pressure ratio.

Example 8.7: Sizing—Saturated-Water Valve What would be the orifice area of a safety relief valve used for the following application?

Fluid	Saturated water
Required capacity	195,200 lb/hr
Allowable overpressure	10%
Set pressure	600 psig
Relieving temperature	470°F

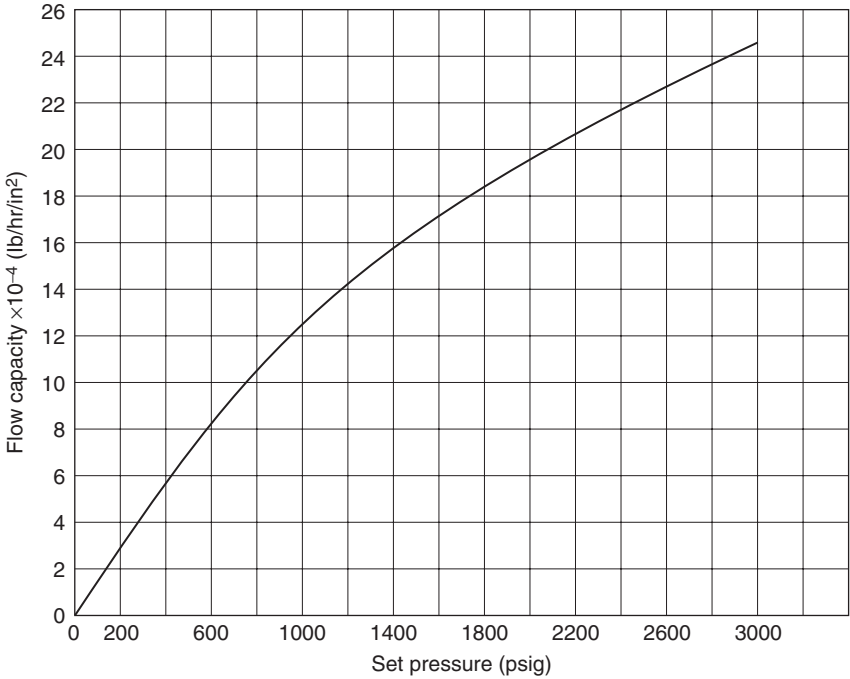


Figure 8.6 Flow capacity curve for rating nozzles.

Solution

Step 1. Review the saturated-water capacity curve (Fig. 8.6) for capacity of 1 in² of orifice area at a given set pressure.

Capacity of 1 in² = 84,000 lb/hr @ 600 psig set pressure

Step 2. Divide the required capacity by the capacity of 1 in² to get the required orifice area:

$$\frac{195,200}{84,000} = 2.32 \text{ in}^2$$

Step 3. Therefore, an “L” orifice valve is required that has a relieving orifice (API) area of 2.853 or ASME area of 3.317 in².

8.1.9 RRV and rupture disk combinations

The rated relieving capacity of a pressure relief valve in combination with a rupture disk is equal to the capacity of the pressure relief valve

multiplied by a combination capacity factor for account for any flow losses attributed to the rupture disk.

The following two situations should be considered when sizing pressure relief valves as combination devices:

1. *Rupture disk not certified with pressure relief valve.* In this situation, the pressure relief valve is sized according to the previous identified methods. This combination of rupture disk and pressure relief valve can only be credited with 90% of its ASME-certified relieving capacity. That means a combination capacity factor of 0.90 may be used.
2. *Rupture disk certified with the pressure relief valve.* In this situation, the particular type of pressure relief valve has actually been flow tested in combination with a rupture disk and a combination capacity factor has been established. The combination capacity factor (Fig. 8.7) is published by the National Board. The ASME-certified relieving capacity should be multiplied by the combination capacity factor to obtain the allowable ASME relieving capacity for the combination of the pressure relief valve and rupture disk.

Example 8.8: Sizing—Combination of Pressure Relief Valve and Rupture Disk Determine the orifice area of a pressure relief valve used in combination with a rupture disk for the following application:

Fluid	Natural gas
Required capacity	7300 lb/hr
Set pressure	210 psig
Overpressure	10%
Back pressure	Atmosphere
Inlet relieving temperature	120°F
Molecular weight	19.0

Given

$$W = 7,300 \text{ lb/hr}$$

$$T = 120 + 460 = 580^\circ\text{R}$$

$$Z = \text{compressibility factor, use } Z = 1.0$$

$$P_1 = (210)(1.10) + 14.7 = 245.7 \text{ psia}$$

$$C = 344$$

$$K = 0.975$$

$$K_b = 1.0 \text{ for atmosphere back pressure}$$

$$M = 19.0$$

Valve Model		Min Size	Minimum Burst Pressure PSIG	Material	Capacity Factor
Rupture Disc Model: Poly-SD	Dresser 1900, 1900-30, 1900-35	1 in.	60	Nickel	0.992
		1 in.	200	SST	0.986
	Dresser 1900, 1900-30	2 in.	75	Alum/Teflon	0.994
	Dresser 3900-1	2 in.	55	Alum/Teflon	0.989
	Dresser 1900E-2, 1900-30E-2, 1900-35E-2	1 in.	60	Nickel	0.990
	Restricted Lift E Orifice Only	1in	200	316 SST	0.987
	Teledyne Ferris 2600 (Double Disc Assy Only)	2 in	83	Nickel	0.974
	Teledyne Ferris 2600 and 4500	1 in	60	Ni/Teflon	0.991
		1 in	60	Nickel	0.997
		1 in	105	Tantalum	0.994
		1 in	142.2	Inconel	1.000
		1.5 in	150	SST	0.985
	Teledyne Ferris 274OUL	1 in	63.5	Ni/Teflon	0.990
	Kunkle 910 to 929, 75	2 in	50	Nickel	0.996
	Kunkle 5000	2 in	50	Nickel	1.000
	Fukui RE	1.5 in	60	Nickel	0.999
Rupture Disc Model: MFK	Anderson Greenwood 323	1 in	88	316 SST	0.9912
		1.5 in	67	316 SST	0.9903
		3 in	39	Tantalum	0.9934
		6 in	14.6	316 SST	0.9621
	Dresser 1900	1 in	59	SST	0.976
		1 in	53	Nickel	0.979
		1.5 in	48	SST	0.979
		1.5 in	57	SST	0.992
		3 in	21	Nickel	0.983
	Lonergan D, DB	1A	30	316 SST	0.972
		1A	50	Nickel	0.988
		3 in	21	316 SST	0.946
		3 in	19.8	Nickel	0.976
	Teledyne Ferris 2600, 4500	1 in	74	SST	0.976
		1 in	79	Nickel	0.997
		1.5 in	58	Nickel	0.990
		3 in	34	Nickel	0.983
		3 in	35	316 SST	0.978
	Crosby JOS, JBS	1 in	60	316 SST	0.967
		1 in	60	Nickel	0.977
		3 in	35	316 SST	0.982
		3 in	35	Nickel	0.995
	Fukui RE	1.5 in	58	Nickel	0.994
		1.5 in	57	316 SST	0.985

Figure 8.7 Combination capacity factor. (Courtesy National Board.)

Solution

$$A = \frac{W\sqrt{TZ}}{CKP_1K_b\sqrt{M}}$$
$$A = \frac{(7300)\sqrt{(580)(1)}}{(344)(0.975)(245.7)(1)\sqrt{19.0}}$$
$$A = 0.490 \text{ in}^2$$

A standard application would require a “G” orifice-style pressure relief valve with an effective area of 0.503 in². In this case the pressure relief valve is used in combination with a rupture disk.

Let us assume that a rupture disk combination factor of 0.90 would be used. The minimum required effective discharge area may be calculated using the following formula:

$$\begin{aligned}\text{Required area} &= \frac{A}{F_{\text{comb}}} \\ &= \frac{0.490}{0.9} \\ &= 0.55 \text{ in}^2\end{aligned}$$

Therefore, this application with a rupture disk would require an “H” orifice-style pressure relief valve with an effective area of 0.875 in^2 . This size is one valve size larger than for pressure relief valve application alone.

8.1.10 Sizing for thermal expansion of trapped liquids

A pressure relief device should be provided where liquid-full equipment can be blocked in and continued heat input cannot be avoided. Flow rates for relieving devices to protect heat exchangers, condensers, and coolers against thermal expansion of trapped liquids can be determined using the following formula:

$$\text{GPM} = \frac{BH}{500GC} \quad (8.9)$$

where GPM = flow rate in U.S. gal/min at the flowing temperature

B = cubical expansion coefficient per °F for the liquid at the expected temperature differential

H = total heat transfer rate, in BTU/hr (maximum exchanger duty during operation)

G = specific gravity referred to water = 1.00 at 60°F (compressibility of the liquid is ignored)

C = specific heat in BTU/lb/°F of the trapped fluid

Notes

1. *Cubical expansion coefficient B .* It is recommended that this value be obtained from the process design data. Typical values of cubical expansion coefficient for hydrocarbon liquids and water at 60°F are:

Gravity of liquid (°API)	B
3–34.9	0.0004
35–50.9	0.0005
51–63.9	0.0006

64–78.9	0.0007
79–88.9	0.0008
89–93.9	0.00085
94–100 and higher	0.0009
Water	0.0001

2. *Specific heat C.* Typical values of specific heats at 100°F for trapped liquids are:

Liquid	<i>C</i>
Water	4.18
Ammonia	2.18
Methane	2.27
Propane	1.75

Example 8.9: Sizing for Thermal Expansion A horizontal heat exchanger vessel handles ammonia at 60°F. What is the flow rate of ammonia in gal/min?

Given

<i>B</i> = thermal cubical expansion	0.0006
<i>C</i> = specific heat of trapped fluid	2.27 Btu/lb/°F
<i>G</i> = specific gravity	0.588
<i>H</i> = total heat transfer	12,000,000 Btu/hr

Solution Flow rate is determined by the following formula:

$$\text{GPM} = \frac{BH}{500GC}$$

$$\text{GPM} = \frac{(0.0006)(12,000,000)}{(500)(0.588)(2.27)}$$

$$\text{GPM} = 10.78$$

Therefore, flow rate is 10.78 gal/min.

8.1.11 Sizing for mixed phases

A pressure relief device handling mixed phases (liquid and vapor) produces flashing with vapor generation as the fluid moves through the device. The vapor generation should be taken into consideration, as it may reduce the effective mass flow capacity of the device.

In the past, the API suggested treating each phase separately, with the total calculated orifice area being the total for all phases. Since then, alternative methodologies have been developed, and new methodologies are under development to handle these complex multiphase systems.

The Design Institute for Emergency Relief Systems (DIERS), sponsored by the American Institute of Chemical Engineers (AIChE), has been active in extensive research toward developing methods for determining pressure relief valve orifice areas for multiphase systems. API RP 520, Part 1, App. D, gives several new techniques for sizing PRVs in multiphase systems. These methods, however, have not been validated by test, and there is no recognized procedure for certifying the capacity of pressure relief valves in two-phase-flow service.

8.2 Rupture Disks

A rupture disk is a precision relief device designed to rupture at a predetermined pressure and temperature. Rupture disks have to be selected and sized very carefully to meet process requirements. The following steps can be used as a guide to selecting the proper type of rupture disk:

1. List the following information:
 - Maximum allowable working pressure of the vessel or system
 - Maximum operating pressure
 - Maximum temperature at the disk location
 - Desired rupture disk burst pressure and temperature
 - Back pressure or vacuum conditions, if any
 - Medium, liquid or gas; corrosion characteristics of the medium
 - Static, cycling, or pulsating device
 - Code requirements: ASME, ISO, API, CEN, etc.
2. Calculate the ratio of maximum operating pressure to minimum burst pressure. Manufacturing range should be taken into consideration in determining minimum burst pressure. The following is an example.

Example 8.10 The variables for rupture disk selection are given below. What is the ratio of maximum operating pressure to minimum burst pressure for the rupture disk?

Maximum operating pressure	70 psig
MAWP	110 psig
Standard manufacturing range	+10% to -5%

Solution If a burst pressure of 100 psig is requested, that allows a manufacturing range of 95–110 psig. In this case, minimum burst pressure is 95 psi. Therefore, the ratio of the maximum operating pressure to minimum burst pressure is $70/90 = 74\%$.

3. Select a disk type that meets the constraints of the pressure ratio calculated above. This ratio should be 0.9 or less. A lower pressure ratio often permits the use of a less expensive disk type.

4. Select an appropriate material that meets the corrosion and/or temperature requirements.
5. Check the manufacturer's bulletin or brochure to assure that the burst pressure is within the available burst pressure ranges for the material and disk type selected. Also, check the size.
6. Select required holders and options, if any.

8.2.1 Sizing method

The ASME Code defines three methods for sizing rupture disks: the coefficient-of-discharge method, the resistance-to-flow method, and the combination capacity method:

Coefficient of discharge method (K_D). The K_D is the coefficient of discharge that is applied to the theoretical flow rate to arrive at a rated flow rate for a simple system. The coefficient-of-discharge method uses the calculated flow capacity of the device and then derates that capacity by a K_D of 0.62. This method is applicable under the following conditions:

- The disk discharges to the atmosphere.
- The disk will be installed within 8 pipe diameters of the vessel nozzle.
- The length of discharge piping will not exceed 5 pipe diameters.
- The inlet and outlet piping are at least the same nominal size as the rupture disk device.

This system is also described by the “8 & 5 rule” as shown in Fig. 8.8.

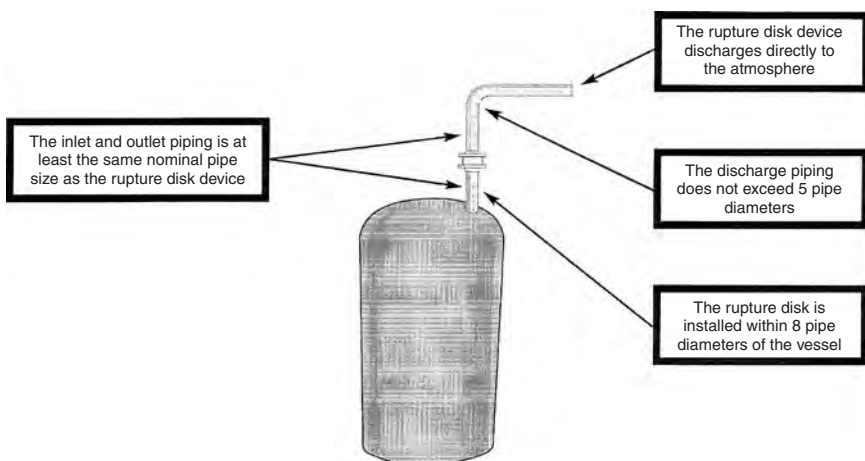


Figure 8.8 Application of coefficient-of-discharge method. (Courtesy Fike Corporation.)

Resistance-to-flow method (K_R). The rupture disk is considered as a flow-resistive element within the relief system. The resistance of the rupture disk is denoted by the certified resistance factor K_R . The K_R value represents the velocity head loss due to the rupture disk device. This head loss is included in the overall system loss calculations to determine the capacity of the relief system. It is also important to note that the certified K_R represents the device (disk and disk holder), not just the rupture disk. If there is no holder, the K_R value is for the disk.

The resistance-to-flow method requires that the calculated relieving capacity of the system be multiplied by 0.90 to allow for uncertainties inherent in this method. This method is applicable under the following conditions:

- When the 8 & 5 rule does not apply
- For calculating the pressure drop between the pressure vessel and the valve, when the disk is installed in combination with a pressure relief valve

Combination capacity method. The combination capacity method is used when a rupture disk is installed on the inlet side of a pressure relief valve. This method requires that a rupture disk of the same nominal size or larger than the pressure relief valve's inlet be used, and one then derates the valve capacity by 0.90 or higher for that disk/valve combination.

Safety Valves for Power Boilers

A power boiler is defined as a boiler in which steam or other vapor is generated at a pressure of more than 15 psi for use external to itself. ASME Code Sec. I—Power Boilers code covers rules for construction of power boilers.

A power boiler is basically a high-pressure boiler, and includes the following types:

Electric boiler—a power boiler or a high-temperature water boiler in which the source of heat is electricity

Miniature boiler—a power boiler or a high-temperature water boiler in which the following limits are not exceeded:

- 16 in (406 mm) inside diameter of shell
- 20 ft² (1.9 m²) heating surface (not applicable to electric boilers)
- 5 ft³ (0.14 m³) gross volume, exclusive of casing and installation
- 100 psig (690 kPa) maximum allowable working pressure

High-temperature water boiler—a water boiler intended for operation at pressures in excess of 160 psi and/or temperatures in excess of 250°F.

Organic fluid vaporizer—a device similar to a boiler in which an organic fluid is vaporized by the application of heat resulting from the combustion of fuel (solid, liquid, or gas).

Safety valves are used on power boilers that generate steam. Power boilers such as electric boilers, miniature boilers, and organic fluid vaporizers are generally fitted with safety valves. On the other hand, power boilers such as high-temperature water boilers use safety relief valves. Figures 9.1 through 9.3 show pictures of safety valves and safety relief valves on various boilers. Figure 9.4 shows a typical safety valve used on a power boiler.

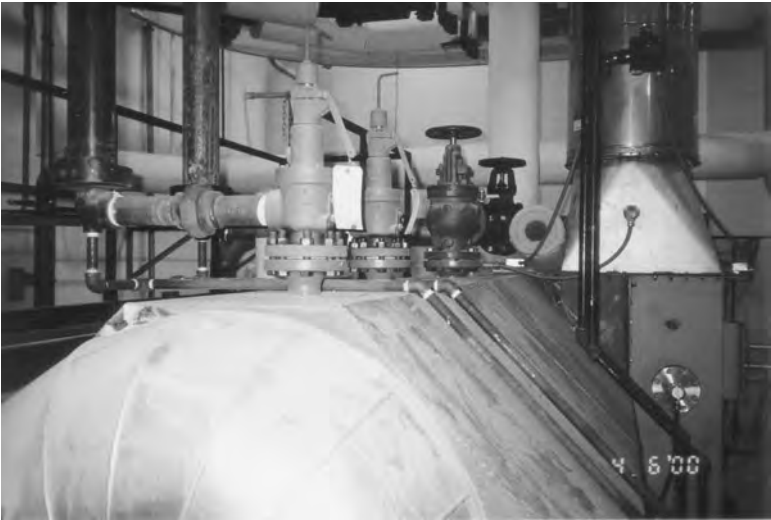


Figure 9.1 A power boiler showing two safety valves.



Figure 9.2 Safety valve on an electric boiler.

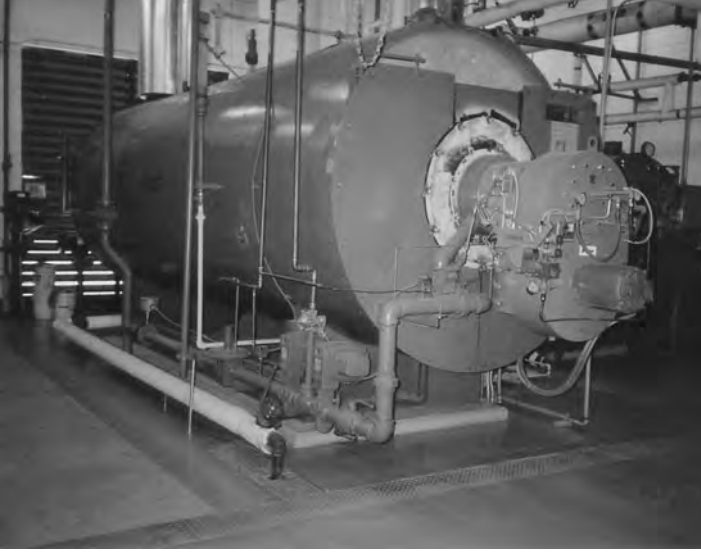


Figure 9.3 A high-temperature water boiler uses a safety relief valve.



Figure 9.4 A typical safety valve. (Courtesy Dresser Flow Control.)

Safety valves and safety relief valves are the most important valves on a power boiler. Catastrophic accidents can occur if safety valves fail to open in case of a power boiler explosion. Great importance is given to the design, construction, inspection, and repair of safety valves. Paragraphs from PG-67 to PG-73 of ASME Code Sec. I describe the rules for safety valves and safety relief valves used for power boilers.

9.1 Operational Characteristics

The operational characteristics of safety valves or safety relief valves used for power boilers are shown in Table 9.1.

Exception: Safety valves on forced-flow-steam generators with no fixed steam and waterline, and safety relief valves used on high-temperature water boilers, may be set and adjusted to close after blowing down not more than 10% of the set pressure.

Overpressure:

No greater than 3% over the set pressure

9.2 Code References

Design, construction, inspection, testing, stamping, and certification of safety valves for power boilers must meet the requirements of ASME Code Sec. I. References to ASME Code Sec. I for these requirements are shown in Table 9.2.

9.3 Design Requirements

Safety valves for power boilers are designed according to the provisions of PG-67 to PG-73 of ASME Code Sec. I. Designs are submitted at the time of capacity certification or testing. The ASME designee reviews the design of the valves for conformity with the requirements of Sec. I.

TABLE 9.1 Operational Characteristics of Safety Valves and Safety Relief Valves

Set-pressure tolerance:	
2 psi	15–70 psi
3%	71–300 psi
10 psi	301–1000 psi
1%	>1000 psi
Blowdown:	
4 psi	<67 psi
6%	>67 psi to 250 psi
15 psi	>250 psi to 375 psi

TABLE 9.2 References to ASME Code Sec. I

Requirements	Reference paragraph
Boiler Safety Valve Requirements	PG-67
Superheater and Reheater Safety Valve Requirements	PG-68
Certification of Capacity of Safety and Safety Relief Valves	PG-69
Capacity of Safety Valves	PG-70
Mounting	PG-71
Operation	PG-72
Minimum Requirements for Safety and Safety Relief Valves	PG-73
Mechanical Requirements	PG-73.1
Material Selection	PG-73.2
Inspection of Manufacturing and/ or Assembly	PG-73.3
Testing by Manufacturers and Assemblers	PG-73.4
Certificate of Conformance	PG-73.6.3
Requirements for Organic Fluid vaporizers	PVG-12
Method of Checking Safety Valve Capacity	A-12
Safety Valves for Power Boilers	A-44, 45, 46, 48, 63

If the design does not meet the requirements of the Code, the ASME designee has the authority to reject or require modifications prior to capacity testing.

9.3.1 Mechanical requirements

Mechanical requirements cover design of the guide, spring, lifting device, seats and disks, drains, wrenching surfaces, and sealing.

1. *Guide.* The guiding arrangements are designed to ensure tightness.
2. *Spring.* The spring is designed to provide full spring compression, not more than 80% of the nominal solid deflection, and permanent set not more than 0.5% of the free height.
3. *Lifting device.* Each safety valve or safety relief valve should have a lifting device that will release the force on the disk when the valve is at a minimum pressure of 75% of the set pressure. The lifting device should not hold the valve disk in the lifted position when the lifting force is released.
4. *Seat and disks.* The seat of a safety valve is fastened to the body in such a manner that seat lifting does not occur. The disks of safety relief valves for high-temperature water boilers should not be lifted when temperatures exceed 200°F (93°C).
5. *Drain.* A drain is provided below seat level for drainage of the safety valve. The minimum drain hole should not be less than $\frac{1}{4}$ in. (6 mm) for a safety valve size NPS $2\frac{1}{2}$ (DN 65) or smaller. The hole size should be a minimum of NPS $\frac{3}{8}$ (DN 10) for valve sizes exceeding NPS $2\frac{1}{2}$ (DN 65).

6. *Wrenching surfaces.* Provisions are made for wrenching surfaces for screwed inlet and outlet connections.
7. *Sealing.* Means should be provided for sealing the valves after adjustments.
8. *Body.* The valve body should be designed to minimize the effects of water deposits.

9.3.2 Material selection

Materials as permitted by ASME Code Sec. I are used for construction of safety and safety relief valves for power boiler service. Materials used for bodies and bonnets or yokes are required to be listed in ASME Code Sec. II, Parts A, B, and identified in Tables 1A and 1B of Sec. II, Part D.

Materials for nozzles, disks, and other parts must be from one of the following categories:

1. Listed in Sec. II
2. Listed in ASTM Specifications
3. Controlled by the manufacturer to ensure that chemical and physical properties are at least equivalent to ASTM Standards.

In the latter case, the manufacturer is responsible for ensuring that the allowable stresses at temperature meet the requirements of Sec. II, Part D, App. I—Nonmandatory Basis for Establishing Stress Values in Tables 1A and 1B.

Cast iron seats and disks are not permitted to be used for safety valves and safety relief valves for power boiler service. It is required that corrosion-resistant materials be used for seats, guides, disks, disk holders, and springs.

9.3.3 Boiler safety valves

Each power boiler is required to have at least one safety valve or safety relief valve. Two or more safety valves are required if the bare-tube water-heating surface is more than 500 ft^2 (47 m^2). Two or more safety valves are also required if the combined bare-tube and extended water-heating surface is more than 500 ft^2 (47 m^2), and steam-generating capacity of the boiler is more than 4000 lb/hr (1800 kg/h). The total valve capacity for each boiler should be able to discharge all the steam generated by the boiler without permitting the pressure to rise more than 6% above the highest safety valve setting, but in no case more than 6% above the maximum allowable working pressure (MAWP) as shown in Fig. 9.5.

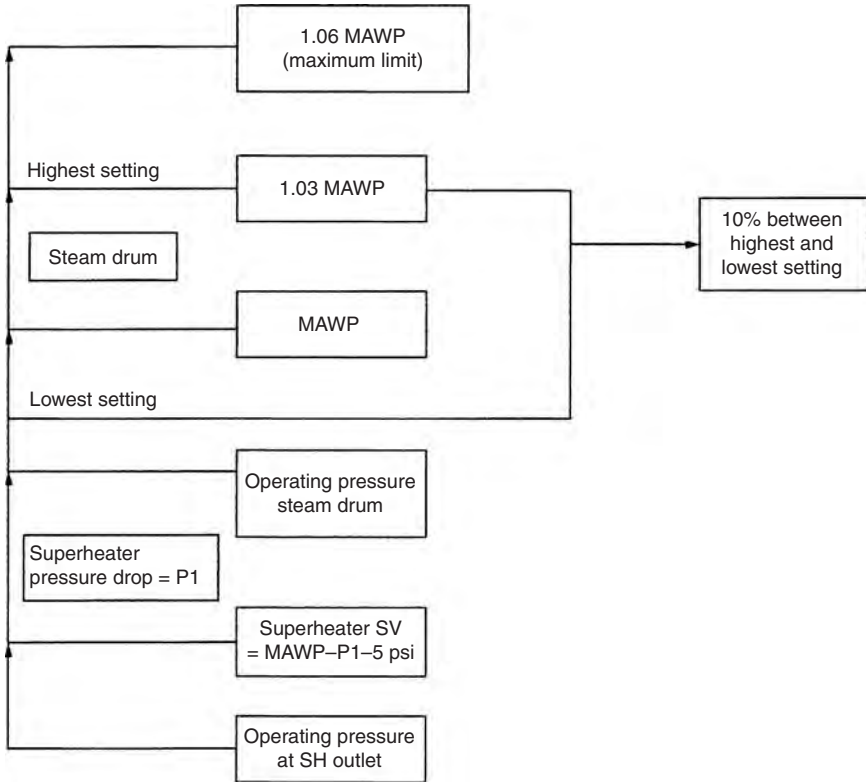


Figure 9.5 Boiler safety valve setting diagram.

One or more safety valves are required to be set at or below the MAWP. The highest pressure setting for any additional valve cannot exceed the MAWP by 3%. The range of pressure settings of all the safety valves on a power boiler shall not exceed 10% of the highest pressure to which any valve is set. On the other hand, the pressure setting of a safety relief valve on a high-temperature water boiler may exceed the 10% range.

All safety valves and safety relief valves for power boilers must be of direct spring-loaded pop type. The coefficient of discharge of safety valves is required to be determined by actual steam flow measurements at a pressure of no more than 3% above the set pressure. All the valves must have capacities accredited. Deadweight or weighted-lever safety valves or safety relief valves are not permitted for use in power boilers.

Safety relief valves are used for high-temperature water boilers. These relief valves must have closed bonnets. The relief valve should operate satisfactorily when relieving water at the saturation temperature corresponding to the pressure at which the valve is set.

A safety valve or safety relief valve over NPS 3 (DN 80), if used for a power boiler operating at more than 15 psig, must have a flanged inlet connection or a weld-end inlet connection. The dimension of flanges is required to confirm the applicable ASME Standards.

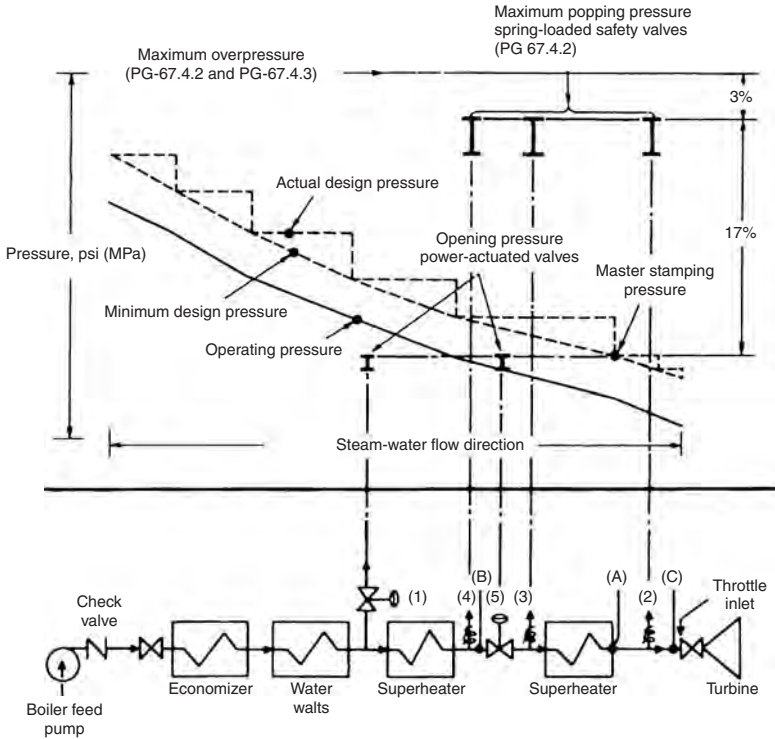
For forced-flow steam generators with no fixed steam and waterline (Fig. 9.6), equipped with automatic controls and interlocks responsive to steam pressure, safety valves must be provided in accordance with par. PG-67.4 of Sec. I. One or more power-actuated pressure relief valves must be provided in direct communication with the boiler when the boiler is under pressure and receive a control impulse to open when the MAWP at the superheater outlet is exceeded. The total relieving capacity should not be less than 10% of the maximum design steaming capacity of the boiler under any operating conditions. The valve(s) may be located anywhere in the pressure part system where they can relieve overpressure.

Spring-loaded safety valves may be provided, with total relieving capacity, including that of power-actuated pressure-relieving capacity if installed, of not less than 100% of the maximum designed steaming capacity of the boiler. In this case, relieving capacity of not more than 30% should be allowed for the power-actuated pressure relief valves actually installed. Any or all the spring-loaded safety valves may be set above MAWP. The set pressures should be such that all the valves in operation, together with power-actuated pressure relief valves, should not raise the operating pressure more than 20% above the MAWP of any part of the boiler.

9.3.4 Superheater safety valves

Each attached superheater is required to be equipped with one or more safety valves. The valve(s) should be located in the steam flow path between the superheater outlet and the first stop valve. The valve(s) may also be located anywhere in the length of the header. The discharge capacity of the safety valve on a superheater may be included in determining the number and size of the safety valves for the boiler if there is no valve between the superheater safety valve and the boiler. In that case, the boiler safety valves must release 75% of the total valve capacity required.

Each superheater, if separately fired and can be separated from the boiler by shutoff, is required to be equipped with one or more safety valves with a total capacity equal to 6 lb of steam per square foot of superheater surface. Alternatively, the manufacturer may calculate the minimum safety valve relieving capacity in lb/hr from the maximum expected heat absorption in Btu/hr, divided by 1000.



Pressure

- (A) = Master stamping (PG-106.3)
- (B) = Component design at inlet to stop valve (PG-67.4.4.1)
- (C) = Turbine throttle inlet (ANSI/ASME B31.1, paragraph 122.1.2, A.4)

Pressure relief valves

- (1) = Power actuated (PG-67.4.1)
- (2), (3), and (4) = Spring loaded safety (PG-67.4.2)
- (5) = Superheater stop (PG-67.4.4)

Relief valve flow capacity (minimum, based on rated capacity of boiler)

- (1) = 10–30% (PG-67.4.1)
- (2) = Minimum of one valve (PG-68.1)
- (2) + (3) when downstream to stop valve (S)"= that required for independently fired superheaters (PG.68.3)
- (2) + (3) + (4) = 100% – (1) (PG-67.4.2)

Relief valve opening pressure (maximum)

- (1) = (A), and (B) when there is stop valve (5) (PG-67.4.1)
- (2), (3), and (4) = (A) + 17% (PG-67.4.2)
- (5) = (A) (PG-67.4.1)

Figure 9.6 Requirements for pressure relief valves for forced-flow steam generators. (Courtesy ASME International.)

The safety valves used on a superheater for relieving superheated steam at a temperature over 450°F (232°C) must have a casing with the base, body, bonnet, and spindle constructed of steel, alloy steel, or any heat-resisting material. The valves must have a flanged inlet, or a weld-end inlet connection.

The capacity of a safety valve on superheated steam should be calculated by multiplying the capacity determined in accordance with PG-69.2 by the appropriate superheat correction factor K_{sh} shown in App. H.

An electronic ball valve system (Fig. 9.7) is recommended for mounting on the superheater outlet header before the superheater outlet safety valve. The electronic ball valve is normally set at a pressure lower than the spring-loaded safety valves, where it can reduce safety valve maintenance and improve boiler efficiency.

A special isolation valve is used to isolate the electronic ball valve. The isolation valve should be of the correct size and should not restrict the capacity of the electronic ball valve. This isolation valve is used to isolate the electronic ball valve in case of leakage. The isolation valve is normally in open position during start-up.

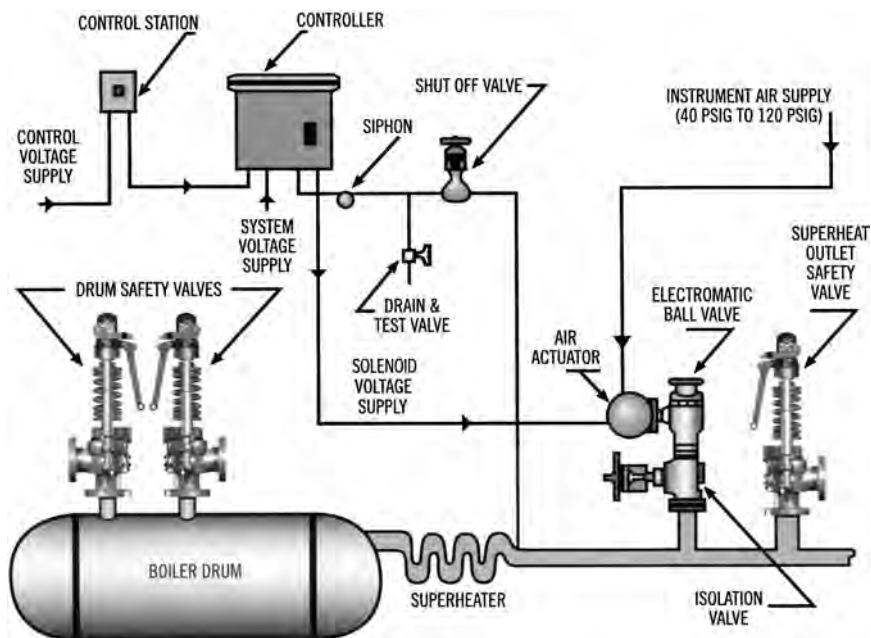


Figure 9.7 Electronic ball valve on superheater outlet header. (Courtesy Dresser Flow Control.)

9.3.5 Reheater safety valves

Each reheater is required to have one or more safety valves, the total capacity of which is at least equal to the maximum steam flow capacity of the heater. The discharge capacity of the reheater safety valves must not be included in determining the safety valve requirements for the boiler. One or more safety valves with a combined capacity of at least 15% of the total capacity should be located in the steam flow path between the reheater outlet and the first stop valve.

The safety valves used on a reheater for relieving superheated steam at a temperature over 450°F (232°C) must have a casing with the base, body, bonnet, and spindle constructed of steel, alloy steel, or any heat-resisting material. The valves must have a flanged inlet, or a weld-end inlet connection.

9.3.6 Organic fluid vaporizer safety valves

An organic fluid vaporizer is considered a power boiler in which an organic fluid is vaporized by the application of heat resulting from the combustion of fuels (solid, liquid, or gaseous). An organic fluid vaporizer is constructed in accordance with the rules of Part PVG of ASME Code Sec. I—Power Boilers.

Specially designed safety valves are used on organic fluid vaporizers as the discharge of the safety valves are conducted back through a condenser to the storage system.

Safety valves should be of a totally enclosed type designed so that vapors escaping beyond the valve seat will not be discharged into the atmosphere. The safety valve should not have a lifting lever.

Safety valves are normally disconnected from the vaporizer annually. The valves should be inspected, repaired if necessary, tested, and installed back on the vaporizer. It should be noted that a qualified safety valve repair shop should repair the safety valves.

The safety valves for organic fluid vaporizers should be tested and certified in accordance with Par. PG-69 of Sec. I. The valves should be stamped with the rated relieving capacity in lb/hr and the fluid identification, in addition to the symbol stamp V.

9.4 Capacity Requirements

The minimum required relieving capacity of a power boiler must be at least equal to the maximum designed steam generation capacity of the boiler. The manufacturer is required to certify the maximum designed steaming capacity in lb/hr of a power boiler.

The manufacturer determines the minimum required relieving capacity of a waste heat boiler. If auxiliary firing is used, the manufacturer

is required to include the effect of such firing in the total output maximum output capacity.

For a high-temperature water boiler, the minimum required capacity is obtained by dividing the maximum output at the boiler nozzle, produced by the highest heating value of fuel for which the boiler is designed, by 1000.

Each economizer, if it can be isolated from the boiler by a shut-off valve, is required to have one or more safety relief valves with a total discharge capacity in lb/hr, divided by 1000. This discharge capacity is determined by the manufacturer from the heat absorption capacity in Btu/hr, and the absorption capacity is required to be stated on the stamping.

9.4.1 Relieving capacity

A safety valve or safety relieve valve should have sufficient capacity to discharge all the steam that is generated by the boiler. The minimum relieving capacity of a power boiler can be determined by either of two methods:

1. By measuring the maximum amount of fuel that can be burned
2. By estimating the pounds of steam generated based on heating surface

Capacity based on fuel burning. The maximum quantity of fuel, C , which can be burned at the time of maximum forcing is determined by a test. The following formula is used to calculate the required minimum relieving capacity of a safety valve based on the maximum amount of fuel burned:

$$W = \frac{C \times H \times 0.75}{1100}$$

where W = steam generated, lb/hr

C = total weight or volume of fuel burned at the time of maximum forcing, lb or ft³

H = heat of combustion of fuel, Btu/lb or Btu/ft³

Total capacity is the summation of capacity of each safety valve, which should be equal to or greater than W .

Capacity based on heating surface. The heating surface of a boiler is defined as the area that is exposed to the heating medium for absorption and transfer of heat to the heat medium. It is the area expressed in ft², and is calculated for the surface receiving the heat. A boiler design is basically a layout of heating surfaces to obtain maximum efficiency and capacity.

The heating surface has been used for capacity calculations for many years. Formerly, 1 boiler horsepower (BHP) was taken as equivalent to 10 ft² of heating surface, which is equivalent to 34.5 lb/hr of steam.

A designer must use the total quantity of heat energy released in a furnace by the fuel for efficient distribution over the heating surfaces of the boiler. The heat release unit is expressed as Btu/hr/ft³ of furnace volume or Btu/hr/ft² of heating surface.

The minimum capacity of the safety valve or safety relief valve is calculated based on the steam generation capacity in lb/hr per square foot of boiler heating surface and waterwall heating surface. The manufacturer is required to certify the heating surface in ft² of the boiler and waterwalls, and stamp total heating surface on the boiler.

If the heating surface (HS) of a fire-tube boiler is not known, the total heating surface may be calculated using the following formula:

Total heating surface = HS(shell) + HS(tube) + HS(heads)

If the total heating surface of a boiler is known, the minimum relieving capacity can be estimated from Table 9.3.

Example 9.1: Safety Valve Capacity Calculation A 72-in-diameter gas-fired horizontal-return tubular (HRT) boiler has 1850 ft² of heating surface and a MAWP of 150 psi. What minimum safety valve capacity is required?

Solution

Horizontal-return tubular boiler (fire-tube boiler)

Fuel type: gas

Heating surface HS = 1850 ft²

From Table 9.3, the relieving capacity of a gas-fired fire-tube boiler is 8 lb/hr per square foot of heating surface. Therefore, the required total relieving

TABLE 9.3 Guide for Estimating Steam Capacity Based on Heating Surface

	Fire-tube boilers	Water-tube boilers
Boiler heating surface		
Hand fired	5	6
Stoker fired	7	8
Oil, gas, or pulverized fuel fired	8	10
Waterwall heating surface		
Hand fired	8	8
Stoker fired	10	12
Oil, gas, or pulverized fuel fired	14	16

capacity for the HRT boiler is

$$1850 \times 8 = 14,800 \text{ lb/hr}$$

The minimum safety valve capacity required is 14,800 lb/hr.

Example 9.2: Heating Surface Calculation An oil-fired horizontal-return tubular boiler (Fig. 9. 8) has 60 in outside diameter and is 15 ft 6 in in length. The MAWP of the boiler is 125 psi. The boiler contains sixty-six (66) 0.120-in-thick wall tubes of 3 1/2-in outside diameter.

(a) What is the total heating surface computed on the tubes, one-half the area of the shell, and one-third the area of blank head (2) 59 in in diameter (disregard tube holes)?

(b) What safety valve relieving capacity is required for this boiler?

Solution

$$D = 60 \text{ in} \quad L = 15 \text{ ft } 6 \text{ in} \quad P = 125 \text{ psi}$$

$$N = 66 \quad t = 0.120 \text{ in} \quad d = 3.5 \text{ in}$$

$$\text{ID of tube} = d - 2t = 3.5 - 2 \times 0.120 = 3.26 \text{ in}$$

(a) Calculation of heating surface: For the shell, the projected area is one-half of the total shell area:

$$\begin{aligned} \text{HS(shell)} &= \frac{\pi DL}{144 \times 2} \\ &= \frac{60 \times 3.1416 \times 15.5 \times 12}{144 \times 2} \\ &= 121.74 \text{ ft}^2 \end{aligned}$$

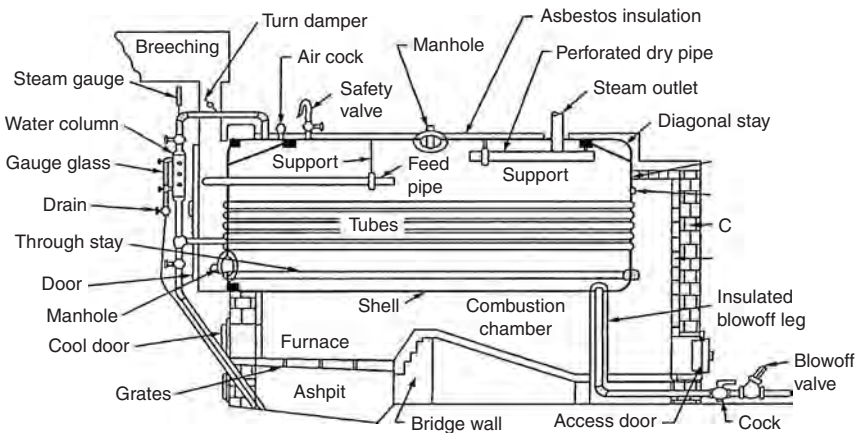


Figure 9.8 Horizontal-return tubular (HRT) boiler.

For the tubes,

$$\begin{aligned} \text{HS(tubes)} &= \frac{\pi d L N}{144} \\ &= \frac{3.1416 \times 3.26 \times 15.5 \times 12 \times 66}{144} \\ &= 873.09 \text{ ft}^2 \end{aligned}$$

For the heads, use one-third of the area of each head x 2 heads:

$$\begin{aligned} \text{HS(heads)} &= \frac{\pi D^2}{4 \times 144} \\ &= \frac{1 \times 3.1416 \times 59 \times 59 \times 2}{3 \times 4 \times 144} \\ &= 12.657 \text{ ft}^2 \end{aligned}$$

The total heating surface is thus

$$\text{HS(shell)} = 121.74$$

$$\text{HS(tubes)} = 873.09$$

$$\text{HS(heads)} = \underline{12.657}$$

$$\underline{1007.487 \text{ ft}^2}.$$

(b) Calculation of relieving capacity: From Table 9.3, steam generation capacity for an oil-fired HRT boiler is 8 lb/ft² of heating surface. Therefore, the relieving capacity required is

$$1007.487 \times 8 = 8059.896 \text{ lb/hr}$$

9.4.2 Capacity checking

Sometimes the capacity of the safety or safety relief valve is not known. In that case, one of the following methods may be used to verify the capacity:

1. *The accumulation test.* This is a test in which all the discharge outlets from the boiler are shut off and fires are forced to the maximum. The safety valve should discharge all the steam generated by the boiler without allowing the pressure to rise more than 6% above the MAWP. This method is not recommended for a boiler with a superheater or reheater or for a high-temperature water boiler.

2. *The fuel measuring test.* This is a test in which the maximum amount of fuel burned is measured. The evaporative capacity is calculated on the basis of the heating value of the fuel by using the formula:

$$W = \frac{C \times H \times 75}{1100}$$

where C = total weight or volume of fuel burned per hour at the time of maximum forcing, lb (kg) or ft^3 (m^3)

3. *The evaporative capacity test.* This is a test in which the maximum evaporative capacity is estimated by measuring the feedwater. That means the amount of feedwater in lb/hr is the maximum evaporative capacity of the boiler in lb/hr. The sum of all the safety valve capacities should be equal to or more than the maximum evaporative capacity.

Example 9.3: Safety Valve Capacity Checking A watertube boiler at the time of maximum forcing uses 3,250 lb/hr of Illinois coal with a heating value of 12,100 Btu/lb. The boiler MAWP is 250 psi and the two 6 in. safety valves each have capacity 10,000 lbs/hr. Are the safety valve capacities adequate?

Given

$$C = 3,250 \text{ lb/hr}$$

$$H = 12,100 \text{ Btu/lb}$$

Solution

Weight of steam generated per hour is found by the formula:

$$W = \frac{C \times H \times 0.75}{1,100}$$

$$W = \frac{3,250 \times 12,100 \times 0.75}{1,100}$$

$$W = 26,812.5 \text{ lb/hr}$$

The sum of safety valve capacities should be equal or greater than 26,812.5 lb/hr. The sum of the two existing safety valve capacities is 20,000 lb/hr, which is less than the required total capacity of 26,812.5 lb/hr.

Therefore, safety valve capacities are inadequate.

9.4.3 Capacity certification

A valve manufacturer is required to have the relieving capacity of the valves certified before applying V code symbol stamp to any safety valve or safety relief valve. The valve capacity is certified by a testing laboratory accredited by the ASME. A sample copy of the valve certificate published by the NB Valve Testing Laboratory is shown in Fig. 9.9.

MOTOYAMA ENGINEERING WORKS, LTD. (MTY) Sendai, Japan

VALVE SERIES OR CAT. NO. - H (HS-HSA-HC-HN-IN-A)
 NB Capacity Certification Number - M40004
 CAPACITY TESTS - Sec. I at Crosby Valve & Gage Co. on
 November 10, 1980
 METHOD OF ESTABLISHING RELIEVING CAPACITY - Coefficient
 0.905 (Nozzle)
 TEST MEDIUM - Steam
 CERTIFIED MEDIUM - Steam
 Set Pressure Definition - Pop
 Blowdown - Adjustable

Inlet Size 1/2 in. and Larger
 Orifice Dia. 0.394 in. Minimum Lift 0.098 in.
 Flow Area 0.122 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	154
30	233
50	336
500	2706

Inlet Size 3/4 in. and Larger
 Orifice Dia. 0.525 in. Minimum Lift 0.131 in.
 Flow Area 0.216 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	272
30	413
50	599
500	4794

Inlet Size 1 in. and Larger
 Orifice Dia. 0.656 in. Minimum Lift 0.164 in.
 Flow Area 0.338 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	427
30	646
50	938
1500	22066
3100	54194

Inlet Size 1 in. and Larger
 Orifice Dia. 0.840 in. Minimum Lift 0.210 in.
 Flow Area 0.554 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	699
30	1059
50	1537
1500	36168
3100	88828

Inlet Size 1-1/2 in. and Larger
 Orifice Dia. 1.050 in. Minimum Lift 0.262 in.
 Flow Area 0.866 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	1094
30	1655
50	2402
1500	56538
3100	138854

Inlet Size 2 in. and Larger
 Orifice Dia. 1.345 in. Minimum Lift 0.336 in.
 Flow Area 1.421 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	1795
30	2715
50	3942
1500	92772
3100	227843

Inlet Size 2-1/2 in. and Larger
 Orifice Dia. 1.608 in. Minimum Lift 0.402 in.
 Flow Area 2.031 sq. in.

Set Pressure PSIG	Sec. I #/Hr Steam
15	2566
30	3881
50	5634
1500	132597
3100	325650

Figure 9.9 Capacity certification report. (Courtesy National Board.)

The rules for ASME acceptance of testing laboratories and Authorized Observers for conducting capacity certification tests of safety and safety relief valves are given in App. A-310 of Sec. I of the ASME Code. An Authorized Observer is an ASME-designated person who supervises capacity certification tests only at testing facilities specified by the ASME. An ASME designee reviews and evaluates the experience of persons interested in becoming Authorized Observers, and makes recommendations to the Society.

The manufacturer and the Authorized Observers sign the capacity test data reports after completion of tests on each valve design and size. The capacity test reports, with drawings for valve construction, are submitted to the ASME designee for review and acceptance.

Capacity certification tests are conducted at a pressure not exceeding set pressure by 3% or 2 psi (7 kPa), whichever is greater. The valves are adjusted so that blowdown does not exceed 4% of the set pressure. The tests are conducted by using dry saturated steam of 98% minimum quality and 20°F (11°C) maximum superheat.

New tests are performed if changes are made in the design of the valve that affect the flow path, lift, or performance characteristics of the valve.

Three methods, (1) the three-valve method, (2) the slope method, and (3) the coefficient-of-discharge method, are permitted for capacity certification. Relieving capacity of a safety valve or safety relief valve may be determined using one of the methods.

Three-valve method. In the three-valve method, a set of three valves for each combination of size, design, and pressure setting is tested. On test, the capacity should stay within the range of $\pm 5\%$ of the average capacity. If the test fails for one valve, it is required to be replaced with two valves. Now a new average capacity of four valves is calculated, and tested again. If the test result for a valve fails to fall within $\pm 5\%$ of the new average, that valve design is rejected.

The rated relieving capacity for each combination of design, size, and test pressure is required to be 90% of the average capacity.

Slope method. In the slope method, a set of four valves for each combination of pipe size and orifice size is tested. The valves are set at pressures covering the range of pressures for which the valves will be used or the range of pressures available at the testing laboratory. The capacities are determined as follows.

The slope W/P of the measured capacity versus the flow pressure for each test is calculated on average:

$$\text{Slope} = \frac{W}{P} = \frac{\text{measured capacity, lb/hr}}{\text{absolute flow rating pressure, psia}}$$

The values obtained from testing are required to stay within $\pm 5\%$ of the average value:

$$\text{Minimum slope} = 0.95 \times \text{average slope}$$

$$\text{Maximum slope} = 1.05 \times \text{average slope}$$

The Authorized Observer is required to witness testing of additional valves at the rate of two for each valve if the values from the testing do not fall within the above minimum and maximum slope values.

When rated, relieving capacity must not exceed 90% of the average slope times the absolute accumulation pressure:

$$\text{Rated slope} = 0.90 \times \text{average slope}$$

The stamped capacity $\leq$ rated slope ($1.03 \times \text{set pressure} + 14.7$) or (set pressure + 2 psi + 14.7), whichever is greater.

Coefficient-of-discharge method. In the coefficient-of-discharge method, a coefficient of discharge, K , is established for a specific valve design. The manufacturer is required to submit at least three valves for each of three different sizes, a total of nine valves, for testing. Each valve is set at a different pressure covering the range of pressures for which the valves will be used or the range of pressures available at the test laboratory. The test is performed on each valve to determine its lift, popping, and blowdown pressures, and actual relieving capacity. A coefficient, K_D , is established for each valve:

$$\text{Individual coefficient of discharge, } K_D = \frac{\text{actual flow}}{\text{theoretical flow}}$$

The actual flow is determined by the test, whereas the theoretical flow, W_T , is calculated using the following formulas:

(a) For a 45° seat,

$$W_T = 51.5 \times \pi DLP \times 0.707$$

(b) For a flat seat,

$$W_T = 51.5 \times \pi DLP$$

(c) For a nozzle,

$$W_T = 51.5AP$$

where W_T = theoretical flow, lb/hr (kg/h)

A = nozzle throat area, in² mm²

P = (1.03 × set pressure + 14.7), psia, or (set pressure + 2 + 14.7), psia, whichever is greater

L = lift pressure at P , in (mm)

D = seat diameter, in (mm)

The coefficient of design K is calculated by multiplying the average of K_D of the nine tests by 0.90. All nine K_D must fall within ±5% of the average coefficient. If any valve fails to meet this requirement, the Authorized Observer is required to witness two additional valves as replacements for each valve that failed, with a limit of four additional valves. If the new valves fail to meet the requirement of the new average value, that particular valve design is rejected.

The rated relieving capacity is determined using the following formula:

$$W \leq W_T \times K$$

where W = rated relieving capacity, lb/hr

W_T = theoretical flow, lb/hr

K = coefficient of discharge

The value of W is multiplied by the following correction factor for valves with range of pressure from 1500 to 3200 psig:

$$\text{Correction factor} = \frac{0.1906P - 1000}{0.2292P - 1061}$$

For power-actuated pressure relief valves, one valve of each combination of inlet pipe size and orifice size used with that inlet pipe size are tested. The valve capacity is tested at four different pressures available at the testing laboratory, and the test result is plotted as capacity versus absolute flow test pressure. A line is drawn through these four points, and all points must stay within ±5% in capacity value and must pass through 0–0. A slope of the line dW/dP is determined and applies to the following equation for calculating capacity in the supercritical region at elevated pressures:

$$W = 1,135.8 \frac{0.90}{51.45} \times \frac{dW}{dP} \sqrt{\frac{P}{v}}$$

where W = capacity, lb of steam/hr (kg/hr)

P = absolute inlet pressure, psia (kPa)

v = inlet specific volume, ft³/lb (m³/kg)

dW/dP = rate of change of measured capacity

After obtaining capacity certification, the power-actuated pressure relief valves are marked with the above-computed capacity.

9.5 Testing by Manufacturers

The manufacturer or assembler is required to test every valve with steam to ensure its popping point, blowdown, and pressure-containing integrity. The test may be conducted at a location where test fixtures and test drums of adequate size and capacity are available to observe the set pressure stamped on the valve. Alternatively, the valve may be tested on the boiler, by raising the pressure to demonstrate the popping pressure and blowdown.

The pressure relief valves are tested at 1.5 times the design pressure of the parts which are cast and welded. This test is required for valves exceeding 1 in (DN 25) inlet size or 300 psig (2070 kPa) set pressure. The test result should not show any leakage.

Pressure relief valves with closed bonnets, designed for a closed system, are required to be tested with a minimum of 30 psig (207 kPa) air or other gas. The test should not show any leakage.

A seat tightness test is required at maximum operating pressure, and the test result should no sign of leakage. The time for testing the valve should be sufficient to ensure that the performance is satisfactory. The manufacturer or assembler is required to have a program for documentation of application, calibration, and maintenance of all test gages.

9.6 Inspection and Stamping

A Certified Individual (CI) provides oversight to assure that the safety valves and safety relief valves are manufactured and stamped in accordance with the requirements of ASME Code Sec. I.

A Certified Individual is an employee of the manufacturer or assembler. The CI is qualified and certified by the manufacturer or assembler. The CI should have knowledge and experience in the requirements of application of the **V** symbol stamp, the manufacturer's quality program, and special training on oversight, record maintenance, and the Certificate of Conformance. Following are the duties of the Certified Individual:

1. Verifying that each valve for which the Code symbol **V** is applied has a valid capacity certification.
2. Reviewing documentation for each lot of items that requirements of the Code have been met.
3. Signing the Certificate of Conformance on ASME Form P-8.

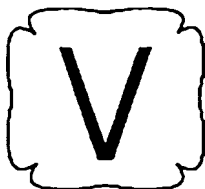


Figure 9.10 ASME code symbol stamp for safety valves and relief valves for power boilers.

Each safety valve or safety relief valve designed, fabricated, or assembled by a Certificate of Authorization holder is stamped with the Code symbol **V**.

The manufacturer or assembler marks each safety valve with the required data, either on the valve or on a nameplate securely attached to the valve. The Code symbol **V** is stamped on the valve or on the nameplate. The marking includes the following data:

1. Name of manufacturer or assembler
2. Manufacturer's design or type
3. Nominal pipe size of the valve inlet, in (mm)
4. Set pressure, psi (kPa)
5. Blowdown, psi (kPa)
6. Capacity, lb/hr (kg/h)
7. Lift of the valve, in (mm)
8. Year built
9. Code **V** symbol stamp (Fig. 9.10)
10. Serial number

9.7 Certificate of Conformance

A Certificate of Conformance for safety valves is a certificate similar to Manufacturer's Data Reports for boilers. The Certificate of Conformance, Form P-8 (Fig. 7.7), is completed by the manufacturer or assembler and signed by the Certified Individual. If multiple duplicate safety valves are identical and manufactured in the same lot, they may be recorded as a single entry.

The manufacturer or assembler is required to retain Certificates of Conformance for a minimum period of 5 years.

9.8 Operation

Safety valves should operate without chattering, and a full lift should be achieved at a pressure not more than 3% above the set pressure. All valves set at pressures of 375 psi (2600 kPa) and above should close after blowing down at a pressure not less than 96% of the set pressure. All valves set at pressures below 375 psi (2600 kPa) should have blowdown pressures as shown in Table 9.4.

Higher values of blowdown are permitted if such higher values are agreed to by the boiler owner and the valve manufacturer. In that case, the manufacturer will make adjustments and mark the higher values.

The minimum blowdown pressure for any safety or safety relief valve is 2 psi (13.4 kPa) or 2% of the set pressure, whichever is greater.

Safety valves for forced-flow steam generator with no fixed steam and waterline, and safety valves for high-temperature water boilers, may be closed after blowing down at pressures not more than 10% of the set pressure. These valves are adjusted and blowdown pressures are marked by the manufacturers.

The popping-point tolerance plus or minus should not exceed the values specified in Table 9.5

The Code requires that the spring shall not be reset for pressure more than $\pm 5\%$ for which the valve is marked. If the manufacturer or assembler adjusts the set pressure within the limits specified above, an additional data tag indicating the new set pressure, capacity, and date should be installed, and the valve resealed.

When the set pressure is changed, requiring a new spring, the spring installation and valve adjustment are done by the manufacturer or assembler. A new nameplate is required to be installed and the valve is resealed.

9.9 Selection of Safety Valves

Proper selection of safety valves is critical to obtaining maximum protection. Sufficient data should be made available to properly size and select safety valves for specific applications. Safety valves are available in a variety of sizes and materials. Each valve is unique and judgments are required in selecting the proper option.

TABLE 9.4 Blowdown Pressures for Safety Valves

Set pressure	Maximum blowdown
<67 psi (462 kPa)	4 psi (14 kPa)
≥ 67 psi (462 kPa) and ≤ 250 (1720 kPa)	6% of set pressure
>250 psi (1720 kPa) and <375 psi (2590 kPa)	15 psi (103 kPa)

TABLE 9.5 Popping-Point Tolerances

Set pressure	Tolerance, plus or minus from set pressure
<70 psi (480 kPa)	2 psi (14 kPa)
>0 (480 kPa) and <300 (2070 kPa)	3% of set pressure
>300 (2070 kPa) and <1000 (6 900 kPa)	10 psi (69 kPa)
>1000 psi (6900 kPa)	1% of set pressure

9.9.1 Ordering information

When ordering safety valves, specify all of the following:

1. Quantity
2. Inlet and outlet size
3. Inlet and outlet flange class and facing
4. Materials of construction
5. Seat pressure seal material
6. Set pressure
7. Maximum inlet temperature
8. Allowable overpressure
9. Fluid and fluid state
10. Backpressure, superimposed constant, and/or variable and built-up
11. Required capacity
12. Accessories:
 - (a) Bolted cap, open or packed lever
 - (b) Test gag
 - (c) “L” lever
 - (d) “R” lever

9.9.2 Specifying safety valves

Example 9.4: Specifying Safety Valves Specify safety valves required for a power boiler of capacity 6500 lb/hr.

Solution

Number of valves	2
Valve inlet	
Size (standard, oversize)	1 – $\frac{1}{2}$ -in standard 250#
Connection (250#, 125# FNPT)	250#

Set pressure	100 psig
Operating pressure	80 psig
Operating, relieving, and design temperatures	325°F/339°F/400°F
Built-up back pressure	5 psig
Allowable overpressure	3%
Orifice size	J
Required capacity	6500 PPH
ASME Boiler and Pressure Vessel Code	ASME Sec. I
Trim (bronze, stainless)	Stainless
Accessories (gag, spring cover, spring coating)	Gag
Customer drawings (for approval, for record)	For approval

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Pressure Relief Valves for Heating Boilers

The rules of ASME Boiler and Pressure Vessel Code Sec. IV constitute the minimum requirements for the safe design, construction, installation, and inspection of low-pressure boilers and hot water heaters which are fired directly with oil, gas, electricity, or other solid or liquid fuels. The types of boilers covered under this Sec. IV are defined below.

- Low-pressure steam boilers—a steam boiler in which the operating pressure does not exceed 15 psi (103 kPa).
- Hot water boilers—a boiler used for generating hot water in which the operating pressure does not exceed 160 psi (1100 kPa) and/or a temperature not exceeding 250°F (121°C). Hot water boilers include hot water heating boilers and hot water supply boilers.
- Potable-water heaters and storage tanks—equipment used for operation at pressures not exceeding 160 psi (1100 kPa) and water temperatures not exceeding 210°F (99°C).

Safety valves are used for low-pressure steam boilers. Figure 10.1 shows a typical low-pressure steam boiler designed under ASME Sec. IV and Fig. 10.2 shows a typical cast-iron safety valve used on a low-pressure steam boiler.

Safety relief valves are used for hot water boilers such as hot water heating boilers and hot water supply boilers. Figure 10.3 shows an ASME-rated safety relief valve on a hot water boiler.

Hot water heaters and hot water storage tanks are generally equipped with temperature and pressure (T&P) relief valves. Figure 10.4 shows a T&P relief valve fitted on a water heater.



Figure 10.1 A typical low-pressure steam boiler.

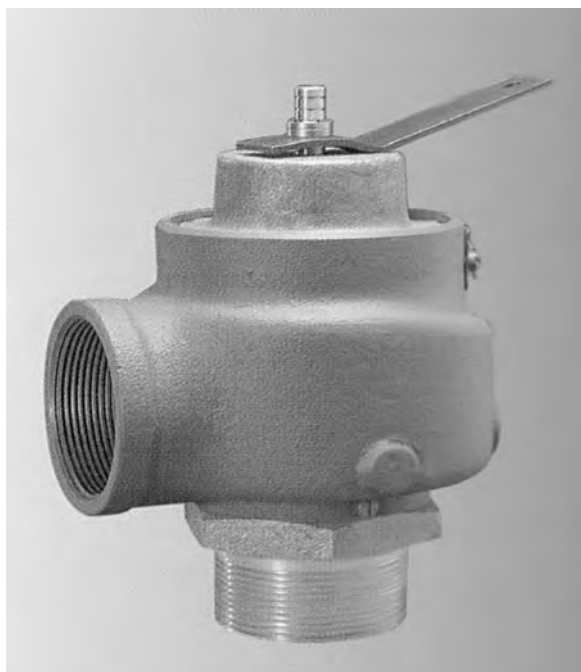


Figure 10.2 A cast-iron safety valve for a low pressure steam boiler. (Courtesy Kunkle Valve.)

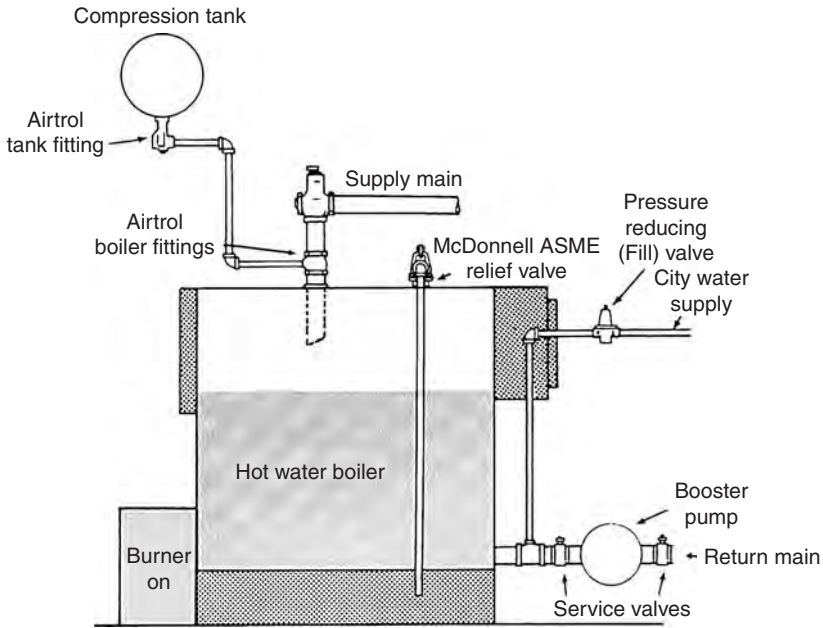


Figure 10.3 Safety relief valve on a hot water boiler. (Courtesy McDonnell & Miller.)

Great importance is given to the design, construction, inspection, and repair of safety valves and safety relief valves for all types of heating boilers. Article 4 of Sec. IV describes the rules for safety valves and safety relief valves used for heating boilers.

10.1 Code References

Table 10.1 lists requirements for design, construction, shop inspection, testing, stamping and certification of safety valves and safety relief valves and their corresponding references in ASME Code Sec. IV.

10.2 Design Requirements

The required rules for pressure-relieving devices are prescribed in Art. 4 of Sec. IV. These rules are applicable for steam boilers, hot water boilers (hot water heating and hot water supply), tanks, and heat exchangers.

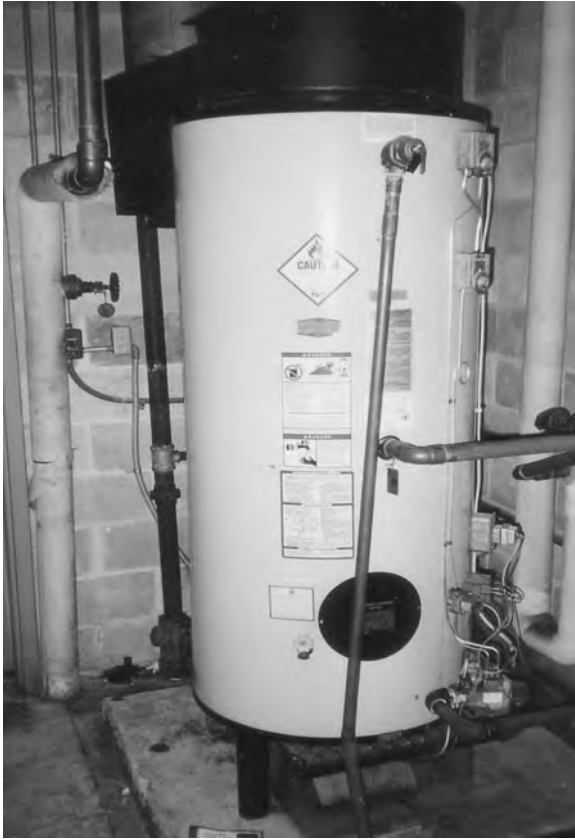


Figure 10.4 T&P relief valve on a water heater.

10.2.1 Safety valve requirements for steam boilers

The safety valve should relieve all the steam generated by a steam heating boiler. Each boiler should have at least one or more officially rated safety valves that are identified with ASME symbol **V**. The valves should be of spring pop type (Fig. 10.5), adjusted and sealed to discharge all the steam at a pressure not exceeding 15 psi (103 kPa). The size of the safety valve should be, as a minimum, NPS $\frac{1}{2}$ (DN 15), and maximum NPS $4\frac{1}{2}$ (DN 115).

The minimum capacity required for the safety valve can be determined by either of the following methods:

1. Determine maximum BTU output at the boiler nozzle and divide that output by 1000. This is applicable for a boiler using any type of fuel.

TABLE 10.1 References to ASME Code Sec. IV

Requirements	Reference paragraphs
A. Pressure-relieving devices for steam boilers and hot water boilers	Art. 4
Pressure Relief Valve Requirements	HG-400
Safety Valve requirements for Steam Boilers	HG-400.1
Safety Relief Valve Requirements for Hot Water Boilers	HG-400.2
Safety and Safety Relief Valves for Tanks and Heat Exchangers	HG-400.3
Minimum Requirements for Safety and Safety Relief Valves	HG-401
Mechanical Requirements	HG-401.1
Material Selection	HG-401.2
Manufacture and Inspection	HG-401.3
Manufacturer's Testing	HG-401.4
Design Requirements	HG-401.5
Discharge Capacities of Safety and Safety Relief Valves	HG-402
Valve Markings	HG-402.1
Pressure at Which Capacity Tests Shall Be Conducted	HG-402.4
Opening Tests of Temperature and Pressure Safety Relief Valves	HG-402.5
Capacity Tests of Temperature and Pressure Safety Relief Valves	HG-402.6
Fluid Medium for Capacity Tests	HG-402.7
Where and by Whom Capacity Tests Shall Be Conducted	HG-402.8
Test Record Data Sheet	HG-402.9
Heating Surface	HG-403
Temperature and Pressure Safety Relief Valves	HG-405
B. Installation requirements for hot water heaters	Art. 8
Safety Relief Valves	HLW-800
Safety Relief Valve Requirements for Water Heaters	HLW-800.1
Mounting Safety Relief Valves	HLW-801
Installation	HLW-801.1
Permissible Mountings	HLW-801.2
Requirements for Common Connection for Two or More Valves	HLW-801.3
Threaded Connections	HLW-801.4
Prohibited Mountings	HLW-801.5
Use of Shutoff Valves Prohibited	HLW-801.6
Safety Relief Valve Discharge Piping	HLW-801.7

- Determine minimum lb (kg) of steam generated per hour per ft² (m²) of boiler heating surface as shown in Table 10.2.

The safety valve capacity of each steam boiler should be such that the pressure cannot rise more than 5 psi (35 kPa) above the maximum allowable working pressure (MAWP) with the fuel-burning equipment operated at maximum capacity. The safety valve capacity should be increased if the operating conditions are changed, or additional heating surfaces are installed.

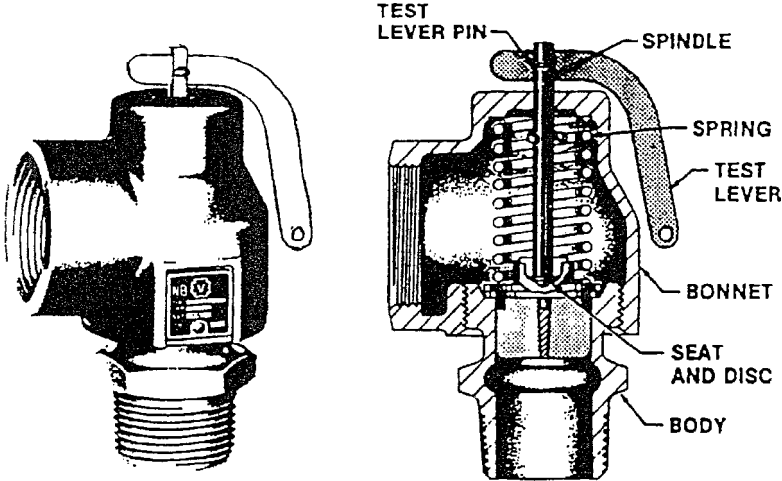


Figure 10.5 Spring-loaded pop safety valve for low-pressure steam boiler.

The minimum safety valve capacity for a cast-iron boiler should be determined by the maximum output method. Generally, a greater relieving capacity is provided than the minimum specified by the rules.

Example 10.1: Safety Valve Capacity Calculation A gas-fired watertube boiler has 1650 ft² of heating surface and MAWP is 15 psig. What safety valve relieving capacity is required?

TABLE 10.2 Minimum lb/hr (kg/h) of Steam per ft² (m²) of Heating Surface

Boiler heating surface	Fire-tube boilers	Water-tube boilers
Hand fired	5 (24)	6 (29)
Stoker fired	7 (34)	8 (39)
Oil, gas, or pulverized fuel fired	8 (39)	10 (59)
Waterwall heating surface:		
Hand fired	8 (39)	8 (39)
Stoker fired	10 (49)	12 (59)
Oil, gas, or pulverized fuel fired	14 (68)	16 (78)

General notes:

1. When a boiler is fired only by a gas having a heat value not in excess of 200 Btu/ft³ (7400 kJ/m³), the minimum safety valve or safety relief valve relieving capacity may be based on the values given for hand-fired boilers above.
2. The minimum safety valve or safety relief valve capacity for electric boilers is 3½ lb/hr/kW (1.6 kg/h/kW) input.
3. The manufacturer may determine the minimum lb/hr/ft² (kg/h/m²) for extended heating surface.

Given

Gas-fired watertube boiler

$$HS = 1650 \text{ ft}^2$$

Solution

From Table 10.2, steam generating capacity is 10 lb/hr per square feet of heating surface for a gas-fired watertube boiler.

Total steam generation capacity of the boiler is $1650 \times 10 = 16,500$ lb/hr.

Therefore, safety valve relieving capacity of 16,500 lb/hr is required.

Heating surfaces. The heating surface is defined as the surface on which one side is water and the other side is products of combustion. The heating surface is measured on the side receiving heat. This measurement is used to determine steam-generating capacity of a boiler. The heating surface is computed as follows:

- Boiler heating surface and other equivalent surface outside the furnace should be measured circumferentially plus any extended surface.
- Waterwall heating surface and other equivalent surface within the furnace is measured as the projected tube area (diameter $\times$ length) plus any extended surface on the furnace side. Heating surfaces of the tubes, fire boxes, shells, tube sheets, and the projected area of headers are considered for this purpose.
- The manufacturer may determine the maximum designed generating capacity based on the total surface when extended surfaces or fins are used. This generating capacity should be included in the total minimum relief valve capacity marked on the stamping or nameplate.

10.2.2 Safety relief valve requirements for hot water boilers

There should be at least one safety relief valve (Fig. 10.6) of the automatic reseating type for each hot water heating or supply boiler. The valve should be identified with ASME code symbol **HV** and should be set at or below the MAWP. The size of the safety relief valve should not be less than NPS $3/4$ (DN 20) or more than NPS $4\frac{1}{2}$ (DN 115). A safety relief valve of size NPS $1/2$ (DN 15) may be used for a boiler with heat input not more than 15,000 Btu/hr (4.4 kW).

If water temperature in hot water heating or supply boilers is limited to 210°F (99°C), one or more T&P safety relief valves may be used in lieu of standard safety relief valves. Such T&P safety relief valves should be ASME rated with the **HV** symbol, of automatic reseating type, and set at or below the MAWP.



Figure 10.6 Bronze safety relief valve for hot water boiler. (Courtesy Kunkle Valve.)

When more than one safety relief valve is used for a hot water boiler, the additional valves should also be ASME rated. These valves should have a set pressure within a range not exceeding 6 psi (40 kPa) above the MAWP of the boiler up to 60 psi (400 kPa), and 5% for valves for boilers having MAWP more than 60 psi (400 kPa).

The relieving capacity in lb/hr (kg/h) of the pressure-relieving devices on a boiler should be greater than that determined by dividing the maximum output in BTU at the boiler nozzle by 1000. Alternatively, the relieving capacity may be determined on the basis of lb/hr (kg/h) of steam generated per ft^2 (m^2) of boiler heating surface as given in Table 10.2. The minimum relieving capacity for a cast-iron boiler should be determined by the maximum output method.

When a single safety relief valve is used on a boiler, the relieving capacity should be such that the pressure cannot rise more than 10% above the MAWP with the fuel-burning equipment operated at maximum capacity. When more than one safety relief valve is used, the overpressure should be limited to 10% above the set pressure of the highest set valve.

10.2.3 Safety and safety relief valves for tanks and heat exchangers

When safety valves and safety relief valves are required for tanks and heat exchangers, the following three conditions should be considered: steam to hot water supply, high-temperature water to water heat exchanger, and high-temperature water to steam heat exchanger.

Steam to hot water supply. The pressure of steam should not exceed the safe working pressure of the hot water tank when the hot water supply is heated directly by steam in a coil or pipe. The size of the safety relief valve should be at least NPS 1 (DN 25). The safety relief valve should be set to relieve at or below the MAWP of the tank. The valve should be installed directly on the tank.

High-temperature water to water heat exchanger. The heat exchanger should be equipped with one or more safety relief valves when high-temperature water is circulated through the coils or pipes of the heat exchanger to heat water for space heating or hot water supply. The safety relief valves should be ASME rated with the symbol **HV**, and set at or below the MAWP of the heat exchanger. The valves should have sufficient relieving capacity to prevent the heat exchanger pressure from rising more than 10% above the MAWP of the vessel.

High-temperature water to steam heat exchanger. The heat exchanger should be equipped with one or more safety valves (Fig. 10.7) when high-temperature water is circulated through the coils or tubes of the heat exchanger to generate low-pressure steam. The safety valves should be ASME rated with symbol **V**, and set to relieve at a pressure not exceeding 15 psi (100 kPa). The valves should have sufficient capacity to prevent the heat exchanger from raising more than 5 psi (35 kPa) above the MAWP of the vessel.

10.2.4 T&P safety relief valves for hot water heaters

A water heater is designed in accordance with Part HLW of Sec. IV of the ASME Code. The requirements for safety relief valves are specified in Art. 8 of Part HLW. Each water heater should have at least one T&P safety relief valve (Fig. 10.8) or at least one safety relief valve. The valves should be marked with the ASME Code symbol **HV**. Minimum size of the valves should be less than NPS $\frac{3}{4}$ (DN 20).

The pressure setting of the T&P pressure relief valve should be less than or equal to the MAWP of the water heater. If any components in the hot water system (such as expansion tanks, storage tanks, piping,



Figure 10.7 Bronze safety valve for steam heat exchanger. (Courtesy Kunkle Valve.)



Figure 10.8 T&P safety relieve valve. (Courtesy Conbraco Industries, Inc.)

etc.) have lower working pressure than the water heater, the valve should be set at the pressure of the component with the lowest MAWP. If more than one valve is used, the additional valve may be set within a range not exceeding 10% over the set pressure of the first valve.

The relieving capacity in Btu/hr of the T&P safety relief valve should not be less than the maximum allowable input of the water heater. The relieving capacity for an electric heater should be 3500 Btu/hr (1.0 kW) per kW of input. The T&P safety relief valve capacity for each water heater should be such that the pressure cannot rise more than 10% above the MAWP with the fuel-burning equipment operated at maximum capacity.

T&P safety relief valves should be installed by either the installer or the manufacturer before a water heater is put into operation.

10.2.5 Mechanical requirements

The design of safety relief valves should incorporate guiding arrangements necessary to ensure consistent operation and tightness. Excessive lengths of guiding surfaces should be avoided. Bottom-guided designs are not allowed on safety relief valves. O-rings and other packing devices, if used on the stems, should be arranged so that they do not affect operation and capacity.

The inlet opening should have an inside diameter equal to or greater than the seat diameter. The maximum opening through any part of the valve should not be less than $\frac{1}{4}$ in (6 mm) in diameter.

The safety valves should be spring loaded and the spring should be designed so that the full-load spring compression is not greater than 80% of the nominal solid deflection. The permanent set of the spring should not exceed 0.5% of the free height.

A body drain below seat level should be provided on all safety valves and safety relief valves. For valves NPS $2\frac{1}{2}$ (DN 65) or smaller, the drain hole should be not less than $\frac{1}{4}$ in (6 mm) in diameter. For valves larger than NPS $2\frac{1}{2}$ (DN 65), the drain hole should be tapped to not less than NPS $\frac{3}{8}$ (DN 10). The body drain connections should not be plugged during or after installation.

Consideration should be given to minimizing the effects of water deposits when designing the body of the valve. The valves should be provided with wrenching surfaces to allow installation without damaging operating parts.

The safety valves should have a controlled blowdown of 2–4 psi (15–30 kPa), and this blowdown need not be adjustable. The set pressure tolerances, plus or minus, for safety valves should not exceed 2 psi (15 kPa), and for safety relief valves 3 psi (20 kPa) for pressures up to 60 psig (400 kPa). These tolerances should not exceed 5% for pressures above 60 psig (400 kPa).

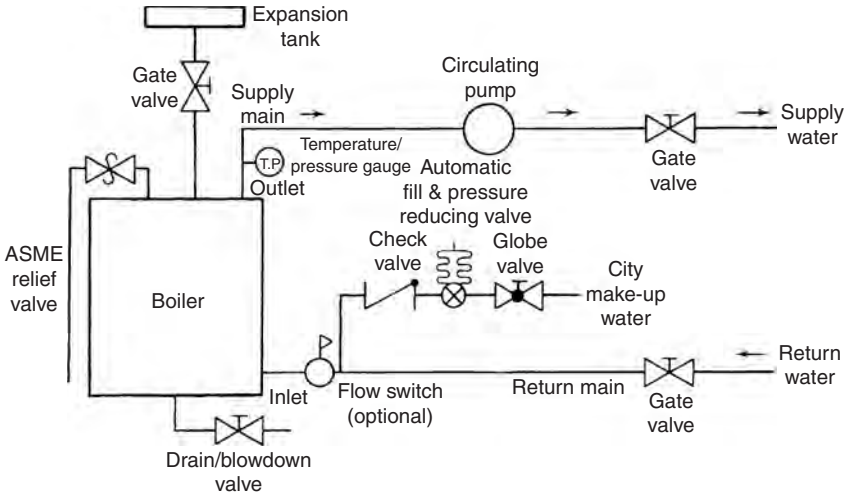


Figure 10.9 Location of a relief valve for a heating boiler.

10.2.6 Material selection

Construction materials of for valve bodies and bonnets or pressure parts should confirm to ASME Sec. II. The manufacturer can use materials other than those listed in ASME Sec. II, if he can establish and maintain specifications with equivalent chemical and physical properties.

Cast-iron seats and disks are not allowed. Adjacent sliding surfaces such as guides and disks should be constructed from corrosion-resistant materials. Springs should be fabricated from corrosion-resistant materials or materials having a corrosion-resistant coating.

Materials used for seats and disks should be able to withstand heat and provide resistance to steam cutting.

10.2.7 Locations

Safety relief valves should be located at the top of a hot water boiler or water heater (Fig. 10.9). The valves may be connected directly to a tapped or flanged opening in the water heater, to a fitting connected to the water heater by a short nipple, to a Y-base, or to a valveless header connecting water outlet on the same heater.

10.3 Manufacture and Inspection

A manufacturer must demonstrate to the satisfaction of an ASME designee that the manufacturing, production, testing facilities, and quality control procedures are in close agreement between the random

production samples and the valves submitted for capacity certification. An ASME designee can inspect manufacturing, inspection, and test operations including capacity at any time.

Each safety relief valve to which the Code symbol **HV** is to be applied must be produced by a manufacturer and/or assembler who is in possession of a valid Certificate of Authorization. A manufacturer or assembler may be granted permission by the ASME to produce pressure relief valves with Code symbol **HV** upon acceptance of a satisfactory recommendation from the ASME designee and payment of administrative fees. The permission expires on the fifth anniversary of the date it is initially granted.

In order to extend permission for 5-year periods, a manufacturer is required to successfully repeat the following tests within the 6-month period before expiration:

1. Two sample production pressure relief valves of a size and capacity within the capability of an ASME-accepted laboratory are selected by an ASME designee.
2. An ASME-accepted laboratory then conducts operational and capacity tests in the presence of an ASME designee. The valve manufacturer may have representatives present to witness the tests.
3. If any valve fails to relieve at or above its certified capacity or fails to meet performance criteria, the test is repeated at the rate of two replacement valves for each valve that failed.
4. If any of the replacement valves fails to meet the capacity or performance requirements, the manufacturer's Code symbol for the particular type of valve will be revoked within 60 days of the authorization. During this period, the manufacturer should demonstrate the cause of such deficiency and the action taken to guard against future occurrence.

Safety valves should be sealed to prevent the valve from being taken apart without breaking the seal. Safety relief valves should be set and sealed so that they cannot be reset without breaking the seal.

10.3.1 Valve markings

A manufacturer and/or assembler should possess a valid Certification of Authorization from the ASME to apply a Code symbol to each safety relief valve. Each safety relief valve is required to be marked with the data as per Par. HG-402.1 of Sec. IV, and markings should include the following:

1. Name or acceptable abbreviation of the manufacturer's name.
2. Manufacturer's design or type number.



Figure 10.10 ASME symbol for a safety relief valve.

3. NPS size _____ in (DN) (the nominal pipe size of the valve inlet).
4. Set pressure _____ psi.
5. Capacity _____ lb/hr (kg/h), or capacity _____ Btu/hr.
6. Year built. Alternatively, a coding may be marked on the valves such that the valve manufacturer can identify the year the valve was assembled and tested.
7. ASME Symbol as shown in Fig. 10.10.

The above data should be marked in such a way that the markings will not be obliterated in service over a period of time. The markings may be stamped, etched, impressed, or cast on the valve or on a nameplate, which should be securely fastened to the valve (Fig. 10.11).

10.4 Manufacturer's Testing

A manufacturer should have a well-established program for testing safety valves and safety relief valves. The testing program should be established for the application, calibration, and maintenance of test gauges.

Each safety valve should be tested to demonstrate its popping point, blowdown, and tightness. Each safety relief valve should be tested to demonstrate its opening point and tightness. Safety valves are tested on steam or air and safety relief valves are tested on water, steam, or air.

Depending on size and design, testing time will vary, but testing time should be sufficient to ensure that test results are repeatable and represent field performance. Test fixtures and test drums should be of adequate size and capacity to assure accurate pop action and blowdown adjustment.

The tightness test is very important for safety relief valves. A tightness test is conducted at maximum expected operating pressure, not exceeding the reseating pressure of the valve.

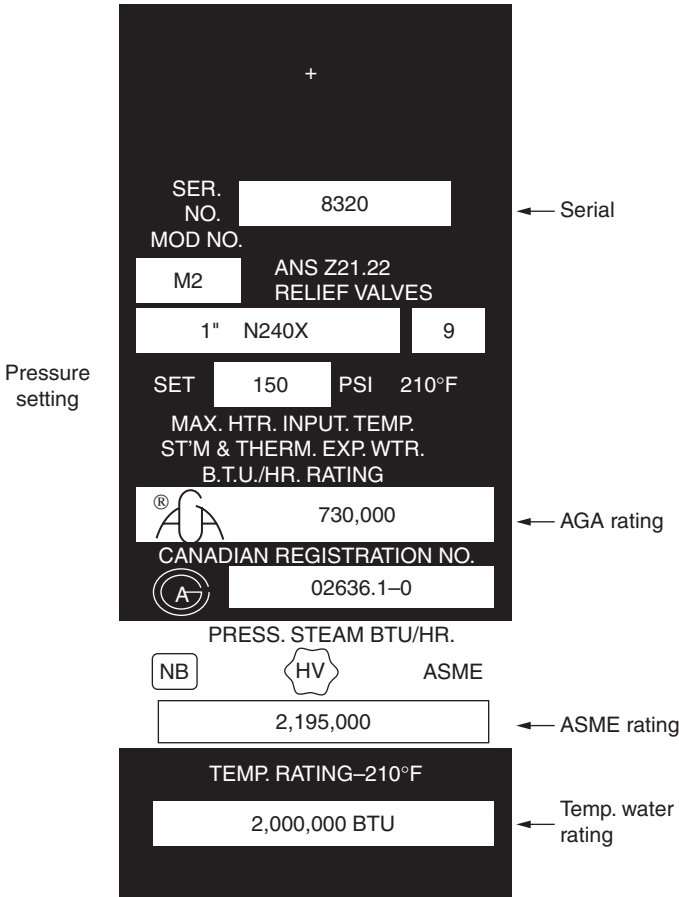


Figure 10.11 Nameplate for a T&P pressure relief valve.

10.5 Capacity Requirements

The manufacturer must submit valves for capacity testing to a place where equipment and personnel are available to perform pressure and relieving-capacity tests. The place, personnel, and authorized observer must be approved by the ASME Boiler and Pressure Vessel Committee.

10.5.1 Calculation of capacity to be stamped on valves

Capacity to be stamped on the valves is determined by tests. The tests must be conducted in the presence of and certified by an observer authorized by the ASME. The valves should be tested using one of the following three methods.

Coefficient method. This coefficient method is based on coefficient calculation and is used for safety relief valves. In this method, tests are conducted to determine the lift, popping, and blowdown pressures, and the capacity of at least three valves each of three representative sizes (a total of nine valves). Each valve should be set at a different pressure. However, safety valves for low-pressure steam boilers should have all nine valves set at 15 psig (100 kPa).

A coefficient of discharge, K_D , is established for each test using the following formula:

$$K_D = \frac{\text{Actual steam flow}}{\text{Theoretical steam flow}}$$

where the average of coefficients K_D of the nine tests is determined as

$$K = \text{average } K_D \times 0.90$$

where K is the coefficient of discharge for the design.

The stamped capacities for all sizes and pressures are determined using the following formulas.

For a 45° seat,

$$W = 51.5\pi DLP \times 0.707K$$

For a flat seat,

$$W = 51.5\pi DLPK$$

For a nozzle,

$$W = 51.5APK$$

where W = weight of steam per hour, lb

D = seat diameter, in

L = lift, in

P = $(1.10 \times \text{set pressure} + 14.7)$ psia for hot water applications

= $(5.0 \text{ psi} + 15 \text{ psi set} + 14.7)$ psia for steam boilers

A = nozzle throat area, in²

The maximum and minimum coefficients determined by the tests of a valve design should not vary more than $\pm 5\%$ from the average. If one or more tests are outside the acceptable limits, one valve of the

manufacturer's choice should be replaced with another valve of the same size and pressure setting or by a modification of the original valve. A new average coefficient should be calculated, excluding the replaced valve. If one or more tests are now outside the acceptable limits, as determined by the new average coefficient, a valve of the manufacturer's choice should be replaced by two valves of the same size and pressure as the rejected valve. A new average coefficient, including the replacement valves, should be calculated. If any valve, excluding the two replaced valves, now falls outside the acceptable limits, the test is considered unsatisfactory.

Slope method. The slope method is used to apply the ASME Code symbol to a design of pressure relief valves. In this method, four valves of each combination of pipe and orifice size are tested. These four valves should be set at pressures to cover the range of pressures for which the valves will be used. The capacities should be based on these four tests as given below.

1. The slope (W/P) for each test should be calculated using the following formula:

$$\text{Slope} = \frac{W}{P} = \frac{\text{measured capacity, lb/hr}}{\text{absolute flow pressure, psia}}$$

All values obtained from the testing should fall with $\pm 5\%$ of the average value:

$$\text{Minimum slope} = 0.95 \times \text{average slope}$$

$$\text{Maximum slope} = 1.05 \times \text{average slope}$$

The test values should be between the minimum and maximum slope value range. The authorized observer may require that additional valves be tested at the rate of two for each valve beyond the maximum values, with a limit of four additional valves.

2. The relieving capacity to be stamped on the valve should not exceed 90% of the average slope $\times$ the absolute accumulation pressure:

$$\text{Rated slope} = 0.90 \times \text{average slope}$$

$$\text{Stamped capacity} \geq \text{rated slope} \times (1.10 \times \text{set pressure} + 14.7 \text{ psia})$$

for hot water applications.

Three-valve method. The three-valve method is used when a manufacturer intends to apply the Code symbol to safety relief valves of one or more sizes of a design set at one pressure. The manufacturer should submit three valves of each size of each design set at one pressure for testing. In this case the stamped capacity should not exceed 90% of the average capacity of the three valves tested.

The discharge capacity as determined by the test of each valve tested should not vary more than $\pm 5\%$ from the average capacity of the three valves tested. If one of the three valve tests falls outside the limits, it may be replaced by two valves and a new average calculated based on all four valves, excluding the replaced valve.

10.5.2 Fluid medium for tests

The tests should be performed with dry saturated steam. This steam may contain 98% quality and 20°F (10°C) maximum superheat. The relieving capacity should be measured by condensing the steam or with a calibrated steam flow meter.

In order to determine the discharge capacity of safety relief valves, steam flow per hour is measured. The discharge capacity in terms of Btu is obtained by steam flow per hour W multiplied by 1000.

10.5.3 Capacity tests of T&P safety relief valves

For determining the capacity of T&P safety relief valves, dummy elements of the same size and shape are used instead of thermal elements, and the relieving capacity is based on the pressure element only. The manufacturer should deactivate the temperature element of the production test valves prior to or at the time of capacity testing.

For determining the set (opening) pressure, the test medium should be water at room temperature. The actual set pressure is defined as the pressure at the valve inlet when the flow rate through the valve is 40 cm³/min. Capacity tests should be performed with steam at a pressure 10% above the actual water set pressure. For production capacity tests, the rated capacity should be based on the actual water set pressure.

10.5.4 Capacity tests for safety and safety relief valves

Safety valves and safety relief valves are tested for conformance to the requirements of ASME PTC 25. The tests are performed at a place where the testing facilities, methods, procedures, and person supervising the tests meet the requirements of ASME PTC 25.

Safety valves should be tested for capacity at 5 psi (35 kPa) over the set pressure for which the valve is set to operate. Capacity tests for safety relief valves for hot water heating and hot water supply boilers should be performed at 110% of the pressure for which the valve is set to operate.

The tests should be conducted under the supervision of and certified by an Authorized Observer (AO). The testing facilities, methods, procedures, and qualifications of the AO should be approved by the ASME on recommendation of an ASME designee. The testing facilities are subject to review by ASME within each 5-year period.

The manufacturer and the AO should sign the capacity test data reports for each model, type, and size of valve. The signed test data reports are submitted to the ASME designee for review and acceptance. When any changes are made in the valve design, capacity certification tests should be repeated.

10.5.5 Test record data sheets

A data sheet for each valve is prepared and signed by the AO witnessing the test. The manufacturer will use that data sheet for construction and stamping the valves of the corresponding design and construction. New tests should be conducted when changes are made in the design that affects the flow path, lift, or performance characteristics of the valve.

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Pressure Relief Devices for Pressure Vessels

A pressure vessel is a closed container designed for the containment of pressure, either internal or external. The pressure may be imposed by an external source, by the application of heat from a direct or indirect source, or by any combination thereof. Pressure vessels are usually subjected to an internal or external operating pressure of more than 15 psig (103 kPa).

Internal pressure in a vessel is developed from the fluid in process applications. External pressure on a vessel may be imposed by an internal vacuum or by pressure of the fluid between an outer jacket and the vessel wall. The components of a vessel may fail, causing dangerous accidents if the vessel cannot withstand the internal or external pressure.

Pressure vessels are designed and constructed in various shapes. They may be cylindrical with heads, spherical, spheroidal, boxed, or lobed. The common types of pressure vessels are boilers, water heaters, expansion tanks, feedwater heaters, columns, towers, drums, reactors, heat exchangers, condensers, air coolers, oil coolers, accumulators, air tanks, gas cylinders, and refrigeration systems.

11.1 Introduction

Pressure vessels contain fluids such as liquids, vapors, and gases at pressure levels greater than atmospheric pressure. Some of the fluids may be corrosive or toxic. All types of industries, from workshops to power generation, pulp and paper to large petrochemical industries, use pressure vessels. Small workshops use air compressor tanks. Petrochemical industries use hundreds of vessels such as towers, drums, reactors etc., for process applications. Depending on the application, the vessels are constructed of either carbon steel or alloy steel.

Most pressure vessels are designed in accordance with codes developed by the ASME and the American Petroleum Institute (API). In addition to these codes, the design engineer uses engineering practices to make the vessel safe. A pressure vessel bears the symbol stamping of the code under which the vessel is designed and constructed. As a pressure vessel operates under pressure, safety is the main consideration during its design, construction, installation, operation, maintenance, inspection, and repair.

Figure 11.1 shows a diagram of a typical pressure vessel. The main components are the shell, head, and nozzles. This cylindrical vessel is horizontal and may be supported by steel columns, cylindrical plate skirts, or plate lugs attached to the shell. The vessel may be used for any type of industrial process application under internal pressure.

Like any other machine, a pressure vessel is composed of many components and fitted with various controls and safety devices. The major components of a pressure vessel are:

- *Shell.* The main component or outer boundary metal of the vessel.
- *Head.* The end closure of the shell. Heads may be spherical, conical, elliptical, or hemispherical.
- *Nozzle.* Fitting for inlet and outlet connection pipes.

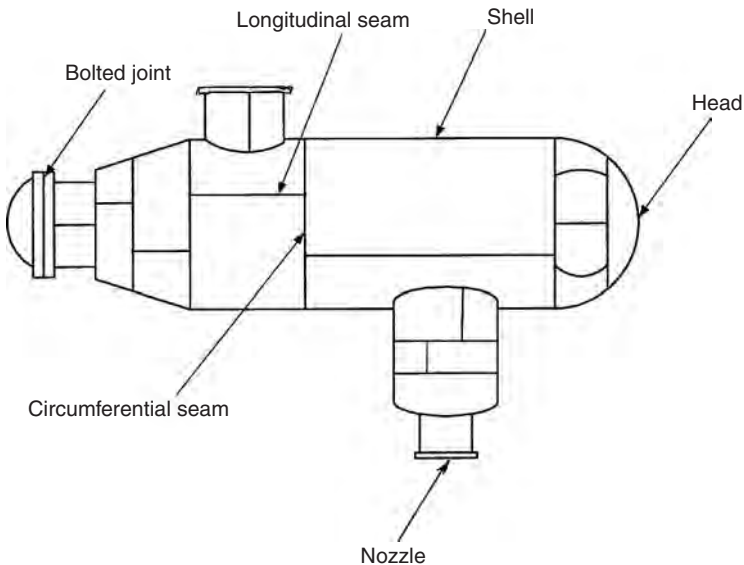


Figure 11.1 Pressure vessel diagram.

11.1.1 Types of pressure vessels

There are many types of pressure vessels, but they are generally classified into two basic categories:

1. *Fired pressure vessels.* In this category, fuels are burned to produce heat, which in turn boils water to generate steam. Boilers and water heaters are examples of fired pressure vessels.
2. *Unfired pressure vessels.* Vessels in this category are used for storage of liquids, gases, or vapors at pressures greater than 15 psig (103 kPa). Examples include air receiver tanks (Fig. 11.2), deaerators (Fig. 11.3), water storage tanks (Fig. 11.4), heat exchangers, and towers.

The scope of this chapter will be limited to discussion of unfired pressure vessels. Throughout this chapter, the terms *pressure vessel*, *vessel*, and *equipment* will mean unfired pressure vessels.

Most pressure vessels are cylindrical in shape. Spherical vessels may be used for extremely high-pressure operation. Vessels may range from a few hundred pounds per square inch (psi) up to 150,000 psi. The operating range of temperature may vary from -100 to 900°F . The ASME Boiler and Pressure Vessel Code, Sec. VIII, Division I, exempts the following vessels from the definition of pressure vessel:

1. Pressure containers which are integral components of rotating or reciprocating mechanical devices, such as pumps, compressors, turbines, generators, etc.
2. Piping systems, components, flanges, gaskets, valves, expansion joints, etc.

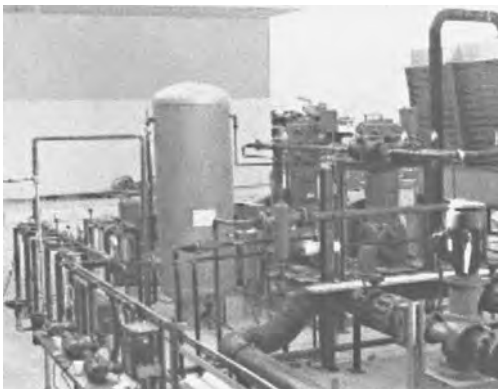


Figure 11.2 An air receiver tank.
(Courtesy Hanson Tank.)

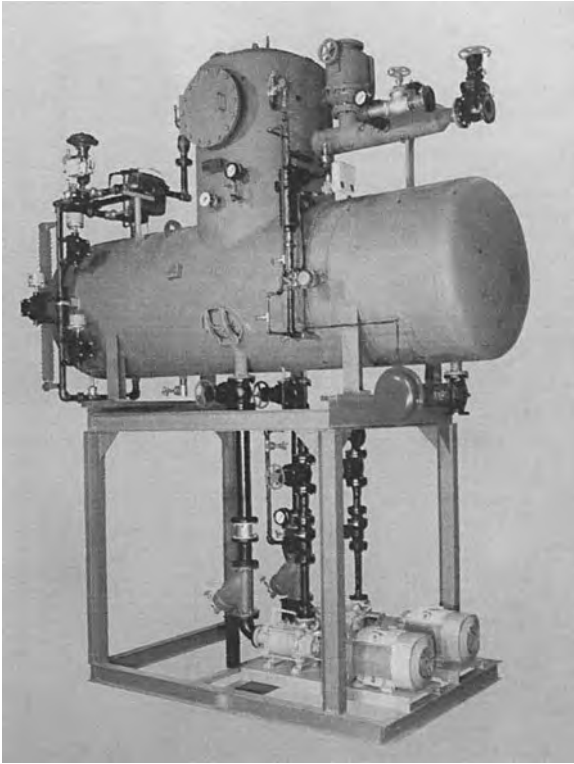


Figure 11.3 A deaerator. (Courtesy U.S. Deaerator Company.)

3. Vessels for containing water under pressure, including those containing air the compression of which serves only as a cushion, when none of the following limitations is exceeded:
 - (a) A design pressure of 300 psi
 - (b) A design temperature of 210°F
4. Hot water supply storage tanks heated by steam or any other indirect means when none of the following limitations is exceeded:
 - (a) A heat input of 200,000 Btu/hr
 - (b) A water temperature of 210°F
 - (c) A nominal water-containing capacity of 120 gal
5. Vessels having an internal or external operating pressure not exceeding 15 psi, with no limitation on size.
6. Vessels having an inside diameter, width, height, or cross-diagonal not exceeding 6 in, with no limitation on length of vessel or pressure.
7. Pressure vessels for human occupancy.

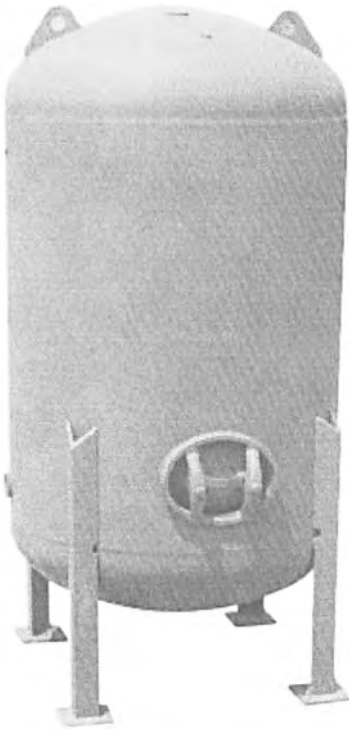


Figure 11.4 A water storage tank.

11.1.2 Pressure vessel codes

Pressure vessels are designed, constructed, inspected, and certified according to the ASME Boiler and Pressure Vessel Code, the API Code, and the Tubular Exchanger Manufacturers Association (TEMA) Code.

ASME boiler and pressure vessel code. ASME Code Sec. VIII is used internationally for construction of pressure vessels. This Code has three separate divisions: Division 1—Pressure Vessels, Division 2—Alternative Rules, and Division 3—Alternative Rules for Construction of High-Pressure Vessels.

ASME Sec. VIII, Division 1—Rules for Construction of Pressure Vessels, contains mandatory requirements, specific prohibitions, and nonmandatory guidance for pressure vessel materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

ASME Sec. VIII, Division 2—Alternative Rules for Construction of Pressure Vessels, provides an alternative to the minimum construction requirements for the design, fabrication, inspection, and certification of pressure vessels with maximum allowable working pressure (MAWP) from 3,000 to 10,000 psig.

ASME Sec. VIII, Division 3—Alternative Rules for Construction of High-Pressure Vessels, are applicable to the design, construction, inspection, and overpressure protection of metallic pressure vessels with design pressures generally above 10,000 psi.

American Petroleum Institute Code. API 510, Pressure Vessel Inspection Code, is widely used in the petroleum and chemical process industries for maintenance inspection, rating, repair, and alteration of pressure vessels. This code is applicable only to vessels that have been placed in service and have been inspected by an authorized inspection agency or have been repaired by a repair organization defined in the code. The code includes provisions for certifying pressure vessel inspectors.

API Standard 572, Inspection of Pressure Vessels, is a Recommended Practice (RP) standard for inspection of pressure vessels (towers, drums, reactors, heat exchangers, and condensers). The standard covers the reasons for inspection, causes of deterioration, frequency and methods of inspection, methods of repair, and preparation of records and reports.

API Standard 620, Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks, provides rules for design and construction of large, welded, low-pressure carbon steel aboveground storage tanks. The tanks are designed for metal temperature not greater than 250°F and with pressures in their gas or vapor spaces not greater than 15 psig. These are low-pressure vessels that are not covered by ASME Sec. VIII, Division 1 Code.

API Standard 650, Welded Steel Tanks for Oil Storage, covers material, design, fabrication, erection, and testing requirements for aboveground, vertical cylindrical, closed- and open-top, welded steel storage tanks in various sizes and capacities. This standard is applicable to tanks with internal pressures of approximately atmospheric pressure, but higher pressure is permitted when additional requirements are met.

API Standard 660, Shell-and-Tube Heat Exchangers for General Refinery Services, defines the minimum requirements for the mechanical design, material selection, fabrication, inspection, testing, and preparation for shipment of shell-and-tube heat exchangers for general refinery services.

API Standard 661, Air-Cooled Heat Exchangers for General Refinery Service, covers the minimum requirements for design, materials, fabrication, inspection, testing, and preparation for shipment of refinery process air-cooled heat exchangers.

TEMA standards. The Tubular Exchanger Manufacturers Association (TEMA) includes manufacturers of shell-and-tube heat exchangers. The TEMA Standards cover nomenclature, fabrication tolerance, general fabrication and performance information, installation, operation and

maintenance, mechanical standard class RCB heat exchangers, flow-induced vibration, thermal relations, physical properties of fluids, and recommended good practice for shell-and-tube heat exchangers.

11.1.3 Pressure relief devices

All pressure vessels as defined by ASME Sec. VIII, regardless of size or pressure, should be provided with pressure relief devices such as pressure relief valves or nonreclosing pressure relief devices such as rupture disks. It is the responsibility of the owner to ensure that pressure relief devices are properly installed prior to operation. The pressure relief devices may be installed either by the vessel manufacturer or by an installing contractor.

The pressure relief devices should protect the pressure vessels, preventing pressure rising more than 10% or 3 psi (20 kPa), whichever is greater, above the MAWP. If multiple pressure relief devices are used, they should prevent the pressure from rising more than 16% or 4 psi (30 kPa), whichever is greater, above the MAWP.

If additional hazard is expected to be created by exposure of a pressure vessel to fire or other unexpected sources of external heat, supplemental pressure relief devices should be installed to protect against excessive pressure. Such supplemental devices should be capable of preventing the pressure from rising more than 21% above the MAWP.

Vessels that are operated completely filled with liquid should be provided with pressure relief devices designed for liquid service, unless otherwise protected against overpressure.

Pressure relief devices should be constructed, located, and installed so that they are readily accessible for inspection, replacement, and repair. Pressure relief devices need not be installed directly on a pressure vessel when either of the following conditions applies:

- The source of pressure is external to the vessel and under control, so that the pressure cannot exceed the MAWP at the operating temperature.
- There are no intervening stop valves between the vessel and the pressure relief devices.

11.2 Pressure Relief Valves

A pressure relief valve is a pressure relief device which is designed to reclose and prevent the further flow of fluid after normal conditions have been restored. Safety, safety relief, and relief valves are examples of pressure relief valves and are used for all types of pressure vessels. Figure. 11.5 shows two water storage tanks connected together; each water storage tank is fitted with a T & P relief valve.

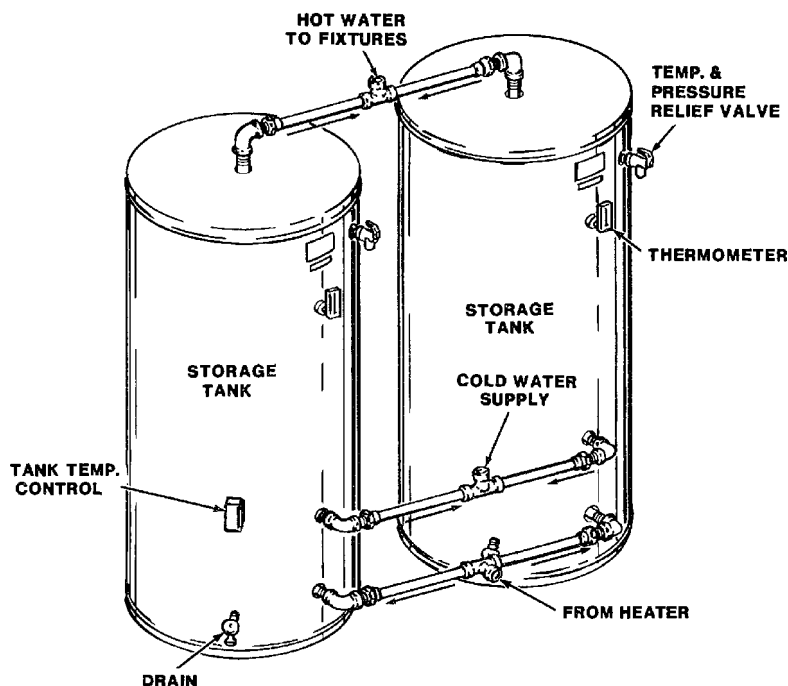


Figure 11.5 Two water storage tanks, each has a T&P relief valve. (Courtesy: A.O. Smith Co.)

The pressure relief valve of the direct spring-loaded type should be used on pressure vessels. Pilot-operated pressure relief valves may be used provided the pilot is self-actuated. The main valve should open automatically at not over the set pressure and discharge its full capacity if some part of the pilot should fail.

The spring of a pressure relief valve (Fig. 11.6) should not be set for any pressure more than 5% above or below that for which the valve is marked. The manufacturer, his authorized representative, or an assembler should perform the initial adjustment, and provide a valve data tag identifying set pressure capacity and date. The valve shall be sealed with a seal identifying the manufacturer, his authorized representative, or the assembler performing the adjustment.

The set pressure tolerances, plus or minus, of pressure relief valves should not exceed 2 psi (15 kPa) for pressures up to 70 psi (500 kPa). These tolerances, plus or minus, should not exceed 3% for pressures above 70 psi (500 kPa).

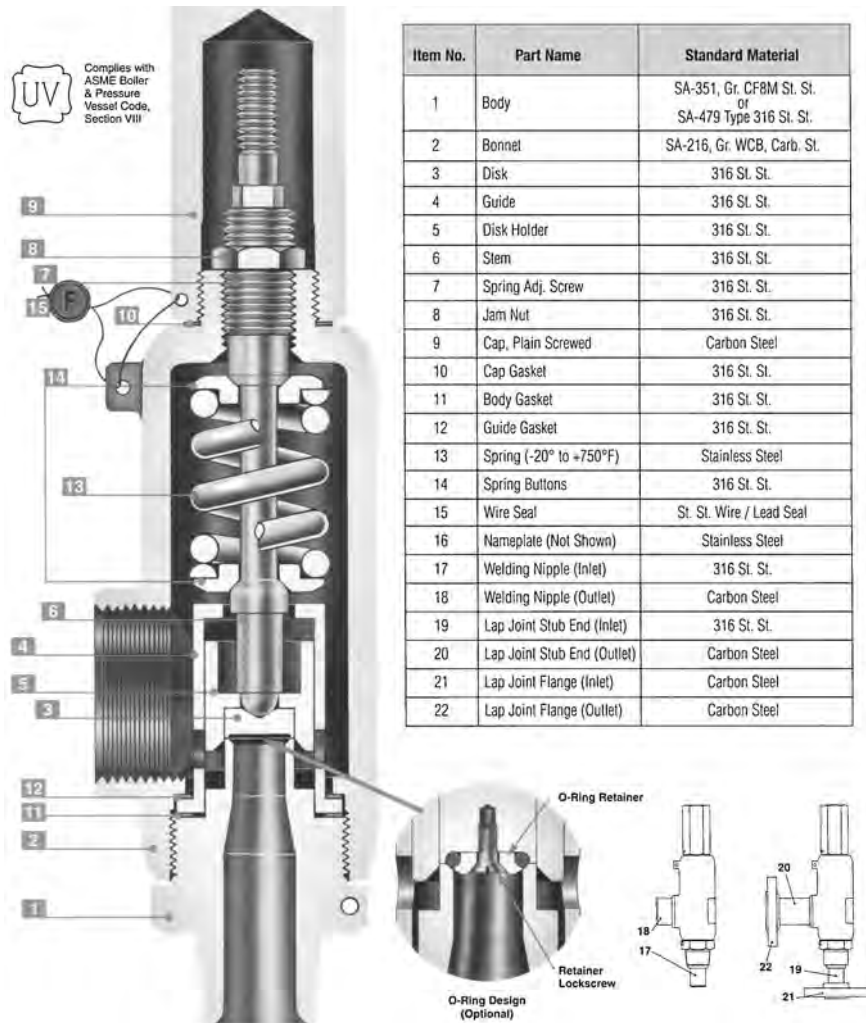


Figure 11.6 Cross-sectional view of a pressure relief valve. (Courtesy Farris Engineering.)

11.2.1 Operational requirements

The set pressure marked on a single pressure relief valve should not exceed the maximum allowable working pressure of the vessel. When more than one pressure relief valve is used, only one valve should be set at or below the maximum allowable working pressure, and the additional valves may be set to open at higher pressure but not higher than 105% maximum allowable pressure. In exceptional case of fire or other external heat, the marked set pressure should not exceed 110% of the maximum allowable working pressure of the vessel.

TABLE 11.1 Operational Requirements for Pressure Relief Valves

Set pressure tolerance:	
±2 psi (15 kPa)	Up to including 70 psi (500 kPa)
±3%	Above 70 psi (500 kPa)
Blowdown:	
Required only during product certification testing; not a requirement for production valves.	
Most manufacturers meet 10%.	
Overpressure:	
3 psi or 10%, whichever is greater.	

The pressure relief valve set pressure should include the effects of static head and constant back pressure. Operational requirements for pressure relief valves are listed in Table 11.1.

11.2.2 Code references

Pressure relief devices for pressure vessels are designed, constructed, inspected, stamped, certified, and installed in accordance with the rules of ASME Code Sec. VIII—Div. 1. ASME Code references for pressure relief valve requirements are given in Table 11.2.

11.2.3 Design requirements

The total capacity of the pressure relief valves connected to any vessel for the release of liquid, air, steam, or other vapor should be sufficient to carry off the maximum quantity that is generated or supplied to the

TABLE 11.2 ASME Code Sec. XIII—Div. 1 References for Pressure Relief Valves

Requirements	Reference paragraph
General	UG-125
Pressure Relief Valves	UG-126
Nonreclosing Pressure Relief Devices	UG-127
Liquid Pressure Relief Valves	UG-128
Marking	UG-129
Code Symbol Stamp	UG-130
Certification of Capacity of Pressure Relief Valves	UG-131
Certification of Capacity of Pressure Relief Valves in Combination with Nonreclosing Pressure Relief Valves	UG-132
Determination of Pressure Relieving Requirements	UG-133
Pressure Setting of Pressure Relief Devices	UG-134
Installation	UG-135
Minimum Requirements for Pressure Relief Valves	UG-136
Minimum Requirements for Rupture Disk Devices	UG-137
Capacity Conversions for Safety Valves	App. 11

vessel without allowing a rise in pressure within the vessel of more than 16% above the MAWP when the pressure relief valves are blowing.

Pressure relief valves used for protection against excessive pressure caused by fire or other external heat should have a relieving capacity sufficient to prevent pressure from rising more than 21% above the MAWP when all pressure relief valves are blowing.

When more than one vessel is connected together by a system of piping not containing valves, they may be considered as one unit for determining the required relieving capacity. Heat exchangers and similar vessels should be protected with pressure relief valves of sufficient capacity to avoid overpressure in case of internal failure.

For prorating the relieving capacity at any relieving pressure greater than $1.1p$ as defined below, a multiplier may be applied to the rated relieving capacity of a pressure relief valve as follows:

$$\text{Multiplier} = \frac{P + 14.7}{1.1p + 14.7}$$

where P = relieving pressure, psig (kPa gauge)

p = set pressure, psig (kPa gauge)

The above multiplier is not applicable for steam pressure above 1500 psig (10.3 MPa gauge). For steam pressure above 1500 psig, the capacity at relieving pressures greater than $1.10p$ should be determined using the equation for steam with the correction for high-pressure steam and the coefficient K for that valve design.

Capacity conversion. The official rated capacity is the capacity stamped on a pressure relief valve and guaranteed by the manufacturer. The rated pressure relieving capacity of a pressure relief valve for other than steam or air should be determined in accordance with Mandatory Appendix 11 of Section VIII—Div. 1.

The capacity of a safety or relief valve in terms of a gas or vapor other than the medium for which the valve was rated, may be determined by using the following formulas:

(a) For steam,

$$W_s = C_N K A P$$

where:

$$C_N = 51.1$$

(b) For air,

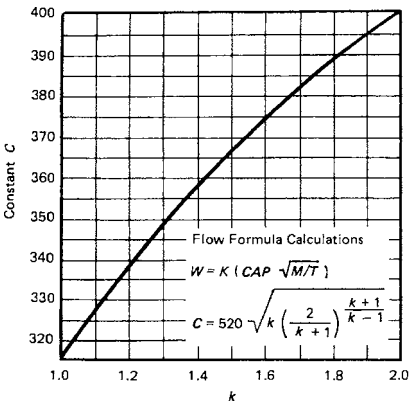
$$W_a = CKAP \sqrt{\frac{M}{T}}$$

where $C = 256$
 $M = 28.97$ mol. Wt.
 $T = 520$ when W_a is the rated capacity

(c) For any gas or vapor,

$$W = CKAP \sqrt{\frac{M}{T}}$$

where W_s = rated capacity, lb/hr (kg/n) of steam
 W_a = rated capacity, converted to lb/hr (kg/n) of air at 60°F (20°C), inlet temperature
 W = flow of any gas or vapor, lb/hr
 C = constant for gas or vapor which is a function of the ratio of specific heats,
 $k = c_p / c_v$ (See Fig. 11.7)
 K = coefficient of discharge
 A = actual discharge area of safety valve, in.² (mm²)
 P = (set pressure × 1.10) plus atmospheric pressure, psia (MPa_{abs})
 M = molecular weight
 T = absolute temperature at inlet [(°F + 460) (K)]



Constant		Constant		Constant	
k	C	k	C	k	C
1.00	315	1.26	343	1.52	366
1.02	318	1.28	345	1.54	368
1.04	320	1.30	347	1.56	369
1.06	322	1.32	349	1.58	371
1.08	324	1.34	351	1.60	372
1.10	327	1.36	352	1.62	374
1.12	329	1.38	354	1.64	376
1.14	331	1.40	356	1.66	377
1.16	333	1.42	358	1.68	379
1.18	335	1.44	359	1.70	380
1.20	337	1.46	361	2.00	400
1.22	339	1.48	363	2.20	412
1.24	341	1.50	364	...	...

Figure 11.7 Constant C for gas or vapor related to ratio of specific heats ($k = c_p/c_v$).
(Courtesy: ASME International)

TABLE 11.3 Molecular Weights of Gases and Vapors

Air	28.97	Freon 22	86.48
Acetylene	26.04	Freon 114	170.90
Ammonia	17.03	Hydrogen	2.02
Butane	58.12	Hydrogen Sulfide	34.08
Carbon Dioxide	44.01	Methane	16.04
Chlorine	70.91	Methyl Chloride	50.48
Ethane	30.07	Nitrogen	28.02
Ethylene	28.05	Oxygen	32.00
Freon 11	137.371	Propane	44.09
Freon 12	120.90	Sulfur Dioxide	64.06

The above formulas may also be used to calculate rated capacity of steam or air when the required flow of any gas or vapor is known,

Notes

1. Molecular weights of some common gases and vapors are given in Table 11.3.
2. If the official rating of a safety valve is known from the stamped data on the valve, KA in either of the following formulas may be calculated:

Official rating in steam Official rating in air

$$KA = \frac{W_s}{51.5P} \qquad KA = \frac{W_a}{CP} \sqrt{\frac{T}{M}}$$

The value of KA is substituted in the above formulas to determine the capacity of the safety valve in terms of new gas or vapor.

3. For hydrocarbon vapors, where value of k is not known, $k = 1.001$ is used and the formula becomes:

$$W = CKAP \sqrt{\frac{M}{T}}$$

where $C = 315$

4. If desired, as in the case of light hydrocarbons, the compressibility factor Z may be included and formula for gases and vapors becomes:

$$W = CKAP \sqrt{\frac{M}{ZT}}$$

Example 11.1: SV for Hydrogen Sulfide Service A safety valve is required to relieve 3,500 lbs/hr of hydrogen sulfide at a temperature of 140 °F. The safety valve is rated at 2,000 lbs steam/hr at the same pressure setting. The owner stated the value of K to be 1.0. Will this valve provide the required relieving capacity in hydrogen sulfide on this pressure vessel?

Given

$$W_{hs} = 3,500 \text{ lbs/hr}$$

$$W_s = 2,000 \text{ lbs/hr}$$

$$\text{Molecular weight of hydrogen sulfide}$$

$$M = 34.08$$

$$\text{Constant } C = 315$$

$$K = 1.0$$

$$T = 140 + 460 = 600$$

$$W = CKAP \sqrt{\frac{M}{T}}$$

Transpose for KAP :

$$KAP = \frac{W}{C \sqrt{\frac{M}{T}}}$$

$$KAP = \frac{3500}{315 \sqrt{\frac{34.08}{600}}}$$

$$KAP = 46.627$$

For steam $W_s = CKAP$

$$W_s = 51.5 \times 46.625$$

$$W_s = 2,401.29 \text{ lbs/hr}$$

The safety relieving capacity required is 2,401.29 lbs/hr but the capacity provided is 2,000 lbs/hr.

Therefore, the valve will not provide required capacity in hydrogen sulfide on this vessel.

Example 11.2: Safety Valve for Propane Service A safety valve is required to relieve 5,000 lbs/hour of propane at a temperature of 125°F. The safety valve is rated at 3,000 lbs/hr steam at the same pressure setting. Will this valve provide the required relieving capacity in propane service on this vessel?

Given

$$W_p = 5,000 \text{ lbs/hr}$$

$$W_s = 3,000 \text{ lbs/hr}$$

$$\text{Molecular weight of propane} = 44.09$$

$$C = 315$$

$$T = 125 + 460 = 585$$

$$W_p = CKAP \sqrt{\frac{M}{T}}$$

Transpose for KAP :

$$KAP = \frac{W_p}{C \sqrt{\frac{M}{T}}}$$

$$KAP = \frac{5000}{315 \sqrt{\frac{44.09}{585}}}$$

$$KAP = 57.81857$$

$$\text{For steam } W_s = 51.5 \times KAP$$

$$W_s = 51.5 \times 57.81857$$

$$W_s = 2,977.65627 \sim 2,978 \text{ lbs/hr}$$

The safety relieving capacity required is 2,978 lbs/hr and the capacity provided is 3,000 lbs/hr.

Therefore, the valve will provide required capacity in propane on this vessel.

Example 11.3: Safety Valve for Air Service A safety valve has rated capacity of 3817 lbs of steam at an assumed pressure setting of 250 psi. What is the relieving capacity in terms of air at 100°F with the same setting pressure?

Given

$$W_T = 3817 \text{ Lbs/M}$$

$$\text{Set pressure of the valve} = 250 \text{ psi}$$

$$T = 100^\circ\text{F}$$

Capacity certification formula for dry saturated steam:

$$W_T = 51.5 AP$$

where $W_T = 3817 \text{ lbs/M}$

$$P = (\text{Set pressure} \times 1.10) + 14.7 = 289.7$$

or $\text{Set pressure} + 3 \text{ psi} + 14.7 = 267.7$

Therefore, greater of $P = 289.7 \text{ psia}$

$$A = \frac{W_T}{51.5P}$$

$$A = \frac{3817}{51.5 \times 289.7}$$

$$A = 0.2558 \text{ in.}^2$$

For air service:

$$W_T = 356AP \sqrt{\frac{M}{T}}$$

where $A = 0.2558 \text{ in.}^2$

$$P = 289.7 \text{ psia}$$

$$M = 28.97$$

$$T = 100^\circ\text{F} + 460 = 560$$

$$W_T = (356)(0.2558)(289.7) \sqrt{\frac{28.97}{560}}$$

$$W_T = 6000 \text{ Lbs/M}$$

Therefore, the relieving capacity in terms of air is 6000 Lbs/M

Pressure setting. When a single pressure relief valve is used, the set pressure marked on the valve should not exceed the MAWP of the vessel. When the required relieving capacity is provided by more than one pressure relief valve, only one valve needs to be set at or below the MAWP; the additional valves may be set to open at higher pressure but in no case at a pressure higher than 105% of the MAWP. If the pressure relief valves are used to protect vessels against excessive pressure caused by exposure to fire or other sources of external heat, the valve set pressure marking should not exceed 110% of the MAWP of the vessel.

The set pressure tolerance for pressure relief valve should not exceed $\pm 2 \text{ psi}$ (15 kPa) for pressures up to and including 70 psi (500 kPa) and

$\pm 3\%$ for pressures above 70 psi (500 kPa). The set pressure tolerance for pressure relief valves for fire service should be within -0% to $+10\%$.

The pressure relief valve set pressure should include the effects of static head and constant back pressure.

Mechanical requirements. Mechanical requirements for pressure relief valves are covered under Par. UG-136(a) of Sec. VIII, Division I, of the ASME Code. A designer must meet the requirements of this paragraph when designing any pressure relief valves to be stamped **UV**.

1. The design should include guiding arrangements to ensure consistent operation and tightness.
2. The spring should be designed to obtain full-lift compression not exceeding 80% of the nominal deflection. The permanent set of the spring should not be more than 0.5% of the free height.
3. A pressure relief valve for air, water over 140°F (60°C), or steam service should have a substantial lifting device. Such a device should release the seating force on the disk when the valve is subjected to at least 75% of the set pressure of the valve. A pilot-operated pressure relief valve should be provided with a lifting device or means for applying pressure to the pilot so that the moving parts are free to move.
4. The seat of a pressure relief valve should be fastened to the body of the valve in such a manner that the seat should not be lifted.
5. The body of a pressure relief valve should be designed in a such a way that there will be minimum deposits.
6. A pressure relief valve with screwed inlet and outlet connections should be provided with wrenching surfaces to allow normal installation without damaging operating parts.
7. All pressure relief valves should be provided with means for sealing all initial adjustments. The manufacturer or assembler should install the seals at the time adjustments are made. Seals are installed to prevent changing the adjustment without breaking the seal. For any pressure relief valve size more than NPS $\frac{1}{2}$ (DN 15), the seal should bear the identification of the manufacturer or assembler making the initial adjustment.
8. A pressure relief valve should be equipped with a drain at the lowest point where liquid can be collected on the discharge side of the disk.
9. For a diaphragm-type pressure relief valve, the space above the diaphragm should be vented to prevent a buildup of pressure above the diaphragm. The valve should be designed carefully so that failure of diaphragm material will not harm the ability of the valve to relieve at the rated capacity.

Materials selection. The materials used in the construction of all pressure relief valves must conform to the materials listed in Secs. II and VIII, Division 1, of the ASME Code. Carbon and low-alloy steel bodies, bonnets, yokes, and bolting subject to in-service temperatures lower than -20°F (-30°C) should meet the requirements of Par. UCS-66 of Sec. VIII, Division 1. Exception to this paragraph is applicable for materials exempted from impact test and if the materials have a coincident ratio of 0.35 or less.

Materials used for nozzles, disks, and other parts contained within the external structure of the pressure relief valve should be one of the following:

- Listed in Sec. II
- Listed in ASTM Specifications
- Controlled by the manufacturer of the pressure relief valve by a specification ensuring control of chemical and physical properties and quality at least equivalent to ASTM standards

Cast iron is not permitted to be used in construction of seats and disks. Adjacent sliding surfaces such as guides and disks or disk holders should be of corrosion-resistant material or having a corrosion-resistant coating. The seats and disks should be of materials which can withstand corrosion of the fluid to be contained.

11.2.4 Capacity certification

A manufacturer of pressure relief valves should have the capacity certified before applying Code symbol **UV** to any pressure relief valve. The capacity should be certified in accordance with Par UG-131 of Sec. VIII, Division 1 of the ASME Code.

Capacity certification of pressure relief valves. Capacity certification tests for compressible fluids should be conducted on dry saturated steam, air, or gas. If dry saturated steam is used for testing, the limits should be 98% minimum quality and 20°F (10°C) maximum superheat. Correction within these limits may be made to the dry saturated condition. Capacity certification tests for incompressible fluids should be conducted on water at a temperature between 40°F (5°C) and 125°F (50°C).

Capacity certification tests should be conducted at a pressure not exceeding the pressure for which the pressure relief valve is set to operate by more than 10% or 3% (20 kPa), whichever is greater. Minimum pressure for capacity certification tests should be at least 3 psi (20 kPa) above set pressure. However, in accordance with Par. UG-131(c)(2),

testing may be conducted at a pressure not exceeding 120% of the stamped set pressure of the valve.

Pressure relief valves for compressible fluids having an adjustable blowdown construction should be adjusted prior to testing so that the blowdown does not exceed 5% of the set pressure or 3 psi (20 kPa), whichever is greater.

Capacity certification of pilot-operated pressure relief valves may be based on tests without the pilot valves installed. The Authorized Observer must ensure that the pilot valve opens the main valve fully at a pressure not exceeding 10% or 3 psi (20 kPa), whichever is greater.

The following methods are used to certify capacity of pressure relief valves constructed under ASME Code Sec. VIII, Divisions 1 and 2.

Coefficient method. For steam:

For nozzle $W = (51.5APK)$

For flat seat $W = (51.5\pi DLPK)$

For 45° seat $W = (51.5\pi DLPK)(0.707)$

For steam at pressures over 1500 psi and up to 3200 psi, the value of W of the certified relieving capacity is determined by:

$$\frac{0.1906P - 1000}{0.2222P - 1061}$$

For air:

$$W = 18.331APK @ 60^\circ\text{F and } 14.7 \text{ psia}$$

For gas or vapor:

$$W = CKAP \sqrt{\frac{M}{T}}$$

For liquid (water):

$$W = 4.814A \sqrt{w(P - P_d)}$$

where W = rated capacity, lb/hr (dry saturated steam), scfm (air), lb/hr (gas or vapor), gal/min (water)

A = nozzle throat area, in²

C = constant for gas or vapor based on ratio of specific heats,

$$K = C_p/C_v$$

D = seat diameter, in

K = average coefficient

L = lift, in

M = molecular weight

P = (stamped set pressure + 3 psi or 10%, whichever is greater)
+ 14.7, psia

or

P = (stamped set pressure + 20%) + 14.7, psia for test per UG-131(c)(2)

P_d = pressure discharge from valve, psia

T = absolute temperature at inlet, °R (= °F + 460)

w = 62.3058 lb/ft³, specific weight of water @70°F

Slope method. The values of slope given have the units scfm or lb/hr/ psia.

W = slope $\times$ [(set pressure + 10%) + 14.7, psia]

or

W = slope $\times$ [(stamped set pressure + 20%) + 14.7] psia for test
per UG-131(c)(2)

For liquid (water):

$$W = Fx\sqrt{(P - P_d)}$$

where F = flow factor

Capacity certification of pressure relief valve in combination with nonreclosing pressure relief devices. Manufacturers of pressure relief valves or rupture disks may have the capacity certified for each combination of pressure relief valve and rupture disk device design. The capacity should be certified in accordance with Par. UG-132 of Sec. VIII, Division 1, of the ASME Code.

11.2.5 Testing by manufacturers

The manufacturer or assembler should conduct production tests for each pressure relief valve to which a Code symbol stamp is to be applied. A manufacturer or assembler must have a written program for the application, calibration, and maintenance of gauges and instruments used for the tests.

Pressure test. The primary parts for each pressure relief valve exceeding NPS 1 (DN 25) inlet size or 300 psi (2100 MPa) set pressure should be tested at a pressure of a minimum of 1.5 times the design pressure. This test is conducted after completion of all machining operations on the parts. The test should show no sign of leakage.

The secondary pressure zone of each closed bonnet pressure relief valve exceeding NPS 1 (DN 25) inlet size designed for discharge to a closed system should be tested with air or gas at a pressure of at least 30 psi (200 kPa). The test should show no sign of leakage.

Production test. Each pressure relief valve should be tested for popping pressure. Pressure relief valves for steam service should be tested with steam, except that valves beyond the capability of the test facility may be tested on air. Necessary corrections should be established by the manufacturer for differentials in popping pressure between steam and air.

Pressure relief valves for gas or vapor may be tested with air. Valves for liquid service should be tested with water or other suitable liquid. When a valve is adjusted to correct for service conditions of superimposed back pressure, temperature, or the differential in popping pressure between steam and air, the actual test pressure (cold differential test pressure) should be marked on the valve per UG-129.

Seat tightness test. After completion of the popping or set pressure tests, a seat tightness test should be conducted. The seat tightness test and acceptance criteria should be in accordance with API 527. The manufacturer's seat tightness procedures are also acceptable if such procedures are agreed to by the user.

11.2.6 Inspection and certification

A manufacturer is required to demonstrate to the satisfaction of a representative of an ASME-designated organization that its manufacturing, production, testing facilities, and quality control procedures of pressure relief devices ensure close agreement between the performance of production samples and performance of those submitted for capacity certification.

Inspection. A representative from an ASME -designated organization may inspect manufacturing and/ or assembly, inspection, and test operations, including capacity, at any time. The manufacturer's Quality Control System should include references to the ASME designated organization. A current copy of the written Quality Control System should make available to a representative from an ASME designated organization,

The Quality Control System should provide a representative from an ASME designated organization to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and other documents as necessary for the ASME designed or a representative from an ASME designated organization to

perform his duties according to the Code. The manufacturer should provide such access either to his own documents or provide copies to the ASME designee.

Marking. The manufacturer or assembler should mark each pressure relief valve NPS $\frac{1}{2}$ (DN 15) and larger with the data as required by Par. UG-129 of Sec. VIII, Division 1. The data should be marked in such a way that the marking will not be wiped out in service over a period of time.

Marking on pressure relief valve. The following markings may be placed on the valve or on a plate to be attached to the pressure relief valve:

1. The name, or an acceptable abbreviation, of the manufacturer and the assembler
2. Manufacturer's design or type number
3. NPS size _____ (the nominal pipe size of the valve inlet)
4. Set pressure _____ psi (kPa) and, if applicable, cold differential test pressure _____ psi (kPa)
5. Certified capacity (as applicable)
6. Year built, or alternatively, a coding identifying the year the valve was assembled or tested
7. ASME Code symbol as shown in Fig. 11.8.

Notes

1. Certified capacity for pressure relief valves should be decided according to the following information:
 - (a) lb/hr of saturated steam at an overpressure of 10% or 3 psi (20 kPa), whichever is greater.
 - (b) gal/min of water at 70°F (20°C) at an overpressure of 10% or 3 psi (20 kPa), whichever is greater for valves certified on water.

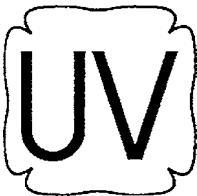


Figure 11.8 ASME Code symbol for pressure relief valve.

- (c) scfm or lb/min of air at an overpressure of 10% or 3 psi (20 kPa), whichever is greater.
 - (d) The manufacturer may specify the capacity in other fluids by using capacity conversions as shown in Mandatory Appendix 11 of Sec. VIII, Division 1.
2. Pilot-operated pressure relief valves may be marked with the name of the manufacturer, the manufacturer's design or type number, the test pressure in lb/in^2 , and the year built, or alternatively identifying the year built. On valves smaller than size NPS $\frac{1}{2}$ (DN), the marking may be made on a metal tag attached by wire or adhesive or other means suitable for service conditions.

Markings on pressure valves in combination with rupture disk devices. Pressure relief valves in combination with rupture disk devices should be marked with capacity as established under Par. UG-127(a)(3)(b)(2) using the factor 0.90, or the combination capacity factor established by test under Par. UG-132(a) or (b), in addition to the above markings on the pressure relief valve.

The markings should be placed on the pressure relief valve or rupture disk device or on a plate. The markings should include the following:

1. Name of manufacturer of valve
2. Design or type number of valve
3. Name of manufacturer of rupture disk device
4. Design or type number of rupture disk device
5. Capacity or combination capacity factor
6. Name of organization responsible for marking

Certification. Each pressure relief valve to which Code symbol **UV** will be applied must be fabricated or assembled by a manufacturer or assembler holding a valid Certificate of Authorization from the ASME. A Certified Individual (CI) is required to provide oversight as required by Par. UG-117(a) of Sec. VIII, Division 1.

The data for each use of the Code symbol must be documented on Form UV-1, Manufacturer's or Assembler's Certificate of Conformance for Pressure Relief Valves (Fig. 11.9).

1.3 Rupture Disks

A rupture disk device is a nonreclosing pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure-containing disk. A rupture disk device may be used as the sole pressure-relieving device on a vessel (Fig. 11.10).

FORM UV-1 MANUFACTURER'S OR ASSEMBLER'S CERTIFICATE OF CONFORMANCE FOR PRESSURE RELIEF VALVES

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured (or assembled) by _____ ① _____

2. Table of Code symbol stamped items:

[illegible]

3. Remarks _____ (14)

CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted above, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the pressure relief devices conform with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

UV Certificate of Authorization No. _____ (15) Expires _____ (16)

Date 17 Signed 18 Name 18
(responsible representative) (Manufacturer or Assembler)

Figure 11.9 Certificate of Conformance for Pressure Relief Valves. (From ASME Sec. VIII—Div. 1.)

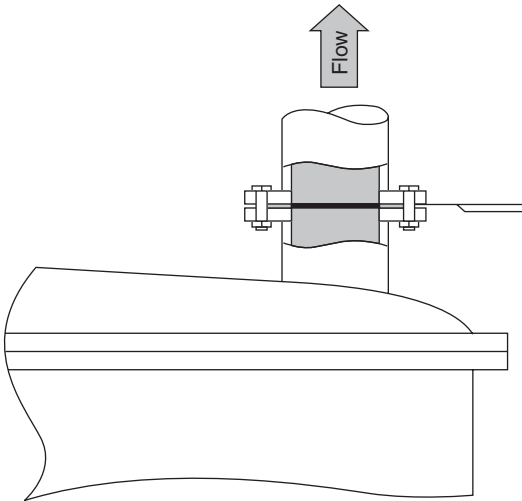


Figure 11.10 Rupture disk installed on a tank.

Application of rupture disk devices to liquid service should be carefully evaluated to assure that the design of the rupture disk device and the dynamic energy of the system on which it is installed will result in sufficient opening of the rupture disk.

11.3.1 Operational characteristics

The operating characteristics, including burst pressure tolerance for rupture disk devices at the specific temperature should be guaranteed by the manufacturer. Operational characteristics of rupture disks are as follows.

Burst pressure tolerance:

± 2 psi (15 kPa)	Up to 40 psi (300 kPa)
$\pm 5\%$	Over 40 psi (300 kPa)

11.3.2 Code references

Rupture disks are designed, constructed, inspected, stamped, certified, and installed in accordance with the rules of ASME Code Sec. VIII—Div. 1. ASME Code references for rupture disk requirements are given in Table 11.4.

11.3.3 Design requirements

A representative from an ASME-designated organization has the authority to review and accept the design for conformity with the requirements of UG-137(a) and UG-137(b). Prior to capacity testing, the representative has the authority to reject or require modification of designs which do not conform to Code requirements.

TABLE 11.4 ASME Code Sec. VIII—Div. 1 References for Rupture Disk Devices

Requirements	Code paragraph
Rupture Disk Device	UG-127(a)
Relieving Capacity	UG-127(b)
Application of Rupture Disk	UG-127(c)
Marking	UG-129(e)
Code Symbol Stamp	UG-130
Capacity Certification	UG-132
Mechanical Requirements	UG-137(a)
Material Selections	UG-137(b)
Inspection of Manufacturing	UG-137(c)
Production Testing	UG-137(d)

11.3.4 Capacity certification

For capacity certification of a rupture disk, the flow resistance K_R has to be determined. The certified flow resistance K_R of the rupture disk device should be either $K_R = 2.4$, or determined according to UG-131(k) through UG-131(r) rules as follows.

Flow resistance certification tests for rupture disks for air or gas service, K_{RG} , should be burst and flow tested with air or gas. Flow resistance tests for liquid service, K_{RL} , should be burst tested with water and flow tested with air or gas. At least one rupture disk for each size of each series should be burst with water and flow tested with air or gas to demonstrate the liquid service flow resistance. Flow resistance certification tests should be conducted at a rupture disk device inlet pressure which does not exceed 110% of the device set pressure.

Flow resistance certification of rupture disk devices should be determined by one of the following methods.

One-size method. For each design, three rupture disks from the same lot should be individually burst and flow tested. The burst pressure should be the minimum of the rupture disk design of the size tested. The certified flow resistance K_R determined (see procedures below) should be applied only to the rupture disk design tested.

Three-size method. The three-size method of flow resistance certification may be used for a rupture disk device design of three or more sizes. The burst pressure should be the minimum of the rupture disk design for each of the sizes tested.

For each design, three rupture disks from the same lot should be burst and flow tested for each of three different sizes of the same design. The certified flow resistance K_R should be applied to all sizes and pressures of the design of the rupture disk tested.

A certified flow resistance K_R may be established for a specific rupture disk design according to the following procedures:

- For each design, the manufacturer submits for test the required disk with cross-section drawings showing the disk design.
- Tests are made on each rupture disk to determine burst pressure and flow resistance at an approved testing facility.
- An average flow resistance is calculated using the individual flow resistances determined above.
- All individual flow resistances should fall within the average flow resistances by an acceptance band of plus or minus three times the average of the absolute values of the derivations of the individual flow resistances from the average flow resistance. Any individual flow

resistance that falls outside this band should be replaced on a two-for-one basis. A new average should be computed and the individual flow resistances evaluated as described above.

- The certified flow resistance K_R for a rupture disk design should not be less than zero. Also, K_R should not be less than the sum of the average flow resistance plus three times the average of the absolute values of the derivations of individual flow resistances from the average flow resistance.
- Flow resistance test data reports for each rupture disk design, signed by the manufacturer and the Authorized Observer witnessing the tests, should be submitted to an ASME-designated organization for review and approval.
- New tests should be performed when changes are made to the design of a rupture disk which affect the flow path or burst performance characteristics of the device.

11.3.5 Testing by manufacturers

The manufacturer should conduct production tests for each rupture disk to which a Code symbol stamp is to be applied. A manufacturer must have a written program for the application, calibration, and maintenance of gauges and instrumentation used for the tests.

Pressure test. The pressure parts for each rupture disk holder exceeding NPS 1 (DN 25) inlet size or 300 psi (2100 kPa) design pressure should be tested at a pressure of a minimum of 1.5 times the design pressure of the parts. This test is conducted after completion of all machining operations on the parts but prior to installation of the rupture disk. The test should show no sign of leakage.

Production test. Each lot of rupture disks should be tested in accordance with Par. UG-137(d)(3). All tests for a given lot should be made in a holder of the same form and pressure area dimensions as that used in service. Sample rupture disks, selected from each lot, should be made from the same material and of the same size as those used in service.

- At least two sample rupture disks from each lot of rupture disks should be burst at the specific disk temperature. Make sure that sample rupture disk marked burst pressures are within the burst pressure tolerance specified by UG-127(a)(1).
- At least four sample rupture disks, but not less than 5% from each lot of rupture disks, should be burst at four different temperatures over the temperature range for which disk will be used. These data are

used to establish a smooth curve of burst pressure versus temperature for the lot of disks. The value of the marked burst pressure is derived from the curve for a specified temperature.

- For prebulged solid metal disks or graphite disks, at least four samples using one size of disk from each lot of material should be burst at four different temperatures distributed over the application range. These data are used to establish a smooth curve of percent change of burst pressure versus temperature for the lot of material.
- At least two disks from each lot of disks, constructed from this lot of material and of the same size as that to be used, should be burst at the ambient temperature to establish room-temperature rating of the lot of disks.

11.3.6 Inspection and certification

A manufacturer is required to demonstrate to the satisfaction of a representative of an ASME-designated organization that its manufacturing, production, testing facilities, and quality control procedures of rupture disks ensure close agreement between the performance of production samples and performance of those submitted for capacity certification.

Inspection. An ASME designee is authorized to inspect manufacturing, assembly, inspection, and test operations at any time. A manufacturer is granted permission by the ASME to use the Code symbol **UD** on rupture disks in accordance with Par. UG-131. This permission expires on the fifth anniversary of the date it was initially granted by the ASME. The permission may be extended for another 5-year period if the following tests are successfully performed within the 6-month period before expiration:

- Two production samples of rupture disks of a size and capacity within the capability of an ASME-approved laboratory are selected by a representative of an ASME-designated organization.
- Burst and flow testing are conducted in the presence of a representative of an ASME-designated organization at an approved testing facility. The disk manufacturer should be notified of the time of the test and may have representatives present to witness the test.
- If any rupture disk fails to meet the performance requirements (burst pressure, minimum net flow area, and flow resistance), the test should be repeated at the rate of two replacement disks, selected and tested in accordance with above steps.
- If any rupture disk fails to meet the performance requirements, that disk will be cause for revocation within 60 days of the authorization to

use the Code symbol. The manufacturer is required to demonstrate the cause of deficiency and action taken to correct the problem for future occurrence.

Marking. The manufacturer or assembler should mark each rupture disk with the data required by Par. UG-129(e) of Sec. VIII, Division 1, of the ASME Code. The data should be marked in such a way that the marking will not be wiped out in service over a period of time.

The rupture disk marking may be placed on the flange of the disk or on a metal tab in accordance with Par. UG-119. The marking should include the following:

1. The name or identifying trademark of the manufacturer
2. Manufacturer's design or type number
3. Lot number
4. Disk material
5. Size _____ [NPS (DN) of rupture disk holder]
6. Marked burst pressure _____ psi (kPa)
7. Specified disk temperature _____ °F (°C)
8. Minimum net flow area _____ in² (mm²)
9. Certified flow resistance (as applicable):
 - (a) K_{RG} _____ for rupture disk certified on air or gases; or
 - (b) K_{RL} _____ for rupture disk certified on liquid; or
 - (c) K_{RGL} _____ for rupture disk certified on air or gases, and liquid
10. ASME Code symbol as shown in Fig. 11.11.
11. Year built, or alternatively, a coding may be marked on the rupture disk so that the disk manufacturer can identify the year the disk was assembled and tested.

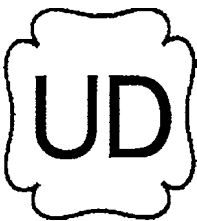


Figure 11.11 ASME Code symbol for rupture disk.

It is required that items 1, 2, and 5 above and flow direction also be marked on the rupture disk holder.

Certification. Each rupture disk to which Code symbol **UD** will be applied must be fabricated or assembled by a manufacturer or assembler holding a valid Certificate of Authorization from the ASME. A Certified Individual (CI) is required to provide oversight as required by Par. UG-117(a) of Sec. VIII, Division 1.

The data for each use of the Code symbol must be documented on Form UD-1, Manufacturer's or Assembler's Certificate of Conformance for Rupture Disk Devices (Fig. 11.12).

FORM UD-1 MANUFACTURER'S CERTIFICATE OF CONFORMANCE FOR RUPTURE DISK DEVICES

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured by

①

2. Table of Code symbol stamped items:

ID #	Date	Cert. #	Qty.	Disk Material	Type	Size (INPS)	Marker Burst Pressure	Specified Disk Temp.	Min. Net Flow Area	Certified Flow Resistance Coefficient	Date Code	CI Name	CI Signature
②	③	④	⑤	⑬	⑥	⑦	⑩	⑪	⑫	⑭	⑮	⑯	⑰

3. Remarks

⑱

CERTIFICATE OF SHOP COMPLIANCE

By the signature of the Certified Individual (CI) noted above, we certify that the statements made in this report are correct and that all details for design, material, construction, and workmanship of the rupture disk devices conform with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

UD Certificate of Authorization No.

⑲

Expires

⑳

Date

㉑

Signed

㉒

(responsible representative)

Name

㉓

(Manufacturer)

Figure 11.12 Certificate of Conformance for Rupture Disk Devices. (From ASME Sec. VIII—Div. 1.)

Pressure Relief Devices for Nuclear Systems

The world's first nuclear power plant was started-up in 1956 at Calder Hall in England, followed in the United States a year later by the initial operation of a 60-MW unit at Shippingport, Pennsylvania. Power production with nuclear energy relies on a sustained neutron chain reaction from the fission process. Reactors produce electricity from fission, employing a variety of fuel forms, coolants, and other materials.

Nuclear power reactors are complex systems whose design represents a balance among various system requirements. Principal among these requirements are nuclear design, materials, economics, thermal hydraulics, and control and safety. The following ASME codes are used for design, construction, inspection, stamping, and certification of nuclear components:

Section III, Subsec. NCA—General Requirements for Division 1 and Division 2

Section III, Division 1:

Subsec. NB—Class 1 Components

Subsec. NC—Class 2 Components

Subsec. ND—Class 3 Components

Subsec. NE—Class MC Components

Subsec. NF—Supports

Subsec. NG—Core Support Systems

Subsec. NH—Class 1 Components in Elevated Temperature Service

Appendices

Section III, Division 2—Code for Concrete Reactor Vessels and Containments

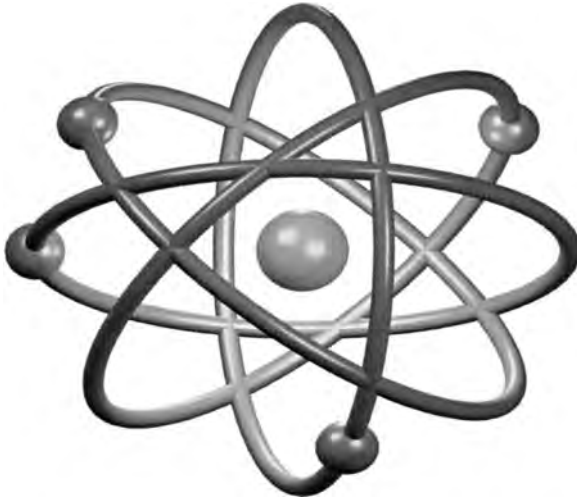


Figure 12.1 Symbol for nuclear systems.

Section III, Division 3—Containment Systems for Storage and Transport Packagings of Spent Nuclear Fuel and High Level Radioactive Material and Waste

Nuclear systems (the nuclear symbol is shown in Fig. 12.1) are protected from the consequences arising from the applications of conditions of pressure and coincident temperature that would cause either the design pressure or the service limits specified in the design specification to be exceeded. Pressure relief devices are used when the operating conditions considered in the Overpressure Protection Report would cause the service limits specified in the design specification to be exceeded.

The overpressure protection of nuclear systems must meet the requirements of Art. NB-7000 of ASME Code Sec. III, Division I, Subsec. NB.

12.1 Nuclear Reactors

A nuclear reactor—the heart of a nuclear steam supply system, which encompasses all components related to the use of nuclear fission as the energy source—is designed to achieve a self-sustained chain reaction with a combination of fissile, fertile, and other materials. Six major reactor types are used throughout the world:

1. Boiling-water reactor (BWR)
2. Pressurized-water reactor (PWR)
3. Heavy-water-moderated reactor (HWR), including the pressure heavy-water reactor (PHWR)
4. Light-water-cooled graphite-moderated reactor (LGR), including the pressure-tube graphite reactor (PTGR)
5. Gas-cooled reactor (GCR), including the high-temperature gas-cooled reactor (HTGR)
6. Breeder reactor, including the liquid-metal fast breeder reactor (LMFBR)

The two most popular reactor designs employ light water as both coolant and moderator. These two light-water reactor systems—the boiling-water reactor (BWR) and the pressurized-water reactor (PWR)—use ordinary (“light”) water as both coolant and moderator. The BWR produces steam through a direct cycle, while the PWR uses an intermediate steam-generator heat exchanger to maintain an all-liquid primary loop and produce steam in a secondary loop. Our discussion of nuclear reactors will be limited to these two types of reactors.

12.1.1 Boiling-water reactors

Boiling water reactors were originally designed by Allis-Chambers and General Electric (GE). The GE design has survived, whereas all Allis-Chambers units have been shut down.

The BWR typically permits bulk boiling of water in the reactor. The operating temperature of the reactor is approximately 570°F, producing steam at a pressure of 1000 psig. Current BWRs have electrical outputs of 570–1300 MWe. A flow diagram of a BWR system is shown in Fig. 12.2.

In Fig. 12.2, water is circulated through the reactor core, picking up heat as the water moves past the fuel assemblies. The water is heated enough to convert to steam. Steam separators in the upper part of the reactor remove water from the steam. Then the steam passes through the main steam lines to the turbogenerators.

The steam, after passing through the turbines, then condenses in the condenser, which is at vacuum and is cooled by water. The condensed steam then is pumped to low-pressure feedwater heaters. The water then passes to feedwater pumps, which in turn pump the water to the reactor and start the cycle all over again.

Safety valves for main steam line. Safety valves are required on the main steam lines (Fig. 12.3) to protect the steam generator from overpressure. A safety valve used as a main steam valve is shown in Fig. 12.4.

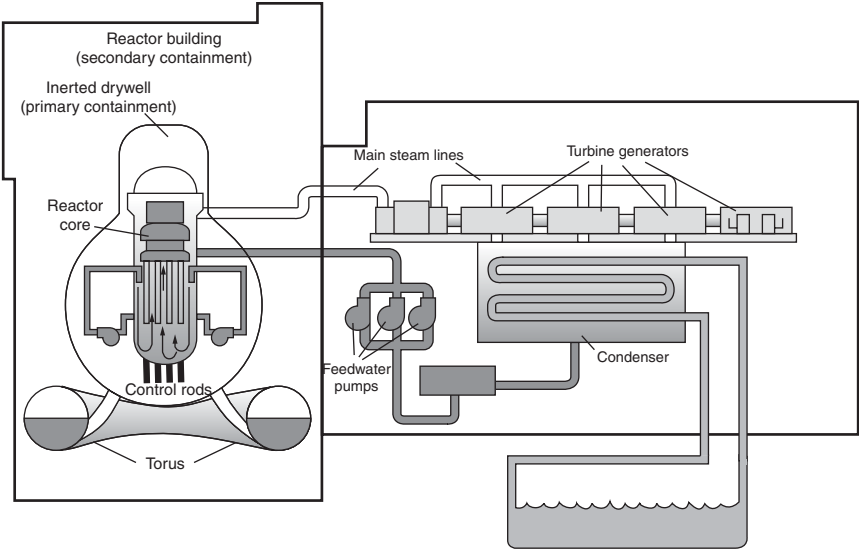


Figure 12.2 Boiling-water reactor system.

This advanced safety valve operates on the principle of pressurization. Fluid or steam flow in the pilot control area is limited and velocity is controlled to prevent erosion and leakage. The closing force acting above the main disk is produced by the system and is a minimum of twice the force acting below the disk until lift set point is fully reached. This principle of

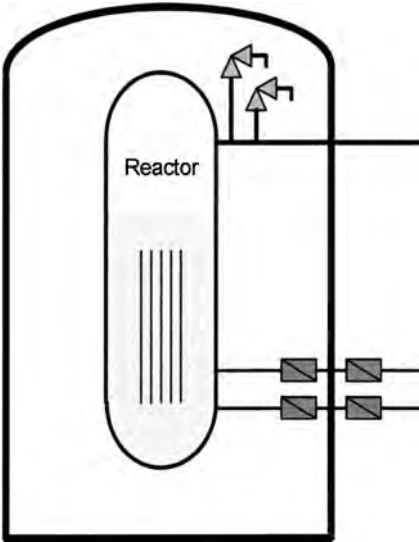


Figure 12.3 Main steam safety valves on a BWR.



Figure 12.4 Main steam relief valve with optional electric motor override feature. (Courtesy CCI Nuclear Valve, Switzerland.)

operation ensures stable valve performance and eliminates simmering and potential for damaging valve chatter if subjected to high-pressure, low-flow conditions.

Reheater safety valve. A reheater safety valve is shown in Fig. 12.5. This valve is specially designed for BWR systems and has a large capacity for reheater use. The reheater safety valve has the following design features:

- Forged and bolted design with inlet separate from outlet
- Material change between inlet and outlet is easily implemented
- Backseat seals gland during relief operation
- Double-acting hydraulic actuator to keep valve completely tight during normal operation
- Hydraulic power operated, to ensure high seat sealing force for constant tight shut-off
- No spring required; steam pressure opens the valve
- Three solenoid bypass valves are provided per actuator for redundancy

12.1.2 Pressurized-water reactors

The pressurized-water reactor was originally designed by Westinghouse Bettis Atomic Power Laboratory for military ship applications, then by the Westinghouse Nuclear Power Division for commercial applications.

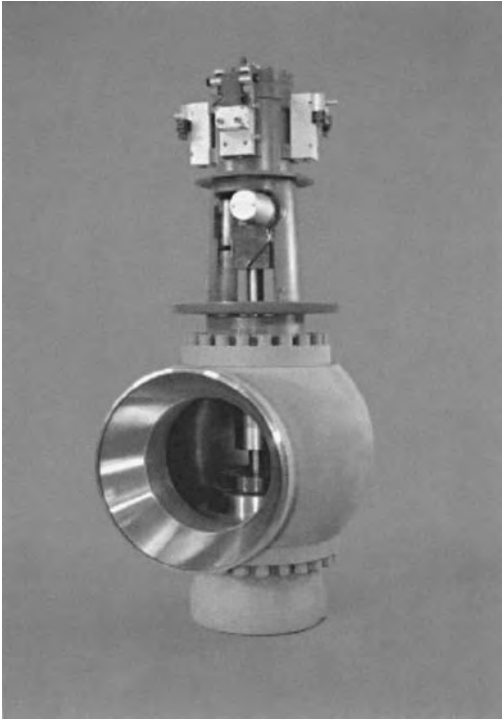


Figure 12.5 Reheater safety valve.
(Courtesy CCI Nuclear Valve,
Switzerland.)

The PWR has three separate cooling systems, but only one of them, the reactor cooling system, is expected to have radioactivity. The reactor cooling system inside the containment (Fig. 12.6) consists of two, three, or four cooling “loops” connected to the reactor, each containing a reactor coolant pump, and a steam generator. The reactor heats water, which

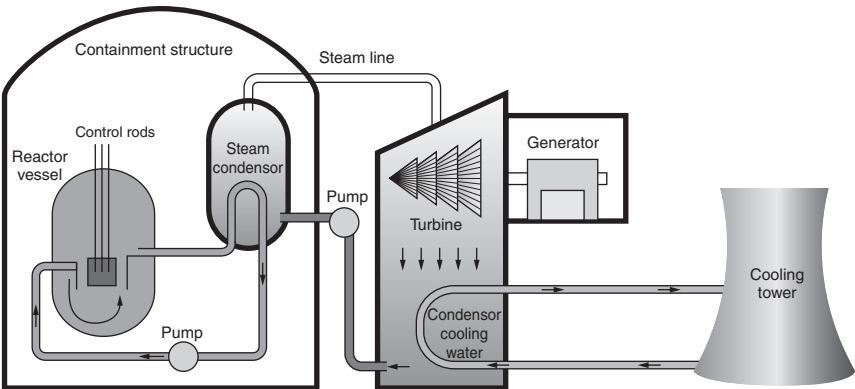


Figure 12.6 Pressurized-water reactor system.

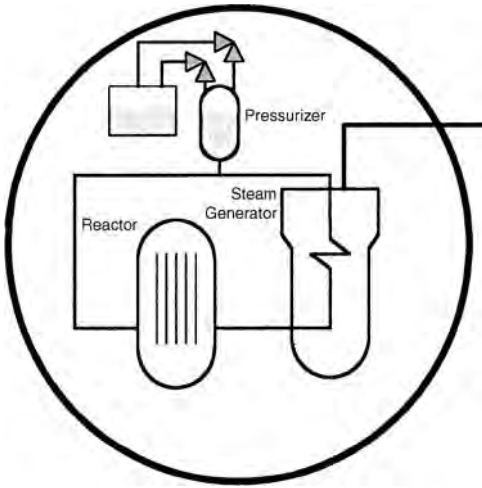


Figure 12.7 Pressurizer relief and safety valves on a PWR.

passes upward past the fuel assemblies from a temperature of about 530°F to a temperature of about 590°F. Pressure is maintained by a pressurizer (Fig. 12.7) connected to the reactor cooling system. Pressure is maintained at approximately 2250 psig through a heater and spray system in the pressurizer.

In a secondary cooling system, which includes the main steam system and the condensate feedwater systems, cooler water is pumped from the feedwater system and passes on the outside of those steam generator tubes, is heated and converted to steam. The steam then passes through the main steam line to the turbine, which is connected to and turns the generator.

The steam from the turbine condenses in a condenser. The condensed water is then pumped by the condensate pumps through low-pressure feedwater heaters, then to the feedwater pumps, then to high-pressure feedwater heaters, then to the steam generators.

Pressurizer safety valve. The purpose of the pressurizer safety valve (Fig. 12.8) is to protect the primary loop of a PWR against overpressure. At a given set pressure, the safety valve opens and releases medium (steam, water, hydrogen) from the pressurizer to the flash tank.

The valve consists of one main safety valve (SV) and one or more pilot valves. Three different pilot valve designs, STV, MV, and MOV, are available. The main pilot valve is the spring-loaded STV, which opens the SV valve at the set pressure. The STV can be fitted with an additional solenoid loading device to improve the closing force. The other pilot valves can be solenoid operated (MV) for quick pressure release, or motor operated (MOV) for bleed function.

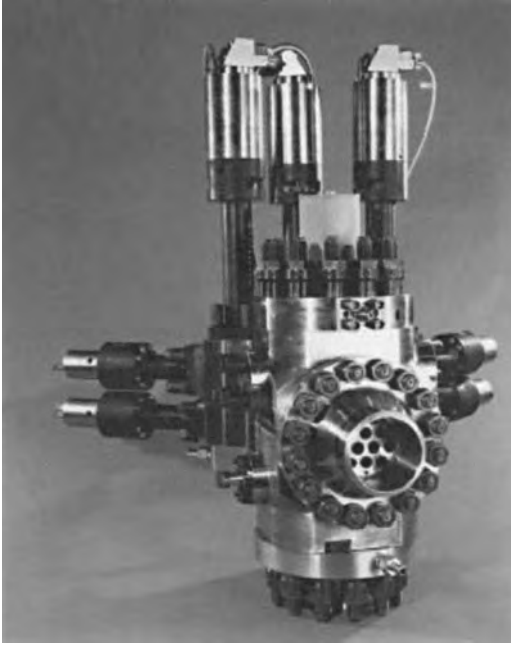


Figure 12.8 Pressurizer overpressure protection safety relief valve. (Courtesy CCI Nuclear Valve, Switzerland.)

In normal operation, the main valve and pilot valves are closed and the whole inner space of the SV is connected to the relief tank. The stem is forced into the valve seat by the system pressure in the inlet nozzle. To open the SV, the upper piston chamber is charged with system medium by one of the pilot valves attached to the main valve.

The main valves and pilot valves are designed and qualified to operate with hydrogen, saturated steam, and saturated water, subcooled water as well as during phase transitions. The design features of the safety valves are as follows:

- High opening and closing reliability due to very high force reserves.
- High tightness because pressure in pressurizer acts in closing direction.
- Lower steam guide shields the stem head from pressure peaks when opening and provides damping.
- Compression spring for keeping closed when primary loop is pressureless. The spring is not required for closing during operation.
- No penetrations through the pressure boundary; completely tight to the outside.

- Double sealing of all connections under system pressure during normal operation.
- Cobalt-free design.
- Permanent discharging of hydrogen, if required.

Main steam safety valve. Figure 12.9 shows a main steam safety valve used for PWR main steam power-operated atmospheric relief around the world. The velocity control technology is used for controlling steam venting when plant operation calls for a minimum valve open position. This velocity control technology is also applied for silencing relief exhaust vent systems to satisfy hearing-protection standards.

The design features of the main steam safety valves are:

- Leak-tight shutoff at normal operating pressure, due to stable disk contact to force regardless of system pressure.
- Stable disk contact force prevents steam cutting.
- Repeatable test performance within required tolerance.



Figure 12.9 Main steam valve, power operated. (Courtesy CCI Nuclear Valve, Switzerland.)

12.2 Overpressure Protection Reports

Par. NB-7111 of Sec. III – Div. 1 defines overpressure as “that pressure which exceeds the Design Pressure and is caused by increase in system fluid pressure resulting from thermal imbalances, excess pump flow, and other similar phenomena capable of causing a system pressure increase of a sufficient duration to be compatible with the dynamic response characteristics of the pressure relief devices.”

An Overpressure Protection Report (OPR) is a report on the protected systems and integrated overpressure provided. The owner or his designee prepares the Overpressure Protection Report I. In accordance with Par. NB-7120, overpressure protection of the components must be provided by any one of the following as an integrated overpressure protection:

1. The use of pressure relief devices and associated pressure sensing elements
2. The use of reactor shutdown system
3. A design without pressure relief devices that does not exceed the service limits specified in the design specification

12.2.1 Content of report

The Overpressure Protection Report should clearly define the protected systems and integrated overpressure protection. The report should include the following as a minimum:

1. Identification of ASME Nuclear Code Section, Edition, Addenda, and Code Cases used in the design of the overpressure protection system.
2. Drawings indicating arrangement of protected system including the pressure relief devices
3. The operating conditions, including discharge piping back pressure
4. An analysis of the conditions that give rise to the maximum pressure-relieving requirements
5. The relief capacity required to prevent a pressure rise in any nuclear component from exceeding by the design pressure more than 10%
6. The operating controls and safety controls of the protected system
7. The redundancy and independence of the pressure relief devices to preclude a loss of overpressure protection in the event of a failure of any pressure relief device, sensing elements, associated controls, or external power sources
8. The extent to which a component can be isolated from the overall system and analysis of the conditions under which additional individual overpressure protection is required

9. The design secondary pressure, which is defined as that value of pressure existing in the passage between the actual discharge area and the outlet for which the discharge system of the pressure relief valve is designed
10. Analysis of transient pressure conditions, considering the effect of liquid and two-phase flow
11. Consideration of set pressure and blowdown limitations, taking into account opening pressure tolerances and overpressure
12. Consideration of burst pressure tolerance and manufacturing design of rupture disk devices
13. Verification that pressure relief devices are not required, if necessary
14. The purge time of the inlet water seal, if the pressure relief valve is installed on a loop seal

12.2.2 Certification of report

The OPR should meet the requirements of Art. NB-700 of ASME Sec. III, Division I: A Registered Professional Engineer competent in the applicable field of design must certify the report on Form A-3, Overpressure Protection Report (Fig. 12.10), after it has been verified against the Code requirements. The Registered Professional Engineer must be qualified in accordance with the requirements of Mandatory App. XXXIII of the Section.

12.2.3 Review of report

The Overpressure Protection Report requires a review if any modification is done during installation. The modification is required to be reconciled with the Overpressure Protection Report. Such modifications should be documented in an addendum to the Overpressure Protection Report. The addendum should contain a copy of the as-built drawing and include one of the following items:

1. A statement that the as-built system has met the requirements of the OPR
2. A revision to the OPR to make it agree with the as-built system
3. A description of changes made to the as-built system to make it comply with the OPR

A Registered Professional Engineer competent in the specific field of design should certify the addendum.

FORM A-3 OVERPRESSURE PROTECTION REPORT (DIV. 1 AND 2)

CERTIFICATION

I, the undersigned, being a Registered Professional Engineer competent in the applicable field of design and overpressure protection requirements, do hereby certify that to the best of my knowledge and belief the Overpressure Protection Report complies with the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division _____, _____ Edition with Addenda up to and including _____.

Overpressure Protection Report and Revision:

Design Specification and Revision:

Certified by _____ P.E.

Registration No. _____ State* _____

Date _____

* or Province of Canada

Figure 12.10 Overpressure Protection Report. (*From ASME Sec. III, Div. I.*)

12.2.4 Filing of report

A copy of the OPR is required to be submitted at the nuclear power plant site prior to the Inspector signing the Owner's Data Report. The report should also be made available to:

- The Authorized Inspector
- The regulatory and enforcement authority having jurisdiction at the nuclear plant site

12.3 Code Requirements

Pressure relief devices for nuclear components are designed, constructed, inspected, stamped, certified, and installed in accordance with the provisions of Sec. III – Div. 1, and Sec. III – Subsec. NCA and Div. 2. ASME Code requirements and corresponding Code references for nuclear pressure relief devices are listed in Table 12.1.

TABLE 12.1 ASME Code Sec. III Requirements for Nuclear Pressure Relief Devices

Code requirements	Code paragraph
General Requirements	NB-7100
Installation	NB-7140
Acceptable Pressure Relief Devices	NB-7150
Unacceptable Pressure Relief Devices	NB-7160
Permitted Use of Pressure Relief Devices	NB-7170
Relieving Capacity	NB-7300
Set Pressures of Pressure Relief Devices	NB-7400
Operating and Design Requirements for Pressure Relief Valves	NB-7500
Safety, Safety Relief, and Relief Valves	NB-7510
Pilot Operated Pressure Relief Valves	NB-7520
Power Actuated Pressure Relief Valves	NB-7530
Safety Valves and Pilot Operated Pressure Relief Valves with Auxiliary Actuating Devices	NB-7540
Alternative Test Media	NB-7550
Nonreclosing Pressure Relief Devices	NB-7600
Rupture Disk Devices	NB-7610
Installation	NB-7620
Certification	NB-7700
Responsibility for Certification of Pressure Relief Valves	NB-7710
Responsibility for Certification of Nonreclosing Pressure Relief Devices	NB-7720
Capacity Certification of Pressure Relief Valves— Compressible Fluids	NB-7730
Capacity Certification of Pressure Relief Valves— Incompressible Fluids	NB-7740
Marking, Stamping, and Data Reports	NB-7800
Pressure Relief Valves	NB-7810
Rupture Disk Devices	NB-7820
Certificate of Authorization to Use Code Symbol Stamp	NB-7830

12.4 Relieving Capacity

The total relieving capacity of the pressure relief devices should take into consideration any losses due to flow through piping and other components. The total relieving capacity should be sufficient to prevent a rise in pressure of more than 10% above the design pressure of any component within the pressure boundary.

12.5 Operating Requirements

The operating requirements for pressure relief valves are covered in Par. NB-7500. This paragraph gives detailed operating requirements for safety valves, safety relief valves, relief valves, pilot-operated pressure relief valves, power-actuated pressure relief valves, and safety valves and pilot-operated pressure relief valves with auxiliary actuating devices.

12.6 Capacity Certification for Pressure Relief Valves

The capacity certification procedures for pressure relief valves are covered in Pars. NB-7730 through NB-7748. These paragraphs prescribe detailed capacity certification requirements for pressure relief valves for both compressible and incompressible fluids. A Capacity Certification is shown in Fig. 12.11.

12.7 Marking, Stamping, and Data Reports

Each pressure relief device constructed within the scope of ASME Sec. III must be constructed by a manufacturer possessing a Code symbol stamp and a valid Certificate of Authorization from the ASME.

DRESSER INDUSTRIES INC. (DAL) Alexandria, Louisiana

VALVE SERIES OR CAT. NO. - 1970 LS & DL 150 psi
NB Capacity Certification Number - M18335
CAPACITY TESTS - Sec. III at Dresser on May 25, 1988
METHOD OF ESTABLISHING RELIEVING CAPACITY - Single Valve Method (Nozzle)
TEST MEDIUM - Water
CERTIFIED MEDIUMS - Liquids
Set Pressure Definition - First Steady Stream

Inlet Size 1-1/2 in. Orifice Dia. 0.815 in.	Minimum Lift 0.260 in. Flow Area 0.5216 sq. in.
Set Pressure PSIG	Sec. III GPM Water
150	172.7

VALVE SERIES OR CAT. NO. - 1975
NB Capacity Certification Number - M18504
CAPACITY TESTS - Sec. VIII at Dresser on April 5, 1956
METHOD OF ESTABLISHING RELIEVING CAPACITY - K = .866(.9) = .779
TEST MEDIUM - Steam
CERTIFIED MEDIUMS - Steam, Air & Gas
Set Pressure Definition - Pop
Blowdown - Fixed

Inlet Size 1/2, 3/4 & 1 in. Bore Dia. 0.375 in.	Minimum Lift 0.105 in. Bore Area 0.110 sq. in.
Set Pressure PSIG	Sec. VIII #/Hr Steam
15	144
30	234
800	3950
1500	7382
2000	10206

VALVE SERIES OR CAT. NO. - 1975 LS & DL 150 psi
NB Capacity Certification Number - M18346
CAPACITY TEST - Sec. III at Dresser on May 25, 1988
METHOD OF ESTABLISHING RELIEVING CAPACITY - Single Valve Method (Nozzle)
TEST MEDIUM - Water
CERTIFIED MEDIUMS - Liquids
Set Pressure Definition - First Steady Stream

Inlet Size 1/2, 3/4, 1 in. Orifice Dia. 0.375 in.	Minimum Lift .118 in. Flow Area 0.110 sq. in.
Set Pressure PSIG	Sec. III GPM Water
150	32.57

VALVE SERIES OR CAT. NO. - 1975 LS & DL 215 psi
NB Capacity Certification Number - M18357
CAPACITY TEST - Sec. III at National Board on February 20, 1985
METHOD OF ESTABLISHING RELIEVING CAPACITY - Single Valve Method (Nozzle)
TEST MEDIUM - Water
CERTIFIED MEDIUMS - Liquids
Set Pressure Definition - First Steady Stream

Inlet Size 1/2, 3/4, 1 in. Orifice Dia. 0.375 in.	Minimum Lift .118 in. Flow Area 0.110 sq. in.
Set Pressure PSIG	Sec. III GPM Water
215	44.0

VALVE SERIES OR CAT. NO. - 1975 LS & DL 225 psi
NB Capacity Certification Number - M18368
CAPACITY TEST - Sec. III at National Board on February 20, 1985
METHOD OF ESTABLISHING RELIEVING CAPACITY - Single Valve Method (Nozzle)
TEST MEDIUM - Water
CERTIFIED MEDIUMS - Liquids
Set Pressure Definition - First Steady Stream

Inlet Size 1/2, 3/4, 1 in. Orifice Dia. 0.375 in.	Minimum Lift .118 in. Flow Area 0.110 sq. in.
Set Pressure PSIG	Sec. III GPM Water
225	45.9

VALVE SERIES OR CAT. NO. - 1975-4 LS & DL
NB Capacity Certification Number - M18560
CAPACITY TESTS - Sec. III at Dresser on March 21, 1989
METHOD OF ESTABLISHING RELIEVING CAPACITY - Slope 3.151 (3.501 x .9)
TEST MEDIUM - Water
CERTIFIED MEDIUMS - Liquids
Set Pressure Definition - First Steady Stream

Inlet Size 1/2, 3/4, 1 in. Orifice Dia. 0.375 in.	Minimum Lift 0.200 in. Flow Area 0.110 sq. in.
Set Pressure PSIG	Sec. III GPM Water
15	13
30	18
1000	104
2000	148

Figure 12.11 Capacity Certification for a nuclear PRV. (Courtesy National Board.)

12.7.1 Pressure relief valves

The manufacturer is required to mark each pressure relief valve with the required data in such a way that the marking will not be obliterated in service. The data should be marked with characters not less than 3/32 in (2.5 mm). The marking should be placed on the valve or on a nameplate fastened to the valve. The ASME Code symbol stamp should be stamped on the valve or nameplate. The marking should include the following:

1. Certificate Holder's design or type number
2. Size _____ [NPS, (DN)] of the valve inlet
3. Set pressure _____ psi (kPa)
4. Certified capacity and overpressure in percent or psi (kPa):
 - (a) lb/hr (kg/h) of saturated steam for valves certified on steam; or
 - (b) scfm at 60°F (15°C) and 14.7 psia (101 kPa) of air for valves certified on air or gas; or
 - (c) gal/min of water at 70°F (20°F) for valves certified on water
5. Applicable official Code symbol stamp as shown in Fig. 12.12

Manufacturer's data reports. A Data Report Form NV-1 (App. K) must be filled out and signed by the Certificate Holder, and signed by the Inspector for each safety and safety relief valve stamped with the Code symbol **NV**.

12.7.2 Rupture disks

The manufacturer is required to mark each rupture disk with the required data in such a way that the marking will not be obliterated in service. The marking should be placed on the flange of the rupture disk or on a metal tab permanently attached thereto. The marking should include the following:



Figure 12.12 ASME Code symbol for nuclear safety valve.

1. Manufacturer's design or type number
2. Lot number
3. Size _____ NPS (DN)
4. Stamped burst pressure _____ psi (kPa)
5. Specified disk temperature _____ °F (°C)
6. Capacity _____ lb/hr (kg/h) of saturated steam or scfm of air at 60°F (15°C) and 14.7 psia/min (101 kPa/min)
7. Year built

Disk holders. Rupture disk holders should be marked with the following data:

1. The name or identifying trademark of the manufacturer
2. Manufacturer's design or type number
3. Size _____ NPS (DN)
4. Year built
5. Serial number

Pressure Relief Devices for Transport Tanks

Transport tanks are used to carry dangerous goods via highway, rail, air, or water. A tank consists of a pressure vessel, service equipment, and external structural components. The ASME Code, Sec. XII—Rules for Construction and Continued Service of Transport Tanks, is applicable for construction and continued service of transport tanks. This Code was first published on July 1, 2004.

The term *pressure vessel* refers to the pressure boundary defined by the geometric shape, but not limited to, the shell, heads, and openings. *Construction of a pressure vessel* includes materials, design, fabrication, examination, shop inspection, testing, certifications, and over pressure protection. The term *continued service* means inspection, testing, repair, alteration, and recertification of a transport tank that has been in service.

The rules of ASME Sec. XII are applicable to pressure vessels intended for transporting dangerous goods with design pressures appropriate for the transportation mode and volumes greater than 450 L (120 gal). The physical scope of the pressure vessel is as follows:

- Internal pressure should be in the range from 0 to 270 bar (full vacuum to 3000 psig).
- The temperature range should be from -269 to 343°C (-452 to 650°F).
- Thickness of the shell and heads should not exceed 38 mm ($1\frac{1}{2}$ in).

The laws and regulations of transport tanks intended for the transportation of dangerous goods are enforced by the Competent Authority, which is the federal government at this time. The Code of Federal

Regulations, Title 49, Parts 100 through 185—Transportation, regulates transportation of dangerous goods.

13.1 Classes of Vessels

Vessel classes are determined by the hazard class of the dangerous goods, pressure, and mode of transport, as required by the Competent Authority. According to the Code of Federal Regulations, Title 49, Part 173, there are nine classes of hazardous materials. For the purpose of obtaining a Certificate of Authorization from the ASME, vessels that meet the requirements of ASME Sec. XII are applicable to the following three classes of vessels:

Class 1 Vessel. This vessel is used for explosive substances. Explosives in Class 1 are divided into six divisions as follows:

- 1.1. Explosives that pose a mass explosion hazard
- 1.2. Explosives that pose a projection hazard but not a mass explosion hazard
- 1.3. Explosives that pose a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
- 1.4. Explosives that present a minor explosion hazard
- 1.5. Explosives that are very insensitive
- 1.6. Explosives that are extremely insensitive articles and that do not pose a mass explosive hazard

Class 2 Vessel. This vessel is used for flammable gas, nonflammable compressed gas, and poisonous gas. Gases in Class 2 are divided into three divisions as follows:

- 2.1. Flammable gas
- 2.2. Nonflammable, nonpoisonous compressed gas, including compressed gas, liquefied gas, pressurized cryogenic gas, compressed gas in solution, asphyxiant gas, and oxidizing gas
- 2.3. Poisonous gas

A trailer tank for transporting liquid natural gas is shown in Fig. 13.1, and a flow schematic for such a tank is shown in Fig. 13.2.

Class 3 Vessel. This vessel is used for flammable liquid and combustible liquid. A trailer tank for multiservice transportation of liquid nitrogen and oxygen is shown in Fig. 13.3.

13.2 Pressure Relief Devices

All transportation tanks, regardless of size and pressure, should be provided with a spring-loaded pressure relief device(s) for protection against overpressure. The owner is responsible for proper installation of pressure



Figure 13.1 A trailer tank for transporting liquefied natural gas. (Courtesy Chart-Ferox, Germany.)

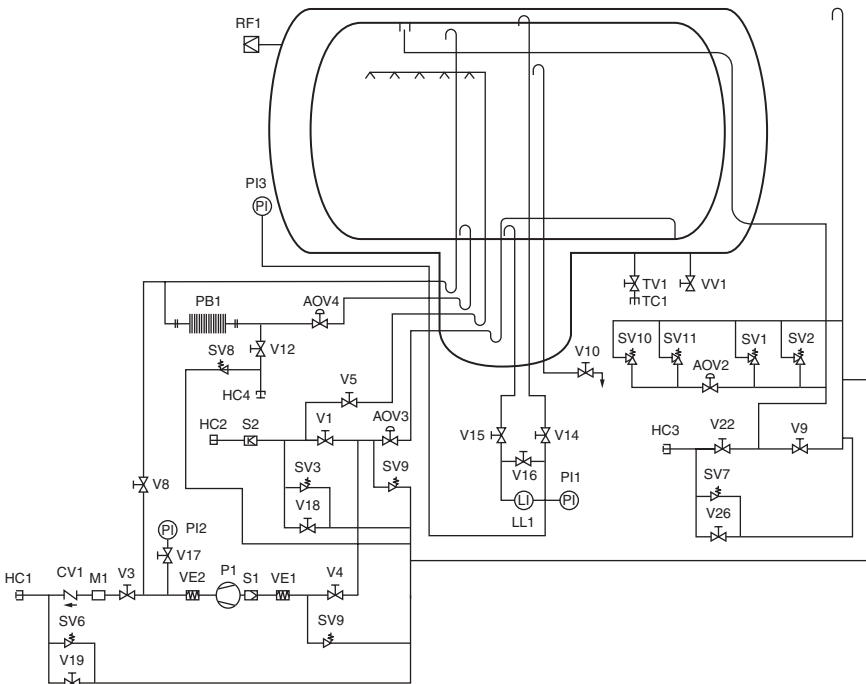


Figure 13.2 Flow schematic of trailer tank for transporting liquefied natural gas.

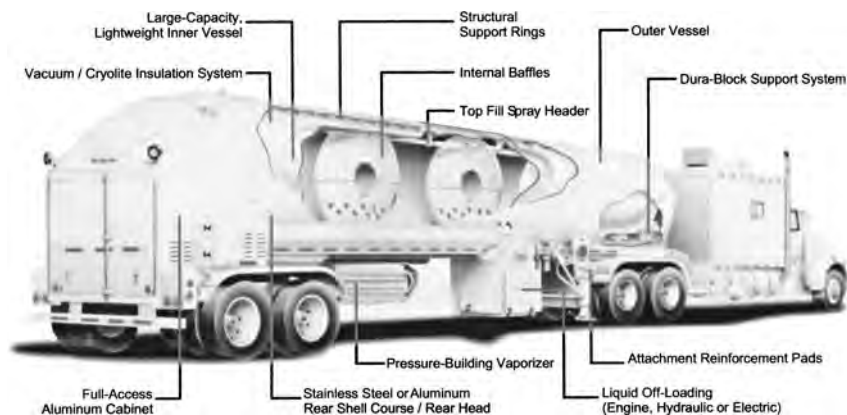


Figure 13.3 A trailer tank for transporting oxygen. (Courtesy Chart-Ferox, Germany.)

relief device(s). It is not necessary for the tank manufacturer to supply such pressure relief device(s).

Regulatory authorities such as the federal government may specify operating characteristics such as set points, capacity requirements, etc., of pressure relief devices used for various applications. In case of conflict between regulatory requirements and ASME Code requirements, the regulatory provisions govern.

A secondary relief device may be installed if specified by the applicable section of the Code.

Pressure relief devices manufactured under ASME Code Sec. XII should be marked with Code symbol **TV** or **TD**. As an alternative, devices stamped **UV** or **UD** under Sec. VIII, Division 1, may be used if the devices meet the additional requirements of Sec. XII.

13.2.1 Determining pressure relief requirements

Transport tanks should not be subjected to pressure exceeding the maximum pressure allowed in the applicable Modal Appendix of ASME Sec. XII. Calculation of pressure-relief capacity requirement should consider fire engulfment and comply with the requirements of the regulatory authority.

Generally the required relief capacity is calculated based on the uninsulated surface area of the tank. Required capacity for liquefied compressed gases and compressed gases is calculated for specific gas in a specific tank.

There are some dangerous goods that may experience unacceptable pressures due to conditions that may occur during transit, requiring special provisions for overpressure protection. In such cases, requirements of the regulatory authority should be followed.

13.2.2 Code references

Pressure relief devices are designed, constructed, inspected, stamped, certified, and installed in accordance with the provisions of ASME Sec. XII. ASME Code requirements for pressure relief devices and corresponding Code references are listed in Table 13.1.

13.2.3 Installation requirements

It is required that tanks with a capacity of 450 L (120 gal) or larger, and permanently mounted in a frame or on a vehicle, should have inlets to

TABLE 13.1 ASME Code Sec. XII Requirements for Pressure Relief Devices for Transportation Tanks

Code requirements	Code paragraph
A. Pressure relief devices	
Protection against Overpressure	TR-100
Determining Pressure Relief Requirements	TR-120
Installation Requirements	TR-130
Capacity Certification—General Requirements	TR-400
Capacity certification of pressure relief valve in combination with rupture disks	TR-410
Capacity certification of pressure relief valve in combination with breaking pin devices	TR-420
B. Pressure relief valves	
General Requirements	TR-200
Design and Mechanical Requirements	TR-210.1
Material Requirements	TR-210.2
Manufacturing and/or Assembly	TR-210.3
Production Testing by Manufacturers	TR-210.4
Marking and Certification	TR-510
C. Rupture disks	
General Requirements	TR-300
Design and Mechanical Requirements	TR-310.1
Material Selections	TR-310.2
Welding and Other Requirements	TR-310.3
Inspection, Manufacture, and Testing	TR-310.4
Production Testing	TR-310.5
Installation Requirements	TR-310.6
Marking and Certification	TR-520
D. Breaking pin devices	
Breaking Pin Devices	TR-320
Breaking Pin Tolerance	TR-320(b)

all pressure relief devices located at or near the top center of the tank. All piping between the pressure relief device and the vapor space of the tank should be not less than the size of the pressure relief device inlet. If two or more pressure relief devices are connected to a single opening, the internal cross-sectional area of the opening should be not less than the combined inlet areas of the pressure relief devices connected to it.

Stop valves should not be used on the inlet or outlet side of a pressure relief device. The size of the discharge lines should be designed in such a manner that any pressure that exists or develops will not reduce the relieving capacity of the pressure relief devices. The installation configuration should not allow accumulation of rain water or debris into outlet openings.

13.3 Requirements for Pressure Relief Valves

Pressure relief valves used for transport tanks should be of the direct-acting, spring-loaded type. The spring of the valve should not be set for pressures greater than 5% above or below the set pressure marked on the valve.

The set pressure tolerances of pressure relief valves should not exceed ± 14 kPa (2 psi) for pressures up to and including 483 kPa (70 psi) and $\pm 3\%$ of set pressure for pressures above 483 kPa (70 psi).

13.3.1 Types of pressure relief valves

Pressure relief valves certified for service in unfired pressure vessels per ASME Code Sec. VIII, Division 1, may be used in a transport tank if the manufacturer or user of the tank finds it suitable for the intended service application.

Generally, two types of pressure relief valves, internal style and external style, are used in transport tank applications.

Internal style. The internal style of pressure relief valve is spring loaded, but it is installed in such a way that most of the body of the valve is inside the tank (Figs. 13.4 and 13.5). The pressure relief valve is actuated by overpressure in the tank car. There are no provisions for manual activation of the valve.

To avoid exposure to toxic or hazardous materials, make sure that the tank car is empty and clean, and that the work area is free of hazardous chemicals, before removing or installing any pressure relief valve.

External style. The external style of pressure relief valve is spring loaded, but it is installed in such a way that most of the body of the valve



Figure 13.4 Internal-style pressure relief valve. (Courtesy Midland Manufacturing.)

remains on the top of the tank (Figs. 13.6 and 13.7). The pressure relief valve is actuated by overpressure in the tank car. There are no provisions for manual activation of the valve.

Prior to installation, ensure that the valve is clean and the gasket sealing surfaces are not damaged. To avoid exposure to toxic or hazardous materials, make sure that the tank car is empty and clean, and that the work area is free of hazardous chemicals, before removing or installing any pressure relief valve.

13.3.2 Design requirements

The design of pressure relief valves should be based on the temperatures, pressure, and type of goods to be transported in the specific applications. The design should incorporate all the features necessary to ensure consistent operation and tightness.

The spring of the valve should be designed so that full-lift spring compression should not be greater than 80% of the nominal solid deflection.

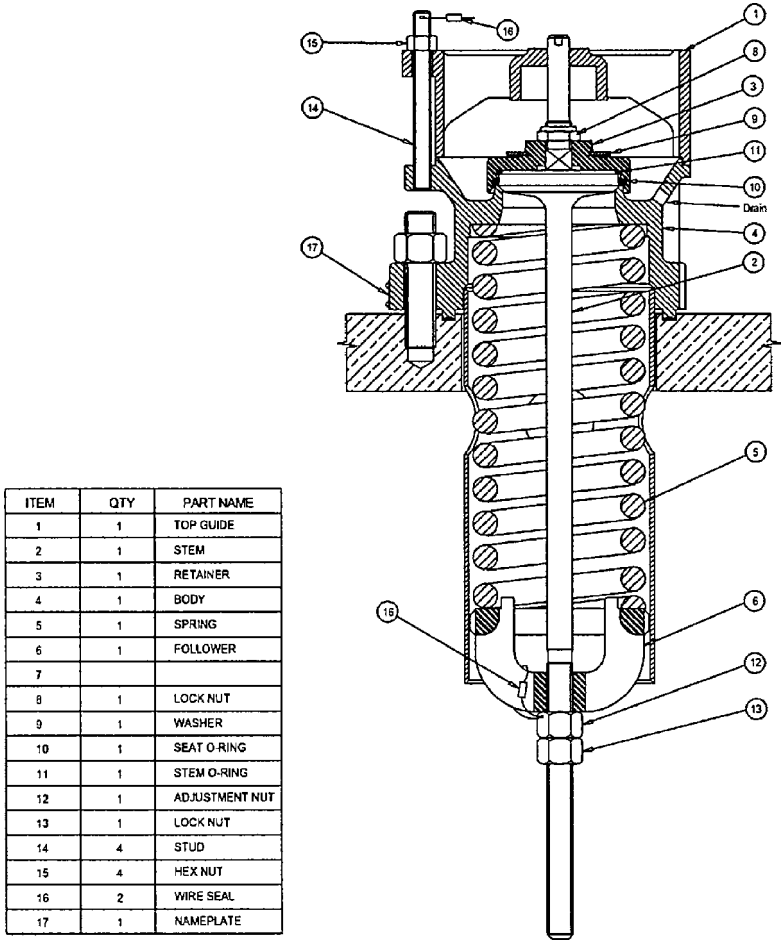


Figure 13.5 Components of an internal-style pressure relief valve.

The permanent set of the spring should not exceed 0.5% of the free height. The permanent set of the spring is defined as the difference between the free height and height measured solid three times after pre-setting at room temperature.

The design of pressure relief valves with external adjustment points should provide a means for sealing adjustments. The seals should be installed in a manner that precludes altering the settings without breaking the seal. The manufacturer or the assembler is responsible for attaching the seals after initial adjustments. Valves without external adjustments must be designed to allow disassembly for cleaning of pressure areas and reassembly without altering operational settings.

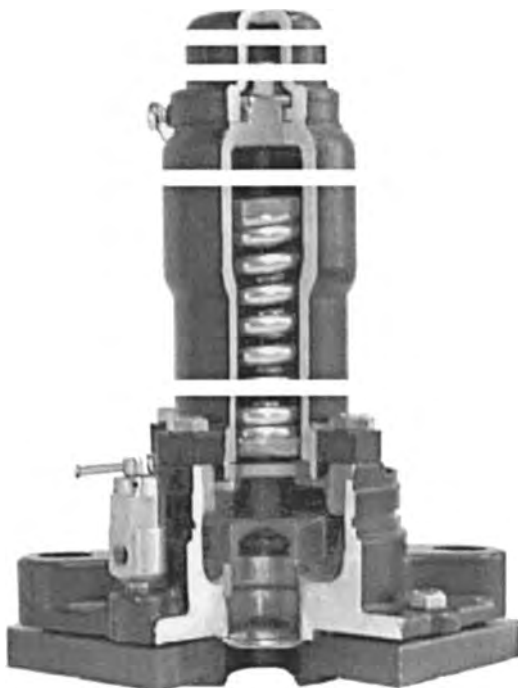


Figure 13.6 Components of an external-style pressure relief valve. (*Courtesy Midland Manufacturing.*)

If the valve seat is not integral with the body, it should be fastened to the body of the valve in such a way that there is no possibility of the seat lifting. The valve body should be provided with a drain port below the level of seat, to minimize collection of deposits and fluids.

All pressure relief valve designs must be submitted for capacity certification or testing by a representative from an ASME-designated organization. The ASME-designated organization has the authority to review designs, and to approve, reject, or require modifications prior to capacity testing.

13.3.3 Materials requirements

The seats and disks of pressure relief valves should be constructed of suitable materials to resist corrosion by the fluid. Cast-iron seats and disks are not permitted.

Adjacent sliding surfaces, such as guides, disk holders, etc., should be of corrosion-resistant materials. Springs should be made of corrosion-resistant material or have a corrosion-resistant coating on them.

ITEM	QTY	PART NAME
1	1	TOP GUIDE
2	1	STEM
3	1	PLUG
4	1	BODY
5	1	OUTER SPRING
6	1	FOLLOWER
7	1	GUIDE
8	1	TOP NUT
9	1	TOP GASKET
10	1	SHAFT SEAL
11	1	ADJUSTING SCREW
12	1	SEAL RETAINER
13	1	INNER SPRING
14	1	CAP
15	1	SET SCREW
16	4	STUD
17	4	NUT
18	1	WIRE SEAL
19	1	RETAINER
20	1	SEAT "O" RING
21	1	PLUG "O" RING
22	1	FLUE "O" RING
23	1	RUPTURE DISC
24	1	FLUE (NOT SHOWN)
25	4	RUP. DISC FLG BOLTS
26	1	RUP. DISC FLANGE
27	1	1/8" VALVE
28	1	NAMEPLATE
29	1	UPPER FILLER

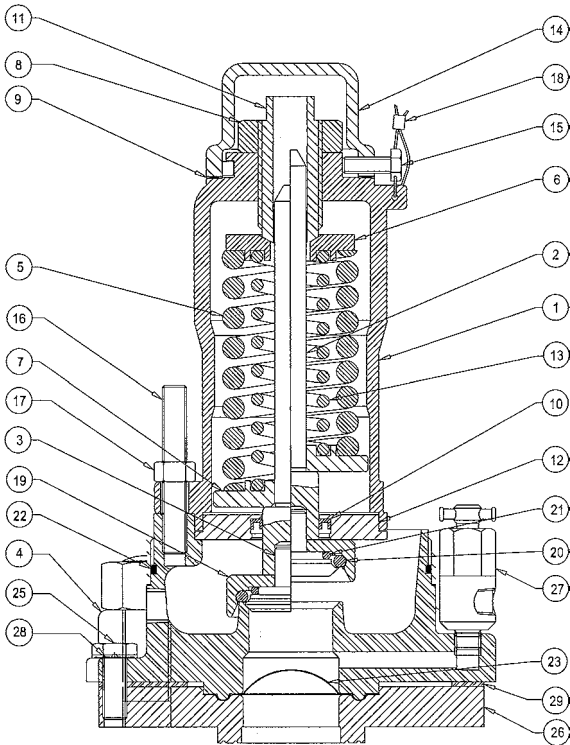


Figure 13.7 Components of an external-style pressure relief valve.

Valve bodies, bonnets, yokes, and bolting should be made of materials acceptable under ASME Sec. XII, or controlled by the manufacturer by a specification ensuring control of chemical and physical properties and quality at least equivalent to ASME standards. Materials subjected to operating or environmental temperature below -29°C (-20°F) should be selected to provide adequate toughness against brittle fracture.

13.3.4 Manufacturing

A manufacturer is required to demonstrate to the satisfaction of a representative from an ASME-designated organization that manufacturing, production, testing facilities, and quality control procedures ensure close agreement between the performance of production samples and valves submitted for capacity certification testing.

A representative from an ASME-designated organization can inspect manufacturing, assembly, inspection, and test operations, including capacity tests, at any time.

If approved by the ASME, a manufacturer is granted permission to apply the Code symbol **TV** to the production pressure relief valves. This permission expires on the fifth anniversary of the date it is initial granted. The permission may be extended for 5-year periods, provided the following tests are successfully repeated within the 6-month period before expiration:

- Two sample production pressure relief valves of a size and capacity within the capability of an ASME-approved laboratory selected by a representative from an ASME-designated organization.
- Operational and capacity tests should be performed in the presence of a representative from an ASME-designated organization at an ASME-approved laboratory. The manufacturer should be notified of the time of the test and may have representatives present to witness the test.
- If any valve fails to relieve at or above its certified capacity or fails to meet performance criteria, the test should be repeated at the rate of two replacement valves for each valve that failed. The selection of the valve is made according to Par. TR-210.3(c)(1).
- If any replacement valve fails to meet the capacity or performance requirements, the failure will cause revocation of authorization to use the Code symbol within 60 days of such failure. The manufacturer must demonstrate the cause of such deficiency and the corrective action taken to guard against future occurrence.

13.3.5 Marking and certification

Each pressure relief valve should be plainly marked by the manufacturer or assembler in such a way that the markings will not be obliterated in service. The markings may be placed either on the valve or on a tag attached to the valve. The minimum markings should include:

1. The name, or an acceptable abbreviation, of the manufacturer or assembler
2. Manufacturer's design or type number and date of manufacture
3. Nominal seat and inlet connection diameters
4. Set pressure, in bar (psig)
5. Certified flowing capacity at full open pressure, in standard cubic feet per minute, scfm (at 60°F and 14.7 psia) of air, or in standard cubic meters per hour (at 16°C and 101 kPa) of air where applicable
6. Year built or, alternatively, a date code that enables the valve manufacturer or assembler to identify the year the valve was assembled or tested
7. ASME Code symbol as shown in Fig. 13.8



Figure 13.8 ASME Code symbol for pressure relief valve for transport tank.

13.3.6 Production testing

The manufacturer is responsible for production testing such as set pressure tests and leakage tests before applying the Code symbol **TV** stamp on pressure relief valves. The manufacturer must have a documented program for the application, calibration, and maintenance of gauges and instruments used during these tests.

The manufacturer must perform the following tests for each pressure relief valve to be Code stamped:

- Set pressure test—Each pressure relief valve should be tested after setting, to demonstrate its set pressure.
- Seat tightness test—Each pressure relief valve should be tested for seat tightness after successful completion of the set pressure test. The seat tightness test is done in accordance with API 527.

13.4 Requirements for Rupture Disks

A rupture disk device is a nonreclosing pressure relief device. The pressure-containing element is a rupture disk, which is tested in the factory by the manufacturer. It is actuated by a pressure buildup inside the tank, due either to substantial heat input into the tank or pressure spikes generated by surging liquid in the tank. A rupture disk device used in transport tank application is shown in Figs. 13.9 and 13.10.

The burst pressure at the specified disk temperature should not exceed the marked burst pressure by more than ± 14 kPa (2 psi) for marked burst pressures up to and including 280 kPa (40 psi), or by more than $\pm 5\%$ for marked burst pressures above 276 kPa (40 psi) unless other requirements are identified by the regulating authority.

It is advisable for all personnel to stay away from the rupture disk device, unless inspection and maintenance has to be performed on it. Exercise extreme caution when inspecting the rupture disk device and/or its disk if there is any pressure in the tank.



Figure 13.9 A rupture disk for a transport tank. (Courtesy Midland Manufacturing.)

13.4.1 Design requirements

Rupture disk devices designed and constructed for service in unfired pressure vessels per Sec. VIII, Division 1, may be used in transport tank service if the manufacturer or user of the tank finds them suitable for the intended service. Suitability for service should be determined based on the temperatures, pressures, and goods to be transported.

Margin between tank operating pressure and rupture disk bursting pressure should be provided, to reduce the potential for premature activation of the rupture disk. The design of a single rupture disk intended to respond to both overpressure and underpressure should be avoided. Instead, two separate rupture disks, designed to relieve overpressure and underpressure independently, should be considered when there is the possibility for tank failure from vacuum as well as overpressure conditions.

The design of rupture disk devices should incorporate all the features necessary to ensure consistent operation and tightness. These devices

ITEM No.	PART NAME
1	Top
2	Base
3	Disc
4	Retainer
5	Swing Pin
6	Nut
7	Stud
8	Hinge Pin
9	Eye Bolt Pin
10	Chain
11	Cotter Pin
12	Eye Bolt
13	Wire Seal

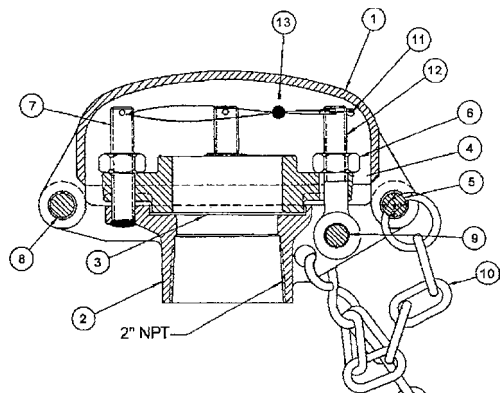


Figure 13.10 Components of a rupture disk.

should be designed to allow normal installation without damaging the rupture disk.

13.4.2 Materials requirements

The rupture disk material is not required to conform to a specification of ASME Sec. II. The manufacturer may control the disk material by a specification ensuring suitability for the service conditions.

Materials for the construction of rupture disk holders should be listed in ASME Code Secs. II and XII. Carbon- and low-alloy steel holders and bolting for service colder than -29°C (-20°F) should be selected for adequate toughness. Materials used in other parts of the disk holder should be one of the following:

- Listed in ASME Sec. II
- Listed in ASTM Specifications
- Controlled by the manufacturer of the rupture disk by a specification ensuring consistent chemical and physical properties equivalent to an ASTM Specification

13.4.3 Manufacturing

A manufacturer is required to demonstrate to the satisfaction of a representative from an ASME-designated organization that manufacturing, production, testing facilities, and quality control procedures ensure close agreement between the performance of production samples and valves submitted for capacity certification testing.

A representative from an ASME-designated organization can inspect manufacturing, assembly, inspection, and test operations, including capacity tests, at any time.

If approved by the ASME, a manufacturer is granted permission to apply the Code symbol **TD** to production rupture disks. This permission expires on the fifth anniversary of the date it is initial granted. The permission may be extended for 5-year periods, provided the following tests are successfully repeated within the 6-month period before expiration:

- Two sample production rupture disk devices, of a size and capacity within the capability of an ASME-approved laboratory, should be selected by a representative from an ASME-designated organization.
- Burst and flow testing should be performed in the presence of a representative from an ASME-designated organization at an ASME-approved laboratory. The manufacturer should be notified of the time of the test and may have representatives present to witness the test.
- If any disk fails to relieve at or above its certified capacity or fails to meet performance criteria, the test should be repeated at the rate of

two replacement disks for each disk that failed. The selection of the disks is made according to Pars. TR-310.4(c)(1) and (c)(2).

- If any replacement disk fails to meet the capacity or performance requirements, the failure will be cause for revocation of authorization to use the Code symbol within 60 days of such failure. The manufacturer must demonstrate the cause of such deficiency and the corrective action taken to guard against future occurrence.

13.4.4 Marking and certification

Every rupture disk should be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service. The rupture disk markings may be placed on the flange of the disk, or on a tab attached as close as possible to the discharge side of the disk so that it will be visible when installed. The markings should include the following:

1. Name or identifying trademark of the manufacturer
2. Manufacturer's design or type number
3. Lot number
4. Disk material
5. Size (NPS or nominal diameter, in or mm)
6. Marked bursting pressure, in psig; an in bar where applicable
7. Specified disk temperature, °F, and °C where applicable
8. Minimum net flow area, in² (cm²)
9. Certified flow resistance coefficient, K_r
10. ASME Code symbol as shown in Fig. 13.11
11. Year built or, alternatively, a date code that enables the disk manufacturer or disk assembler to identify the year the disk was manufactured or the disk and holder assembly was assembled

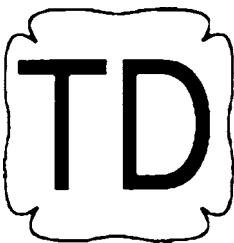


Figure 13.11 ASME code symbol for rupture disk for transport tank.

13.4.5 Production testing

The manufacturer is responsible for production testing such as pressure tests, set pressure tests, and leakage tests before applying the Code symbol **TD** to rupture disks. The manufacturer must have a documented program for the application, calibration, and maintenance of gauges and instruments used during these tests.

The manufacturer must perform the following tests for rupture disks to be Code stamped:

- **Pressure test**—The pressure parts of each rupture disk holder exceeding DN 25 (NPS 1) inlet size or 2 070 kPa (300 psi) design pressure where materials are either cast or welded should be tested at a pressure of 1.3 times the design pressure. The result of the test should show no sign of leakage.
- **Burst test**—Each lot of rupture disks should be tested for bursting. A lot of rupture disk means the quantity of disks manufactured of a given material specification at the same time, of the same size, thickness type, heat, heat-treatment condition, and manufacturing process. The manufacturer is responsible for conducting the following tests: At least two sample rupture disks from each lot should be burst at the specific disk temperature. The burst pressure should be within the burst pressure tolerance specified by TR-300(b).

13.4.6 Installation requirements

A rupture disk may be either installed as the sole pressure-relieving device on the vessel or installed between a pressure relief valve and the tank. A rupture disk should not be installed on the discharge side of a pressure relief valve.

The following criteria should be met if a rupture disk is installed between a pressure relief valve and a tank:

- The combined flow capacity of the spring-loaded pressure relief valve and the rupture disk should be sufficient to meet the requirements of Art. TR-1 of the Modal Appendices.
- The marked capacity of a pressure relief valve when installed with a rupture disk should be multiplied by a factor of 0.90 of the rated relieving capacity of the valve alone.
- The space between a rupture disk device and a pressure relief valve should be provided with a pressure gauge, try cock, free vent, or other suitable telltale indicator. This will permit detection of disk rupture or leakage at pressures lower than the set point of the valve.

- The opening provided through the rupture disk, after bursting, should be sufficient to permit a flow equal to the capacity of the pressure relief valve, and the design should assure that the bursting will not interfere with the functioning of the valve. Also, the flow area of the burst rupture disk should not be less than 90% of the area of the inlet of the valve.

13.5 Requirements for Breaking Pin Devices

Each breaking pin device should have a rated pressure at which the pin breaks at the specified temperature. The breaking pin is identified by a lot number. The manufacturer must guarantee that the pin will break at the rated pressure and specified temperature within the following tolerances:

Rated pressure, kPa (psi)		Pin Breaking Tolerance, $\pm$ kPa (psi)
Min.	Max.	
207 (30)	1035 (150)	34.5 (5)
1036 (151)	1898 (275)	69 (10)
1899 (276)	2588 (375)	103.5 (15)

When used as the sole pressure-relieving device, the rated pressure of the breaking pin plus the breaking tolerance should not exceed the maximum allowable overpressure of the tank. If used as part of a combination relief device, the rated pressure of the breaking pin plus the breaking tolerance should not exceed the set point of the pressure relief valve.

The rated pressure at the specified temperature should be verified by breaking two or more sample pins from each lot of the same material and size as those to be used. The lot size should not exceed 25.

The space between a breaking pin device and a pressure relief valve should be provided with a pressure gauge, try cock, free vent, or other suitable telltale indicator. This arrangement will permit detection of pin breakage or device breakage at pressures lower than the set point of the pressure relief valve.

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Pressure Relief Devices for Petroleum Industries

The petroleum industry began with the drilling of the first commercial oil well in 1859 and the opening of the first refinery two years later to process the crude oil into kerosene. The evolution of refining from simple distillation to modern sophisticated processes has created a need for safety. The safe processing of crude oil into flammable gases and liquids at high temperatures and pressures using pressure vessels, equipment, and piping subjected to stress and corrosion requires considerable knowledge, control, and expertise. These vessels are specially designed to withstand the corrosive environment of petroleum products.

Pressure-relieving devices protect pressure vessels, equipment, and piping in the petroleum industry by automatically opening at predetermined pressures and preventing the destructive consequences of excessive pressures in process systems and storage vessels.

The American Petroleum Institute (API) is the primary trade association, representing more than 400 members in all aspects of the oil and gas industry. API members come from all segments of the industry, from the largest major oil company to the smallest of independents. They are producers, refiners, suppliers, pipeline operators, and marine transporters. The API has published many codes and standards for the oil and gas industry, but the following standards are applicable to pressure-relieving devices:

API 510: Pressure Vessel Inspection Code: Inspection, Rating, Repair, and Alteration

RP 520: Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries

Part I—Sizing and Selection

Part II—Installation

RP 521: Guide for Pressure-Relieving and Depressuring Systems

Std 526: Flanged Steel Pressure Relief Valves

Std 527: Seat Tightness of Pressure Relief Valves

RP 576: Inspection of Pressure Relieving Devices

Std 620: Design and Construction of Large, Welded, Low-Pressure Storage Tanks

Std 650: Welded Steel Tanks for Oil Storage

Std 2000: Venting Atmospheric and Low-Pressure Storage Tanks

Bull. 2521: Use of Pressure-Vacuum Vent Valves for Atmospheric Pressure Tanks to Reduce Evaporation Loss

14.1 Refining Operations

Refining is the process of converting one complex mixture of hydrocarbons into a number of complex mixtures of hydrocarbons. A petroleum refining process is shown in Fig. 14.1. Petroleum refining begins with the distillation, or fraction, of crude oils (Fig. 14.2) into separate hydrocarbon groups.

Petroleum refining processes and operations can be separated into six basic areas:

1. Fractionation (distillation)—separation of crude oil in atmospheric and vacuum towers into groups of hydrocarbon compounds
2. Conversion—processes for changing the size and/or structure of hydrocarbon molecules
3. Treatment—processes for preparing hydrocarbon streams for additional processes to prepare finished products
4. Formulating and blending—processes of mixing and combining hydrocarbon fractional additives and other components to produce finished products
5. Other refining operations—including light-ends recovery, sour-water stripping, solid waste water treatment, process water treatment, cooling, storage (Fig. 14.3) and handling, hydrogen production, acid and tail gas treatment, and sulfur recovery
6. Auxiliary operations and facilities—including steam and power generation, process and fire water systems, flares and relief systems, furnaces and heaters, pumps and valves, supply of nitrogen and other plant gases, etc.

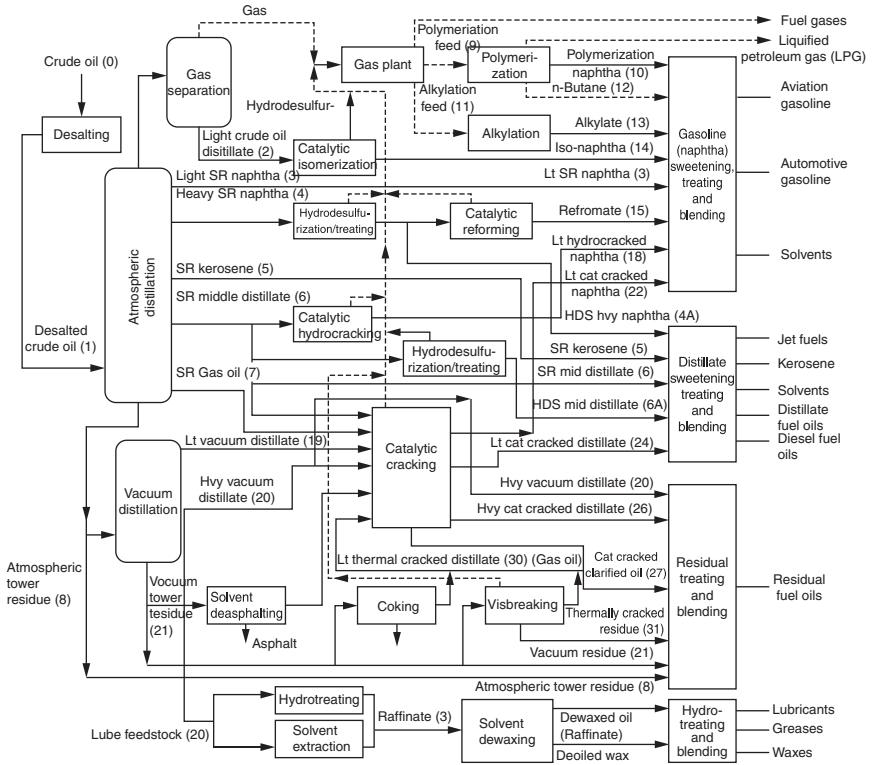


Figure 14.1 Petroleum refining process. (Courtesy Federal OSHA.)



Figure 14.2 Crude unit of a refinery.

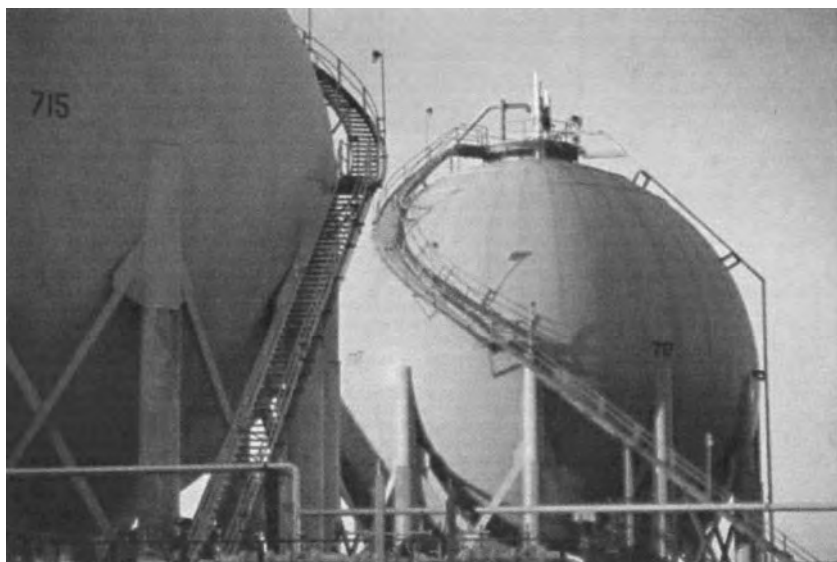


Figure 14.3 Refinery tank. (Courtesy Saudi Aramco.)

14.2 Protection of Petroleum Equipment

Pressure-relieving devices are used to protect equipment in the oil and petrochemical industries. Most common automatic devices, such as pressure relief valves, pilot-operated pressure relief valves, and rupture disks, are fitted on various types of pressure vessels installed in petroleum industries. Pressure relief valves or rupture disks may be used independently or in combination with each other to provide required protection against excessive pressure accumulation in vessels.

Figure 14.4 shows a pressure relief valve used on a refinery vessel. 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.

Figure 14.5 shows a rupture disk installed on a refinery vessel. A rupture disk is a nonreclosing pressure relief device 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.

14.3 Protection of Tanks

Refinery tanks require special protection from either positive or vacuum overpressure, as shown in Fig. 14.6. A pressure vacuum relief valve provides protection against positive or vacuum overpressure, prevents air

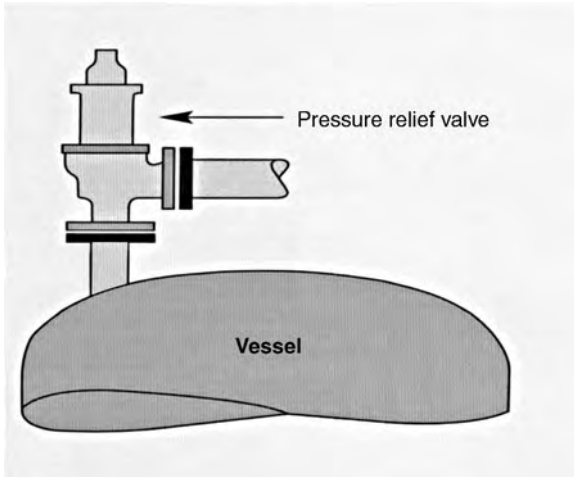


Figure 14.4 Pressure relief valve on a refinery vessel.

intake, evaporative or blanketing product losses, and helps contain odorous, hazardous, and potentially explosive vapors.

A pressure relief valve may be used separately on a tank for vent-to-atmosphere applications. Utilizing the latest technology, this pressure relief valve can provide protection against positive overpressure, prevent

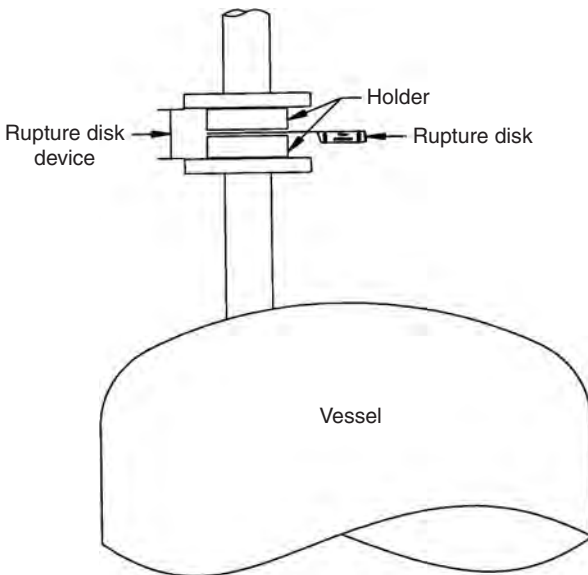


Figure 14.5 Rupture disk installed on a refinery vessel. (From API RP 520, Part II.)

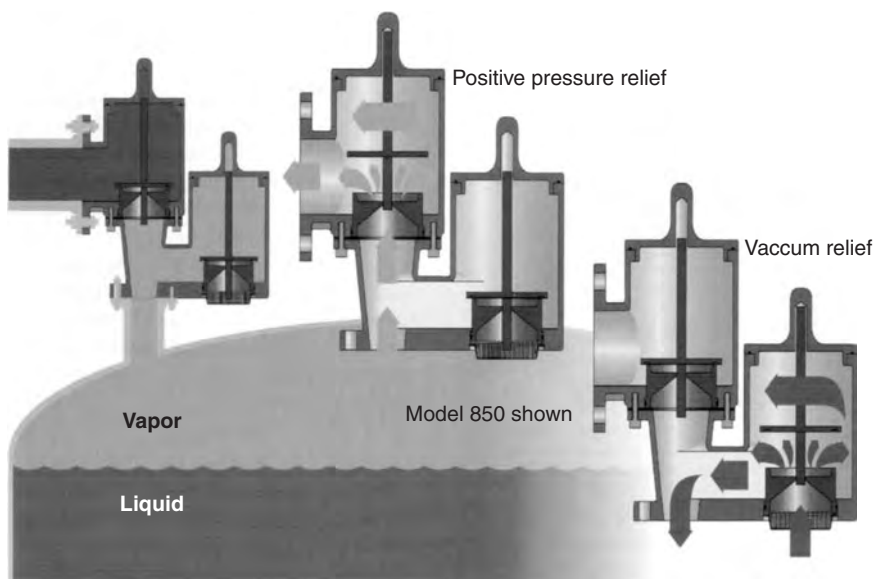


Figure 14.6 Refinery tank protection. (Courtesy Enardo, Inc.)

air intake and evaporative loss of product, and help contain odorous and potentially hazardous vapors.

A vacuum relief valve may be used separately on a tank for vent-from-atmosphere applications. Utilizing the latest technology, this vacuum relief valve provides protection against vacuum over pressure, prevents evaporative loss of product, and helps contain odorous and potentially hazardous vapors.

14.4 Fire Sizing

A pressure vessel or pressure-containing equipment should be fire sized in case the vessel is exposed to fire, even if the contents of the vessel are not flammable. A fire may occur due to leakage of flammable material from equipment and pipelines, or may be caused due to misoperation.

If a fire occurs accidentally, the burning material immediately spreads to adjacent vessels and equipment. In case of an open fire around the vessel, heat is absorbed by anything coming in contact with the flames or hot gases of the fire. If this heat absorption in a vessel continues for a long time, the vessel contents become heated and pressure rises until the pressure relief valve opens.

Given these fire hazards, it is necessary to consider the probability of fire exposure when sizing pressure relief valves.

14.4.1 Fire sizing standards

The rules for fire sizing depend on the codes, standards, and jurisdictional requirements at the location of installation. The following standards are recommended in addition to the jurisdictional requirements for fire sizing of pressure relief devices:

- API RP 520 Part 1, Recommended Practices for the Design and Installation of Pressure-Relieving Systems in Refineries
- API Standard 2000, Venting Atmospheric and Low Pressure Storage Tanks
- API Standard 2510, Design of LP Gas Installations
- NFPA (National Fire Protection Association) 58—Storage and Handling of Liquefied Petroleum Gases
- CGA (Compressed Gas Association), CGA S-13

14.4.2 Fire sizing for liquid hydrocarbons

Most of the hydrocarbon liquid is stored in a tank. The following information is needed to calculate the required orifice area for pressure relief valves on vessels containing liquids that are exposed to fire:

- Tank size (shape and dimensions)
- Mounting (horizontal or vertical; height above ground)
- Fluid composition
- Normal liquid level (NLL): % full, depth of fluid, or liquid-full
- Operating pressure
- Set pressure
- Operating temperature
- Saturation temperature at P_1
- K (ratio of specific heat)
- M (molecular weight)
- Z (compressibility factor); if not known, assume $Z = 1$
- F environmental factor: The F factors in Table 14.1 should be used in the calculation. If sufficient information is not available, assume $F = 1$.

Based on the above information, the following steps may be followed in fire sizing a tank containing liquid hydrocarbons.

TABLE 14.1 *F* Environmental Factors for Fire Sizing for Liquid Hydrocarbons

Type of vessel	<i>F</i> factor
Bare vessel	1.0
Insulated vessel:	
4	0.3
2	0.15
1	0.075
0.67	0.05
0.50	0.0376
0.4	0.03
0.33	0.026
Water application facilities, on bare vessel	1.0
Depressuring and empty facilities	1.0

Step 1. Determine the total wetted surface area using the following formula:

$$\text{Total wetted surface area } (A) = F_{wp} \times \text{total vessel surface area}$$

where F_{wp} is the wetted perimeter factor. The total surface area A for various vessel shapes is given below.

Sphere	$A = \pi D^2$
Vertical cylinder with flat ends	$A = \pi(DL + D^2/2)$
Vertical cylinder with elliptical ends	$A = \pi(DL + 2.61)D^2$
Vertical cylinder with hemispherical ends	$A = \pi(DL + D^2)$
Horizontal cylinder with flat ends	$A = \pi(DL + D^2/2)$
Horizontal cylinder with elliptical ends	$A = \pi(DL + 2.61)D^2$
Horizontal cylinder with hemispherical ends	$A = \pi(DL + D^2)$

It is recommended that the total wetted surface area A be at least the wetted surface included within a height of 25 ft above ground level, or in the case of spheres, at least the elevation of the maximum horizontal diameter or a height of 25 ft, whichever is greater.

Step 2. Determine heat absorption using the following formulas:

(a) When prompt fire-fighting efforts and adequate drainage exist:

$$Q = 21,000F(A)^{0.82}$$

where Q = total heat absorption into the wetted surface in BTU/hr

F = environmental factor (Table 14.1)

A = total wetted surface area in ft²

- (b) When prompt fire-fighting efforts and adequate drainage do not exist:

$$Q = 34,500F(A)^{0.82}$$

Step 3. Determine the rate of vapor or gas vaporized from the liquid:

$$W = \frac{Q}{H_{\text{vap}}}$$

where W = mass flow, lb/hr

Q = total heat absorption into the wetted surface, BTU/hr

H_{vap} = latent heat of vaporization, BTU/lb

(Determine latent heat of vaporization from the fluid properties.)

Step 4. Calculate the minimum required relieving area using the following formula for gas and vapor sizing:

Example 14.1: Liquid Sizing—Fire Determine the vapor discharge capacity in lb/hr for a tank containing propane, with the following information for fire sizing.

Vessel information

Tank size	6 ft diameter × 12 ft long, seam to seam, elliptical heads
Mounting	Horizontal and 3 in above ground
Fluid	Propane
Normal liquid level	80% filled
F factor	1.0 (no insulation)
Operating pressure	150 psig
Set pressure	225 psig
Saturation temperature	140°F
K	1.13
M (molecular weight)	44.09
Z (compressibility factor)	1.0
Latent heat of vaporization	110 Btu/lb

Solution

Wetted surface area: Enter 80% filled on the graph in Fig. 14.7, and determine $F_{WP} = 0.67$.

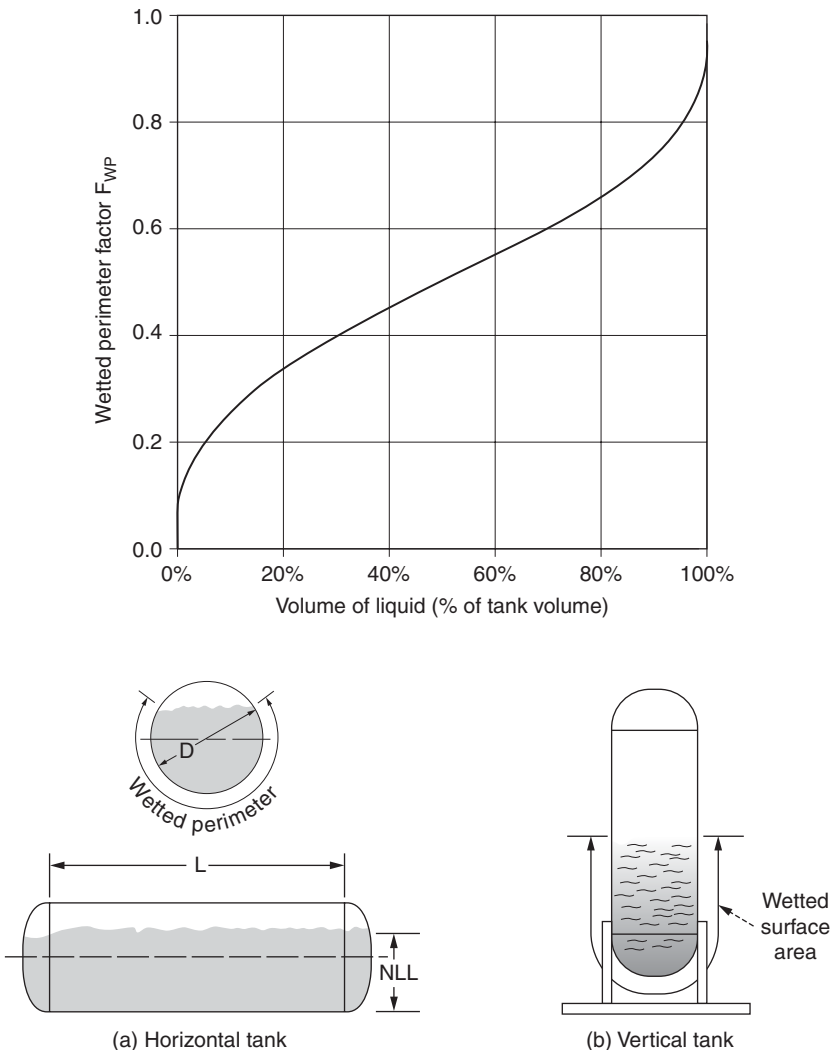


Figure 14.7 Hydrocarbon tanks. (Courtesy Dresser Flow Control.)

Select the total surface area A formula for a horizontal cylinder with elliptical ends.

$$A = F_{WP} \times [(DL + 2.61D^2)]$$
$$A = 0.67 \times (\pi \times 6 \times 12 + 2.61 \times 6 \times 6) = 214.5 \text{ ft}^2$$

Heat absorbed:

$$Q = 21,000FA^{0.82}$$

$$Q = 21,000(1)214.5^{0.82}$$

$$Q = 1,713,940 \text{ Btu/hr}$$

Vapor generated:

$$W = \frac{Q}{\text{latent heat of vaporization}}$$

$$W = \frac{1,713,940}{110}$$

$$W = 15,581 \text{ lb/hr}$$

14.4.3 Fire sizing for vessels containing gases

Many tanks contain vapor or gas. The following information is needed to calculate the required orifice area for pressure relief valves on vessels containing vapor or gas:

- Tank size: shape-describing dimensions
- Mounting: horizontal or vertical; height above ground
- Fluid: composition by names and specific heats
- Operating pressure, P_o (psia)
- Set pressure, P (psig)
- Operating temperature, T_o ($^{\circ}\text{F} + 460$)

The required orifice area for a pressure relief valve on a gas-containing vessel exposed to fire can be determined using the following formula:

$$A = \frac{F_1 \times A_1}{\sqrt{P_1}}$$

where A = effective discharge area of the valve, in^2

A_1 = exposed surface area of the vessel, ft^2

P_1 = upstream relieving pressure, psia
 = set pressure (psig) + overpressure (psia) + atmospheric pressure (psia)

C = coefficient determined by the ratio of specific heat of flue gas and standard conditions.

F_1 = minimum recommended value is 0.01. When the minimum value is unknown, $F_1 = 0.045$ should be used. F_1 can be determined using the following formula:

$$F_1 = \frac{0.1406}{CK_D} \times \frac{(T_w - T_1)^{1.25}}{(T_1)^{0.6506}}$$

T_w = vessel wall temperature, °R. The API recommended maximum wall temperature is 1100°F for carbon steel vessels.

K_D = effective coefficient of discharge

T_1 = gas temperature at the upstream pressure, °R, can be determined using the following formula:

$$T_1 = \frac{P_1 \times T_o}{P_o}$$

where P_1 = flow pressure, psia = $(P \times 1.21) + 14.7$

P_o = nominal operating pressure, psia

T_o = normal operating temperature absolute, °R

T_1 = relieving temperature = $T_1 - 460$

Example 14.2: Gas Sizing—Fire Determine the orifice size for a pressure relief valve for fire sizing a vessel containing isobutene vapor, with the following information provided.

Vessel information

Tank size	5 ft diameter × 12 ft long seam to seam, flat ends
Mounting	Horizontal and 2 in above grade
Fluid	Isobutane vapor
K (for isobutane)	1.094
C	327
Operating pressure	110 psi
Set pressure	150 psig
Operating temperature	160°F
Relieving temperature	Not known
T	1025°F

Solution**Step 1.** Calculate flowing pressure.

$$P_1 = 150 \times 1.21 + 14.7 = 196.2 \text{ psia}$$

$$P_o = 110 + 14.7 = 124.7 \text{ psia}$$

$$T_o = 160 + 460 = 620^\circ\text{R}$$

Step 2. Calculate flowing temperature.

$$T_1 = \frac{196.2 \times 620}{124.7} = 975^\circ\text{R}$$

Fahrenheit flowing temperature or gas temperature at P_1 :

$$T_1 = 975 - 460 = 515^\circ\text{F}$$

Step 3. Determine relief valve factor F_1 .

$$F_1 = \frac{0.1406(T_w - T_1)^{1.25}}{CK_D \times (T_1)^{0.6506}}$$

$$F_1 = \frac{0.1406(1485 - 975)^{1.25}}{(327)(0.95)(975)^{0.6506}}$$

$$F_1 = 0.012$$

Step 4. Determine exposed vessel surface area.Select wetted surface area A formula for horizontal cylinder with flat ends.

$$A_s = \pi \left(DL + \frac{D^2}{2} \right)$$

$$A_s = \pi \left(5 \times 12 + \frac{25}{2} \right)$$

$$A_s = 227.8 \text{ ft}^2$$

Step 5. Now calculate orifice area.

$$A = \frac{F_1 \times A_s}{\sqrt{P_1}}$$

$$A = \frac{0.012 \times 227.8}{\sqrt{196.2}}$$

$$A = 0.1952 \text{ in}^2$$

14.5 Seat Tightness Test

The manufacturer is required to test tightness of metal and soft seated pressure relief valves, including those of conventional, bellows, and pilot operating designs. API RP 527, Seat Tightness of Pressure Relief Valves, describes methods for determining seat tightness.

The maximum allowable leakage rates are defined for pressure relief valves with set pressures from 15 psig (103 kPag) to 6000 psig (41,379 kPag). The test medium for determining the seat tightness—air, steam, or water—should be the same as that used for determining the set pressure of the valve. For dual-service valves, the test medium—air, steam, or water—should be the same as the primary relieving medium.

Persons who are experienced in the use and functions of pressure relief valves should perform the procedures outlined in this standard.

14.5.1 Testing with air

Test apparatus. A test arrangement for determining seat tightness with air is shown in Fig. 14.8.

Leakage should be measured using a tube with an outside diameter of 5/16 in (7.9 mm) and a wall thickness of 0.035 in (0.89 mm). The tube end should be cut square and smooth. The tube opening should be $\frac{1}{2}$ in. (12.7 mm) below the surface of the water. The tube should be perpendicular to the surface of the water.

Arrangement should be made to safely relieve or contain body pressure in case the valve pops accidentally (Fig. 14.9).

Test procedure

Test medium—The test medium should be air or nitrogen at close to ambient temperature.

Test configuration—The valve should be mounted vertically on the test stand, and the test apparatus should be attached to the valve outlet,

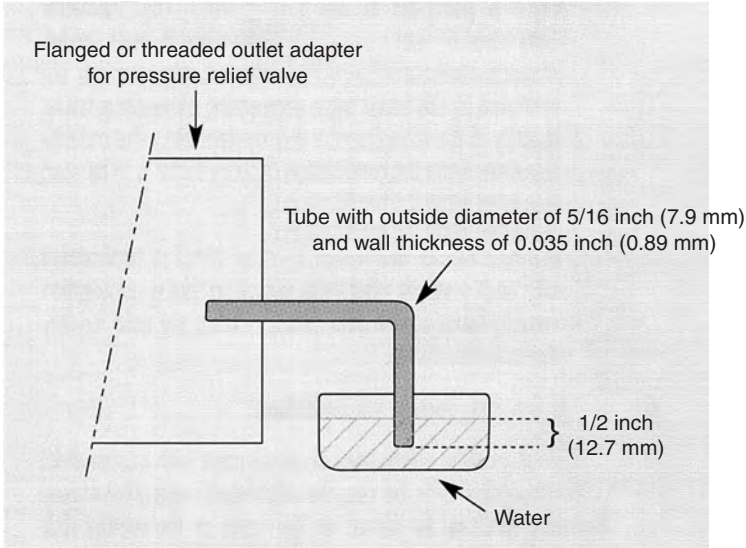


Figure 14.8 Apparatus to test seat tightness with air. (From API RP 527.)

as shown in Fig. 14.8. All openings such as caps, drain holes, vents, etc., should be closed.

Test pressure—For a valve whose set pressure is greater than 50 psig (345 kPag), the leakage rate in bubbles per minute should be determined with the test pressure at the valve inlet held at 90% of the set

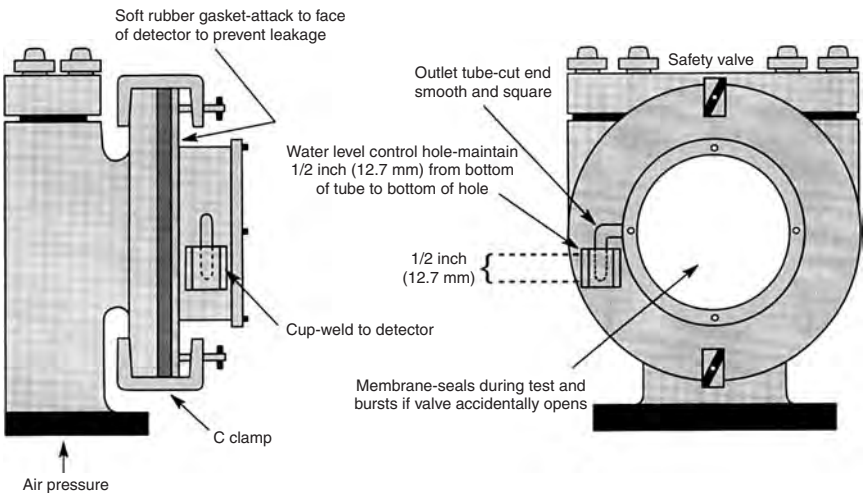


Figure 14.9 Device to relieve body pressure caused by accidental popping of the valve. (From API RP 527.)

pressure. For a valve set at 50 psig (345 kPag) or less, the test pressure should be held at 5 psig (34.5 kPag) less than set pressure.

Leakage test—Before the leakage test, the set pressure should be demonstrated, and all valve body joints and fittings should be checked with a suitable solution to ensure that all joints are tight.

Before the bubble count, the test pressure should be applied for at least 1 min for a valve whose nominal pipe size is 2 in (50 mm) or smaller; 2 min for a valve whose nominal pipe size is 2½, 3, or 4 in (65, 80, or 100 mm); and 5 min for a valve whose nominal pipe size is 6 in (150 mm) or larger. The valve should be observed for leakage for at least 1 min.

Acceptance criteria. For a valve with a metal seat, the leakage rate in bubbles per minute should not exceed the values as shown in Table 14.2. For a soft seat valve, there should be no leakage for 1 min (zero bubbles per minute).

14.5.2 Testing with steam

Test procedure

Test medium—The test medium should be saturated steam.

Test configuration—The valve should be mounted vertically on the steam test stand.

Test pressure—For a valve whose set pressure is greater than 50 psig (345 kPag), the seat tightness should be determined with the test pressure at the valve inlet held at 90% of the set pressure. For a valve

TABLE 14.2 Air Test—Maximum Seat Leakage Rates for Metal-Seated Pressure Relief Valves

Set pressure at 60°F (15.6°C)		Effective orifice sizes 0.307 in and smaller approximate leakage per 24 hr		
Psig	mPa	Leakage rate (bubbles/min)	Standard ft ³	Standard m ³
15–1000	0.103–6.896	40	0.60	0.017
1500	10.3	60	0.90	0.026
2000	13.0	80	1.20	0.034
2500	17.2	100	1.50	0.043
3000	20.7	100	1.50	0.043
4000	27.6	100	1.50	0.043
5000	38.5	100	1.50	0.043
6000	41.4	100	1.50	0.043

set at 50 psig (345 kPag) or less, the test pressure should be held at 5 psi (34.5 kPa) less than set pressure.

Leakage test—Before starting the seat tightness test, the set pressure should be demonstrated, and the set pressure should be held for at least 3 min. Any condensate in the body bowl should be removed before the seat tightness test. Air or nitrogen may be used to dry condensate.

After any condensate has been removed, the inlet pressure should be increased to the test pressure. Tightness should then be checked visually using a black background. The valve should then be observed for leakage for at least 1 min.

Acceptance criteria. For both metal and soft seated valves, there should be no audible or visible leakage for 1 min.

14.5.3 Testing with water

Procedure

Test medium—The test medium should be water at close to ambient temperature.

Test configuration—The valve should be mounted vertically on the water test stand.

Test pressure—For a valve whose set pressure is greater than 50 psig (345 kPag), the seat tightness should be determined with the test pressure at the valve inlet held at 90% of the set pressure. For a valve set at 50 psig (345 kPag) or less, the test pressure should be held at 5 psi (34.5 kPa) less than the set pressure.

Leakage test—Before starting the seat tightness test, the set pressure should be demonstrated, and the outlet body bowl should be filled with water, which should be allowed to stabilize with no visible flow from the valve outlet. The inlet pressure should then be increased to the test pressure. The valve should then be observed for 1 min at the test pressure.

Acceptance criteria. For a metal seated valve whose inlet has a nominal pipe size of 1 in or larger, the leakage rate should not exceed 10 cm³/hr per inch of nominal inlet size. For a metal seated valve whose inlet has a nominal pipe size of less than 1 in, the leakage rate should not exceed 10 cm³/hr. For soft seated valves, there should be no leakage for 1 min.

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Installation

Installation of pressure relief devices requires careful consideration. Marginal installation can render the pressure relief devices inoperable or severely restrict their abilities to perform properly and cause high maintenance costs.

Pressure relief devices are installed according to the local jurisdictional rules and national codes. Good engineering practices should be exercised if there are no rules in the jurisdiction having authority.

Installation of pressure relief valves should be done by organizations experienced in installation, repair, maintenance, and testing. The installer must comply with the requirements of the following standards and codes:

- ASME Sec. 1, Power Boilers
Pars. PG-67 through PG-73
- ASME Sec. IV—Heating Boilers
Article 4—Pressure Relieving Devices
Article 8—Installation Requirements
- ASME Sec. VIII, Division 1, Pressure Vessels
Nonmandatory Appendix M—Installation and Operation
- ASME B31.1 Pressure Piping
Nonmandatory Appendix II—Rules for the Design of Safety Valve Installations
- API RP 520—Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries
Part I—Sizing and Selection
Part II—Installation
- API RP 521—Guide for Pressure-Relieving and Depressing Systems
- API RP 576—Inspection of Pressure-Relieving Devices

15.1 Installation of Pressure Relief Valves

Pressure relief valves normally should be installed in the upright position with the spindle vertical. The valve may be installed in other position than the vertical position provided that:

- The valve design is satisfactory for such position
- The media is such that material will not accumulate at the inlet of the valve; and
- Drainage of the discharge side of the valve body and discharge piping is adequate

The pressure relief valves should be installed in such a way that their proper functioning will not be hampered by the vessel's contents. The valves for use in compressible fluid service should be connected to the vessel in the vapor space above any contained liquid or to piping connected to the vapor space in the vessel. Pressure relief valves intended for use in liquid service should be connected below normal liquid level.

The opening through all pipes and fittings between a pressure vessel and its pressure relief valve should have at least the area of the pressure relief valve inlet. The openings in the vessel should be designed to provide unrestricted flow between the vessel and its pressure relief valve.

There should be no intervening stop valves between the vessel and its pressure relief valve or between the pressure relief valve and the point of discharge. There are also rules for installation of inlet and discharge piping to and from pressure relief valves. In summary, the installation of pressure relief valves should cover the following areas:

- Preinstallation handling and storage
- Inlet piping
- Discharge piping
- Vent piping
- Drain piping
- Isolation valves

15.1.1 Preinstallation handling and testing

Proper preinstallation handling and testing can help ensure that pressure relief valves and their associated piping remain clean, free of damage, and operational.

Pressure relief valves should be handled very carefully. The internal parts of pressure relief valves are precision machined and fitted together

to maintain perfect alignment. Rough handling of valves may damage the seats or cause misalignment that can lead to leakage.

Handling and storage. Pressure relief valves are checked for tightness in the manufacturer's shop before they are shipped to the owner. The pressure relief valves should be shipped in an upright position. This is especially important for large valves and valves with low pressure settings.

Pressure relief valves should be handled carefully. The valves are shipped with a protective covering over the inlet and the outlet to prevent damage to the flanged surfaces and to prevent entry of foreign particles. The protective covering should be left intact if valves are required to be stored before installation. It is recommended to use a clean and dry covered area for storage of pressure relief valves.

Inspection and testing. The condition of all pressure relief valves should be inspected visually when the shipment is received. The manufacturer's recommendation should be followed for details relating to the specific valve. All protective materials should be removed before installation. The valves should be tested before installation to confirm their opening pressure setting.

Cleaning of systems. The systems on which the valves are installed should be thoroughly inspected and cleaned. If possible, the system should be purged before the valve is installed. The valve should be kept isolated during pressure testing of the system, either by blanking or by closing a stop valve.

15.1.2 Inlet piping

It is extremely important that the inlet piping to pressure valves is designed properly. Sometimes, pressure relief valves are installed at the most physically convenient location, without properly considering flow conditions.

Pressure loss can occur during flow in an inlet pipe. The pressure loss in an inlet pipe may be large, between 10% and 30%, or as small as 3%, depending on the size, geometry, and inside condition of the pipe. API RP 520, Part 2, and ASME Code Sec. VIII, Division 1, recommend a maximum inlet pressure loss to a pressure relief valve of 3%. This pressure loss is the sum of the total losses due to penetration configuration at the vessel, inlet pipe loss, and, when a block valve is used, loss through it. The losses should be calculated using the maximum actual rated flow through the pressure relief valve, using K_D , not K . Pressure drop limitations and piping configurations are shown in Figs. 15.1 and 15.2.

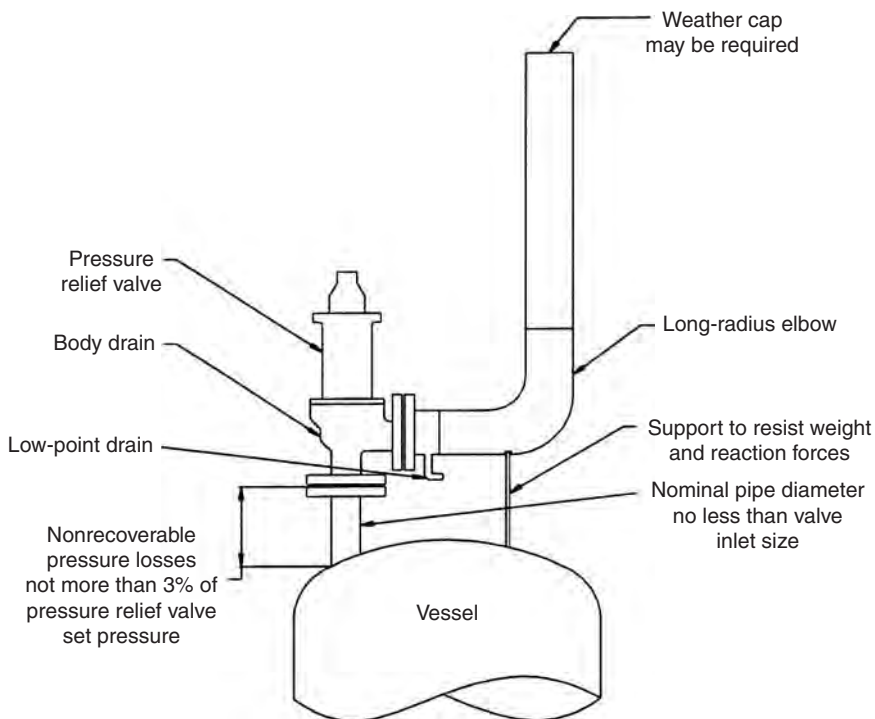


Figure 15.1 Safety valve installation with open discharge. (From APT RP 520, Part II.)

Remote sensing can be used for pilot-operated pressure relief valves when there is excessive inlet pressure loss or when the main valve should be located at a pressure source different from the sensing pilot because of service limitations of the main valves (Fig. 15.3).

Remote sensing permits the pilot to sense the system pressure upstream of the piping loss. Remote sensing may eliminate valve cycling and chattering for a pop-action, pilot-operated pressure relief valve and permits a modulating pilot-operated pressure valve to achieve full lift at the required overpressure. Although remote sensing helps to achieve full lift, any pressure drop in the pipe reduces the relieving capacity.

Inlet piping design. It is recommended that the equivalent L/D (pipeline length-to-pipeline diameter) ratio of the inlet piping to the pressure relief valve inlet be kept at 5 or less. Many pipe fittings and tank penetrations have larger L/D ratios. Figure 15.4 shows some common fittings and tank penetrations and their equivalent ratios. It can be seen from the figure that only the straight inlet pipe with a concentric reducer produces the recommended L/D ratio of 5 or less. If these guidelines are not followed, rapid cycling or chatter may occur.

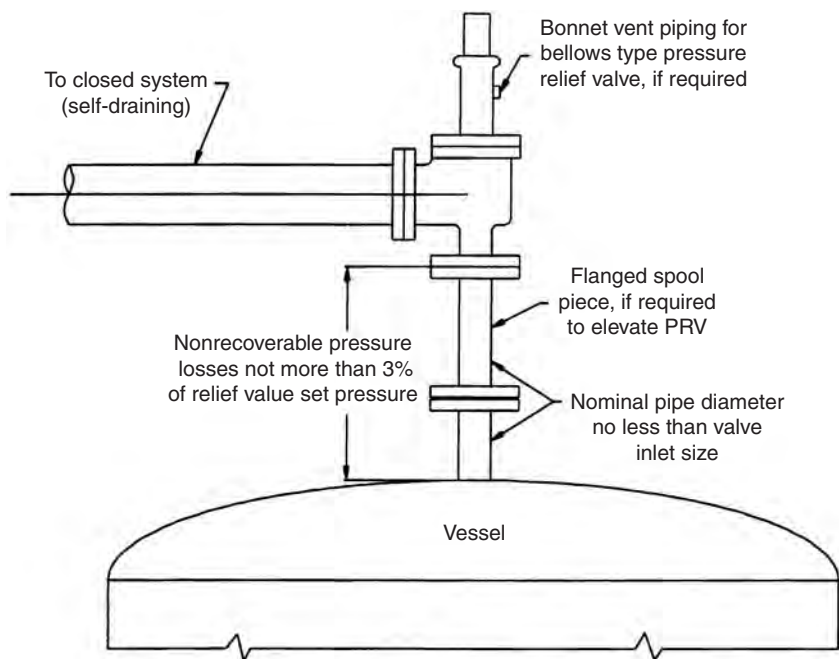


Figure 15.2 Pressure relief valve installation with closed discharge. (From API RP 520, Part II.)

Pressure losses occur in all piping during flow. If these pressure losses are high, pressure relief valve cycling or chatter may occur, substantially reducing the relieving capacity of the valve. Even if the valve does not cycle rapidly or chatter, the relieving capacity will still be reduced, because relieving capacity is proportional to inlet pressure.

To minimize inlet pressure losses, the equivalent L/D ratio should not be greater than 5. If this ratio cannot be obtained because of the piping geometry or fittings, then piping and fittings one pipe size larger than the pressure relief valve inlet should be used. Some recommended tank penetrations and valve inlet piping designs are shown in Fig. 15.5.

In order to reduce pressure loss in the inlet piping, the following methods can be adopted:

- Increase the diameter of the pipe.
- Ensure that any corners are suitably rounded. The corners should have a radius of not less than one-quarter of the bore.
- Reduce the inlet pipe length.
- Install the valve at least 8 to 10 pipe diameter downstream from any converging or diverging “Y” fitting or any bend.

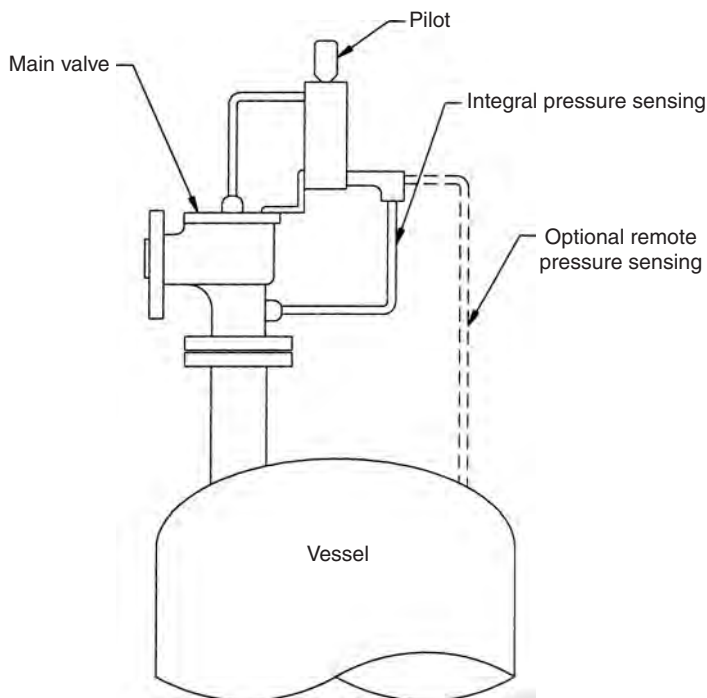


Figure 15.3 Pilot-operated relief valve installation. (From *API RP 520, Part II*.)

- Avoid take-off branches in the inlet piping, as this may increase the pressure drop.

Inlet piping arrangements. The most recommended inlet pipe arrangement is as follows:

- The inlet pipe is the same size or larger than the pressure relief valve inlet (Fig. 15.6).
- The inlet pipe length does not exceed the face-to-face dimension of a standard tee of the proper pressure class.

Various other inlet piping arrangements are shown from Figs. 15.7 through Fig. 15.8.

Vibration considerations. Vibrations that occur in inlet piping systems are random and complex. These vibrations may cause leakage at the seats of pressure relief valves, premature opening, or fatigue failure of certain valve parts, inlet and outlet piping, or both. Regardless of amplitude,

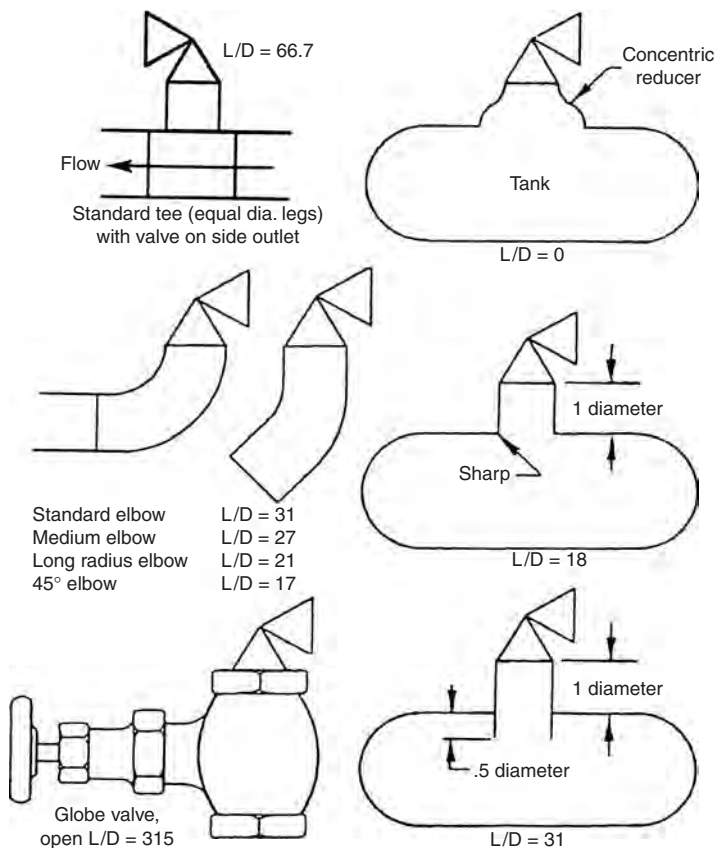


Figure 15.4 Equivalent lengths of various fittings. (Courtesy Crane Co.)

high-frequency vibrations are more detrimental to the tightness of the pressure relief valve than are low-frequency movements.

The effects of vibration can be reduced by minimizing the cause of vibrations, by additional piping support, or by providing greater pressure differentials between the operating pressure and set pressure. The use of pilot-operated relief valves or soft-seated pressure relief valve can also reduce vibration.

Effects of turbulence. Pressure relief valves should not be located where unstable flow patterns are present (Fig. 15.9). The distance shown in Fig. 15.9 should not be less than 10 pipe diameters, to avoid unstable flow. The branch entrance should have a well-rounded and smooth corner to minimize turbulence and resistance to flow.

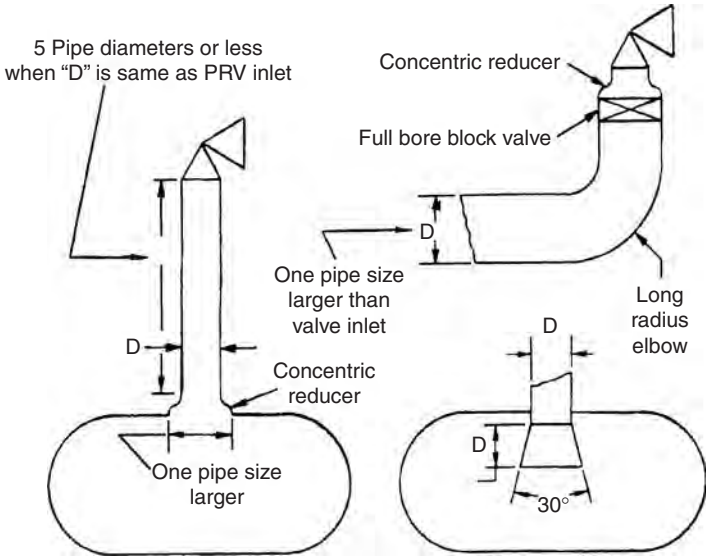


Figure 15.5 Tank penetrations and inlet piping designs.

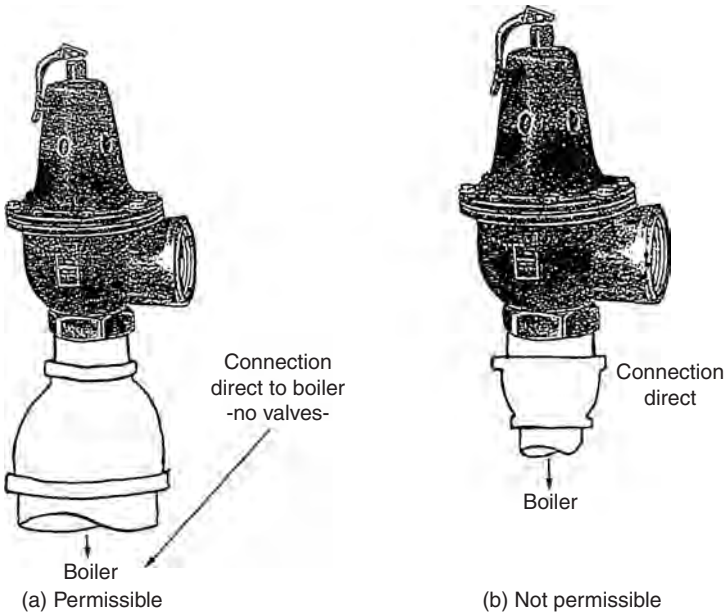


Figure 15.6 Inlet piping.

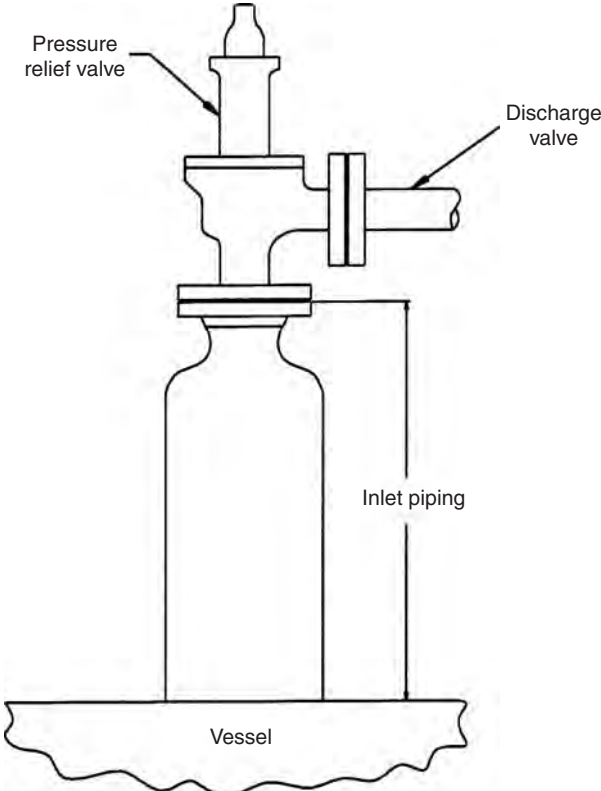


Figure 15.7 Pressure relief valve mounted on a long inlet pipe. (From API RP 520, Part II.)

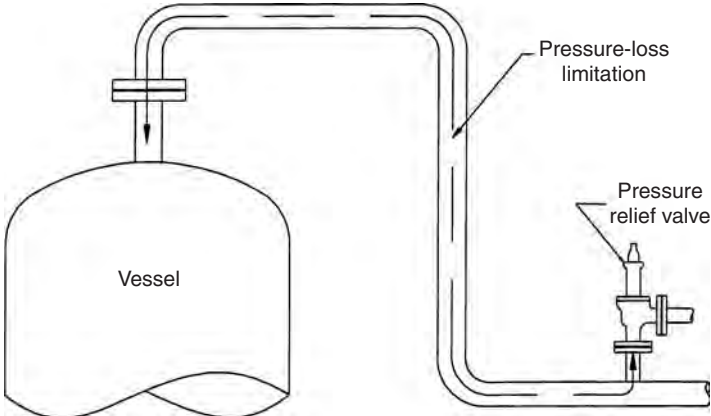


Figure 15.8 Pressure relief valve mounted on a process line. (From API RP 520, Part II.)

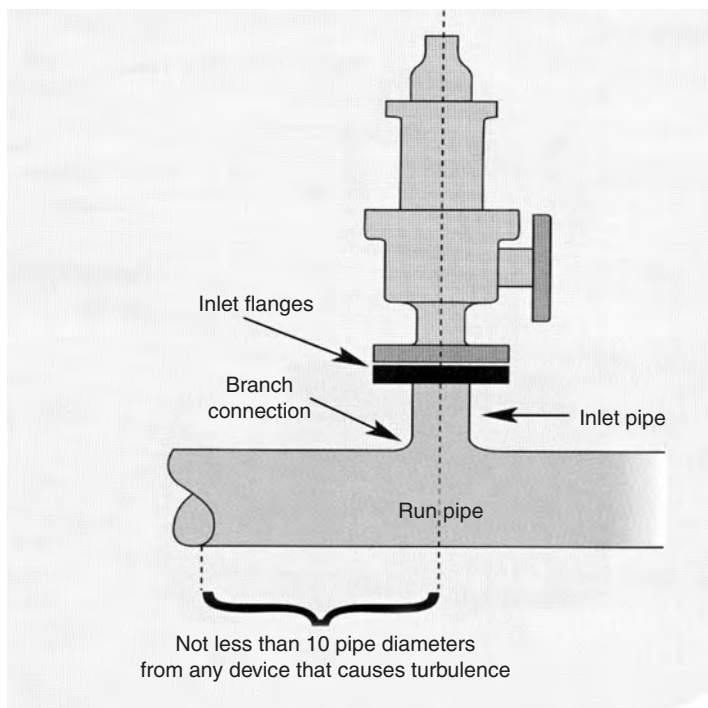


Figure 15.9 Turbulence at pressure relief valve inlet. (Courtesy Dresser Flow Control.)

When pressure relief valve branch connections are mounted near to the vessel and cause unstable flow patterns, the branch connection should be mounted farther downstream to avoid unstable flow.

Process laterals. Generally, process laterals should not be connected to the inlet piping of pressure relief valves (Fig. 15.10). Exceptionally, this may be allowed after analyzing the data to ensure that the pressure drop at the inlet of the valve is not exceeded under simultaneous conditions of rated flow through the valve and maximum possible flow through the process lateral.

15.1.3 Discharge piping

The discharge piping installation should provide for proper pressure relief valve performance and adequate drainage, preferably a free-draining system. Consideration should be given to the type of discharge system used, the back pressure on the pressure relief system, and the set pressure

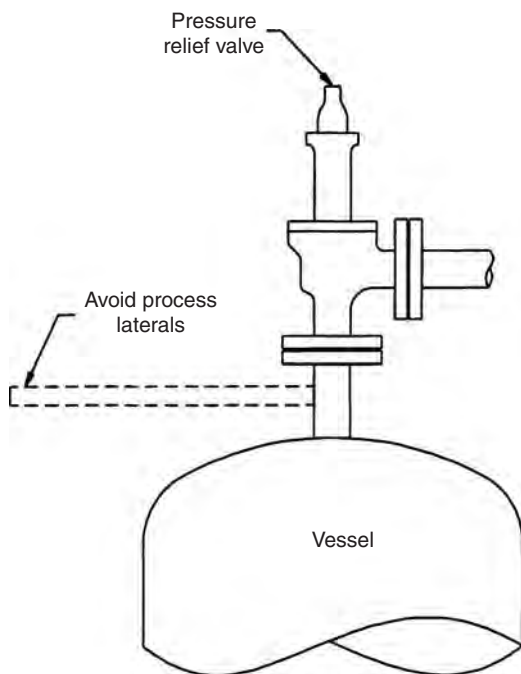


Figure 15.10 Process lateral connected to PRV inlet piping. (From API RP 520, Part II.)

relationships of the pressure relief valves in the system. See Fig. 15.11 for general requirements of discharge piping.

When discharge piping for pressure relief valves is designed, consideration should be given to the combined effect of superimposed and built-up back pressure on the operating characteristics of the pressure relief valves. The discharge piping system should be designed so that back pressure does not exceed an acceptable value for any pressure relief valves.

Discharge piping is more critical for direct spring-operated valves than for pilot-operated valves. Like inlet piping, pressure losses occur in discharge headers with large equivalent L/D ratios. Excessive back pressure can reduce the lift of a direct spring-operated valve, and enough back pressure can cause the valve to reclose and/or chatter. As soon as the valve closes, the back pressure in the discharge header decreases and the valve opens again. Rapid cycling or chatter can occur again. Figure 15.12 explains typical effects of variable back pressure on capacity of conventional pressure relief valves.

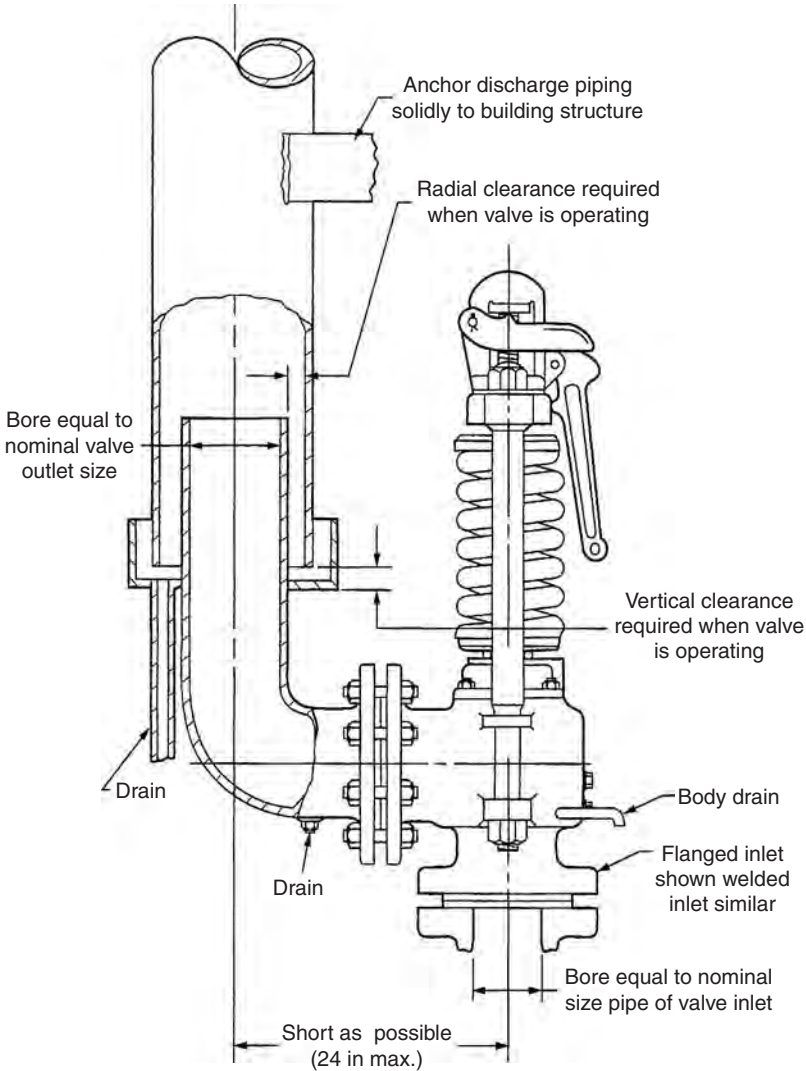


Figure 15.11 Installation of a safety valve. (From ASME Sec. VII.)

Normal operating and flow capacity performance of pressure relief valves can be obtained by using the following discharge piping recommendations:

- Discharge piping should be at least the same size as the valve outlet connection and may have to be increased to a larger value (Fig. 15.13).

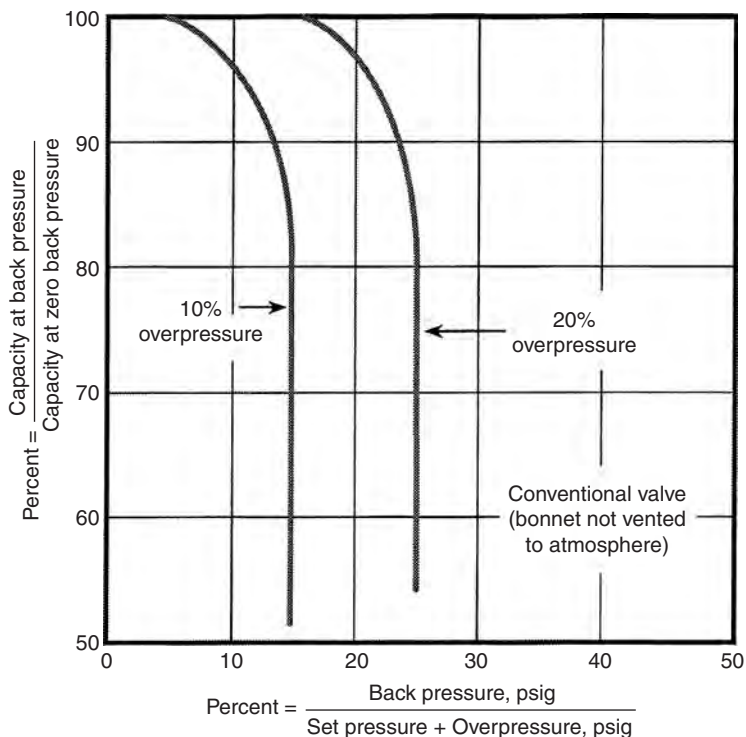


Figure 15.12 Effects of variable back pressure on capacity of conventional pressure relief valves.

- Flow direction changes should be minimized. When necessary, use long-radius elbows and gradual transitions.
- The drain of the valve should be vented to a safe area. Avoid low spots in discharge piping or drain them.

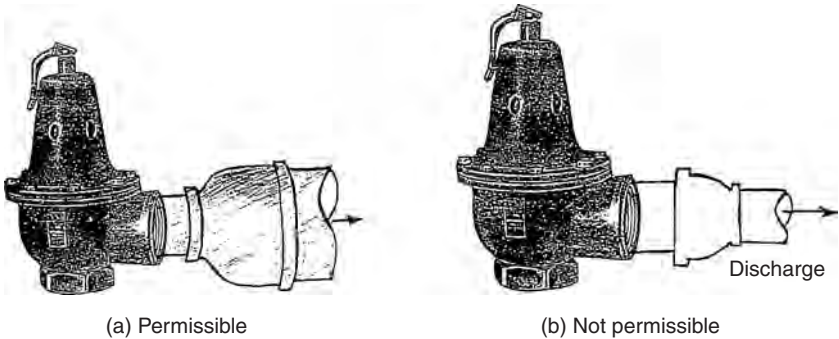


Figure 15.13 Discharge piping.

- Proper pipe supports should be used to overcome the following problems: thermal effects, static loads due to pipe weight, and stresses due to discharge reactive thrust forces.

Installation of discharge piping for two safety valves on a power boiler is shown in Fig. 15.14.

Manifolds. A manifold should be sized so that it can handle the capacity when all the manifold valves are discharging. The pipework should be large enough to cope with generating unacceptable levels of back pressure. The volume of the manifold should be increased as each valve outlet enters it, and these connections should enter the manifold at an angle of no greater than 45° to the direction of flow (Fig. 15.15). The manifold should be properly secured and drained.

Generally, a manifold is not recommended for steam service. It can be used for steam service if proper consideration is given to all aspects of design and installation.

Reaction forces. A pressure relief valve with a larger orifice used for higher pressure may generate substantial reactive forces during valve relief. In some cases, external bracing may be required to balance this reactive force.

The reaction forces for a pressure relief valve discharging gas, vapor, or steam directly to atmosphere without discharge piping should be



Figure 15.14 Safety valves installed on a power boiler.

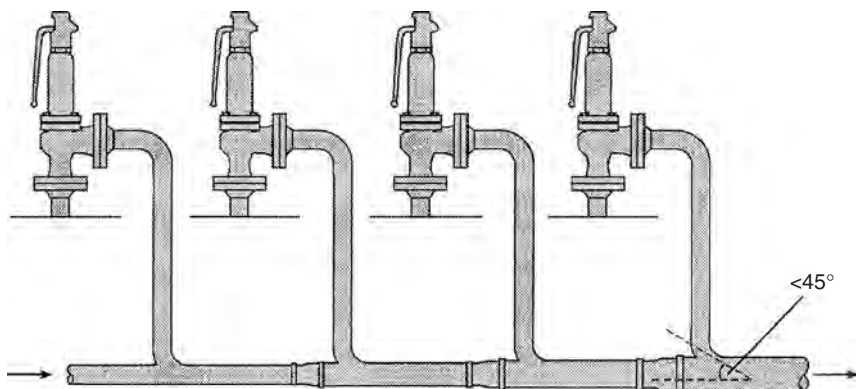


Figure 15.15 A manifold discharge system. (Courtesy Spirax Sarco, U.K.)

calculated. API RP 520, Part II, gives the following formula for calculation of this force (Refer to Fig. 15.16):

$$F_T = \frac{W \sqrt{[kT/(k+1)M]}}{366} + (A_o \times P_2) = F_H + F_V$$

where F_T = reactive force at the point of discharge to the atmosphere (lb)

W = flow of any gas or vapor (lb/hr)

k = ratio of specific heats (C_p/C_v)

T = inlet temperature, absolute ($^{\circ}\text{F} + 460$)

M = molecular weight of flowing media

A_o = area of the outlet at the point of discharge (in^2)

P_2 = static pressure at the point of discharge (psig)

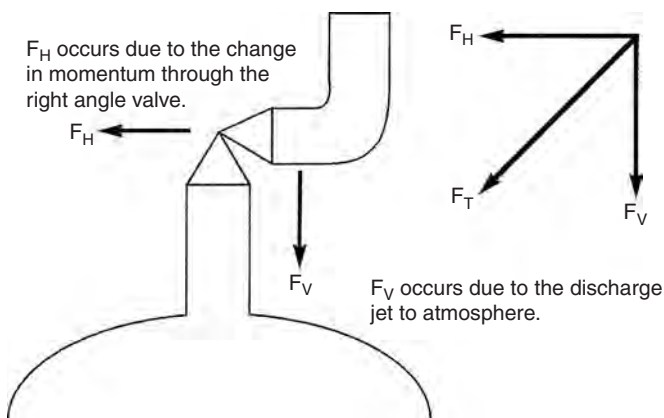


Figure 15.16 Reactive forces.

Noise. When a pressure relief valve discharges, it creates a noise in the surrounding area. The noise level of gases, vapors, and steam as a result of the discharge of a pressure relief valve should be calculated.

Noise level is calculated at a distance of 100 ft from the point of discharge. (Fig. 15.17). The noise level is measured in decibels (dB). API RP 521 gives the following formula for calculation of noise level:

$$L_{100} = L + 10 \log_{10} \left(\frac{0.29354 W k T}{M} \right)$$

where L_{100} = sound level at 100 ft from the point of discharge, dB

L = noise intensity measured as sound pressure level at 100 ft from the discharge (Fig. 15.17)

W = maximum relieving capacity, lb/hr

k = ratio of specific heats of fluid ($k = 1.3$ for steam)

T = absolute temperature of the fluid at the valve inlet, °R

M = molecular weight of the gas or vapor

When noise level is required to be measured at a distance other than 100 ft, the following equation may be used:

$$L_p = L_{100} - 20 \log_{10} \left(\frac{r}{100} \right)$$

where L_p = sound level at a distance r from the point of discharge, dB

r = distance from the point of discharge, feet

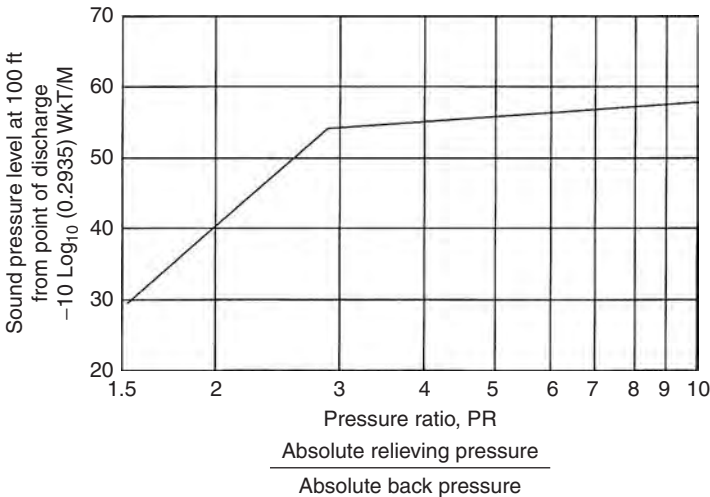


Figure 15.17 Noise intensity at 100 ft from point of discharge.

The federal Occupational Safety and Health Act, 1970, allows 85 dB for period of 8 hr at a workplace. Table 15.1 provides a comparison of noise levels from different sources.

15.1.4 Power piping systems

ASME B31.1 contains rules governing the design, fabrication, materials, erection, and examination of power piping systems. Appendix II of ASME B31.1 presents rules for the design of safety valve installation for power piping systems.

All components in the safety valve installation should be given consideration, including the complete piping system, the connection to the main header, the safety valve, valve and pipe flanges, the downstream discharge or vent piping, and the system support. App. II of Sec. B31.1 covers all these aspects of power piping systems.

Open discharge installation. An open discharge installation is an installation in which fluid is discharged directly to the atmosphere or to a vent pipe that is uncoupled from the safety valve. Figure 15.18 shows a typical open discharge installation with an elbow installed at the valve discharge to direct the flow into a vent pipe.

As shown in Fig. 15.18, the value of l should be limited to a value less than or equal to $4D_o$, and m should be limited to a value less than or equal to $6D_o$, where D_o is the outside diameter of the discharge pipe.

Closed discharge installation. A closed discharge installation is an installation where the effluent is carried to a distant spot by a discharge pipe which is connected directly to the safety valve. A closed discharge installation is shown in Fig. 15.19.

TABLE 15.1 Relative Noise Levels

Source of noise	Decibels
Jet aircraft on takeoff	130
Threshold of feeling	120
Elevated train	110
Loud highway	100
Loud truck	90
Plant site	80
Vacuum cleaner	70
Conversation	60
Offices	50

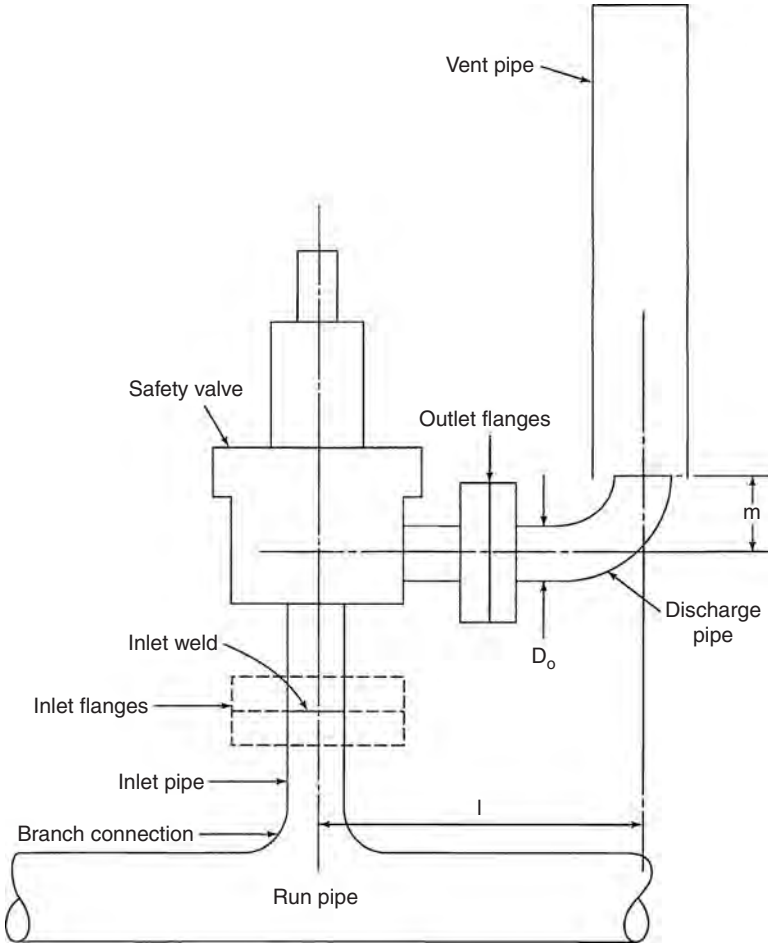


Figure 15.18 Open discharge system. (From ASME B 31.1.)

15.1.5 Isolation valves

Isolation block valves may be used for maintenance purposes to isolate a pressure relief valve from the vessel it protects or from its downstream disposal system. The installation of isolation valve permits the pressure relief valve to be inspected, maintained, or repaired without shutting down the process unit. ASME Code Sec. VIII, Division 1, App. M, discusses proper application of isolation valves and the administrative controls that should be in place when isolation block valves are used.

Figure 15.20 shows typical pressure relief valve installation with an isolation valve. Since improper use of an isolation valve may render a pressure relief valve inoperative, the installation of the isolation valve

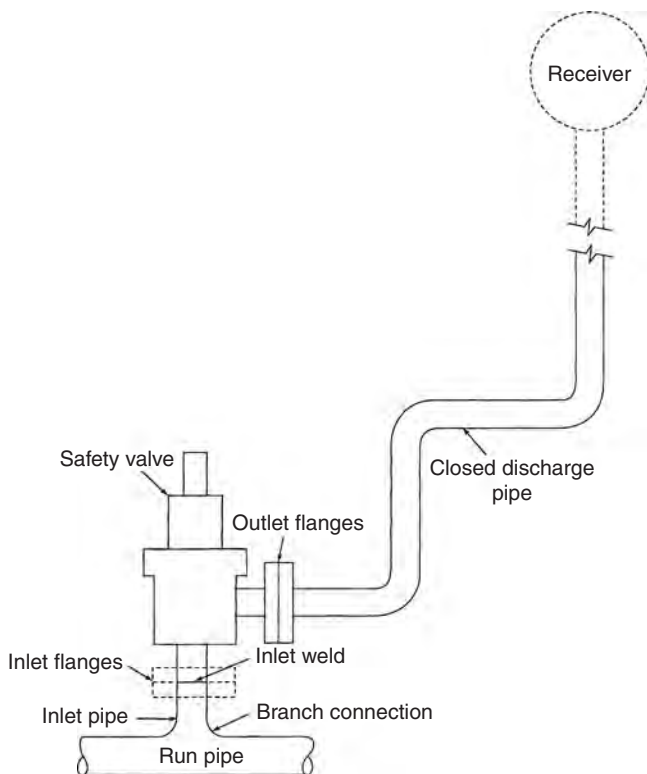


Figure 15.19 Closed discharge system. (From ASME B 31.1.)

should be carefully evaluated to ensure that plant safety is not compromised. A pressure relief valve should not be used as a block valve to provide positive isolation. In addition, local jurisdictional requirements must be followed for installation.

Inlet isolation valve. ASME Code Sec. VIII, Division 1, App. M, recommends that the inlet isolation (stop) valve should be full bore. The opening through all pipe and fittings between a pressure vessel and its pressure relief valve should have the area of the pressure relief device inlet. Therefore, the minimum flow area of the isolation valve should be equal or greater than the inlet area of the pressure relief valve.

The following guidelines apply if isolation valves are installed at the inlets of the pressure relief valves:

- Valves should be suitable for the line service classification.
- Valves should have the capability of being locked or car sealed open.

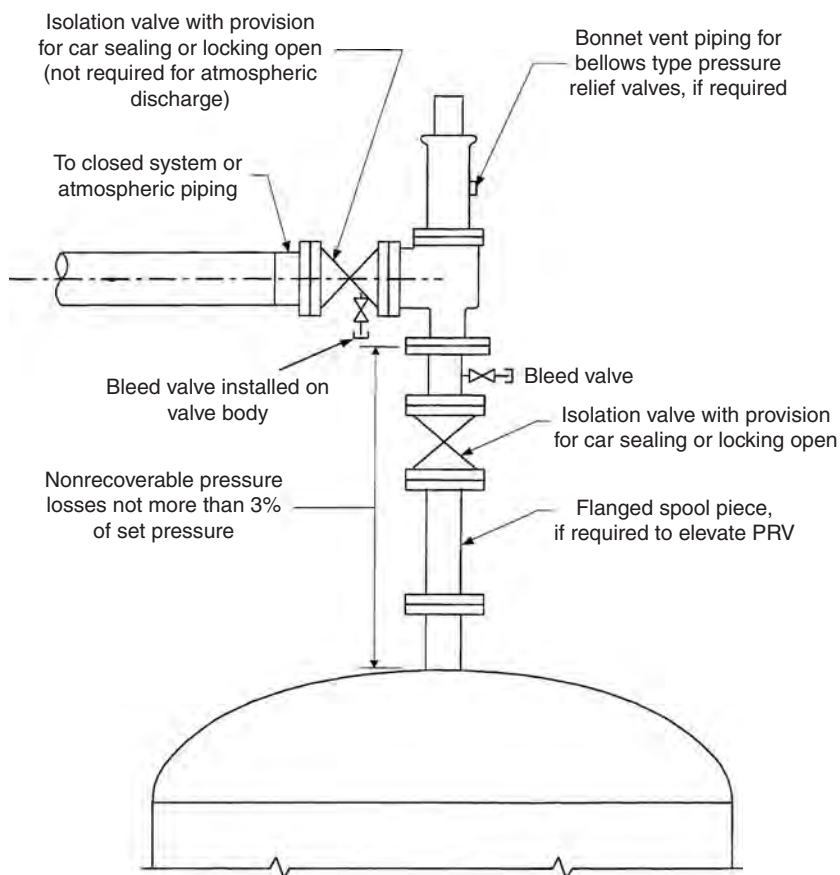


Figure 15.20 Pressure relief valve installation with an isolation valve. (From *API RP 520 Part II*.)

- If a gate valve is used, it should be installed with the stem oriented horizontally.
- A bleed valve should be installed between the inlet isolation valve and the pressure relief valve for depressurizing the system prior to maintenance work.
- Use an interlocking system between the inlet and outlet isolation valves to assist with proper sequencing.

Outlet isolation valve. The outlet isolation valve also should have full bore. The minimum flow area of the outlet isolation valve should be

equal to or greater than the outlet area of the pressure relief valve. When the outlet isolation valve is used in conjunction with an inlet isolation valve, the outlet isolation valve should be opened fully prior to the inlet isolation valve.

The following guidelines apply if isolation valves are installed at the outlets of pressure relief valves:

- Valves should be suitable for the line service classification.
- Valves should have the capability of being locked or can be sealed open.
- A bleed valve should be installed between the outlet isolation valve and the pressure relief valve for depressurizing the system prior to maintenance work.

15.1.6 Vent piping

Based on the type of pressure relief valve, proper ventilating of the bonnets and pilots is required to ensure proper operation of the valve.

Bonnets on conventional pressure relief valves do not have any special venting requirements. Open bonnets are normally used in steam service and are exposed directly to the atmosphere. Valves with closed bonnets are internally vented to the pressure relief valve discharge.

Pilots are often vented to the atmosphere under operating conditions, as the discharge during operation is small. When vent discharge to the atmosphere is not allowed, the pilot should be vented either to the discharge piping or through a supplementary piping system to a safe location.

15.1.7 Drain piping

It is recommended that the discharge piping from pressure relief valves be drained properly to prevent the accumulation of liquids on the downstream side of the pressure relief valve. The outlet piping to closed systems should be self-draining to a liquid disposal point. If the discharge piping is not self-draining and the valve is located where liquids could accumulate at the outlet, drain piping should be provided. The drain piping can be installed on the discharge piping or at the valve in the body connection provided for this purpose.

As drain piping is a part of the entire ventilating system, precautions that apply to the discharge system are also applicable for the drain piping. The drain piping installation should not affect the valve performance. It is reminded that flammable, toxic, or corrosive fluids be piped to a safe location.

15.1.8 Bolting and gasketing

Gaskets, flange facings, and bolting should meet the service requirements for the pressures and temperature. The gaskets should be dimensionally correct for the specific flanges; they should fully clear the pressure relief valve inlet and outlet openings.

15.2 Installation of Rupture Disks

A rupture disk device may be used as the sole pressure relief device, as shown in Fig. 15.21. It may also be installed between a pressure relief valve and the vessel (Fig. 15.22) or on the downstream side of a pressure relief valve.

If a rupture disk is used between the pressure relief valve and the vessel, the space between the rupture disk and the pressure relief valve should have a free vent, pressure gauge, trycock, or other suitable telltale indicator. If a rupture disk is installed on the outlet of a pressure relief valve, consideration should be given to the valve design so that it opens at its proper pressure setting regardless of any back pressure that may accumulate between the valve and the rupture disk.

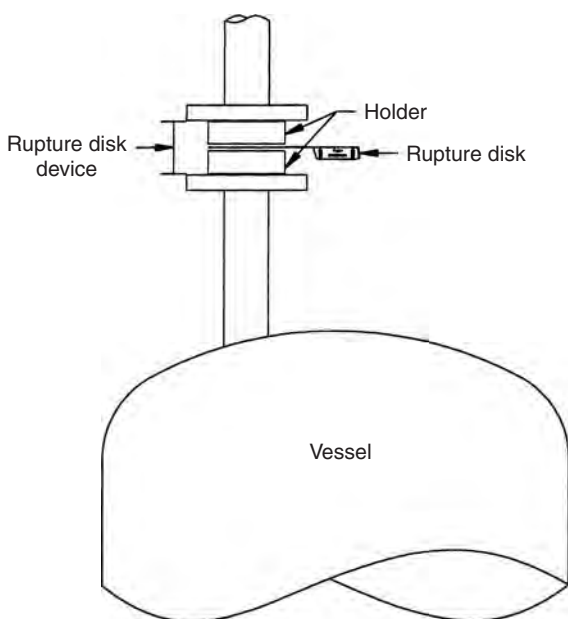


Figure 15.21 Rupture disk installation. (From API RP 520 Part II.)

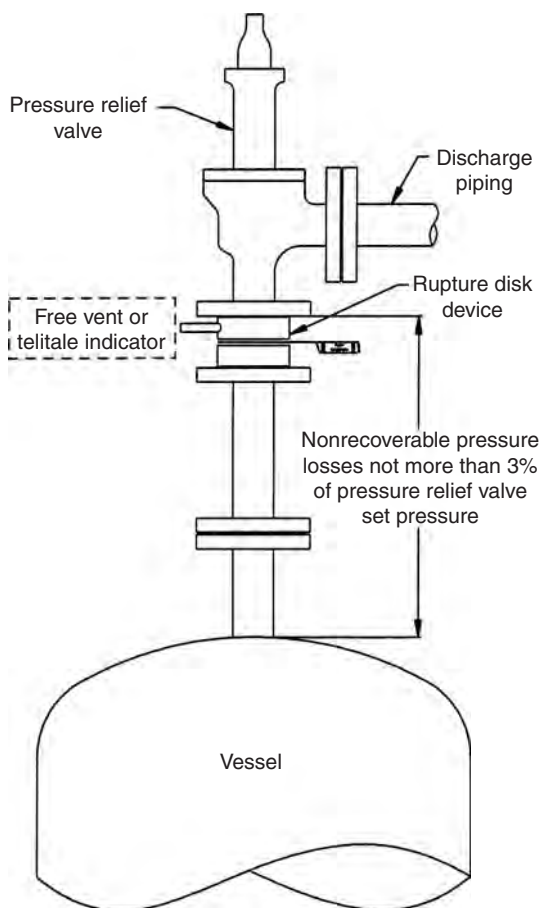


Figure 15.22 Installation of rupture disk in combination with pressure relief valve. (From API RP 520 Part II.)

Rupture disks are installed according to the manufacturer's instructions and local jurisdictional requirements, if any. The installation of rupture disks should be done by personnel qualified in the proper handling of rupture disks devices and their installation.

It is also important that the installer comply with the following code requirements while handling and installing rupture disks:

- API RP 520, Part I—Sizing and Selection of Pressure Relief Devices
- API RP 520, Part II—Installation of Pressure Relief Devices
- API RP 576—Inspection of Pressure Relief Devices

15.2.1 Preparation for installation

The installing contractor should make necessary preparations prior to installation of rupture disks. The following items should be checked:

1. Holder and flange sizes and rating are the same.
2. Companion flanges are
 - a. Undamaged
 - b. Clean and free of debris, gasket residue, and corrosion
 - c. Parallel and aligned
3. Selected gaskets should seal at the recommended torque.
4. Generally, rupture disks are provided with shipping protectors or supports. Remove such shipping protectors and supports prior to installation.
5. Make sure that the rupture disk type is appropriate for the holder. Also, ensure that the rupture disk type has been selected based on burst pressure, temperature, material, etc., for the application.
6. Proper tools should be used for installation. The flange ends and nuts should be clean.

15.5.2 Inspection

All rupture disks should be thoroughly inspected before installation. The manufacturer's instructions must be followed with respect to the rupture disk. The following points should be noted:

- The seating surfaces should be clean, smooth, and undamaged.
- The disks should be checked for physical damage to the seating surface or the prebulged disk area.
- Damaged or dented disks should not be used.
- The safety heads of bolted construction should be checked for proper torque as recommended by the manufacturer.
- The knife blades on reverse buckling disks should be checked for physical damage. Nicked or dull blades should not be used.

15.2.3 Installation guidelines

The contractor installing rupture disks should take all precautions for correct installation. The manufacturer's instructions should be followed for such precautions. The following guidelines should be practiced for installation:

1. Make sure that the rupture disk vents to a safe area.
2. Assemble the disk and holder in shop, if possible.

3. Keep the rupture disk in the original packing until ready for installation.
4. Look for flow arrows on the disks. Verify correct orientation of disk in holder and of holder in piping.
5. Follow manufacturer's instructions for proper torque and tightening sequences.
6. Verify that the application is designed in such a way that fluid accumulation on the downstream side of a rupture disk device cannot influence and elevate the rated pressure of the disk.

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Chapter 16

Operation

Many pressure relief devices never operate except during a test. The equipment operator or operating engineer must ensure that pressure relief devices are in operating condition by testing the devices from time to time.

Pressure relief valves are designed to function based on the relationship of a number of critically dimensioned parts and the valve spring. These relationships determine the force geometry necessary for reliable operation.

The owner has the responsibility to establish and maintain a system that ensures that a vessel is not operated without overpressure protection. These responsibilities include, but are not limited to, the following:

- Establish the pressure relief philosophy and the administrative control requirements.
- Establish procedures to ensure that equipment is adequately protected against overpressure.
- Ensure that authorization to operate identified valves is clear and that personnel are adequately trained for this task.
- Establish the analysis procedures and basis to be used in determining the potential level of pressure if the stop valves are closed.

16.1 General Guidelines for Operation

Due to the variety of service conditions and the various designs of safety and safety relief valves, only general guidelines can be given regarding operation. App. M of Section VIII—Div. 1 may be used as nonmandatory guidelines for pressure relief valve operation.

The following general advisory information should be reviewed and then used for a specific application:

1. Leakage may be observed when there is dirt or scale sitting on the seating face. This usually occurs during the periodic lifting required by the authorized inspector or routine maintenance personnel. Further lifting of the lever will generally clear any dirt that might have been on the seating surface.
2. The vast majority of safety valve leakage occurs after initial manufacture and test. The problem may result from damage during shipping or transportation. Other reasons are mishandling, contamination, or poor installation.
3. Most safety valve standards do not include detailed shut-off parameters. Recommended test procedures as specified in API-527 are commonly used throughout the safety valve industry.
4. The test procedures for valves that have been set on air involve blocking all secondary leakage paths while maintaining the valve at 90% of the set pressure on air. The outlet of the valve is connected to a 6-mm-ID pipe, the end of which is held 12.7 mm below the surface of water contained in a transparent vessel. The number of bubbles discharged from this tube should be 20 bubbles per minute.
5. For valves set on steam or water, the leakage rate should be assessed using the corresponding setting medium. For steam, there should not be any visible leakage against a black background for 1 min after a 3-min stabilization period. For water, a small leakage is allowed, depending on the orifice area, of 10 mL/hr per inch of nominal inlet diameter.
6. A test using accurate flow-measuring equipment that is calibrated in accordance with the requirements of API 527 may be used instead of the above test procedures.
7. Neither should additional load be applied to the easing lever nor should the valve be gagged in order to increase the seat tightness. This may affect the operating characteristics and result in the safety valve failing to lift in overpressure conditions.
8. If there is heavy seat leakage, the valve can be refurbished or repaired, but only by an authorized repairer, working with approval from the original equipment manufacturer (OEM), and using information supplied by the manufacturer.
9. The valve should be sent to repair if any repair is necessary. An authorized repair company should repair the valve using information supplied by the original equipment manufacturer.
10. The safety valve should not be used as a control valve to regulate system operating pressure. Excessive operation will cause the seat to leak and require more frequent valve maintenance.

16.2 Visual Examination

Pressure relief valves may be exposed to contaminating elements when they are not operating. An operator should make a thorough visual inspection before testing a pressure relief valve. The following observations should be recorded:

1. Gagging of the valve
2. Evidence of corrosion or pitting
3. Evidence of leaking
4. Whether drain lines from the discharge pipe and valve casing are piped to a safe area. Fig. 16.1 shows that the pressure relief valve has no discharge pipe. The operator should report to the maintenance personnel for installation of a discharge pipe and a drain line from the discharge pipe to a safe area.
5. Whether a cap and lever have been installed on the valve
6. Whether the valve is properly sealed
7. Whether exhaust piping and the muffler flow path are free and open
8. Residue buildup on the valve
9. Whether all the valves have been installed in an upright position with the spindle vertical



Figure 16.1 A pressure relief valve without a discharge pipe.

16.3 Safety Valve Operation

All tests for valve operating characteristics should be performed under conditions that simulate those present when the valve requires operating. The most accurate way to test a safety valve is on the boiler at operating conditions. However, this method is not recommended for valves set above 600 psi opening pressure.

If operation of the safety valve is doubtful because of solids depositing below the seat of the valve, it is helpful to hand lift the valve at suitable intervals to blowout the deposits. Eliminating deposits by water treatment is an advisable method than hand lifting of the safety valve.

16.3.1 Hand lift operation

Test or lifting levers are provided on pressure relief valves as required by the applicable code. Where simple levers are provided, they should hang down, and the lifting fork should not contact the lifting nuts on the valve spindle (Fig. 16.2A). Uploads caused by the lifting mechanism bearing the spindle will cause the valve open below the set pressure.

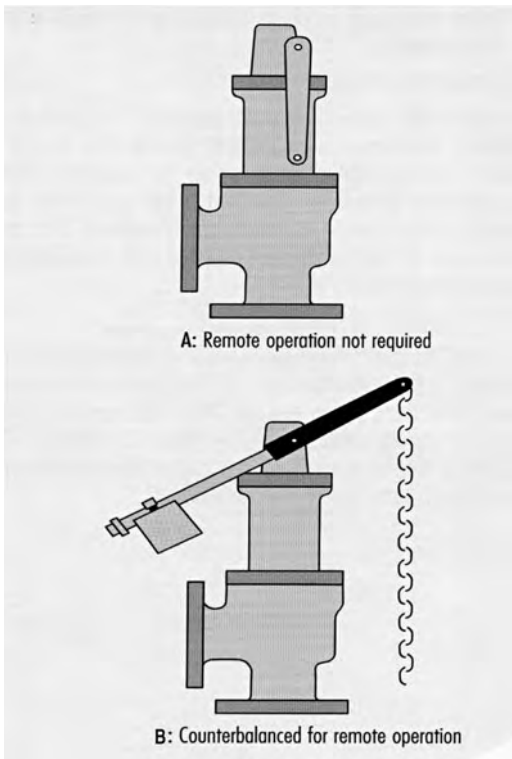


Figure 16.2 Positions for lifting lever. (Courtesy Dresser Flow Control.)

To hand lift test the valve operation with the boiler operating at design pressure, raise the lift lever (Fig. 16.3) to the full opening position, then release it to allow the valve to snap closed as it would if it had opened automatically. A safety valve should not be opened with the hand lifting gear when the steam pressure is less than 75% of the set pressure of the lowest set on the valve.

To facilitate hand lifting or hand lifting from a remote location, a small chain may be attached to the lever of the safety valve (Fig. 16.2B).

An operator should ensure that all personnel are cleared from the area near the valve before hand lifting, because there may a large amount of overflow steam.



Figure 16.3 Hand lift testing of safety valve by an operator.

16.3.2 Operation testing

After visual examination and successful hand lift testing, an operator should test each safety valve for the following operating characteristics.

Opening pressure. The following variation in the set pressure, as defined in PG-72.2 of ASME Code Sec. I, is permissible. Care should be taken that the system gauge pressure is accurate. The gauge calibration should be noted and recorded.

Stipulated pressure, psig	Permissible variation
15 to 70	±2 psi
Over 70 to 300	±3%
Over 300 to 1000	±10 psi
Over 1000	±1 psi

Closing pressure. ASME Code Sec. I, PG-72.1, requires valve closure at specific closing points, depending on the boiler unit design. The valve may perform inconsistently, chatter, or damage itself if the closing pressure is too close to the popping pressure.

Capacity. Measurement of the spindle travel (lift) may be used to determine if a valve designed is discharging its rated capacity. The spindle should travel a distance equal to or greater than the “Lift” stamped on the nameplate. If travel is less than the “Lift” value on the nameplate, the capacity is reduced by an approximate linear proportion based on the reduced travel compared with the full lift. For example:

Nameplate lift = 0.500

Tested spindle = 0.375

Present valve capacity = $0.375/0.500$ nameplate capacity

Present capacity = 0.75 of nameplate capacity

The lift measurement provides meaningful results as long as the adjusting rings are correctly adjusted and the safety valve is properly installed.

Differential pressure. The most common cause of failure of a safety valve to open at the set pressure is the accumulation of corrosive deposits between the disk and seat. This usually occurs when the safety valve “weeps” or leaks slightly. To overcome this situation, the system operating pressure should be lower than the set pressure of the safety valve, with minimum differentials recommended as follows:

Boiler design pressure, psig	Minimum differential as a percentage of boiler design pressure
Over 15 to 300	10% but not less than 7 psi
Over 300 to 1000	7% but not less than 30 psi
Over 1000 to 2000	5% but not less than 70 psi
Over 2000	Per designer's judgment

Above 2000 psig, the pressure differential between operating pressure and the maximum allowable working pressure (MAWP) is a matter for the designer's judgment, taking into consideration such factors as satisfactory operating experience and the intended service conditions.

Hydraulic lift assist device. Some safety valves device may be tested for opening pressure while the boiler is operating at reduced pressures. The valves are tested after a hydraulic lift assist device (Fig. 16.4) has been installed to augment the steam lifting force. This device eliminates the need to raise the system pressure above the operating level to check opening pressure (set point) of the valve for opening.

The lift assist device does not permit the safety valve to go into full lift. It does not provide data about blowdown. Therefore, performance of the safety valve cannot be verified.

Testing by lift assist device should be used only with safety valves designed for such devices, to develop a preliminary setting for new valves or when there is uncertainty as to whether the valve set pressure complies with the nameplate data.

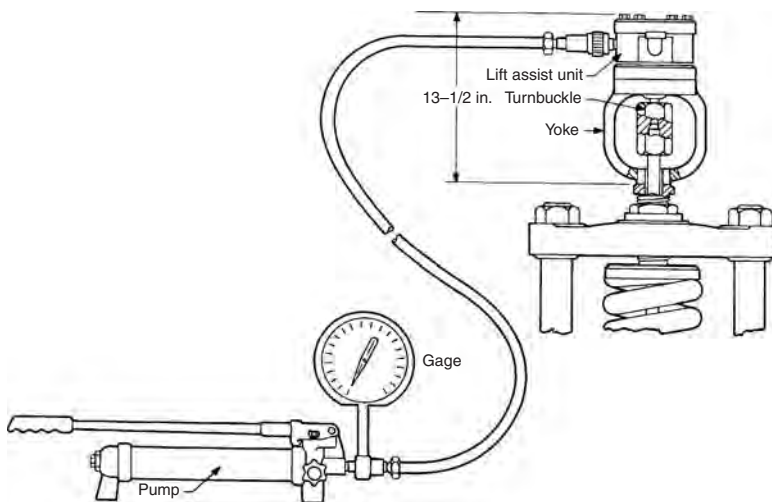


Figure 16.4 Hydraulic lift assist device. (From ASME Sec. VII.)

16.3.3 Precaution for hydrostatic test

Before performing a boiler hydrostatic test in which safety valves are set to less than the design pressure, contact the original valve manufacturer for the proper procedure. When making a hydrostatic test above the pressure setting of the safety valve, either remove the safety valve and blank the opening or clamp the valve disk securely to its seat. A suitable safety valve gag (Fig. 16.5) may be used to secure the valve to its seat and may be used during hydrostatic test.

Extreme care should be taken not to tighten the gag screw excessively, which can damage the spindle and/or seat. Hydrostatic plugs may be used when recommended by the valve manufacturer. An operator should ensure that safety valves are restored to working condition after the hydrostatic test and that all blanks, gags, and plugs are removed. If there is any doubt about their operation, test the safety valves before the boiler is again placed in service.

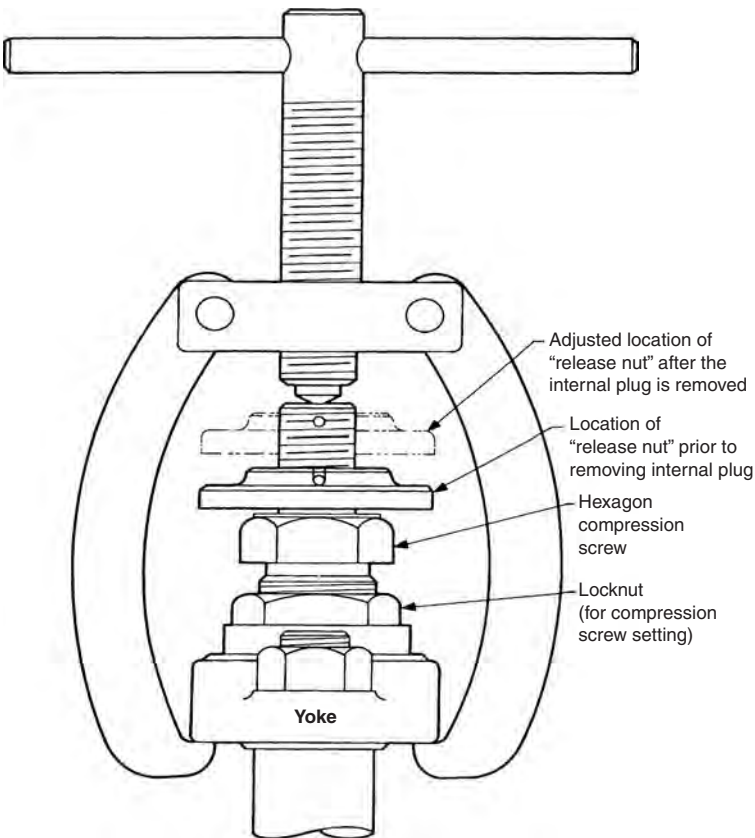


Figure 16.5 A typical test gag. (From ASME Sec. VII.)

16.4 Safety Relief Valve Operation

Safety relief valves are generally used on the auxiliary systems such as heaters, condensate returns, boiler feedwater pumps, turbines, evaporators, economizers, compressors, etc. General guidelines are available for safety relief valve operation based on the corrosiveness of the media, the application, and the trim component metallurgy. The testing frequency may range from 6 months to 2 years for an individual safety relief valve.

In addition to the general guidelines for operation, the owner should have a safety relief valve operation program in place. The program should include the following:

- Hire qualified operators and operation engineers.
- Provide training on operation and safety.
- Maintain experienced manpower.

Though an operator or operating engineer may be responsible for operation of equipment, he or she should also ensure that the following tests are done on safety relief valves.

16.4.1 Valve tightness test

A limited leakage is allowed after a safety relief valve lifts and reseats. This acceptable leakage rate is available from the valve manufacturer's manual. API Standard 527 provides a table for allowable leakage in a bubble test when the pressure under the valve seat is 90% of the cold differential test pressure. This type of test would be applicable to pressure-tight bonnet-design valves.

See Par. 20.3.3 and Fig. 20.7 for details about the valve tightness test. The leakage rates for safety relief valves for set pressures to 1000 psig are shown in Table 16.1.

Another simple leak test is performed by placing a wet paper towel over the outlet flange of the valve with the pressure under the valve seat at 90% of the cold differential test pressure and observing whether the

TABLE 16.1 Leakage Rate for Safety Relief Valves for Set Pressures to 1000 psig

Type of valve	Manufacturer's orifice size	Maximum leakage rate, bubbles/min	Approximate leakage rate, scf/min
Conventional	F and smaller	40	0.60
	G and larger	20	0.30
Balanced bellows	F and smaller	50	0.75
	G and larger	30	0.45

towel ruptures. This test is used to verify tightness in noncritical applications. The wet paper towel test is applicable to pressure-tight bonnet-design valves only.

A cold rod test is used to detect seat leakage for exposed spring or nonpressure-tight bonnet-design valves in steam service. This test is performed by removing the valve discharge pipe and placing a cold rod near the valve seat. The formation of condensate on the rod indicates valve leakage.

16.4.2 Lift and blowdown

Lift is a very important characteristic, as full relieving capacity of the valve can only be achieved at full rated lift. Blowdown is the difference between the set pressure and the closing pressure of the valve.

The system operating pressure should be below the valve closing pressure. Blowdown is a meaningful characteristic for gas, steam, or air applications.

16.4.3 Testing

A safety relief valve should be tested after any maintenance work. This testing can be performed on a test stand designed for compressed air (for air or gas applications) or pressurized water (for liquid applications).

A test stand can verify the quality of workmanship for all functions. The capacity of the test stand determines the maximum size of the valve that can be lift and blowdown tested. See Chap. 20 for details of valve testing.

All valves should be sealed after testing to ensure that no further adjustments are made. Testing of the safety relief valve should be performed by qualified personnel.

16.5 Operator's Responsibilities

An operator is responsible for safe operation of equipment, including pressure relief devices. Though an operator's principal job is to operate the main equipment, his or her responsibilities relating to pressure relief devices might include the following:

- Initiating work requests
- Overseeing that devices are reinstalled in their proper locations
- Preparing in-service reports
- Checking for leaking pressure relief devices
- Making sure that the correct block valves are locked or sealed open or closed as required.
- Checking vents and drains for operability

SETTING RECORD AND REPAIR ORDER FOR PRESSURE-RELIEVING DEVICES

To Mr./Ms. _____:

Please relieve, dismantle, repair, and reset the following relief valves. Return properly executed original of this form to the engineering-inspection group after completion of work. _____

Legend

Unit _____	Deposits and corrosion
Inspector _____	N = None
Order no. _____	L = Light
Date _____	M = Medium
Foreman _____	H = Heavy

Parts		Test medium	Dismantled/ valve stuck
B = Bonnet	N = Nozzle	A = Air	N = No
Be = Bellows	S = Seat	S = Steam	Y = Yes
Bo = Body outlet	Sp = Spring	W = Water	
D = Disk	St = Stem	N = Nitrogen	
G = Guide		O = Other inert gas	

[illegible]

Figure 16.7 Work request for setting record and repair. (From API RP 576.)

Chapter 17

Maintenance

The functioning and service life of a pressure relief valve depends primarily on regular maintenance. Pressure relief valves can provide long periods of trouble-free service if proper maintenance is done when necessary.

Maintenance on pressure relief valves should be done by personnel qualified and experienced in handling, maintenance, and repair of valves. Maintenance personnel require special training and experience to work with pressure relief valves.

A pressure relief valve maintenance program should be developed to ensure the following valve operating characteristics:

- Opens at the set pressure
- Closes at the proper pressure
- Rated lift is achieved

The above information is available from the pressure relief valve nameplate. If the nameplate is missing or nameplate information can not be read, a duplicate nameplate should be ordered from the original valve manufacturer. The duplicate nameplate should be installed after obtaining approval from the jurisdiction.

The maintenance of pressure relief devices should be done by experienced mechanics under the supervision of a maintenance engineer. Duties and responsibilities of maintenance mechanics should be clearly defined to avoid confusion. The responsibilities of maintenance mechanics might include the following:

- To perform mechanical work required to install, test, reinstall, and attach identification tags to pressure relief devices
- To maintain specification records to facilitate repairs

- To furnish test reports
- To initiate purchase orders for spare parts

17.1 Valve Specification Records

The specification record for a pressure relief valve provides a permanent record for specifying a pressure relief valve. Maintenance departments must have complete specification records of valves. A specification record is required to properly repair or replace the valve. A specification record for a pressure relief valve is shown in Fig. 17.1.

When a valve is received at the shop, it is inspected and tested by the maintenance personnel in “as received” condition. A report such as the testing report for a pressure relief valve is filled out to document the results of this inspection and testing. Maintenance personnel may have to repair the valve on the basis of inspection and test results. Orders and records such as the condition repair, and setting record for a valve should be filled out as appropriate.

17.2 Maintenance Procedures

Planned maintenance procedures ensure longer and better performance for pressure relief valves. Testing, inspection, and repair should be performed on a pressure relief valve at a frequency determined by the valve’s maintenance history. Individual records should be maintained on each valve to provide an accurate history of the activities for that valve:

- Date and result of inspections
- Date and result of operation

Device No.	Unit	Location	Set Pressure	Test Interval
Make _____ Style _____ Body and bonnet material _____ Nozzle and disk material _____ Trim material _____ Spring material: ☐ Carbon steel ☐ Alloy Spring no. _____ Flange sizes Inlet _____ Outlet _____ Orifice _____ Back pressure _____ Spring set pressure _____ Relieving pressure _____ Normal operating temperature _____ Remarks _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ Maintenance engineer's phone no. _____				

Figure 17.1 Specification record for a pressure relief valve. (From API RP 576.)

- Date and result of testing
- Date of repairs and nature of repair work
- Any changes in the set pressure or capacity
- Operating and design parameters of the vessel on which the valve is installed

Maintenance of pressure relief valves includes, but is not limited to, the following: pretest, disassembly, repairs, assembly, and valve testing.

17.2.1 Pretest

Pretest is the testing of a pressure relief valve prior to disassembly to determine opening point, blowdown, and seat tightness. Pretest results assists maintenance planning in determining service schedules.

After the valve removed from the service, and before the valve is dismantled, the pop pressure of the valve should be obtained. The pressure which is recorded at this stage is called “as received” pop pressure. A valve should be visually inspected after the pop test to estimate its condition when removed from service. This inspection should made by a mechanic to determine corrosion, deposits, and unusual conditions.

17.2.2 Disassembly

The pressure relief valve should be carefully dismantled in accordance with the manufacturer’s recommendations. All the parts to should be disassembled and inspected to determine the extent of repairs required. Facilities should be made available for segregation of the parts as the valve is dismantled.

17.2.3 Repairs

Repair includes cleaning, reconditioning, replacement, lapping, and minor machining of parts. The valve parts that require cleaning are the nozzles, springs, and seats. Hard deposits should be cleaned with solvents, brushed with wire, or carefully scraped. All the components should be checked for wear, damage, roughness, or corrosion. Parts that are damaged beyond tolerance should be replaced or reconditioned. If evidence of wear is found on the disk or nozzle, their seating surfaces should be machined or lapped.

17.2.4 Assembly

Assembly of the valve and valve components (parts) is done after necessary repairs have been completed. The components should be reassembled in accordance with the manufacturer’s instructions. Clearances

between assembled parts should be checked. The spring should be adjusted to pop as close to the desired set pressure as possible. Blowdown rings should be adjusted carefully and accurately.

17.2.5 Valve testing

Testing of the valve is done to set the valve to the nameplate set pressure, blowdown, and to check seat tightness. Changing to valve nameplate set pressure and/or service medium (air to steam, etc.) may require changing a spring and or other internal parts.

After reassembly of the valve, the spring should be adjusted for the last time to ensure that valve will relieve at the required cold differential testing pressure (CDTP). After the valve has been adjusted, it should be popped at least once to prove the accuracy of the setting. When tested with water, the pressure will be raised slowly to the required setting. A small continuous stream of water from the valve discharge indicates attainment of the CDTP. The pressure at which the valve releases should be within the tolerances.

Once the valve is set to pop at CDTP, it should be checked for leakage. It can be tested on the test block for seat tightness by increasing the pressure on the valve to 90% of the CDTP and observing the discharge side of the valve for evidence of leakage.

17.3 Types of Maintenance

A number of guidelines for pressure relief valve service and maintenance are available to ensure that that valves work properly. Overall maintenance of pressure relief valves are classified as: routine maintenance, in-line maintenance, and preventive maintenance.

17.3.1 Routine maintenance

Many valve seat rings are not removable, and these can be reprofiled and relapped in the body (Fig. 17.2).

It is important that the size of the seat orifice be maintained exactly in line with original drawings, since a change can alter the effective area and thus affect the set pressure.

It is not permitted for the disk to be lapped directly onto the seat in the body, since a groove may be created on the disk preventing consistent shutoff after lifting.

In the case of resilient seal valves, usually the seal, which is an O-ring or disk, can be changed in the disk assembly.

Figure 17.3 shows a discharge pipe disconnected. The maintenance mechanic should fix this type of problem as part of routine maintenance.



Figure 17.2 A mechanic performing safety valve maintenance. (Courtesy Mobile Valve Repair Ltd., Canada.)



Figure 17.3 A discharge pipe is disconnected.

17.3.2 In-line maintenance

Removing a damaged safety valve from its position and repairing it in the shop takes time. Ultimately it costs money for downtime and spare valve inventory. If a valve can be repaired in-line, downtime can be eliminated and cost can be saved for spare valve inventory.

Figures 17.4 and 17.5 show a safety valve boring machine which can be used for in-line maintenance. The machine is designed to mount directly on the safety valve and rework nozzles up to 4 in (100 mm) in diameter. This machine can combine various tool bits and tool holders to remachine valve bushing seats to the manufacturer's original specifications. The boring machine can also machine outside diameter, inside diameter, and bushing seat faces to close tolerances.

The safety valve boring machine consists of a compact pneumatic power head and spindle, a set of mounting fixtures, and tool heads for a range of machining operations. The power head features a 1.2-hp (0.90-kW) pneumatic motor that drives a worm gear reduction, for plenty of torque at the tool head. The spindle turns in ball bearings to ensure smooth operation.

The tooling assembly consists of the tool head, the tool set fixture, the boring and facing heads (Fig. 17.6), and the tool bits. A draw bolt holds the tool head to the spindle. The tooling assembly does three basic valve remachining operations: boring, turning, and facing.



Figure 17.4 Safety valve boring machine. (Courtesy Climax Machine Tools, Inc.)

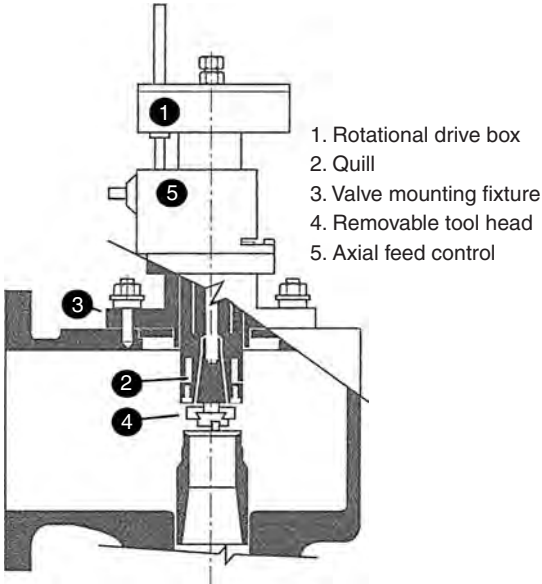


Figure 17.5 Parts of a valve boring machine.

The safety valve boring machine mounts on the valve with a fixturing assembly that consists of mounting fixtures, adapter rings, and clamp bars. The adapter ring, machined to fit standard valve bore sizes, centers and aligns the machine in the valve opening. The adapter ring raises the machine slightly above the flange surface to ensure alignment with the valve axis. The valve mounting fixture uses existing valve flange studs.

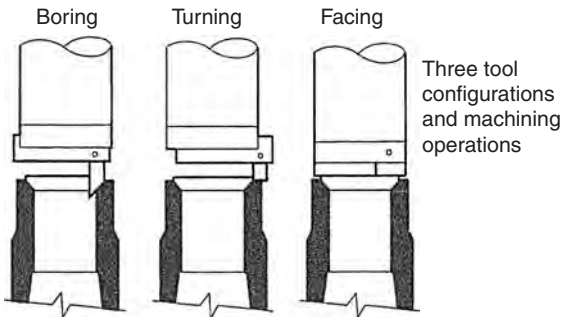


Figure 17.6 Tool configurations of valve boring machine.

17.3.3 Preventive maintenance

Personnel responsible for maintenance should evaluate the following objectives when establishing a preventive maintenance program:

- Provide for safety of personnel.
- Guard against damage to the equipment.
- Comply with jurisdictional laws, rules, and codes.
- Minimize loss of production during normal operation.
- Reduce maintenance by extending the time period between major maintenance of pressure relief devices.

The preventive maintenance program should be established based on operating and maintenance experience. The corrosiveness of the fluid, the application, and the trim metallurgy are primary elements that determine frequency of maintenance. The frequency may be as short as 6 months or as long as 2 years for an individual pressure relief valve. The maintenance program also depends on the type of pressure relief valves used in the plant.

An effective preventive maintenance program should have the following elements:

- A procedure should be in place for permissible overpressure, set pressure, set pressure for multiple relief devices, and set pressure tolerance.
- Install pressure relief valves properly.
- Consider providing secondary capacity for the “unknowns.”
- Consider providing secondary relief devices.
- Watch for corrosion and leakage!
- Consider using isolation valves.
- Consider using vacuum support.
- Take measures against pulsating pressures and water hammer effect.
- Visually inspect piping every 6 months.
- Reduce inlet pressure to zero before underrating any work.
- Provide atmospheric discharge lines with adequate rain and moisture protection.

17.4 Testing

All pressure relief valves are required to be tested on the service medium for which they are intended. Steam valves should be tested on steam (Fig. 17.7), and air and gas valves should be tested on air.

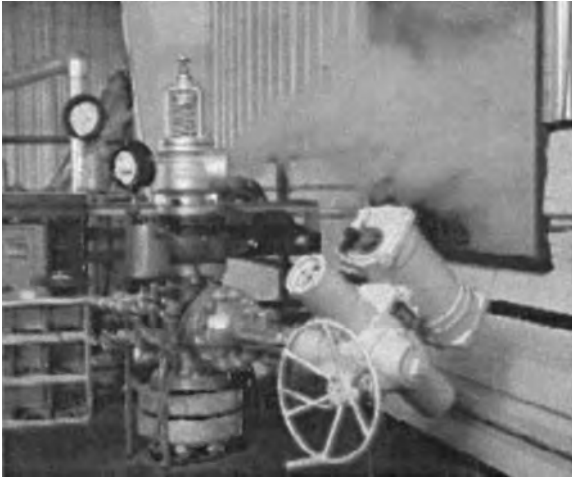


Figure 17.7 Testing of safety valve by steam. (Courtesy Mobile Valve Repair Ltd., Canada.)

Prior to mounting the pressure relief valves to the test fixture, follow the procedures given below:

- Clean the test fixture and purge the system of any loose contaminants.
- Make sure that test gauges are calibrated prior to testing the pressure relief valves.
- Secure the pressure relief valve inlet to the test fixture. Be sure to use the wrench surface of the nozzle when tightening.

Preheat the steam system, including accumulator, test vessel, and pressure relief valve, prior to setting. Allow time necessary to warm up the system. Proper steam quality should be maintained to achieve valve performance.

17.4.1 Setting

The steps for setting the pressure on the pressure relief valves are given in Chap. 20.

17.4.2 Blowdown adjustment

It may be necessary to make minor adjustment to the warn ring and control ring to obtain required blowdown and proper valve performance. The blowdown requirements under the ASME Code are given in Chap. 20.

17.4.3 Seat tightness test

A seat tightness test is performed on all pressure relief valves after final set pressure and blowdown requirements have been satisfied. It is extremely important to practice safety precautions when performing seat tightness tests on steam and air. See Chap. 20 for seat tightness test.

17.5 Causes of Improper Performance

When a pressure relief valve does not function normally, there is always a reason. Maintenance engineers should look for the causes of improper performance and rectify them.

17.5.1 Rough handling

Pressure relief valves are checked for tightness in the manufacturer's shop before they are shipped to the user. Rough handling of the valve may change the set pressure, damage lifting levers, damage tubing and tube fittings, damage pilot assemblies or cause internal or external leakage when the valve is in service. Rough handling can occur during shipment, maintenance, or installation.

The valves should be shipped in an upright position – especially for large valves and valves with low set pressure. Rough handling during shipment may cause a valve to leak excessively in service or during testing. The rough handling may expose the valve inlet allowing dirt or foreign particles that could damage the valve seating surface.

Rough handling during maintenance can degrade the tolerances, and destroy valve alignment. Valve inlets and outlets should be covered before the valves leave the shop.

Rough handling of pressure relief valves during installation may cause poor valve performance in service. Bumping or dropping the valve should be carefully avoided.

17.5.2 Corrosion

Corrosion is a basic cause of many problems encountered with pressure relief valves. Corrosion often appears as pitted or broken parts, deposits of corrosive residue, or a general deterioration of material of the valve. A corroded safety valve is shown in Fig. 17.8.

Corrosion can be slowed down by selecting more suitable materials for the fluids being run. Proper maintenance is also a consideration, as a leaky valve allows fluids to circulate in the upper parts of the valve, which may contribute to corrosion of its movable parts.



Figure 17.8 A corroded safety valve.

In some applications, a rupture disk device installed on the inlet of a pressure relief valve may provide added corrosion protection for the valve internals.

17.5.3 Damaged seating surfaces

In accordance with API Standard 527, a very precise flatness of seating surfaces (0.0000348 in) must be maintained on metal-seated pressure relief valves. Any imperfection in seating surfaces will contribute to improper valve action.

There are many causes of damaged valve seats, including the following:

- Corrosion.
- Foreign particles such as mill scale, welding spatter, corrosive deposits, or dirt may enter into the valve inlet and pass through the valve when it opens. These particles may damage the seat contact required for tightness in most pressure relief valves.
- Improper or lengthy piping to the valve inlet or obstructions in the line. These can cause a valve to chatter.

- Rough handling during maintenance, such as bumping, dropping, jarring, or scratching of valve parts.
- Leakage past the seating surfaces of a valve after it has been installed. Seat leakage may also result from the operating pressure being too close to the set pressure of the valve.
- Improper blowdown ring setting can cause chattering in pressure relief valves.

17.5.4 Failed springs

Spring failure may occur in two forms—weakening of the spring, and a total failure of the spring. Although spring may be weakened and fail due to the use of improper materials at high temperature service, most of the springs fail due to corrosion.

When corrosion is the reason for failure, the following actions may be taken:

- A spring material that resists the action of corrosive agent may be used.
- The spring may be isolated by a bellows.
- The spring may be coated with a corrosion-resistance coating that can withstand the operating temperature and environment.

17.5.5 Improper setting and adjustment

The manufacturer's recommendations should be followed to eliminate improper setting and adjustment by indicating how to adjust the pressure relief valves for temperature, back pressure, and other factors. Generally, pressure relief valves are set in the maintenance shop on appropriate test equipment.

The following guidelines may be used for proper setting and adjustment:

- Vapor-service valves should be tested on air or inert gas. Steam-service valve should be tested on steam, but air may be used if suitable corrections are applied. Liquid-service valves should be set using water.
- The size of the test stand is important, as insufficient surge volume might not cause a distinct pop, and may cause an incorrect set pressure.
- Consult the manufacturer for proper techniques for setting pilot-operated pressure relief valves for liquid service.
- Gauges should be calibrated frequently on a regularly calibrated dead-weight tester.

- The valve adjusting rings control either the blowdown (the difference between the set pressure and reseating pressure) or valve blowdown and simmer, depending on the design of the valve. The rings should be adjusted to obtain pop on the valve test drum, and then readjusted for proper blowdown.
- The manufacturer should be contacted regarding the proper blowdown ring settings for liquid or vapor service.

17.5.6 Plugging and sticking

In refineries, process solids such as coke or solidified products may plug various parts of the pressure relief valve and its connected piping. In addition, monomer service may lead to polymer formation and plugging.

The following steps may be taken to avoid plugging and sticking:

- All valve parts, especially guiding parts, should be checked for any type of fouling surfaces.
- Lubricate all bearing surfaces, such as the spindle to the disk holder, spring buttons to the spindle, disk to disk holder, and threads.
- Valves may malfunction due to sticking of the disk or disk holder in the guide, which may be caused by corrosion. Sticking of valves may also result from matching of valve parts outside the tolerance limits.
- Sticking of pressure relief valves may also be caused by poor alignment of the valve disk.
- If corrosion is the cause of sticking, possible solutions are:
 - The use of a bellows to protect moving parts from the corrosive substances.
 - An O-ring seat can seal the guiding surfaces from the lading fluid until a relief cycle occurs.
 - The use of a rupture disk on the valve inlet should isolate the valve internals from the upstream process materials.

17.5.7 Misapplication of materials

Special attention is required in selection of materials for severe corrosion or unusual pressure or temperature conditions in the process. The proper materials for the valves may be selected based on the following guidelines:

- Determine the materials to be used, considering the temperature, pressure, corrosion resistance, and atmospheric conditions of service.
- Read manufacturers' catalogs for a wide choice of special materials and accessories for various chemical and temperature conditions.

- Note that hydrogen sulfide (H_2S) attacks carbon steel springs, and chloride attacks 18Cr-8Ni steel disks.
- Care should be taken to record the identity of special materials and the locations requiring them.

17.5.8 Improper discharge piping test

Blinds should be installed when hydrostatic tests of discharge piping are performed. The following might result if blinds are not used:

- The disk, spring, and body area on the discharge side of the valve may be fouled.
- The bellows of a valve may be damaged by excessive back pressure.
- The dome area/or pilot assembly may be fouled and damaged by the backflow of fluid.

17.6 Troubleshooting

Like any other mechanical equipment, pressure relief valves give troubles during operation. Maintenance personnel are responsible for diagnosis of troubles and taking corrective actions to restore valves' normal operation. Table 17.1 offers guidelines for troubleshooting.

17.7 Spare Parts

The maintenance department should stock spare parts which may be required on emergency basis. Commonly supplied spare parts are:

- Springs (Fig. 17.9)
- Disks
- Disk holders
- Nozzles
- Rings
- Guides
- Spindles
- Resilient seals
- Gaskets
- Compression screws

TABLE 17.1 Troubleshooting of Pressure Relief Valves

Trouble	Diagnosis	Corrective action
1. PRV is leaking	Minimum operating-to-set point is too close	Maintain a minimum operating-to-set point differential
	Foreign material is lodged under the seat	Clean dirt or foreign material
	Seating surface is damaged	Repair worn or damaged seating surface
2. PRV is chattering	Improper piping at inlet or outlet	Install piping at inlet and outlet properly
	Valves are oversized	Size and select valves properly
	Back pressure may be present, which may not have been accounted for in the original sizing	Review sizing formulas
	Valves holes may be plugged	Make sure all holes are not plugged and any shipping plugs have been removed
	Valve may be worn or damaged	Replace or repair
3. PRV not popping at the set pressure	Valve not operating within tolerance limit	Review testing specification and ensure that the valve is operating within the allowed tolerances
	Gauge reading not correct	Make sure that the gauge reading is properly installed and calibrated
	Improper inlet piping	Make sure that the inlet piping has the least area of the PRV inlet
	Back pressure not proper	Ensure that back pressure has proper been accounted for in the original valve sizing and selection
	Valve is worn or damaged	Repair and replace the PRV
4. PRV is not closing	Dirt or foreign material is lodged under the seat	Clean off the dirt or foreign material
	Operating pressure is below the reseating pressure of the valve	Slowly bring the system back to normal operating pressure. Make sure that a minimum operating-to-set point differential is maintained
	Valve is worn or damaged	Repair or replace the PRV

(Continued)

TABLE 17.1 Troubleshooting of Pressure Relief Valves (Continued)

Trouble	Diagnosis	Corrective action
5. Blowdown	Blowdown is too short ($<2\%$ of set)	Adjust rings Check spring range (high)
	Excessive blowdown (PRV is hanging up)	Adjust rings Check spring range (low) Check alignment
6. Excessive simmer	Adjustment	Raise lower ring
	Wide nozzle seat	Remachine nozzle seat and lap to correct
7. PRV flutters	Misalignment	Check alignment
	Seat damage	Disassemble and check seats

When ordering valve parts, the following information should be furnished to the vendors:

- Quantity
- Valve model (See manufacturer's catalog)
- Construction material
- Set pressure
- Maximum inlet temperature
- Allowable overpressure
- Service

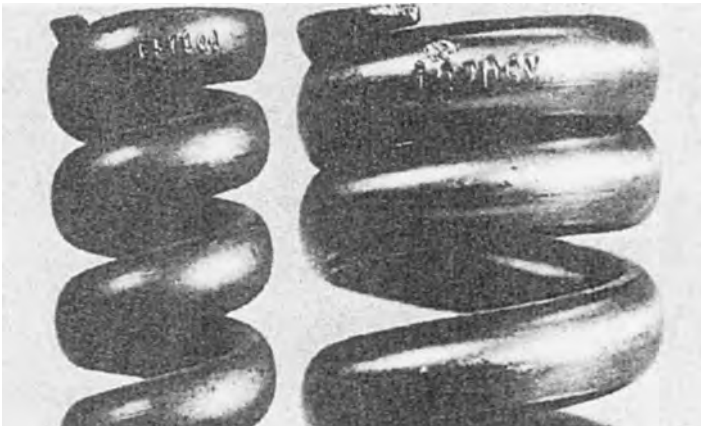


Figure 17.9 Springs for pressure relief valves.

- Required capacity
- Accessories
- Code requirements

17.8 Storage

Pressure relief valves and their parts should be properly stored and protected. Performance of the pressure relief valve may be seriously affected if they are not stored properly. Rough handling may damage flanges or cause misalignment of the valve parts. It is recommended to leave valves in their shipment cases and store them in a dry place under cover until they are to be used.

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Chapter 18

Inspection

A properly designed, constructed, and installed pressure relief device is supposed to ensure safety of personnel and protect equipment during abnormal circumstances. Inspection of pressure-relieving devices is performed to ensure that they provide this protection in case of emergency situations.

Inspection of pressure relief devices should determine the general physical and operating conditions of these devices, and ensure their performance. In order to make this determination, thorough inspection in the shop and visual inspection on stream are conducted.

The inspection should include necessary factors which could affect the pressure relief valve performance. The followings are considered important factors:

- Temperature variation, both system and ambient
- Vibration
- Residue on valve internal parts
- Valve body mechanical stresses
- Line turbulence
- Sizing and configuration of discharge piping
- Sizing and configuration of inlet piping
- Bore diameter

Pressure relief devices are inspected by an Authorized Inspector (AI) who is qualified by the jurisdiction. Depending on jurisdictional laws and rules, pressure relief devices are inspected regularly by an AI. Inspection is a complex technique, and the AI must have knowledge and experience

about ASME and API Codes. In the absence of jurisdictional laws and rules, inspection should be conducted by an engineer experienced in pressure relief device technology.

The AI performs inspection according to the national codes and jurisdictional requirements. The following codes and standards are used for inspection of pressure relief devices:

- API RP 576—Inspection of Pressure Relief Devices
- API RP 520, Part I—Sizing and Selection of Pressure Relief Devices
- API RP 520, Part II—Installation of Pressure Relief Devices
- ASME Sec. VIII, Division 1—Pressure Vessels
- ANSI/NB 23—Inspection Code

18.1 Authorized Inspectors

Currently there is no certificate requirement for pressure relief device inspectors. The inspection of pressure relief devices is done as a part of inspection of the vessel by an Authorized Inspector, who is employed either by the jurisdiction or by an insurance company. An insurance company employing an AI must write boiler and machinery insurance in the jurisdiction where the inspector performs inspections.

An AI has knowledge, experience, and training in pressure vessel codes and has to qualify by passing a written examination under jurisdictional requirements. Once a person passes the examination, the jurisdiction issues a Certificate of Competency (Fig. 18.1). An AI is considered

CERTIFICATE OF COMPETENCY		
STATE OF FLORIDA FLORIDA DEPARTMENT OF FINANCIAL DIVISION OF STATE FIRE MARSHAL TALLAHASSEE, FLORIDA 32399-0300		
THIS IS TO CERTIFY THAT: NEIL MATTHEWS 3340 SHELLEY DRIVE GREEN COVE SPRINGS, FL 32043-	REPRESENTING: STATE OF FLORIDA STATE FIRE MARSHAL OFFICE 200 EAST GAINES STREET TALLAHASSEE, FL 32399-0342	
INSPECTOR ID #: 019	ISSUE DATE: 01/01/2004	EXPIRATION DATE: 12/31/2004
IS CERTIFIED PURSUANT TO THE PROVISIONS OF CHAPTER 554, FLORIDA STATUTES, AS A DEPUTY BOILER INSPECTOR OR AS A SPECIAL INSPECTOR.		
 TOM GALLAGHER CHIEF FINANCIAL OFFICER	 MOHAMMAD A. MALEK, P.E. CHIEF BOILER INSPECTOR	
FORM #DI4-357		

Figure 18.1 A certificate of competency. (Courtesy State of Florida.)

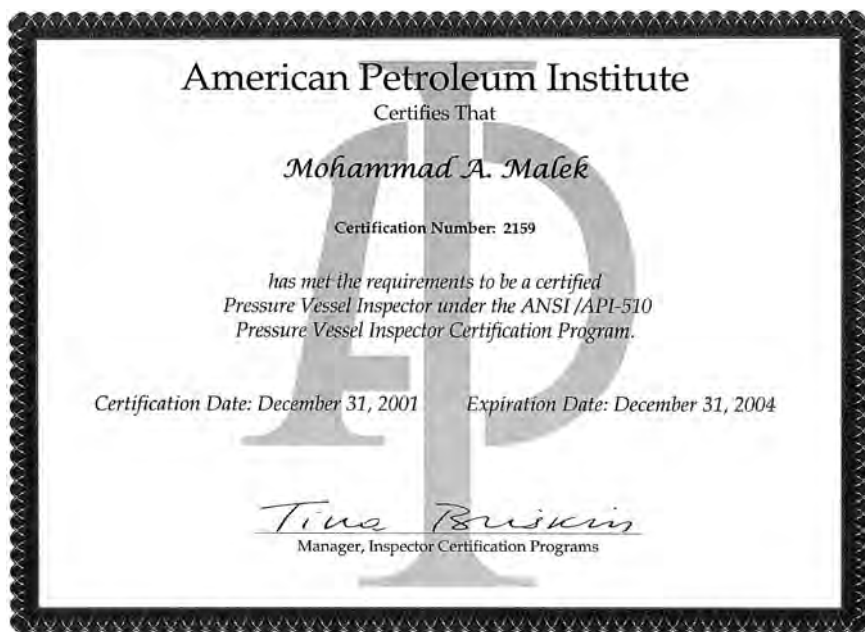


Figure 18.2 API-510 Pressure vessel inspector's certificate. (Courtesy API.)

qualified for inspection when he or she has such a Certificate of Competency.

The American Petroleum Institute (API) qualifies pressure vessel inspectors in accordance with the provisions of API 510—Pressure Vessel Inspection Code. These certified pressure vessels inspectors also perform inspection of pressure relief devices in the petroleum and refinery industries. A pressure vessel inspector's certificate under API-510 is shown in Fig. 18.2.

It is necessary to develop experienced pressure relief valve inspectors all over the world. A certificate with the title *Safety Valve Inspector* (SVI) is an excellent idea for promoting pressure relief valve safety worldwide.

18.2 Types of Inspections

Pressure relieving devices are installed on pressure equipment to release excess pressure due to operational problems, external fires, and other abnormal conditions. Inspections should determine the exact conditions of these devices, and ensure that their performance is satisfactory for a given installation.

To ensure that pressure relief devices will function in case of abnormal circumstances, the following types of inspections are performed:

- Inspection of new installations
- Routine inspection
- Shop inspection
- Visual on-stream inspection
- In-service testing
- Unscheduled inspection

18.2.1 Inspection of new installations

All new pressure relief valves should be inspected and tested before and after they are installed on equipment. Inspect the pressure relief valves visually and verify cold differential test pressure (CDTP) pressure. This inspection should determine any damage or changes in factory adjustment due to shipping. Be sure to confirm the set pressure, and keep appropriate records.

Pressure and/or vacuum vent valves on atmospheric storage tanks should be inspected after installation but before the tank is hydrostatically tested or put into service.

18.2.2 Routine inspection

Routine inspection is carried out when the plant is shutdown and maintenance manpower is available. Generally, the interval between routine inspections is determined by operating experience in the various processes involved. The interval of a pressure relief device in a corrosive or fouling service would be shorter than the interval required for the same device for non-fouling, non-corrosive service.

All relief valves not equipped with block valves should be inspected at this time. If an inspection carried out during this shutdown, the inspection should be scheduled for the next shutdown. Even the pressure relief valves with block valves may be inspected to minimize process interruptions, and avoiding inspection in operation.

18.2.3 Shop inspection

Periodically, pressure relief devices are removed, disassembled, and inspected in the shop. This inspection is referred to as shop inspection.

Each pressure relief valve in the shop should carry an identification tag or other means to show its company equipment number. This number allows ready identification of the equipment that the valve should be installed on. An operating history of each tag number since

its last shop inspection should be obtained and should include the following information:

- Information on upsets and their effect on the valve
- The extent of any leakage while in service
- Any other evidence of malfunctioning

As soon as a pressure relief valve is received in the shop, a visual inspection should be made. Any deposits, corrosion products or obstructions in the valve should be recorded and removed.

Qualified maintenance personnel do a thorough overhaul in the shop and make the pressure relief devices ready for service. Prior to the installation of a pressure relief valve, the inlet and outlet piping should be inspected for presence of internal deposits. If fouling is observed, the piping should be cleaned.

18.2.4 Visual on-stream inspection

A visual on-stream inspection is similar to a survey and is considered a control measure rather than normal inspection. A full visual on-stream inspection should ensure the following:

- The relief valve does not leak. Detection and correction of leakage eliminates product loss, and prevents fouling.
- Bellows vents are open and clear.
- Upstream and downstream block valves are sealed or chained or locked in proper position.
- Valve body drains and vent stack drains are open.

18.2.5 In-service testing

An electronic valve tester (EVT) is a digital computerized and hydraulic-assisted device used to test and set pressure relief valves while in service. The EVT is portable and may be used under normal operating conditions without overpressurizing the system. The set point of spring-loaded valves may be tested and certified while in service. An electronic valve tester is shown in Fig. 18.3.

Pressure relief valves which fail the EVT test are required to be removed for repair. Total downtime and maintenance costs are reduced substantially because of the time saved for valve removal and installation. Since the EVT is calculated from simmer point, potential damage to valve seats from full-flow or low-capacity testing is minimized. Electronic valve testing produces computerized certifications for valve records.



Figure 18.3 In-line valve testing. (Courtesy B & HES, Inc.)

18.2.6 Unscheduled inspection

An inspection is required when emergency situation occur involving operation of pressure relief devices. If a valve fails to open at the set pressure, it requires immediate inspection. If the valve opens at the set pressure but does not reset properly, urgent inspection is also required. Other emergency situation involves leakage, characteristics of the leaking substances, and their environmental and human impact.

Unscheduled inspection is also performed on pressure relief valves if left for an extended shutdown. This inspection ensures that corrosion, fouling, tempering and other conditions have not occurred during the extended shutdown.

18.3 Safety Valve Inspection

Safety valves are used primarily on steam boilers and other gas-type services. This type of valve is usually spring loaded with full-opening pop action. The safety valve should meet the applicable code, be identified with a V symbol, and should be set to relieve at or below the MAWP of the vessel. Figure 18.4 shows inspection of two safety valves by an Authorized Inspector.



Figure 18.4 Safety valve inspection by an AI.

An AI or insurance company inspector should make note of the following important points when inspecting safety valves:

1. All boilers and pressure vessels must have one or more overpressure protective devices. Make sure that these devices are officially rated with ASME Code symbol **V**.
2. Check that the seals that are attached in a manner that prevents the valve from being taken apart and reset without breaking the seals. Broken or missing seals are indications of tampering. If there has been tampering, the set pressure and relieving capacity require confirmation prior to resealing.
3. Note the set lifting pressure as stamped on the valve or nameplate against the MAWP of the vessel.
4. Check the minimum relieving capacity on the valve or nameplate against the maximum capacity loading that can be applied.
5. The condition of the valve attachment bolting should be inspected. Sometimes the bolting loosens due to vibration. This puts uneven stresses on the valve body, or causes leakage at the connection.
6. Inspect the inlet line between the boiler or vessel and the valve. There should be no reductions, restrictions, or intervening stop valves.

7. Look at the valve proper, and check for cracks in the body, broken springs, and broken or defective levers. Make sure that there is no accumulation of rust, soot, scale, or other foreign particles in the casing or body spring area.
8. If no discharge piping is attached, look inside the discharge opening for evidence of leakage. The leakage shows up in the form of white-like mineral deposits, or heavy corrosive deposits. This deposit can interfere with normal operation of the valve.
9. If discharge piping is attached, make sure that it is independently supported from the valve body so that the piping loads and stresses are not transmitted to the valve body. Safety valve bodies are not designed to carry this loading.
10. Make sure that the discharge piping is carrying full size to a safe point of discharge with no restrictions or intervening stop valves. A common mistake is to reduce the cross-sectional area of a common line where two or more discharge lines enter a common line.
11. It is permitted by the Code to header discharge lines together, provided the cross sectional areas of the common lines equals the sum (cross sectional areas) of all discharge lines entering the common.
12. Safety valves must be installed in an upright position with the spindle vertical to assure proper operation.
13. If the discharge line is fitted with a drip pan, make sure that the drip pan and the drip pan drain line are free of scale and other foreign deposits.
14. Drip pan drains and valve casing drains can be piped together. Ensure that they are piped to a safe point of discharge, and free of obstructions.
15. A safe point of discharge from the safety valve is an area where the discharge does not exit directly on personnel or property that may be damaged by the discharge.
16. Drainage holes at the low point of the discharge piping are required to assure that moisture does not accumulate in the piping and the top of the valve seat. Check the drain holes and make sure that they are open.
17. Hazardous or lethal chemicals or gases should be piped to a dump tank which provides sufficient capacity to contain accidental discharge.
18. Nonlethal gases which act as oxygen displacers should be piped to an outdoor area. Make sure that the discharge point is clear of any outside air inlets to any building. It should be at least 20 ft from any window, entrance, or air inlet.

18.4 Safety Relief Valve Inspection

Safety relief valves are used primarily on water boilers, hot water heaters, and other liquid type services. This type of valve is usually spring loaded without full-opening pop action, and has a factory-set opening pressure, which is nonadjustable. The safety relief valve should meet the code, and be identified with an **V**, **HV**, **NV**, or **TV** symbol, and should be set to relieve at or below the maximum allowable working pressure (MAWP) of the vessel.

An Authorized Inspector or insurance company inspector should make note of the following important points when inspecting safety relief valves:

1. When more than one safety relief valve is installed per unit of vessel, make sure that they are installed properly according to the applicable code.
2. The line between the vessel and safety relief valve should have no reductions, restrictions, or intervening stop valves. Figure 18.5 shows that an intervening stop valve is located between the vessel and the pressure relief valve, which is not permitted by the ASME Code. Make sure that this stop valve is removed.



Figure 18.5 A stop valve is wrongly installed between the vessel and safety relief valve.

3. The safety relief valve should be installed top or side at the highest possible part of the vessel proper. In no case may this valve be installed below the lowest permissible water level of the vessel.
4. The safety relief valve should be connected directly to a tapped or flanged opening in the vessel.
5. The discharge pipe should be as short as possible, and arranged to avoid undue stress loadings on the valve.
6. If the valve discharges liquids, the discharge piping should be piped to the floor or drain areas to minimize scalding of personnel.
7. The piping discharge point should be no closer than one pipe diameter above the floor, or any obstruction. It should be no higher above the floor than three pipe diameters.
8. A common error is to set the discharge pipe directly on a drain plate. The webbing in the plate reduces the safety relief valve capacity. Check the discharge piping exit point to ensure that it is not obstructed in any manner.
9. Inspect the body casing and spring area for cracked or broken parts. Look for leakage in the area in the form of white-like mineral deposits or corrosion that might obstruct the movement of spring or operation of the valve.
10. Examine the discharge piping exit point for evidence of relief valve leakage. If any leakage is found, it should be corrected or the valve replaced.
11. A safety relief valve should have a try lever and should be sealed. Safety relief valve inlet size should not be smaller than $\frac{3}{4}$ in, nor greater than 4 in.
12. A safety relief valve is required to be installed with the valve spindle in the vertical position to assure proper operation.

18.5 Rupture Disk Inspection

All rupture disk devices should be thoroughly inspected before installation. The manufacturer's instructions should be followed for specific rupture disks. The seating surfaces of the rupture disk holder should be clean, smooth, and undamaged.

Rupture disks should be checked for physical damage to the seating surfaces or the prebulged area. Damaged or dented disks should not be used. The disk should not be reinstalled once it has been removed from its holder, even though it has not been ruptured. The safety head or bolted construction should be checked for proper torque as recommended by the manufacturer.

The knife blades on reverse buckling disks should be checked for physical damage and sharpness. Nicked or dull blades should be refurbished or replaced.

Inlet and discharge piping for rupture disks should meet the same criteria as established for safety relief valves and safety valves.

Rupture disks should be replaced on a regular schedule based on their application, manufacturer's recommendations, and user's past experience. If the risk of a rupture disk opening prematurely is low, and inlet and outlet fouling is monitored, the disk may be left in place indefinitely.

18.6 Records and Reports

An Authorized Inspector or insurance company inspector usually completes a report after inspection of a vessel. The report contains a lot of information about the safety relief devices.

Figure 18.6 is an example of a boiler reinspection report submitted by an insurance inspector to the State of Florida. In his report, the inspector has specified that the safety valve's capacity is 450,000 Btu/hr whereas the boiler requires 1,093,000 Btu/hr relieving capacity. The inspector has written this insufficient capacity as a violation of Par. PG-70 of ASME Code Sec. I. The inspector has asked the owner to replace the safety valve with an ASME-approved valve capable of relieving the total heat output of the boiler.

Figure 18.7 shows a form for historical records indicating dates and results of inspections and tests necessary for the follow-up phase of the pressure-relieving inspection program. The record also indicates periodic reviews to determine if the planned inspection intervals for a device are being realized. It is important that the records offer a practical basis for establishing and maintaining safe and economical inspection intervals for the device.

**DIVISION OF STATE FIRE MARSHAL
BUREAU OF FIRE PREVENTION
BOILER SAFETY PROGRAM**

RE-INSPECTION REPORT—ALL BOILERS

This inspection is intended for your safety and the safety of the citizens of Florida. Your cooperation is greatly appreciated.

PLEASE PRINT

Last Inspection Date	
1 Date Inspected 02/08/2005	Kind of Inspection ☐ Int. ☒ Ext.
Jurisdictional No. FL-055331	Other No. NB 33836
Certificate Passed? ☒ Yes ☐ No Bill To: ☒ Owner ☐ User	
2 Owner's Address (Street) R I U Hotels 3101 Collins Avenue	
Nature of Business Hotel	
Owner's City Miami Beach	
State FL	
Zip 33140	
3 User's Name- Object location Same	
Specific Location in Plant Boiler Room	
User's Address (Street) Same	
User's City Same	
State FL	
Zip 33140	
4 TYPE ☐ FT ☒ WT ☐ CI Yr. Built 1996 Manufacturer A.O. Smith	
USE ☐ Power ☐ Process ☐ Steam Heat ☐ HWH ☒ HWS Fuel Gas	
Method of Firing Auto	
Capacity Gas. Auto	
5 Pressure Allowed: This Insp. 160 Prev. Insp. 160 psig Safety Relief Valve Setting 160 psig	
LWGO installed ☒ Yes ☐ No	
Tested ☐ Yes ☒ No	
6 Controlling Code Section ☐ I ☒ IV	
7 Number of Safety/Safety Relief Valves 1	
Relieving Cap. Rated 1,093,000 ☐ Lb./hr. ☒ STU/hr.	
Capacity Previous 450,000 ☐ Lb./hr. ☒ STU/hr.	
Issue Certificate ☐ Yes ☒ No	
If No, explain in Remarks	
Code Violations with reference: / Remarks / Boiler Stamping 1.14 The installed safety valve is of insufficient capacity and cannot relieve the total output of the boiler. Replace the safety valve with an ASME approved valve capable of relieving the total heat output of the boiler. The pressure setting shall be no higher than 160 PSI. Pursuant to A.S.M.E. Code Section IV, Article 7 ASME Code Section I, Paragraph PG-70. Rafael Fernandez, Chief Engineer, 305-673-9335	
Continue on reverse side	
10 Violations recorded in previous inspection report, dated <u>Not Applicable</u>	
have ☐ been corrected ☐ not been corrected. ☐ recommend action be initiated to shut down installation.	
The following safety violations of the Florida Boiler Safety Code have been recorded. The signature below certifies that corrective action on all violations will be completed within _____ days. Telephone # _____	
Signature of Owner or Representative _____ Title _____ Date _____	
I hereby certify that this is a true report and a result of my inspection.	
PRINT NAME OF INSPECTOR Gail Phillips	
SIGNATURE OF INSPECTOR	
I.D. NO. 271	
EMPLOYED BY: CNA INSURANCE CO.	
I.D. NO. 9165	

Figure 18.6 Inspection report indicating insufficient safety valve capacity. (Courtesy State of Florida.)

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Chapter 19

Repairs

Repair work is necessary to restore a pressure relief device to a safe and satisfactory condition. Pressure relief devices should be carefully repaired in accordance with the manufacturers' manuals and recommendations. The repair method should conform to a national standard, and the work should be done by qualified repairers. If the repair is not done properly, the pressure relief device may give major technical problems in service.

Pressure relief valves may be repaired on the system or may be repaired in a valve repair shop. Repairs on pressure relief valves should be performed by a repairing firm or person, who has necessary tools and surface finish data for the valves. As a part of repair process, all dimensions of the nozzle, disk, disk holder, ring, guide, and spindle should be checked and restored to their original standard.

If all the dimensions and surface finish data is not available for repair, the parts should be replaced by the parts from the original valve manufacturer. The valve may not function properly when parts supplied by a company other than original valve manufacturer is used. All parts to be used should be free from scoring damage to critical guiding surfaces.

On completion of all repairs, pressure relief valve should be tested and sealed to ensure that no unauthorized adjustments are made. Generally, testing is done in a valve repair shop, where necessary testing facilities are available and the shop has adequate test capacities. If all the valve operating characteristics cannot be tested in the shop, they should be verified when the boiler is on line.

19.1 Repairers

A repair organization must have experience in handling, maintenance, and repair of all types of pressure relief devices. Most jurisdictions have qualification requirements for a repair organization in the laws and rules.

Generally, jurisdictions permit a “VR” stamp holder to repair all types of pressure relief valves. The VR Certificate of Authorization is issued by the National Board of Boiler & Pressure Vessel Inspectors. A sample Certificate of Authorization to use the VR stamp is shown in Fig. 19.1.

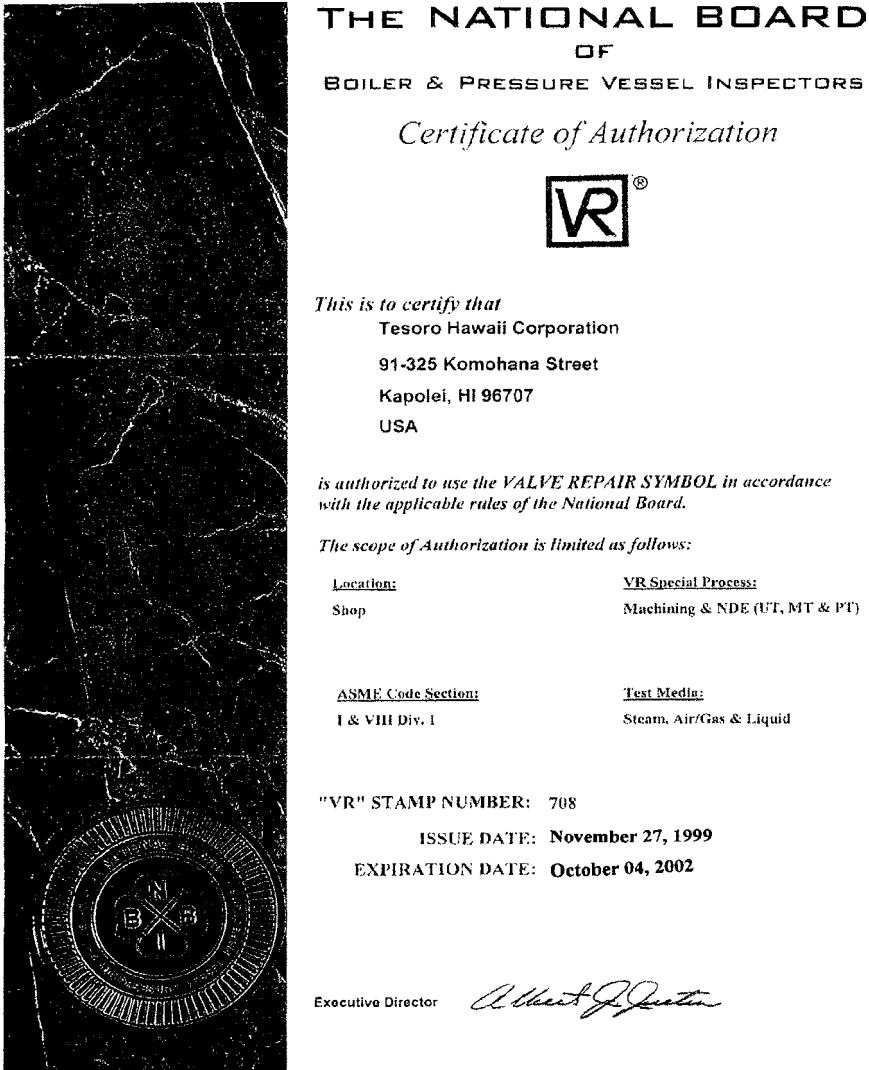


Figure 19.1 A VR Certificate of Authorization. (Courtesy National Board.)

Each repair organization should have a fully documented quality control system. As a minimum, the following requirements and sets of documentation should be included in the quality control system:

- Title page
- Revision log
- Contents page
- Statement of authority and responsibility
- Organization chart
- Scope of work
- Drawings and specification controls
- Material and part control
- Repair and inspection program
- Welding, nondestructive examination, and heat treatment procedures
- Valve testing, setting, leak testing, and sealing
- General example of the valve repair nameplate
- Procedures for calibrating measurement and test gauges
- Controlled copies of the quality system manuals
- Sample forms
- Repair personnel training or qualifications

Each repair organization should also have a fully documented training program that will ensure repair personnel are qualified within the scope of the repair work.

19.2 Repair of Pressure Relief Valves

The repair organization should establish procedures for repairing spring-loaded pressure relief valves. The procedures should cover step-by-step repair methods to ensure proper repairs.

Generally, repair of pressure relief valves is done in a shop, where all the machines, equipment, and tools for repair are readily available. A valve repair shop is shown in Fig. 19.2.

19.2.1 Visual inspection as received

When pressure relief valves are received in the shop, each valve should be visually inspected to detect problems. Generally, this inspection is made by repair mechanic as a routine procedure. An authorized



Figure 19.2 Safety valve repair shop. (Courtesy Mobile Valve Repairs Ltd., Canada.)

inspector (AI) or pressure vessel inspector should be called for inspection if unusual corrosion, deposits or conditions are noted.

The results of the visual inspection should be recorded on appropriate forms. Pay attention to the following areas:

- Check valve identification number
- Check complete nameplate data
- Check external adjustment seals
- Check bonnet for venting on bellow-type valves
- Check appearance of any unusual damage, missing or misapplied parts
- Check flanges for evidence of pitting or roughening
- Check springs for evidence of corrosion or cracking
- Check bellows for evidence of corrosion, cracking or deformation (for bellows type pressure relief valves)
- Check inlet and outlet nozzles for evidence of deposits of foreign material or corrosion
- Check external surfaces for any indication of corrosive atmosphere or of mechanical leakage

- Check compression screws for sign of wear, pitting and galling
- Check body wall thickness
- Check pilots and associated parts (for pilot operated relief valves)

19.2.2 Preliminary test as received

A preliminary performance test is conducted prior to actual repair of the valve to identify any problems the valve faced in service. Generally, the pressure relief valve is mounted on the test block, and the inlet pressure is slowly increased. The pressure at which the valve relieves is recorded as the “as received” pop pressure or set pressure. The preliminary test should record:

- Set pressure or cold differential test pressure (CDTP) as per the manufacturer’s recommendations and the ASME Code.
- The test pressure should not exceed 116% of the set pressure.
- Conduct at least three tests to obtain consistent results.
- If results do not correlate with field performance, then make necessary correction to obtain fluid and temperature conditions.
- Record preliminary test results and test bench identification data.

19.2.3 Disassembly

Pressure relief valves should be dismantled in accordance with the manufacturer’s drawings, manuals, and instructions. At each stage of disassembly, the various components should be visually inspected for evidence of wear and corrosion. The valve stem, guide, disk, and nozzle should be visually inspected very carefully.

Follow the following steps for disassembly of pressure relief valves:

- Secure the valve inlet wrenching surface in a soft jaw vise, vertically.
- Remove the seal wire from the warn ring and control ring screw.
- Remove cap, lever, and release nut assembly.
- Loosen jam nut on adjusting screw.
- Record measurement and remove adjusting screw.
- Remove bonnet or yoke.
- Remove spring and washers, and put identification tags.
- Remove spindle and disk assembly.
- Remove ring pins.
- Record measurement and remove adjusting rings, nozzle, and guide.

19.2.4 Cleaning parts

Each part should be cleaned after disassembly of a safety relief valve. Parts may be cleaned with solvents, emery paper, wire brush, sandblasting, or carefully scraped. The valve parts should be properly marked and segregated so that they are not mixed with parts of other valves.

Proper parts cleaning and condition is a vital part in pressure relief valve performance and valve life. Parts which show signs of wear, pitting, corrosion or any other damage should be replaced.

Follow the procedures below to clean all parts of pressure relief valves:

- Wire all small parts together and clean by means of an abrasive.
- Do not clean using a chemical solution.
- Protect seating surfaces, guiding surfaces, and threads prior to cleaning.
- Protect valve nameplate when sandblasting body.
- Avoid sandblasting stems, nozzles, disks, and guides whenever possible.
- Never use steel shot to clean any parts.

19.2.5 Inspection

After cleaning, all the components should be inspected for wear, corrosion, and other deterioration. Each part should be checked for dimensions with reference to the original valve manufacturer's drawings and specifications.

Perform the following inspection on pressure relief valve components:

- Check spring for damage such as erosion, corrosion, cracking, breakage or compression below free height.
- Check nozzle for cracks using a suitable nondestructive examination (NDE) method. Look for any unusual wear.
- Check disk assembly for cracks using a suitable NDE method. Look for any unusual wear.
- Check spindle for trueness, bearing areas, and threaded condition.
- Check guide for wear and galling.
- Check adjusting rings for worn threads and wear.
- Check ring pins for bent or broken pin and thread condition.
- Check bellows, if applicable, for pin holes and corrosion.
- Check flange gasket facings for wear and cuts.
- Damaged springs, bellows and soft goods should be rejected.
- Parts that are worn beyond tolerance or damaged should be rejected.

19.2.6 Machining

The valve body, flanges, and bonnet may be reconditioned by machining or suitable means. Machine the nozzle and disk as necessary to maintain the manufacturer's critical dimension charts.

19.2.7 Lapping

Lapping is required to restore the smooth seating surface of pressure relief valves. If evidence of wear or damage is noticed on the disk or nozzle, their seating surfaces may be lapped. Lapping can be done by hand or by a machine as shown in Fig. 19.3.

Lapping of the disk or nozzle by hand to remove minor seat damage is accomplished using a ring lap. The following is the lapping process:

- When using a ring lap, ensure that the lap covers the entire seating surface.
- Apply a thin even amount of compound to the ring lap and place it onto the disk.
- Begin lapping in a oscillating motion (back and forth), applying light even pressure.
- Lap part for 1-2 minutes.
- Remove ring lap and clean both parts thoroughly.
- Continue lapping sequence until disk/nozzle seat surface shows a gray shadow across the entire surface.

Polishing is accomplished in the same way with a few exceptions. A different ring lap should be used for polishing. This allows the seat to be polished quicker.

Lapping compounds vary from coarse to very fine. Generally a medium compound is used first, then a very fine compound to finish the piece. The plate and the part should be thoroughly cleaned after each different



Figure 19.3 Lapping machine.
(Courtesy Electron Microscopy Sciences.)

compound is used. Coarse compounds should be used for removing deep scratches and must always followed by finer grades. The following lapping compounds are recommended:

- 320 grit for removing small cuts
- 600 grit for removing scratches
- 1000 grit for finishing work
- 1200 grit for polishing

19.2.8 Adjusting rings

Install the lower ring and guide ring to the same position they were when removed, or to the manufacturer's specifications.

19.2.9 Bearing points

Grind all bearing areas with grinding compound to make sure they are round and true.

19.2.10 Assembly

After all the parts have been inspected, reconditioned or replaced, the valve should be assembled in accordance with the manufacturer's drawings and instructions. In fact assembly is the opposite process of disassembly. Each part should be clean, free from burrs and not damaged prior to assembly. Attention should be paid to the seats on the nozzle and disk. Seats must be free from nicks and scratches.

The following operation is included in assembly of the pressure relief valve:

- Secure the valve nozzle wrenching surface in a soft jaw vise with the nozzle seat vertical
- Check clearance between assembled parts
- Assemble all the parts according to the instructions
- Do not oil and seating surfaces
- Adjust spring to pop as close to the desired set pressure as possible
- Set blowdown carefully and accurately

19.2.11 Testing

All valves should be tested on the service medium for which they are intended. The following steps should be taken prior to mounting the valve to the test fixture:

- Clean the test fixture and purge the system for any loose contaminants.
- Ensure that test gauges are calibrated.
- Secure the valve inlet to the test fixture. Ensure to use the wrench surface of the nozzle when tightening.

Testing should be done in accordance with manufacturer's recommendations and the appropriate ASME Code. All test data should be recorded. Testing (see par. 20.3 for details) includes:

- Setting valve to set pressure
- Setting valve to blowdown
- Checking seat tightness

Changes to valve set pressure and or service medium (air to steam, etc.) may require changing of spring and/or other components. Consult the original valve manufacturer when making such changes.

19.2.12 Sealing

A pressure relief valve should be sealed to prevent unauthorized alteration or tampering. After final adjustment and acceptance by a quality control inspector, all external adjustments should be sealed with a safety seal.

The most common method is to use sealing wire to secure the cap to the spring housing and housing to the body. It may also be used to lock any blowdown adjuster pins into position. The wire is subsequently sealed with a lead seal, which may bear identification of the repair organization or setter's trademark.

A sealed cap showing a lead seal is indicated in Fig. 19.4.

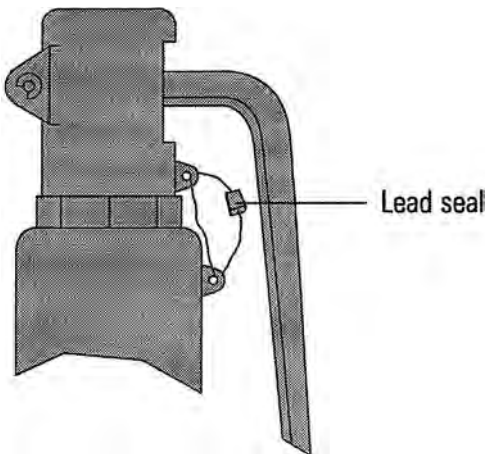


Figure 19.4 Sealed cap shows a lead seal. (Courtesy Spirax Sarco, U.K.)

19.3 Repair Nameplates

The repairer is required to install a repair nameplate on each repaired pressure relief valve. A repair nameplate identifying the repairer and date of repair should be attached to the valve. If set pressure has been changed, the new set pressure and new capacity should be indicated on the original nameplate or stamping. The new capacity determined by calculations based on which the valve was originally certified. The original nameplate should never be removed from the pressure relief valve.

A repair nameplate is shown in Fig. 19.5.

19.4 Documentation

Repair of pressure relief valves should be properly documented. The document should include condition, repair, and setting record for each pressure relief valve. A document form for pressure relief device is shown in Fig. 19.6.

REPAIRED BY VR NATIONAL BOARD VR CERTIFICATE NUMBER	<table style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="border-bottom: 1px solid black; text-align: center;">CERTIFICATE HOLDER</td> </tr> <tr> <td colspan="2" style="text-align: center;">(2)</td> </tr> <tr> <td colspan="2" style="border-bottom: 1px solid black; text-align: center;">(TYPE/MODEL NUMBER)</td> </tr> <tr> <td style="width: 50%; border-bottom: 1px solid black; text-align: center;">SET PRESSURE</td> <td style="width: 50%; border-bottom: 1px solid black; text-align: center;">CAPACITY</td> </tr> <tr> <td colspan="2" style="text-align: center;">(2)</td> </tr> <tr> <td colspan="2" style="border-bottom: 1px solid black; text-align: center;">REPAIR IDENTIFICATION</td> </tr> <tr> <td colspan="2" style="border-bottom: 1px solid black; text-align: center;">DATE REPAIRED</td> </tr> </table>	CERTIFICATE HOLDER		(2)		(TYPE/MODEL NUMBER)		SET PRESSURE	CAPACITY	(2)		REPAIR IDENTIFICATION		DATE REPAIRED	
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Figure 19.5 Pressure relief valve repair nameplate. (Courtesy National Board.)

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Chapter 20

Shop Testing

A pressure relief valve is tested in a shop to determine its performance. It is important to determine the set pressure and tightness of the valve before putting it into operation. The testing is usually performed on a test stand with facilities for applying pressure to a valve and indicating pressure applied. Most test stands have facilities for testing with either air or water, to simulate the media handled by pressure relief valves. Bottled nitrogen is used for high-pressure valves.

It is not possible to make accurate adjustments of pressure relief valves without some way of measuring their performance. The shop test indicates performance as closely as possible but does not exactly duplicate field conditions. In a shop test, the amount of liquid or gas a pressure relief valve can handle is limited, and it is not practical to measure relieving capacity or blowdown. A test stand with insufficient surge volume may fail, causing a distinct pop, which may result in an inaccurate set pressure. If used properly, a test stand can provide a good indication of the pressure at which the valve will open and its tightness.

The set pressure and tightness are tested according to the applicable codes. The following national codes are applied to test the performance of pressure relief valves:

- ASME Code Sec. 1—Power Boilers
- ASME Code Sec. IV—Heating Boilers
- ASME Code Sec. VIII, Division 1—Pressure Vessels
- ASME PTC 25—Power Test Code for Pressure Relief Devices
- API 510—Pressure Vessel Inspection Code
- API Std 527—Seat Tightness of Pressure Relief Valves

Pressure relief valves should be tested at intervals that are frequent enough to verify that the valves perform reliably. This may include testing pressure relief valves on newly installed equipment.

The intervals between pressure relief valve testing should be determined by the performance of the valves in the particular service concerned. Test intervals on pressure relief valves in typical process services should not exceed 5 years, unless service experience indicates that a longer interval is acceptable. For clean and noncorrosive services, maximum intervals may be increased to 10 years.

If service records indicate that a pressure relief valve was heavily fouled or stuck in the last inspection or test, the service interval should be reduced. The service records should be reviewed to determine the cause of the fouling or the reasons for the relief valve not operating properly.

20.1 Test Media

Generally, the medium for shop testing of pressure relief valves are air, nitrogen, water, and steam. All pressure relief valves are required to be tested on the service medium for which they are intended. Steam valves should be tested on steam, and air and gas valves should be tested on air.

20.1.1 Testing with air

Most test stands are designed to use air for testing of pressure relief valves. Air is nontoxic and readily available. Air is also compressible, causes valves to relieve with a short pop, and closely approximates operating conditions for pressure relief valves in hydrocarbon and other gas service. Air is generally used to test safety, relief, and pressure relief valves for set pressure and tightness.

20.1.2 Testing with nitrogen

Test stands are also designed to use nitrogen for testing of pressure relief valves. Generally, nitrogen is supplied in bottles, and these bottles can be connected to the test stand system.

20.1.3 Testing with water

Test stands may be including facilities for testing relief valves with a liquid test medium such as water. Water is nontoxic and inexpensive. Moreover, water allows close simulation of operating conditions. A water test is generally used for measuring set pressure, as very small water leaks often cannot be detected. Tightness tests are usually conducted with air. However, leakage tests can be done in accord with API Standard 527.

20.1.4 Testing with steam

Generally, steam is used for testing of safety valves. Steam is supplied by a steam pipe from a boiler room, or the test stand may include a small high-pressure boiler for supplying steam to the test stand.

The test should be conducted with dry saturated steam with 98% minimum quality. Capacity should be corrected to the dry saturated condition from other condition.

20.2 Test Stands

A test stand is the assembly of equipment and facilities required for testing pressure relief valves at the shop. Every safety valve repair shop should have a test stand so that it is available at any time. Though the designs of test stands vary, manufacturers offer test stands as package units (Fig. 20.1). Generally, the test stand consists of all the equipment and facilities required for testing.

20.2.1 Test stand with air system

The air system test stand includes a compressor or other source of high-pressure air, a supply reservoir, a test drum, or a surge tank. The source of air should be large to accumulate enough air to cause the valves to open at the set pressure. Figure 20.2 shows a schematic diagram of a test stand with an air supply system.



Figure 20.1 A package test stand. (Courtesy: Farris Engineering.)

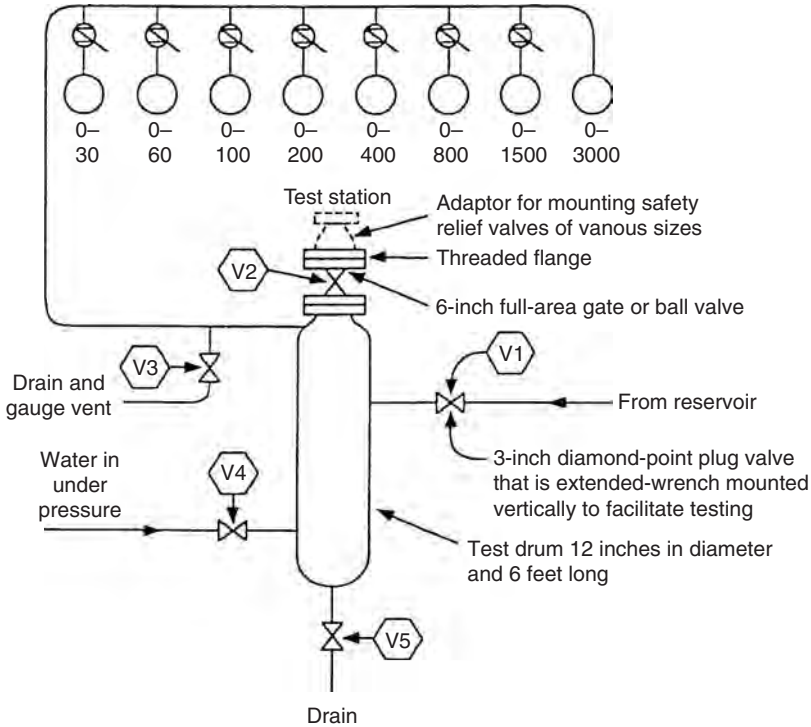


Figure 20.2 Layout of air supply system for safety relief valve testing. (From *API RP 576*.)

Construction. The air supply system should be constructed in such a way that air will be available at the possible highest pressure. The air pressure can be raised further by injecting water under pressure into the test drum until the required pressure is available.

The layout in Fig. 20.2 shows a single drum. Test drum pressure and piping are made of oxidation-resistant materials. Piping from reservoir to test stations is designed for minimum pressure drop.

The test station has been designed for valves with screwed connections. A duplicate station for flanged valves can be added if required. Flange valves should be secured to the test station by bolting, clamping, or use of a pneumatic clamping device.

The layout in Fig. 20.2 shows the following valves:

V1: plug valve on pipeline from reservoir to test drum

V2: globe valve on top of test drum

V3: gate valve for drain and pressure gauge vent

V4: gate valve on inlet water pipeline under pressure to test drum

V5: gate valve on drain line from test drum.

The layout shows eight pressure gauges with the following ranges:

Gauge no. 1: 0–30 psi

Gauge no. 2: 0–60 psi

Gauge no. 3: 0–100 psi

Gauge no. 4: 0–200 psi

Gauge no. 5: 0–400 psi

Gauge no. 6: 0–800 psi

Gauge no. 7: 0–1500 psi

Gauge no. 8: 0–3000 psi

Pressure gauges with additional ranges can be installed if required.

Operation. The operation of the valve test stand is simple. When the test stand is not in use, valves V1, V2, and V5 should be closed. Valve V3 should be opened to prevent possible buildup of pressure in the test drum if valve V1 is leaking.

The test drum should be blown down to remove any accumulation of dust or sediment. To blow the test drum, close valve V3, open valve V2, and release air through the drum by opening and closing valve V1. Follow the sequence below to test a valve:

- Close valve V2.
- Secure the valve to the test station.
- Open valve V2.
- If valve set pressure is lower than available air pressure, slowly increase pressure through valve V1 until the valve pops. Then close V1.
- If valve set pressure is higher than available air pressure, open valve V1 and fill test drum with maximum air pressure available. Then close valve V1. Open valve V4 and increase pressure by inserting water under pressure until valve opens. Then close valve V4 and drain water from the test drum by opening and closing valve V5.
- If necessary, adjust valve spring so that the safety relief valve opens at the required set pressure.
- Vent test drum to 90% of set pressure.
- Test safety relief valve for leakage.
- After satisfactory test, close valve V2.

Remove the safety relief valve from the test station. Loosen bolts or clamps to allow pressure in the adapter and valve nozzle to escape.

Vent the test drum through V3 to approximately 75% of the set pressure of the next valve to be tested. Repeat the above steps.

Pressure gauge calibration. Pressure gauges used on the test stand should give accurate reading of valve testing. In order to ensure accuracy, the pressure gauges should be calibrated from time to time.

The Dead Weight Tester is generally regarded as the most accurate method in calibration of pressure gauges, and is either used as a primary or secondary pressure standard. Various models are available in single or dual piston models with a range of 0-10,000 psi. Most of the Dead Weight Tester has a standard accuracy of 0.025%. A hydraulic dead weight tester is shown in Fig. 20.3

The operating principle of a dead weight tester is simple. When fluid pressure generated by a screw pump acts on the bottom of a vertically free floating piston, the force produced pushes the load free piston vertically upwards. The piston floats freely in its cylinder and the pressure in the circuit is determined by the weights loaded on the piston divided by the effective area of the piston with corrections for value of acceleration due to gravity, air buoyancy, surface tension and datum level difference.

20.2.2 Multipurpose test stand

Where air pressure is not available, a water system may be used to test relief valves. The water system test stand generally includes a



Figure 20.3 A hydraulic dead weight tester (Courtesy: TTI, Inc.)

positive-displacement pump that develops the necessary high pressure for piping, valves, and other instruments necessary to control the test. A multipurpose test stand is shown in Figs. 20.4 and 20.5.

The multipurpose valve test system comes complete with a built-in control console and test bottles. The system permits operation up to 3000 psi maximum allowable working pressure in air medium and 10,000 psi maximum allowable working pressure in water medium.

The test stand is equipped with a dual-channel digital read-out instrument with peak load. This instrument is designed to measure the pop and reset pressure and store the test data for recall until the next test is performed.

Both the air system test stand and the water system test stand use a manifold. Many different sizes of flanges are installed on the manifold for testing different types of valves. Several precision pressure gauges are connected to the manifold to cover the wide range of pressures required for testing. The pressure gauges should be calibrated and a calibration record should be maintained.

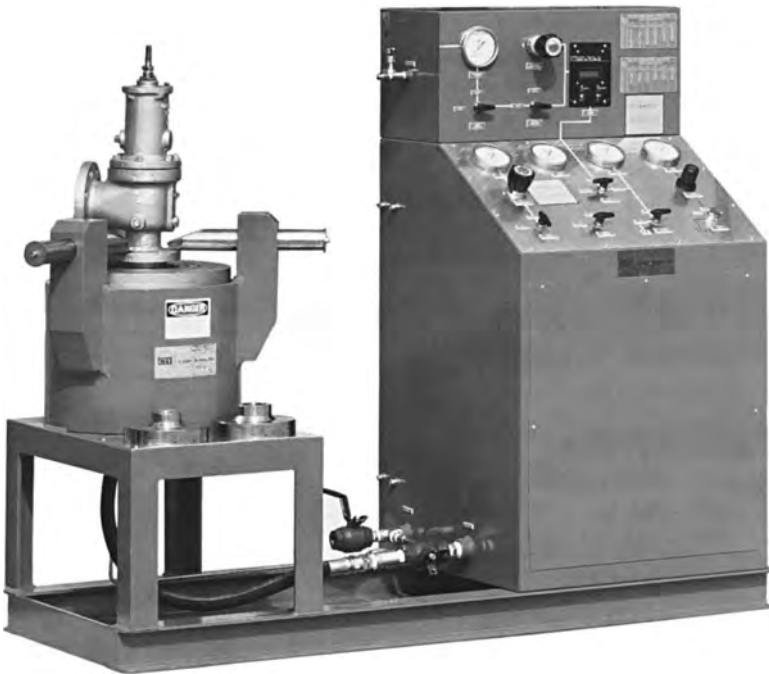


Figure 20.4 Universal test stand for testing by air and water. (Courtesy Calder Testers, Inc.)

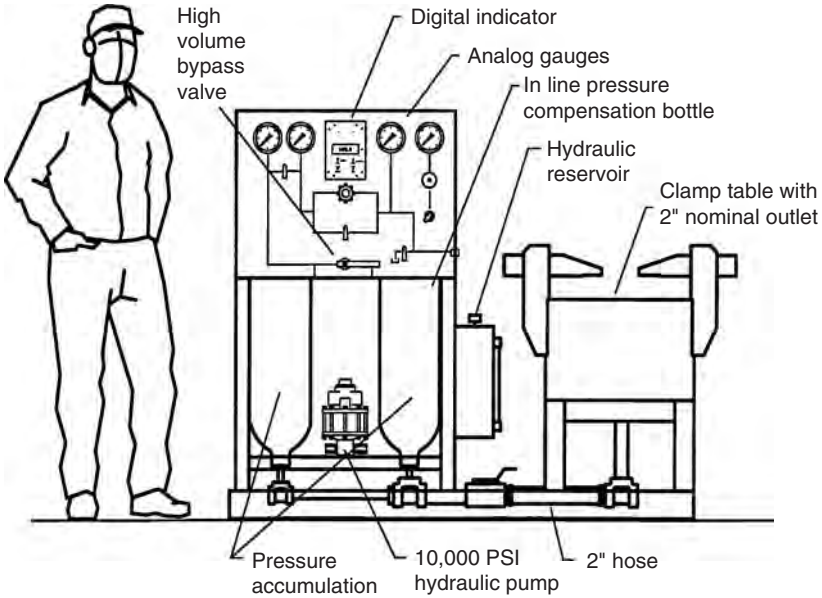


Figure 20.5 Safety relief valve air or water tester—schematic view. (Courtesy *Calder Testers, Inc.*)

20.2.3 Portable tester

A portable pressure relief valve tester (Fig. 20.6) is used for testing pressure relief valves on site instead of in the shop. This tester is suitable for testing range up to 3000 psi.

The portable unit is complete with test plate, clamps, controls, and adapters, all mounted in a heavy-duty powder-coated case with wheels and handles. The unit requires only high-pressure nitrogen or air to perform testing.



Figure 20.6 Portable pressure relief valve tester. (Courtesy *Barbee Engineered Testing Systems.*)

The clamping fixture includes an 18-in-square test plate with built in O-ring grooves, and four hold-down clamps with T-slots. The test unit has a 6-in dial, all stainless steel gauges, a mirror dial, and red-hand maximum-pressure pointers. Pressure ranges are 0–1500 psi and 0–3000 psi. The test control system includes a high-pressure nitrogen regulator, adjustable from 50 to 2500 psi.

Any shop interested in ordering this unit should specify test pressure ranges and sizes of valves to be tested.

20.3 Testing

A pressure relief valve should always be tested after any maintenance or repair work. This testing is usually done on a test stand operating on compressed air (for air or gas applications) or pressurized water (for liquid applications). The testing includes set pressure, blowdown, and seat tightness.

20.3.1 Set pressure

Full pressure valve actuation is the most reliable technique to ensure that the pressure relief valves are operating properly. After the valve has been adjusted, it should be popped at least once to prove the accuracy of the setting. The manufacturer's recommendations should be closely followed when setting pressure of any pressure relief valve.

The following steps should be followed in setting the pressure on pressure relief valves:

- Bring the system pressure up slowly until set (pop) point is reached or 10% above, whichever occurs first. If the valve does not pop, close the test vessel isolation valve, vent pressure, and adjust the set pressure.
- Turn the compression screw clockwise to increase the set pressure; turn the compression screw counterclockwise to decrease the set pressure.
- Do not adjust the set pressure when the pressure relief valve inlet pressure is more than 50% of set pressure.
- Tighten the compression screw locknut after each set pressure adjustment.
- Pop the valve a minimum of two times after final adjustments, to verify set pressure repeatability.
- Follow ASME set pressure and blowdown requirements when setting valves for ASME Code service.
- The following temperature correction is required for valves which are tested and set in air, but installed in steam service:

Correction Factor to Compensate for Temperature above 250°F

Specified set pressure	Increase in setting
All set pressures	5%

Table 20.1 shows set pressure tolerance for pressure relief valves under ASME codes and non-code.

20.3.2 Blowdown

It may be necessary to make minor adjustments to the warn ring and control ring to obtain required blowdown and proper valve performance. The following procedures are used to increase or decrease the blowdown by adjusting the control ring:

- If the control ring is moved downward toward the nozzle seat, it increases blowdown, sharpens pop action (high lift), and increases secondary lift.
- If the control ring is moved upward, it reduces blowdown.

TABLE 20.1 Set Pressure Tolerance, Blowdown, and Overpressure

SET PRESSURE TOLERANCE/BLOWDOWN/OVERPRESSURE			
Set Pressure psig or inches HG	Set Pressure Tolerance	Blowdown	Overpressure
ASME Section I - Power Boilers			
15 to 66	± 2 psig	2 to 4 psig	2 psig
67 to 70	± 2 psig	2 psig to 6%	3%
71 to 100	± 3%	2 psig to 6%	3%
101 to 250	± 3%	2% to 6%	3%
251 to 300	± 3%	2% to 15 psig	3%
301 to 375	± 10 psig	2% to 15 psig	3%
376 to 1000	± 10 psig	2% to 4%	3%
1001 and higher	± 1%	2% to 4%	3%
ASME Section IV - Heating Boilers			
Steam ≤ 15 psig	± 2 psig	2 to 4 psig	33.3%
Hot Water 15 to 60	± 3 psig	N/A *	10%
Hot Water 60 and higher	± 5%	N/A *	10%
ASME Section VIII - Pressure Vessels			
15 to 30	± 2 psig	N/A *	3 psig
31 to 70	± 2 psig	N/A *	10%
71 and higher	± 3%	N/A *	10%
Non-Code Set Pressure Tolerance			
5	± .5 psig	N/A *	3 psig
6 to 9	± 1 psig	N/A *	3 psig
10 to 14	± 2 psig	N/A *	3 psig
Vacuum Set Point Tolerances			
0 to 9	± 1 inch HG	N/A *	6 inch HG
10 to 19	± 2 inches HG	N/A *	6 inch HG
20 and higher	± 4 inches HG	N/A *	6 inch HG

* Contact factory for accurate blowdown setting.
Courtesy Spence Engineering Company.

Table 20.1 shows blowdown tolerance for pressure relief valves under ASME codes and non-code.

20.3.3 Seat tightness test

A seat tightness test is performed on all pressure relief valves after final set pressure and blowdown requirements have been satisfied. It is extremely important to practice safety precautions when performing seat tightness tests on steam and air.

Follow the requirements given below for seat tightness test:

- Tightness requirement—steam: No visible signs of leakage for 1 min with valve inlet pressure held at 90% of set pressure.
- Tightness requirement—air: No audible leakage for 1 min with inlet pressure held at 90% of set pressure.

Figure 20.7 illustrates a typical test arrangement for determining seat tightness of a pressure relief valve. Leakage measurement should be made by using 5/16-in.-OD tubing with a 0.035-in wall. The tube end should be cut square and smooth, and be set parallel to and $\frac{1}{2}$ in length below the surface of the water, according to API RP 527.

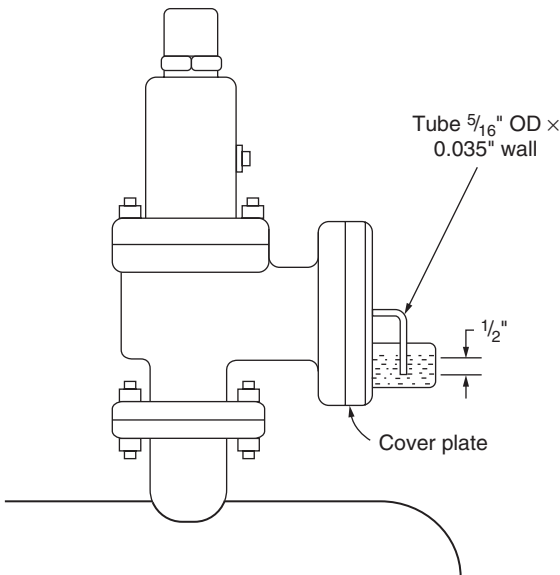


Figure 20.7 Air receiver.

TABLE 20.2 Acceptable Leakage Rates

LEAK TESTING (in accordance with API 527)

Test Pressures - ≤ 50 psig test at 5 psig below set pressure
> 50 psig test at 90% of set pressure

Service	Set Pressure psig	Size	Acceptable Leakage rate
Metal Seats			
Steam	15 – higher	All	No audible or visible leakage for 1 min
Air	15 – 1000	≤ .307 sq in orifice	40 bubbles/min
		> .307 sq in orifice	20 bubbles/min
Liquid	15 – higher	< 1" inlet	10 cc/hr per inch of inlet size
		≥ 1" inlet	10 cc/hr
Soft Seats			
Steam	15 – higher	All	No audible or visible leakage for 1 min
Air	15 – 1000	≤ .307" orifice size	0 bubbles/min
		> .307" orifice size	0 bubbles/min
Liquid	15 – higher	< 1" inlet size	0 cc/hr per inch of inlet size
		≥ 1" inlet size	0 cc/hr

Courtesy Spence Engineering Company.

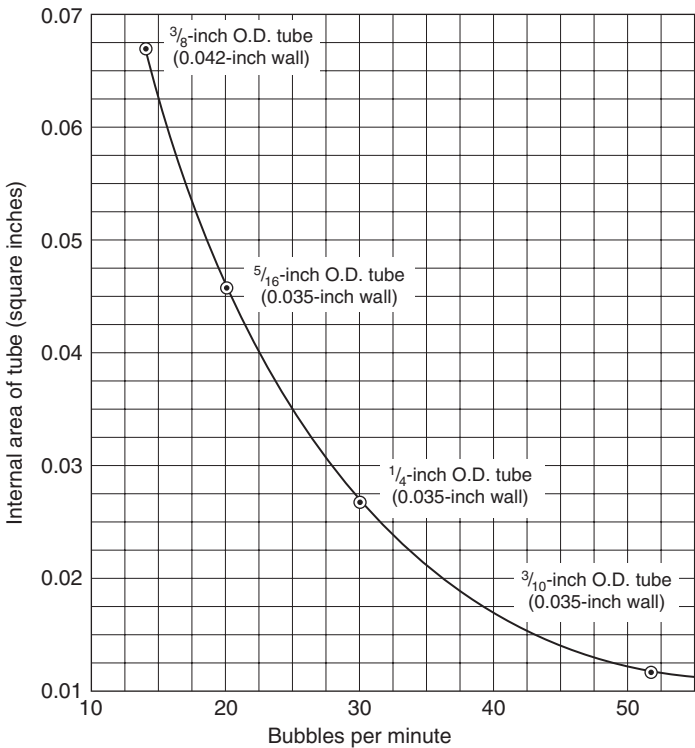


Figure 20.8 Leakage rate @ 0.3 ft³ in 24 hours. (From API RP 576.)

The following steps should be performed to determine the leakage rate of safety relief valves:

- Mount the valve vertically as shown in Fig. 20.7.
- Hold the pressure at the pressure relief valve inlet at 90% of set pressure immediately after popping.
- Use air at ambient temperature as the pressure medium for gas/vapor valves.
- For estimating actual leakage, 20 bubbles per minute equals up to approximately 0.30 standard cubic feet per 24 hours.

The Table 20.2 and Figure 20.8 indicate acceptable leakage rate when leaktesting is performed in accordance with API 527. Where applicable, the bonnet, bellows, gasketed joints, and auxiliary piping should be inspected for leakage.

20.4 Test Reports

A suitable system of keeping records is essential to the effective administration and control of any pressure-relieving device program in a process industry. The system should be simple and as clear as possible.

A test report on pressure relief devices should be recorded during the test of the pressure relief valves at the shop. The test report for each valve should indicate: set pressure, pop pressure, type of test used (standard or dry seal), disposition, and condition of the valve. The person who tested the valve should sign this report and date it. A typical testing report for a pressure-relieving device is shown in Fig. 20.9.

20.5 Rupture Disk Testers

A rupture disk is tested for burst pressure. Rupture disks should be thoroughly examined at intervals determined on the basis of service. Various testers are available in the market for testing of rupture disks. A portable rupture disk is shown in Fig. 20.10.

TESTING REPORT FOR A PRESSURE-RELIEVING DEVICE

Fill in this report for each device tested and send this report to the quality-assurance group.

Date tested _____	Type _____
Device no. _____	Make _____
Unit _____	Style _____
Location _____	Material _____
Size _____	Special material _____
Inlet _____	Body _____
Orifice _____	Trim _____
Outlet _____	

Fill in blanks below on one side only.

From unit	From spare stock or check of new device
Date last bench tested _____	Set pressure _____
Popped at _____	Check pressure _____
Set pressure _____	
Check (dirty pop) pressure _____	
If set pressure changed, new set pressure _____	
Test used	
Standard _____	
Dry seal _____	
Disposition	
To unit _____	
To spare _____	
To junk _____	
Condition	
Leaking _____	
Stuck _____	
Fouled _____	
Corroded _____	
Tested by _____	

Figure 20.9 Test report for a pressure relief valve. (From API RP 576.)



Figure 20.10 Portable rupture disk tester. (Courtesy Calder Testers, Inc.)

Terminology

21.1 Terminology for Pressure Relief Valves

Accumulation: Accumulation is the pressure increase over the maximum allowable working pressure (MAWP) of the vessel during discharge through the pressure relief valve. Accumulation is expressed as a percentage of that pressure, or actual pressure units.

Backflow preventer: A backflow preventer is a part of a pilot-operated pressure relief valve used to prevent the valve from opening and flowing backwards when the pressure at the valve outlet is greater than the pressure at the valve inlet.

Back pressure: Back pressure is the pressure on the discharge side of a safety relief valve. Back pressure is expressed as a percentage of set pressure, or actual pressure units.

Blowdown: Blowdown is the difference between set pressure and reseating pressure of a pressure relief valve.

Blowdown pressure: The value of decreasing inlet static pressure at which no further discharge is detected at the outlet of a pressure relief valve after the valve has been subjected to a pressure equal to or above the popping pressure.

Breaking pin: The load-carrying element of a breaking pin device.

Built-up back pressure: Built-up back pressure is pressure which develops at the valve outlet as a result of flow, after the safety valve has been opened.

Chatter: Chatter is the abnormal, rapid reciprocating motion of the movable parts of a valve, in which the disk contacts the seat.

Closing pressure: Closing pressure is the point at which the valve recloses. Closing pressure on a test stand may differ from the blowdown, which is the closing pressure under actual service conditions.

Coefficient of discharge: The ratio of the measured relieving capacity to the theoretical relieving capacity.

Cold differential test pressure (CDTP): The inlet static pressure at which a pressure relief valve is adjusted to open on the test stand. This test pressure includes corrections for service conditions of superimposed back pressure and/or temperature.

Constant back pressure: A superimposed back pressure which is constant with time.

Differential between operating and set pressures: The operating pressure should not exceed 90% of the set pressure. It is recommended that the valve be set as high above the operating pressure as possible.

Flutter: Flutter is abnormal, rapid reciprocating motion of the movable parts of a valve, in which the disk does not contact the seat.

Leak test pressure: The specified inlet static pressure at which a quantitative seat leakage test is performed in accordance with a standard procedure.

Lift: Lift is the actual travel of the disk away from the closed position when a valve is relieving.

Maximum allowable working pressure: Maximum allowable working pressure (MAWP) is the maximum gauge pressure permissible in a vessel at a designated temperature. It is the highest pressure at which the primary safety relief valve is set.

Operating pressure: Operating pressure is the gauge pressure to which the vessel is normally subjected during operation.

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

Overpressure: Overpressure is a pressure increase over the set pressure of the primary relieving service. Generally, overpressure is expressed as a percentage of set pressure.

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

Primary pressure: The pressure at the inlet in a pressure relief valve.

Rated capacity: Rated capacity is the percentage of measured flow at an authorized percent overpressure submitted by the applicable code. Rated capacity is expressed in:

- pounds per hour (lb/hr) or kilograms per hour (kg/h) for vapor;
- standard cubic feet per minute (scfm) or normal cubic meters per minute (lncm/min) or m³/min for gases; and
- gallons per minute (gpm) or liters per minute (L/min) for liquids.

Resealing pressure: The value of decreasing inlet static pressure at which no further leakage is detected after closing.

Seat tightness pressure: Seat tightness pressure is the specified inlet static pressure at which a quantitative seat leakage test is performed in accordance with a standard procedure.

Secondary pressure: The pressure existing in the passage between the actual discharge area and the valve outlet in a safety, safety relief, or relief valve.

Set pressure: Set pressure is the gauge pressure at the valve inlet, for which the safety relief valve has been adjusted to open under service conditions. In liquid service, the inlet pressure at which the valve starts to discharge determines set pressure. In gas or vapor service, the inlet pressure at which the valve pops determines the set pressure.

Simmer: Simmer is characterized by the audible passage of a gas or vapor across the seating surfaces just prior to “pop.” The difference between this “start-to-open pressure” and set pressure is simmer. Generally, simmer is expressed as a percentage of set pressure.

Superimposed back pressure: Superimposed back pressure is the pressure in the discharge header before the safety valve opens. There are two types of superimposed back pressure:

Constant superimposed. This type of back pressure remains essentially at a fixed value (constant) and exists (superimposed) continuously prior to and during opening of the valve. (e.g., 20 psig/1.38 bar).

Variable superimposed. This type of back pressure varies or changes over a range from a minimum to a maximum, or vice versa. (e.g., 0 to 20 psig/1.38 bar). The actual back pressure at any specific time depends on conditions in the piping system to which the outlet of the valve is connected.

Valve trim: Valve trim includes the nozzle and disk.

21.2 Terminology for Rupture Disks

Burst pressure: The burst pressure is the inlet static pressure at which a rupture disk device functions.

Knife blade: A component with multiple blades used with reverse-acting rupture disks to cut the disk when it reverses.

Lot of rupture disks: A lot of rupture disks are those disks manufactured of a material at the same time, and of the same size, thickness, type, heat, and manufacturing process, including heat treatment.

Marked burst pressure: A marked burst pressure is the pressure marked on the rupture disk device, or its nameplate, or on the tag of the rupture disk, indicating the burst pressure at the coincident disk temperature.

Specified burst pressure: A specified burst pressure is the increasing inlet static pressure at a specified temperature, at which a rupture disk is designed to function.

Rupture disk: A rupture disk is the pressure-containing element in a rupture disk device that is designed to burst at its rated pressure at a specified temperature.

Rupture disk holder: A rupture disk holder is the structure which clamps a rupture disk in position.

Vacuum support: A vacuum support is a component of a rupture disk to prevent flexing due to upstream vacuum or downstream back pressure.

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1914 ASME Boiler Code*

The following excerpts are reprinted from the first boiler code, “Rules for the Construction of Stationary Boilers and for Allowable Working Pressures” (ASME, New York, 1914).

Part I NEW INSTALLATIONS Section 1 Power Boilers

Safety Valves

- 269** *Safety Valve Requirements.* Each boiler shall have two or more safety valves, except a boiler for which one safety valve is 3-in. size or smaller is required by these Rules.
- 270** The safety valve capacity for each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than six percent above the maximum allowable working pressure, or more than six percent above the highest pressure to which any valve is set.
- 271** One or more safety valves on every boiler shall be set at or below the maximum allowable working pressure. The remaining valves may be set within a range of three percent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed ten percent of the highest pressure to which any valve is set.
- 272** Safety valves shall be of the direct spring loaded pop type with seat and bearing surface of the disc either inclined at an angle of about 45 deg. or flat at an angle of about 90 deg to the center line of spindle. The vertical lift of the valve disc measured immediately after sudden lift due to the pop may be made any amount desired up to a maximum of 0.15 in. respective

*Courtesy ASME International.

of the size of the valve. The nominal diameter measured at the inner edge of the valve seat shall be not less than 1 in. or more than 4½ in.

- 273** Each safety valve shall have plainly stamped or cast on the body:
- a The name or identifying trade-mark of the manufacturer
 - b The nominal diameter with the words “Bevel Seat” or “Flat Seat”
 - c The steam pressure at which it is set to blow
 - d The lift of the valve disc from its seat, measured immediately after sudden lift due to the pop
 - e The weight of steam discharged in pounds per hour at the pressure for which it is set to blow.
- 274** The minimum capacity of a safety valve or valves to be placed on a boiler shall be determined on the basis of 6 lb. of steam per hour per sq. ft. of boiler heating surface for water tube boilers, and 5 lb. for all other types of power boilers, and upon the relieving capacity marked on the valves by the manufacturer, provided such marked relieving capacity does not exceed that given in Table 8. In case the relieving capacity marked on the valve or valves exceeds the maximum given in Table 8, the minimum safety valve capacity shall be determined on the basis of the maximum relieving capacity given in Table 8 for the particular size of valve and working pressure for which it was constructed. The heating surface shall be computed for that side of the boiler surface exposed to the products of combustion, exclusive of the superheating surface. In computing the heating surface for this purpose only the tubes, shells, tube sheet and the projected area of headers need be considered.
- 275** Safety valve capacity may be checked in any one of three different ways, and if found sufficient, additional capacity need not be provided:
- a By making an accumulation test, by shutting off all other steam discharge outlets from the boiler and forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond six per cent as specified in Par. 270.
 - b By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel.
 - c By determining the maximum evaporative capacity by measuring the feed water. The sum of the safety valve capacities marked on the valves, shall be equal to or greater than the maximum evaporative capacity of the boiler.
- 276** When two or more safety valves are used on a boiler, they may be either separate or twin valves made by mounting individual valves on Y-bases, or duplex, triplex or multiplex valves having two or more valves in the same body casing.
- 277** The safety valve or valves shall be connected to the boiler independent of any other steam connection, and attached as close as possible to the boiler, without any unnecessary intervening pipe or fitting. Every safety valve shall be connected so as to stand in an up right position, with spindle vertical, when possible.

- 278 Each safety valve shall have full sized direct connection to the boiler. No valve of any description shall be placed between the safety valve and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, it shall be not less than the full size of the valve, and shall be fitted with an open drain to prevent water from lodging in the upper part of the safety valve or in the pipe.
- 279 If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed that as to avoid any possibility of restriction of the steam passage due to deposit. When an elbow is placed on a safety valve discharge pipe, it shall be located close to the safety valve outlet or the pipe shall be securely anchored and supported. All safety valve discharges shall be located or piped as to be carried clear from running boards or working platforms used in controlling the main stop valves of boilers or steam headers.
- 280 When a boiler is fitted with two or more safety valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined area of all of the safety valves with which it connects.
- 281 Safety valves should operate without chattering and shall be set and adjusted as follows: To close after blowing down not more than 4 lb. on boilers carrying an allowed pressure less than 100 lb. per sq. in. gage. To close after blowing down not more than 6 lb. on boilers carrying pressures between 100 and 200 lb. per sq. in. gage inclusive. To close after blowing down not more than 8 lb. on boilers carrying over 200 lb. per sq. in. gage.
- 282 Each safety valve used on a boiler shall have a substantial lifting device, and shall have the spindle so attached that the valve disc can be lifted from its seat a distance not less than one-tenth of the nominal diameter of the valve, when there is no pressure on the boiler.
- 283 The seats and discs of safety valves shall be of non-ferrous material.
- 284 Springs used in safety valves shall not show a permanent set exceeding $\frac{1}{32}$ in. ten minutes after being released from a cold compression test closing the spring solid.
- 285 The spring in a safety valve shall not be used for any pressure more than 10 percent above or below that for which it was designed.
- 286 A safety valve over 3-in. size, used for pressures greater than 15 lb. per sq. in. gage, shall have a flanged inlet connection. The dimensions of the flanges shall conform to the American standard in Tables 15 and 16 of the Appendix.
- 287 When the letters *A S M E Std* are plainly stamped or cast on the valve body this shall be a guarantee by the manufacturer that the valve conforms with the details of construction herein specified.
- 288 Every superheater shall have one or more safety valves near the outlet. The discharge capacity of the safety valve or valves on an attached superheater may be included in determining the number and sizes of the safety valves for the boiler, provided there are no intervening valves between the superheater safety valve and the boiler.

- 289 Every safety valve used on a superheater, discharging superheated steam, shall have a steel body with a flanged inlet connection, and shall have the seat and disc of nickel composition or equivalent material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.
- 290 Every boiler shall have proper outlet connections for the required safety valve or valves, independent of any other steam outlet connection of any internal pipe in the steam space of the boiler, the area of opening to be at least equal to the aggregate area of all of the safety valves to attach thereto.

Section 2 Heating Boilers

- 347 *Outlet connections for safety and Water Relief Valves.* Every boiler shall have proper outlet connections for the required safety, or water relief valve or valves, independent of any other connection outside of the boiler or any internal pipe in the boiler, the area of the opening to be at least equal to the aggregate area of all of the safety valves with which it connects. A screwed connection may be used for attaching a safety valve to a heating boiler. This rule applies to all sizes of safety valves.
- 348 *Safety Valves.* Each steam boiler shall be provided with one or more safety valves of the spring-pop type which cannot be adjusted to a higher pressure than 15 lb. per sq. in.
- 349 *Water Relief Valves.* Each hot water boiler shall be provided with one or more relief valves with open discharges having outlets in plain sight.
- 350 A *hot-water* boiler built for a maximum allowable working pressure of 30 lb. per sq. in. and used exclusively for heating buildings, or for hot-water supply, shall be provided with a water relief valve or valves, which cannot be adjusted for a pressure in excess of 30 lb. per. sq. in.
- 351 No safety or water relief valve shall be smaller than 1 in. nor greater than 4½ in. nominal size.
- 352 When two or more safety or water relief valves are used on a boiler they may be single or twin valves.
- 353 Safety or water relief valves shall be connected to boilers independent of other connections and be attached directly or as close as possible to the boiler, without any intervening pipe or fittings except the Y-base forming a part of the twin valve or the shortest possible connection. A safety or water relief valve shall not be connected to an internal pipe in the boiler. Safety valves shall be connected so as to stand upright, with the spindle vertical, when possible.
- 354 No shut-off of any description shall be placed between the safety or water relief valves and boilers, nor on discharge pipes between them and the atmosphere.
- 355 When a discharge pipe is used its area shall be not less than the area of the valve on aggregate area of the valves with which it connects, and the

discharge pipe shall be fitted with an open drain to prevent water from lodging in the upper part of the valve or in the pipe. When an elbow is placed on a safety or water relief valve discharge pipe, it shall be located close to the valve outlet or the pipe shall be securely anchored and supported. The safety or water relief valves shall be so located and piped that there will be no danger of scalding attendants.

- 356** Each safety valve used on a *steam* heating boiler shall have a substantial lifting device which shall be so connected to the disc that the latter can be lifted from its seat a distance of not less than one-tenth of the nominal diameter of the seat when there is no pressure on the boiler. A relief valve used on a hot-water heating boiler need not have a lifting device.
- 357** Every safety valve or water relief valve shall have plainly stamped on the body or cast thereon the manufacturer's name or trade mark and the pressure at which it is set to blow. The seats and discs of safety or water relief valves shall be made of non-ferrous material.
- 358** The minimum size of safety or water relief valve or valves for each boiler shall be governed by the grate area of the boiler, as shown by Table 9.* When the conditions exceed those on which Table 9 is based, the following formula for bevel and flat seated valves shall be used:

$$A = \frac{W \times 70}{P} \times 11$$

in which

A = area of direct spring-loaded safety valve per square foot of grate surface, sq. in.

W = weight of water evaporated per square foot of grate surface per second, lb.

P = pressure (absolute) at which the safety valve is set to blow, lb. per sq. in.

- 359** *Double Grate Down Draft Boilers.* In determining the number and size of safety valves or water relief valves the grate area shall equal the area of the upper grate plus one-half of the area of the lower grate.
- 360** *Boilers Fired With Oil or Gas.* In determining the number and size of safety or water relief valve or valves for a boiler using gas or liquid fuel, 15 sq. ft. of heating surface shall be equivalent to one square foot of grate area. If the size of grate for use of coal is evident from the boiler design, such size may be the basis for the determination of the safety valve capacity.

*Tables 8 & 9 are not furnished here.

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Appendix B

Spring-Loaded Pressure Relief Valve Specification Sheet*

SPRING-LOADED PRESSURE RELIEF VALVE SPECIFICATION SHEET			Sheet No. _____ Page _____ of _____	
			Requisition No. _____	
			Job No. _____	
			Date _____	
			Revised _____	
			By _____	
GENERAL			BASIS OF SELECTION	
1.	Item Number:		5.	Code: ASME VIII ☐ Stamp Required: Yes ☐ No ☐
2.	Tag Number:		Other ☐ Specify: _____	
3.	Service, Line, or Equipment Number:		6.	Comply with API 526: Yes ☐ No ☐
4.	Number Required:		7.	Fire ☐ Other ☐ Specify: _____
			8.	Rupture Disk: Yes ☐ No ☐
VALVE DESIGN			MATERIALS	
9.	Design Type:		17.	Body:
	Conventional ☐ Bellows ☐ Balanced Piston ☐		18.	Bonnet:
10.	Nozzle Type: Full ☐ Semi ☐		19.	Seat (Nozzle): _____ Disk: _____
	Other ☐ Specify: _____		20.	Resilient Seat:
11.	Bonnet Type: Open ☐ Closed ☐		21.	Guide:
12.	Seat Type: Metal-to-Metal ☐ Resilient ☐		22.	Adjusting Ring(s):
13.	Seat Tightness: API 527 ☐		23.	Spring: _____ Washer: _____
	Other ☐ Specify: _____		24.	Bellows:
CONNECTIONS			25.	Balanced Piston:
14.	Inlet Size: _____	Rating: _____ Facing: _____	26.	Comply with NACE MR0175: Yes ☐ No ☐
15.	Outlet Size: _____	Rating: _____ Facing: _____	27.	Other ☐ Specify: _____
16.	Other ☐ Specify: _____			
SERVICE CONDITIONS			ACCESSORIES	
33.	Fluid and State:		28.	Cap: Screwed ☐ Bolted ☐
34.	Required Capacity per Valve and Units:		29.	Lifting Lever: Plain ☐ Packed ☐ None ☐
35.	Molecular Weight or Specific Gravity:		30.	Test Gag: Yes ☐ No ☐
36.	Viscosity at Flowing Temperature and Units:		31.	Bug Screen: Yes ☐ No ☐
37.	Operating Pressure and Units:		32.	Other ☐ Specify: _____
38.	Set Pressure and Units:			
39.	Blowdown: Standard ☐ Other ☐			
40.	Latent Heat of Vaporization and Units:			
41.	Operating Temperature and Units:		SIZING AND SELECTION	
42.	Relieving Temperature and Units:		49.	Calculated Orifice Area (in square inches):
43.	Built-up Back Pressure and Units:		50.	Selected Effective Orifice Area (in square inches):
44.	Superimposed Back Pressure and Units:		51.	Orifice Designation (letter):
45.	Cold Differential Test Pressure and Units:		52.	Manufacturer:
46.	Allowable Overpressure in Percent or Units:		53.	Model Number:
47.	Compressibility Factor, Z:		54.	Vendor Calculations Required: Yes ☐ No ☐
48.	Ratio of Specific Heats:			

*From API RP 520, Part I.

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C

Pilot-Operated Pressure Relief Valve Specification Sheet*

*From API RP 520, Part I.

PILOT-OPERATED PRESSURE RELIEF VALVE SPECIFICATION SHEET		Sheet No. _____ Page of	
		Requisition No. _____	
		Job No. _____	
		Date _____	
		Revised _____	
		By _____	
GENERAL		BASIS OF SELECTION	
1. Item Number:		5. Code: ASME VIII: ☐ Stamp Required: Yes ☐ No ☐	
2. Tag Number:		Other ☐ Specify:	
3. Service, Line, or Equipment Number:		6. Comply with API 526: Yes ☐ No ☐	
4. Number Required:		7. Fire ☐ Other ☐ Specify:	
		8. Rupture Disk: Yes ☐ No ☐	
VALVE DESIGN		MATERIALS, MAIN VALVE	
9. Design Type: Piston ☐ Diaphragm ☐ Bellows ☐		20. Body:	
10. Number of Pilots:		21. Seat (Nozzle): Piston:	
11. Pilot Type: Flowing ☐ Nonflowing ☐		22. Resilient Seat: Seals:	
12. Pilot Action: Pop ☐ Modulating ☐		23. Piston Seal:	
13. Pilot Sense: Internal ☐ Remote ☐		24. Piston Liner/Guide:	
14. Seat Type: Metal-to-Metal ☐ Resilient ☐		25. Diaphragm/Bellows:	
15. Seat Tightness: API 527 ☐		MATERIALS, PILOT	
Other ☐ Specify:			
16. Pilot Vent: Atmosphere ☐ Outlet ☐			
Other ☐ Specify:		26. Body/Bonnet:	
		27. Internals:	
		28. Seat: Seals:	
CONNECTIONS		29. Diaphragm:	
		30. Tubing/Fittings:	
14. Inlet Size: Rating: Facing:		31. Filter Body: Cartridge:	
15. Outlet Size: Rating: Facing:		32. Spring:	
16. Other ☐ Specify:		33. Comply with NACE MR0175: Yes ☐ No ☐	
		34. Other ☐ Specify:	
SERVICE CONDITIONS		ACCESSORIES	
43. Fluid and State:		35. External Filter: Yes ☐ No ☐	
44. Required Capacity per Valve and Units:		36. Lifting Lever: Plain ☐ Packed ☐ None ☐	
45. Molecular Weight or Specific Gravity:		37. Field Test Connection: Yes ☐ No ☐	
46. Viscosity at Flowing Temperature and Units:		38. Field Test Indicator: Yes ☐ No ☐	
47. Operating Pressure and Units:		39. Backflow Preventer: Yes ☐ No ☐	
48. Set Pressure and Units:		40. Manual Blowdown Valve: Yes ☐ No ☐	
49. Blowdown: Standard ☐ Other ☐		41. Test Gauge: Yes ☐ No ☐	
50. Latent Heat of Vaporization and Units:		42. Other ☐ Specify:	
51. Operating Temperature and Units:		SIZING AND SELECTION	
52. Relieving Temperature and Units:			
53. Built-up Back Pressure and Units:		59. Calculated Orifice Area (in square inches):	
54. Superimposed Back Pressure and Units:		60. Selected Effective Orifice Area (in square inches):	
55. Cold Differential Test Pressure and Units:		61. Orifice Designation (letter):	
56. Allowable Overpressure in Percent or Units:		62. Manufacturer:	
57. Compressibility Factor, Z:		63. Model Number:	
58. Ratio of Specific Heats:		64. Vendor Calculations Required: Yes ☐ No ☐	

Rupture Disk Specification Sheet*

RUPTURE DISK DEVICE SPECIFICATION SHEET		Sheet No. _____ Page _____ of _____	
		Requisition No. _____	
		Job No. _____	
		Date _____	
		Revised _____	
By _____			
General			
1. Item Number		3. Service, Line, or Equip. No.	
2. Tag Number		4. Design Code or Standard	
Service Conditions (include applicable units)			
5. Vessel or Piping MAWP			
6. Fluid			
7. Fluid State (initiating rupture)			
8. Fluid State (relieving conditions)			
9. Required Relieving Capacity			
10. Molecular Weight or Specific Gravity			
11. Viscosity at Relieving Temperature			
12. Compressibility Factor (Z)			
13. Specific Heat Ratio			
14. Normal Maximum Operating Pressure			
15. Normal Maximum Operating Temperature			
16. Pressure Fluctuations (static, cyclic, pulsating)			
17. Superimposed Back Pressure			
18. Built-up Back Pressure			
19. Back Pressure			
20. Inlet Vacuum Conditions			
21. Outlet Vacuum Conditions			
22. Disk Located Upstream of Valve (yes/no)			
23. Disk Located Downstream of Valve (yes/no)			
24. Nonfragmenting Design (yes/no)			
Connections			
25. Nominal Pipe Size		27. Flange Face (inlet/outlet)	
26. Flange Standard & Class		28. Piping Schedule or Bore	
Rupture Disk Holder		Rupture Disk	
29. Holder Tag No.		41. Nominal Disk Size	
30. Nominal Holder Size		42. Disk Type	
31. Design Type		43. Model Designator	
32. Model Designator		44. Quantity Required	
33. Quantity Required		45. Manufacturing Range	
34. Holder Material (inlet)		46. Specified Burst Temperature	
35. Holder Material (outlet)		47. Specified Burst Pressure	
36. Gauge Tap (yes/no) & Size		48. Max Marked Burst Pressure	
Accessories		49. Min Marked Burst Pressure	
37. Studs & Nuts (y/n) & Matl		50. Operating Ratio	
38. Jackscrews (yes/no)		51. Max Flow Resistance K ₉₀	
39. Telltale Assy (y/n) & Matl		52. Rupture Disk Materials	
40. Other			
		53. Manufacturer's Data	

Note: Indicate items to be filled in by the manufacturer with an asterisk (*).

*From API RP 520, Part I.

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E

ASME Application for Accreditation*

*Courtesy ASME International.



ASME International

Three Park Avenue, New York, NY 10018

ASME

Application for Accreditation

Company:

(Company name as it will appear on the Certificate)

Division:

(Division, department, etc., if it is to appear on the Certificate)

This application is for the following location:

Address:

(Give full address)

City

State

Country

Postal code

___ Plant

___ Field Site

___ New

___ Renewal

If renewal, complete the following:

Current Certificate Number(s):

Expiration date:

Check the Certificate(s) and stamps being applied for:

___ *A Assembly, boilers

___ *M Miniature boilers

___ *PP Pressure piping

___ *S Power boilers

___ *E Electric boilers

___ V Boiler safety valves, manufacturer

___ V Boiler safety valves, assembler

___ *H Heating boilers

___ H Heating boilers, cast iron

___ *HLW Lined potable water heaters

___ HV Heating boiler safety valves

___ *U Pressure vessels, Div. 1

___ UV Pressure vessel safety valves, manufacturer, Div. 1 & 2

___ UV Pressure vessel safety valves, assembler, Div. 1 & 2

___ UD Rupture disk devices

___ *UM Miniature vessels

___ *U2 Pressure vessels, Div. 2

___ *U3 Pressure vessels, Div. 3

___ UV3 Pressure vessel safety valves, manufacturer, Div. 3

___ UV3 Pressure vessel safety valves, assembler, Div. 3

___ *RP Reinforced plastic pressure vessels

___ PRD Laboratory or observer

* Important: If marked with an * you must complete the following:

The Authorized Inspection Agency performing our Code Inspection is

Special Provisions: Please check if you wish to operate under any of the following provisions:

☐ UG-90(c)(2), Multiple duplicate pressure vessels

☐ HG-515.4(b), Multiple duplicate boilers

☐ RI-160, Multiple duplicate fiber reinforced plastic pressure vessels

Caution: Please read these paragraphs carefully to make sure you wish to operate under any of these provisions before checking a box. Applicants who incorrectly check a box may have an inappropriate Team assigned to their review, which may increase costs and/or delay the review.

--- Application must be signed on page 2 ---

A1.37-10/03 (1/2) LH

Company Abbreviation: Please indicate if the company chooses to use an abbreviation on the nameplate or in the stamping.

__ Yes __ No If yes, the abbreviation will consist of _____

Note: A Certificate Holder may use either the company's full name or the above abbreviation on the nameplate or in the stamping. The Certificate Holder must list the company's full name as listed on the ASME Certificate on the ASME Manufacturer's Data Report.

Accreditation Agreement

The organization listed on the front of this Application for Accreditation (the "Applicant") performs or subcontracts the design, fabrication, production, testing, assembly, construction and/or installation of items at the address given, and makes this application to The American Society of Mechanical Engineers (ASME) for the appropriate Certificate of Accreditation, Certificate of Acceptance, or Certificate of Authorization permitting use of the associated Code Symbol Stamp. The Applicant:

- (1) Agrees to use the Certificate and/or Stamp in accordance with the applicable ASME Code or Standard governing this application.
- (2) Agrees to return the stamp and/or Certificate anytime ASME may so request, at the time the Applicant discontinues the work covered, or at the time of expiration, if not renewed.
- (3) Accepts the conduct of announced or unannounced audits as required by the appropriate ASME accreditation body. Access to the inspection site to conduct audits, reviews or surveys, including travel to and from the site, is the responsibility of the Applicant. If access is blocked or impeded, ASME is not responsible for the Applicant failing to receive, or continue to have accreditation.
- (4) Agrees to indemnify and hold harmless ASME and its agents from and against any costs (including legal fees and expenses) and any direct, indirect, incidental or consequential damages (including loss of profits or business opportunity) arising out of any claim or cause of action in any way related to this Agreement or the subject matter hereof, including but not limited to claims based on contract, tort (including negligence), strict liability or breach of warranty (express or implied).
- (5) Understands that the Applicant's use of the ASME mark may be allowed provisionally by ASME in its discretion until a decision is made on an appeal of an action of an ASME subcommittee, committee or board and accepts the obligation to pay all legal fees and expenses and ASME's cost for recovering the Certificate and stamp if not returned.

Legal Company Name: _____

Signed: _____
Signature must be by a Company Officer or Designee

Title: _____

Date: _____



Three Park Avenue, New York, NY 10016

Form D

Company: _____
(Company name as it will appear on the Certificate)

Division: _____
(Division, department, etc., if it is to appear on the Certificate)

Location (provide full address):

Corporate/Mailing	Plant	Field Site
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Contact name: _____ Telephone: _____

Title: _____ Fax: _____

E-mail: _____

Jurisdictional Authority (if applicable): _____

Authorized Inspection Agency of record (if applicable): _____

Recommended hotel or motel for team (provide name, full address, and telephone numbers):

First choice

Second choice

_____	_____
_____	_____
_____	_____
_____	_____

Recommended airport (include city name): _____

Miles from airport to lodging: _____ Miles from lodging to office/plant/site: _____

Recommended airport to lodging transfer:

___ Taxi	Signed: _____
___ Limo	Title: _____
___ Hotel provided limo	Date: _____
___ Rent car	
___ Pickup by company	

Please provide the following information if Refund of advanced deposit (if applicable) is to be done electronically:
Name of Bank:_____ ABA Routing Number:_____
SWIFT Code:_____ Account Number:_____
Account Name:_____



ASME International

Three Park Avenue, New York, NY 10016

FORM H

Application for: ☐ Acceptance as a Testing Laboratory (Pressure Relief Devices)
☐ Acceptance of Authorized Observers

(Company Name as it will appear on the Certificate)

(Department, Division, etc.)

This application is for the following Testing Laboratory location:

(Give Full Address)

City State Country Zip Code
New Renewal Additional Authorized Observer
(see below)

If renewal complete the following: Current Certificate Number:

Expiration Date:

Indicate the testing medium(s) which will be used in the capacity certification testing performed by the applicant.

Air Nitrogen Water
Natural Gas Steam Liquids
Other

Indicate the individuals which you wish to have accepted as Authorized Observers

Name

Check if individual was previously
accepted as an Authorized Observer

Signed:

(Signature must be by a Company Officer)

Title:

Date:

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F

ASME-Accredited Testing Laboratories*

*Courtesy ASME International.



**CODES & STANDARDS
CONFORMITY ASSESSMENT**

Three Park Avenue tel 1.212.591.0501
New York, NY fax 1.212.591.8599
10016-5990 U.S.A. www.asme.org

**Testing Laboratories Holding ASME Certificates of Acceptance
For Conducting Tests of Pressure Relief Devices**

CAUTIONARY NOTE: This document is an unofficial listing of the holders of Certificates of Acceptance for Conducting Tests of Pressure Relief Devices. As the status of this list changes constantly, caution is suggested in its use.

ANDERSON GREENWOOD CROSBY

Alan West, V.P., Engineering
104 Iise Ranch Road
New Tilton, Texas 77437
(PRD-017) Issued 08/23/02, Expires 05/02/07
Testing Medium: Nitrogen & Water
(281) 274-4550 Fax (281) 274-4532

ANDERSON GREENWOOD CROSBY

David Tuttle, QA Manager
43 Kendrick Street
Wrentham, Massachusetts 02093
(PRD-001) Issued 02/22/01, Expires 02/27/06
Testing Medium: Steam, Air & Water
(508) 384-4640 Fax (508) 384-7984
e-mail: dtuttle@tycoepg.com

BS&B SAFETY SYSTEMS, INC.

Zhengqiang Wang, Design Engr.
7455 E. 46th Street
Tulsa, Oklahoma 74145
(PRD-019) Issued 05/24/04, Expires 03/30/09
Testing Medium: Air
(918) 664-3724 Fax (918) 664-3776

CONTINENTAL DISC CORPORATION

Robert J. Doelling, V/P Engineering
3150 West Heartland Drive
Liberty, Missouri 64068
(PRD-011) Issued 09/14/04, Expires 08/17/09
Testing Medium: Air & Water
(816) 752-1500 Fax (816) 792-2277
e-mail: bdoelling@contdisc.com

DRESSER FLOW CONTROL, DRESSER, INC.

Richard Crichton, Test Engineer
Research & Development Laboratory
US Highway 3225 @ 167 North
Alexandria, Louisiana 71309-1430
(PRD-008) Issued 05/06/02, Expires 04/12/07
Testing Medium: Air, Steam & Water
(318) 640-6209 Fax (318) 640-6096
e-mail: Richard.Crichton@consolidatedvalve.com

ENGINEERED CONTROLS INTERNATIONAL, INC.

Richard Kelly, Engineering Lab Manager
100 Rego Drive
Elon, North Carolina 27244
(PRD-020) Issued 01/13/00, Expires 01/13/05
Testing Medium: Nitrogen
(336) 449-7707 Fax (336) 449-6594

A9.30-09/04 LH

EDF INDUSTRY BRANCH RESEARCH AND DEVELOPMENT DIVISION

Jean Francois Beraïl, Water Steam Testing Group Manager
Mechanics and Technology - MTC Laboratory
Département Mécanique Et Technologie Des Composants
EDF Pole Industrie Site Des Renardières MTC 1
Moret Sur Loing Cedex
France 77818
(PRD-022) Issued 04/03/01, Expires 04/03/06
Testing Medium: Steam
(33) 1 60736073 Fax (33) 1 60736149

FARRIS ENGINEERING

Paul Papa: Director of Engrg.
Division of Curtiss-Wright Flow Control Corporation
10195 Brecksville Road
Brecksville, OH 44141
(PRD-021) Issued 01/31/01, Expires 01/31/06
Testing Medium: Air & Water
(440) 838-7690 Fax (440) 838-5194
e-mail: ppapa@farris.curtisswright.com

FIKE CORPORATION

Richard Tucker, Quality Engineer
704 South 10th Street
Blue Springs, MO 64013
(PRD-023) Issued 08/28/01, Expires 08/28/06
Testing Medium: Nitrogen
(816) 229-3405 Fax (816) 229-5082
e-mail: Richard.Tucker@Fike.com

LESER GMBH & CO., KG

Ekhard Stueber
Wendenstrasse 133-135
D-20537 Hamburg, Germany
(PRD-014) Issued 04/04/00, Expires 12/23/04
Testing Medium: Air & Water
(49) 40-25165-172 Fax (49) 40-25165-572
e-mail: stueber.e@leser.com

**THE NATIONAL BOARD OF BOILER &
PRESSURE VESSEL INSPECTORS**

S. F. Harrison, Jr., Dir.
of Pressure Relief Dept.
National Board Testing Laboratory
7437 Pingue Drive
Worthington, Ohio 43085
(PRD-010) Issued 05/04/01, Expires 05/21/06
Testing Medium: Steam, Air & Water
(614) 888-8320 Fax (614) 848-3474
e-mail: harrison@nationalboard.org

G

Physical Properties of Gas or Vapor

Gas or Vapor	M Molecular Weight	k Specific Heat Ratio	C Gas Constant
Acetone	58.08	1.12	329
Acetylene (Ethyne)	26.04	1.26	343
Air	28.97	1.40	356
Ammonia, Anhydrous	17.03	1.31	348
Argon	39.95	1.67	378
Benzene (Benzol or Benzole)	78.11	1.12	329
Boron Trifluoride	67.82	1.20	337
Butadiene-1,3 (Divinyl)	54.09	1.12	329
Butane-n (Normal Butane)	58.12	1.09	326
Butylene (1-Butene)	56.11	1.11	328
Carbon Dioxide	44.01	1.29	346
Carbon Disulfide (C. Bisulfide)	76.13	1.21	33
Carbon Monoxide	28.01	1.40	356
Carbon Tetrachloride	153.82	1.11	328
Chlorine	70.91	1.36	353
Chloromethane (Methyl Chloride)	50.49	1.28	345
Cyclohexane	84.16	1.09	326
Cyclopropane (Trimethylene)	42.08	1.11	328
Decane-n	142.29	1.04	320
Diethylene Glycol (DEG)	106.17	1.07	323
Dimethyl Ether (Methyl Ether)	46.07	1.11	328
Dowtherm A	165.00	1.05	321
Dowtherm E	147.00	1.00	315
Ethane	30.07	1.19	336
Ethyl Alcohol (Ethanol)	46.07	1.13	330
Ethylene (Ethene)	28.05	1.24	341
Ethylene Glycol	62.07	1.09	326
Ethylene Oxide	44.05	1.21	338
Fluorocarbons:			
12, Dichlorodifluoromethane	120.93	1.14	331
13, Chlorotrifluoromethane	104.47	1.17	334
13B1, Bromotrifluoromethane	148.93	1.14	331
22, Chlorodifluoromethane	86.48	1.18	335
115, Chloropentafluoroethane	154.48	1.08	324
Glycerine (Glycerin or Glycerol)	92.10	1.06	322
Helium	4.00	1.67	378
Heptane	100.21	1.05	321

Gas or Vapor	M Molecular Weight	k Specific Heat Ratio	C Gas Constant
Hexane	86.18	1.06	322
Hydrogen	2.02	1.41	357
Hydrogen Chloride, Anhydrous	36.46	1.41	357
Hydrogen Sulfide	34.08	1.32	349
Isobutane (2-Methylpropane)	58.12	1.10	327
Isoprene (2-Methyl-1, 3 Butadiene)	68.12	1.09	326
Isopropyl Alcohol (Isopropanol)	60.10	1.09	326
Krypton	83.80	1.71	380
Methane	16.04	1.31	348
Methyl Alcohol (Methanol)	32.04	1.20	337
Methylamines, Anhydrous			
Monomethylamine (Methylamine)	31.06	1.02	317
Dimethylamine	45.08	1.15	332
Trimethylamine	59.11	1.18	335
Methyl Mercaptan (Methanethiol)	48.11	1.20	337
Napthalene (Napthaline)	128.17	1.07	323
Natural Gas (specific gravity = 0.60)	17.40	1.27	344
Neon	20.18	1.64	375
Nitrogen	28.01	1.40	356
Nitrous Oxide	44.01	1.30	347
Octane	114.23	1.05	321
Oxygen	32.00	1.40	356
Pentane	72.15	1.07	323
Propadiene (Allene)	40.07	1.69	379
Propane	44.10	1.13	330
Propylene (Propene)	42.08	1.15	332
Propylene Oxide	58.08	1.13	330
Styrene	104.15	1.07	323
Sulfur Dioxide	64.06	1.28	345
Sulfur Hexafluoride	146.05	1.09	326
Steam	18.02	1.31	348
Toluene (Toluol or Methylbenzene)	92.14	1.09	326
Triethylene Glycol (TEG)	150.18	1.04	320
Vinyl Chloride Monomer (VCM)	62.50	1.19	336
Xenon	131.30	1.65	376
Xylene (p-Xylene)	106.17	1.07	323

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Superheat Correction Factor*

Flowing Pressure (psia)	Superheat Correction Factor, K_{sh} , Total Temperature, °F, of Superheated Steam																
	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
50	0.987	0.957	0.930	0.905	0.882	0.861	0.841	0.823	0.805	0.789	0.774	0.759	0.745	0.732	0.719	0.708	0.696
100	0.998	0.963	0.935	0.909	0.885	0.864	0.843	0.825	0.807	0.790	0.775	0.760	0.746	0.733	0.720	0.708	0.697
150	0.984	0.970	0.940	0.913	0.888	0.866	0.846	0.826	0.808	0.792	0.776	0.761	0.747	0.733	0.721	0.709	0.697
200	0.979	0.977	0.945	0.917	0.892	0.869	0.848	0.828	0.810	0.793	0.777	0.762	0.748	0.734	0.721	0.709	0.698
250	...	0.972	0.951	0.921	0.895	0.871	0.850	0.830	0.812	0.794	0.778	0.763	0.749	0.735	0.722	0.710	0.698
300	...	0.968	0.957	0.926	0.898	0.874	0.852	0.832	0.813	0.796	0.780	0.764	0.750	0.736	0.723	0.710	0.699
350	...	0.968	0.963	0.930	0.902	0.877	0.854	0.834	0.815	0.797	0.781	0.765	0.750	0.736	0.723	0.711	0.699
400	...	...	0.963	0.935	0.906	0.880	0.857	0.836	0.816	0.798	0.782	0.766	0.751	0.737	0.724	0.712	0.700
450	...	...	0.961	0.940	0.909	0.883	0.859	0.838	0.818	0.800	0.783	0.767	0.752	0.738	0.725	0.712	0.700
500	...	...	0.961	0.946	0.914	0.886	0.862	0.840	0.820	0.801	0.784	0.768	0.753	0.739	0.725	0.713	0.701
550	...	...	0.962	0.952	0.918	0.889	0.864	0.842	0.822	0.803	0.785	0.769	0.754	0.740	0.726	0.713	0.701
600	...	...	0.964	0.958	0.922	0.892	0.867	0.844	0.823	0.804	0.787	0.770	0.755	0.740	0.727	0.714	0.702
650	...	...	...	0.958	0.927	0.896	0.869	0.846	0.825	0.806	0.788	0.771	0.756	0.741	0.728	0.715	0.702
700	...	...	...	0.958	0.931	0.899	0.872	0.848	0.827	0.807	0.789	0.772	0.757	0.742	0.728	0.715	0.703
750	...	...	...	0.958	0.936	0.903	0.875	0.850	0.828	0.809	0.790	0.774	0.758	0.743	0.729	0.716	0.703
800	...	...	0.960	0.942	0.906	0.878	0.852	0.830	0.810	0.792	0.774	0.759	0.744	0.730	0.716	0.704	...
850	...	...	...	0.962	0.947	0.910	0.880	0.855	0.832	0.812	0.793	0.776	0.760	0.744	0.730	0.717	0.704
900	...	...	...	0.965	0.953	0.914	0.883	0.857	0.834	0.813	0.794	0.777	0.760	0.745	0.731	0.718	0.705
950	...	...	...	0.969	0.958	0.918	0.886	0.860	0.836	0.815	0.796	0.778	0.761	0.746	0.732	0.718	0.705
1000	...	...	...	0.974	0.959	0.923	0.890	0.862	0.838	0.816	0.797	0.779	0.762	0.747	0.732	0.719	0.706
1050	...	...	...	...	0.960	0.927	0.893	0.864	0.840	0.818	0.798	0.780	0.763	0.746	0.733	0.719	0.707
1100	...	...	...	...	0.962	0.931	0.896	0.867	0.842	0.820	0.800	0.781	0.764	0.749	0.734	0.720	0.707
1150	...	...	...	...	0.964	0.936	0.899	0.870	0.844	0.821	0.801	0.782	0.765	0.749	0.735	0.721	0.708
1200	...	...	...	...	0.966	0.941	0.903	0.872	0.846	0.823	0.802	0.784	0.766	0.750	0.735	0.721	0.708
1250	...	...	...	...	0.969	0.946	0.906	0.875	0.848	0.825	0.804	0.785	0.767	0.751	0.736	0.722	0.709
1300	...	...	...	...	0.973	0.952	0.910	0.878	0.850	0.826	0.805	0.786	0.768	0.752	0.737	0.723	0.709
1350	...	...	...	...	0.977	0.958	0.914	0.880	0.852	0.828	0.807	0.787	0.769	0.753	0.737	0.723	0.710
1400	...	...	...	...	0.982	0.963	0.918	0.883	0.854	0.830	0.808	0.788	0.770	0.754	0.738	0.724	0.710
1450	...	...	...	...	0.987	0.968	0.922	0.886	0.857	0.832	0.809	0.790	0.771	0.754	0.739	0.724	0.711
1500	...	...	...	...	0.993	0.970	0.926	0.889	0.859	0.833	0.811	0.791	0.772	0.755	0.740	0.725	0.711
1550	...	...	...	...	0.972	0.930	0.892	0.861	0.835	0.812	0.792	0.773	0.756	0.740	0.726	0.712	0.700
1600	...	...	...	...	0.973	0.934	0.894	0.863	0.836	0.813	0.792	0.774	0.756	0.740	0.726	0.712	0.700
1650	...	...	...	...	0.973	0.936	0.895	0.863	0.836	0.813	0.791	0.772	0.755	0.739	0.724	0.710	0.698
1700	...	...	...	...	0.973	0.938	0.895	0.863	0.835	0.811	0.790	0.771	0.754	0.738	0.723	0.709	0.697
1750	...	...	...	...	0.974	0.940	0.896	0.862	0.835	0.810	0.789	0.770	0.752	0.736	0.721	0.707	0.695
1800	...	...	...	...	0.975	0.942	0.897	0.862	0.834	0.810	0.788	0.768	0.751	0.735	0.720	0.705	0.693
1850	...	...	...	...	0.976	0.944	0.897	0.862	0.833	0.809	0.787	0.767	0.749	0.733	0.718	0.704	0.692
1900	...	...	...	...	0.977	0.946	0.898	0.862	0.832	0.807	0.785	0.766	0.748	0.731	0.716	0.702	0.690
1950	...	...	...	...	0.979	0.949	0.898	0.861	0.832	0.806	0.784	0.764	0.746	0.729	0.714	0.700	0.688
2000	...	...	...	...	0.982	0.952	0.899	0.861	0.831	0.805	0.782	0.762	0.744	0.728	0.712	0.698	0.686
2050	...	...	...	...	0.985	0.954	0.899	0.860	0.830	0.804	0.781	0.761	0.742	0.726	0.710	0.696	0.684
2100	...	...	...	...	0.988	0.956	0.900	0.860	0.828	0.802	0.779	0.759	0.740	0.724	0.708	0.694	0.682
2150	...	...	...	...	...	0.956	0.900	0.859	0.827	0.801	0.778	0.757	0.738	0.722	0.706	0.692	0.680
2200	...	...	...	...	...	0.955	0.901	0.859	0.826	0.799	0.776	0.755	0.736	0.720	0.704	0.690	0.678
2250	...	...	...	...	...	0.954	0.901	0.858	0.825	0.797	0.774	0.753	0.734	0.717	0.702	0.687	0.675
2300	...	...	...	...	...	0.953	0.901	0.857	0.823	0.795	0.772	0.751	0.732	0.715	0.699	0.685	0.673
2350	...	...	...	...	...	0.952	0.902	0.856	0.822	0.794	0.769	0.748	0.729	0.712	0.697	0.682	0.670
2400	...	...	...	...	...	0.952	0.902	0.855	0.820	0.791	0.766	0.745	0.726	0.709	0.694	0.679	0.667
2450	...	...	...	...	...	0.951	0.902	0.854	0.818	0.789	0.765	0.743	0.724	0.707	0.691	0.675	0.663
2500	...	...	...	...	...	0.951	0.902	0.852	0.816	0.787	0.762	0.740	0.721	0.704	0.688	0.674	0.661
2550	...	...	...	...	...	0.951	0.902	0.851	0.814	0.784	0.759	0.738	0.718	0.701	0.685	0.671	0.658
2600	...	...	...	...	...	0.951	0.903	0.849	0.812	0.782	0.756	0.735	0.715	0.698	0.682	0.668	0.654
2650	...	...	...	...	...	0.952	0.903	0.848	0.809	0.779	0.754	0.733	0.713	0.696	0.680	0.666	0.652
2700	...	...	...	...	...	0.952	0.903	0.846	0.807	0.776	0.750	0.728	0.708	0.691	0.675	0.661	0.647
2750	...	...	...	...	...	0.953	0.903	0.844	0.804	0.773	0.747	0.724	0.703	0.687	0.671	0.657	0.643
2800	...	...	...	...	...	0.956	0.903	0.842	0.801	0.769	0.743	0.721	0.701	0.684	0.668	0.653	0.639
2850	...	...	...	...	...	0.959	0.902	0.839	0.798	0.766	0.739	0.717	0.697	0.679	0.663	0.649	0.635
2900	...	...	...	...	...	0.963	0.902	0.836	0.794	0.762	0.735	0.713	0.693	0.675	0.659	0.645	0.631
2950	...	...	...	...	...	0.962	0.902	0.834	0.790	0.758	0.731	0.708	0.688	0.671	0.655	0.640	0.626
3000	...	...	...	...	...	0.961	0.901	0.831	0.786	0.753	0.726	0.704	0.684	0.666	0.650	0.635	0.622
3050	...	...	...	...	...	...	0.899	0.827	0.782	0.749	0.722	0.699	0.679	0.661	0.645	0.630	0.617
3100	...	...	...	...	...	...	0.896	0.823	0.777	0.744	0.716	0.693	0.673	0.656	0.640	0.625	0.612
3150	...	...	...	...	...	...	0.894	0.819	0.772	0.738	0.711	0.688	0.668	0.650	0.634	0.620	0.607
3200	...	...	...	...	...	...	0.899	0.815	0.767	0.733	0.705	0.682	0.662	0.644	0.628	0.614	0.601

*From ASME Section I.

SUPERHEAT CORRECTION FACTOR, K_{sh}

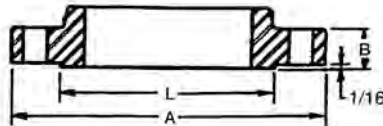
Flowing Pressure (MPa)	Superheat Correction Factor, K_{sh} Total Temperature, °C, of Superheated Steam														
	205	225	250	275	300	325	350	375	400	425	450	475	500	525	550
0.50	0.991	0.966	0.942	0.919	0.896	0.876	0.857	0.839	0.823	0.807	0.792	0.778	0.765	0.752	0.74
0.75	0.995	0.972	0.946	0.922	0.899	0.878	0.859	0.841	0.824	0.808	0.793	0.779	0.766	0.753	0.74
1.00	0.985	0.973	0.95	0.925	0.902	0.88	0.861	0.843	0.825	0.809	0.794	0.78	0.766	0.753	0.741
1.25	0.981	0.976	0.954	0.928	0.905	0.883	0.863	0.844	0.827	0.81	0.795	0.781	0.767	0.754	0.741
1.50	...	...	0.957	0.932	0.907	0.885	0.865	0.846	0.828	0.812	0.796	0.782	0.768	0.755	0.742
1.75	...	...	0.959	0.935	0.91	0.887	0.866	0.847	0.829	0.813	0.797	0.782	0.769	0.756	0.743
2.00	...	...	0.96	0.939	0.913	0.889	0.868	0.849	0.831	0.814	0.798	0.784	0.769	0.756	0.744
2.25	...	...	0.963	0.943	0.916	0.892	0.87	0.85	0.832	0.815	0.799	0.785	0.77	0.757	0.744
2.50	...	...	...	0.946	0.919	0.894	0.872	0.852	0.834	0.816	0.8	0.785	0.771	0.757	0.744
2.75	...	...	...	0.948	0.922	0.897	0.874	0.854	0.835	0.817	0.801	0.786	0.772	0.758	0.745
3.00	...	...	...	0.949	0.925	0.899	0.876	0.855	0.837	0.819	0.802	0.787	0.772	0.759	0.746
3.25	...	...	...	0.951	0.929	0.902	0.879	0.857	0.838	0.82	0.803	0.788	0.773	0.759	0.746
3.50	...	...	...	0.953	0.933	0.905	0.881	0.859	0.84	0.822	0.804	0.789	0.774	0.76	0.747
3.75	...	...	...	0.956	0.936	0.908	0.883	0.861	0.841	0.823	0.806	0.79	0.775	0.761	0.748
4.00	...	...	...	0.959	0.94	0.91	0.885	0.863	0.842	0.824	0.807	0.791	0.776	0.762	0.748
4.25	...	...	...	0.961	0.943	0.913	0.887	0.864	0.844	0.825	0.808	0.792	0.777	0.762	0.749
4.50	...	...	...	0.944	0.917	0.89	0.866	0.845	0.826	0.809	0.793	0.777	0.763	0.749	0.737
4.75	...	...	...	0.946	0.919	0.892	0.868	0.847	0.828	0.81	0.793	0.778	0.764	0.75	0.737
5.00	...	...	...	0.947	0.922	0.894	0.87	0.849	0.829	0.811	0.794	0.779	0.765	0.751	0.738
5.25	...	...	...	0.949	0.926	0.897	0.872	0.85	0.83	0.812	0.795	0.78	0.765	0.752	0.738
5.50	...	...	...	0.952	0.93	0.899	0.874	0.851	0.831	0.813	0.797	0.78	0.766	0.752	0.739
5.75	...	...	...	0.954	0.933	0.902	0.876	0.85	0.833	0.815	0.798	0.782	0.768	0.754	0.741
6.00	...	...	...	0.957	0.937	0.904	0.878	0.855	0.834	0.816	0.798	0.783	0.768	0.753	0.74
6.25	...	...	...	0.96	0.94	0.907	0.88	0.856	0.836	0.817	0.799	0.783	0.768	0.754	0.74
6.50	...	...	...	0.964	0.944	0.91	0.882	0.859	0.837	0.818	0.801	0.784	0.769	0.754	0.741
6.75	...	...	...	0.966	0.946	0.913	0.885	0.86	0.839	0.819	0.802	0.785	0.769	0.755	0.742
7.00	...	...	...	0.947	0.916	0.887	0.862	0.84	0.82	0.802	0.786	0.77	0.756	0.742	0.729
7.25	...	...	...	0.949	0.919	0.889	0.863	0.842	0.822	0.803	0.787	0.771	0.756	0.743	0.73
7.50	...	...	...	0.951	0.922	0.891	0.865	0.843	0.823	0.805	0.788	0.772	0.757	0.744	0.73
7.75	...	...	...	0.953	0.925	0.893	0.867	0.844	0.824	0.806	0.788	0.772	0.758	0.744	0.731
8.00	...	...	...	0.955	0.928	0.896	0.869	0.846	0.825	0.806	0.789	0.773	0.758	0.744	0.732
8.25	...	...	...	0.957	0.932	0.898	0.871	0.847	0.827	0.807	0.79	0.774	0.759	0.745	0.732
8.50	...	...	...	0.96	0.935	0.901	0.873	0.849	0.828	0.809	0.791	0.775	0.76	0.746	0.732
8.75	...	...	...	0.963	0.939	0.903	0.875	0.85	0.829	0.81	0.792	0.776	0.76	0.746	0.733
9.00	...	...	...	0.966	0.943	0.906	0.877	0.852	0.833	0.811	0.793	0.777	0.761	0.747	0.734
9.25	...	...	...	0.97	0.947	0.909	0.879	0.853	0.832	0.812	0.794	0.777	0.762	0.747	0.734
9.50	...	...	...	0.973	0.95	0.911	0.881	0.855	0.833	0.813	0.795	0.778	0.763	0.748	0.732
9.75	...	...	...	0.977	0.954	0.914	0.883	0.857	0.834	0.814	0.796	0.779	0.764	0.749	0.735
10.00	...	...	...	0.981	0.957	0.917	0.885	0.859	0.836	0.815	0.797	0.78	0.764	0.749	0.735
10.25	...	...	...	0.984	0.959	0.92	0.887	0.86	0.837	0.816	0.798	0.78	0.764	0.75	0.736
10.50	...	...	...	0.961	0.923	0.889	0.862	0.838	0.817	0.799	0.781	0.765	0.75	0.737	0.723
10.75	...	...	...	0.962	0.925	0.891	0.863	0.839	0.818	0.799	0.782	0.766	0.751	0.737	0.724
11.00	...	...	...	0.963	0.928	0.893	0.865	0.84	0.819	0.8	0.782	0.766	0.751	0.737	0.724
11.25	...	...	...	0.964	0.93	0.893	0.865	0.84	0.819	0.799	0.781	0.765	0.75	0.736	0.723
11.50	...	...	...	0.964	0.931	0.894	0.865	0.84	0.818	0.798	0.78	0.764	0.749	0.735	0.722
11.75	...	...	...	0.965	0.932	0.894	0.865	0.839	0.817	0.797	0.78	0.763	0.748	0.734	0.721
12.00	...	...	...	0.966	0.933	0.894	0.864	0.839	0.817	0.797	0.779	0.762	0.747	0.733	0.719
12.25	...	...	...	0.967	0.935	0.895	0.864	0.839	0.816	0.796	0.778	0.761	0.746	0.732	0.718
12.50	...	...	...	0.967	0.936	0.896	0.864	0.838	0.816	0.796	0.777	0.76	0.745	0.731	0.717
12.75	...	...	...	0.968	0.937	0.896	0.864	0.838	0.815	0.795	0.776	0.759	0.744	0.729	0.716
13.00	...	...	...	0.969	0.939	0.896	0.864	0.837	0.814	0.794	0.775	0.758	0.743	0.728	0.715
13.25	...	...	...	0.971	0.94	0.897	0.864	0.837	0.813	0.792	0.774	0.757	0.741	0.727	0.713
13.50	...	...	...	0.972	0.942	0.897	0.863	0.837	0.813	0.792	0.773	0.756	0.74	0.725	0.712
14.00	...	...	...	0.976	0.946	0.897	0.863	0.835	0.811	0.79	0.771	0.753	0.737	0.723	0.709
14.25	...	...	...	0.978	0.947	0.898	0.862	0.834	0.81	0.789	0.77	0.752	0.736	0.721	0.707
14.50	...	...	...	0.948	0.898	0.862	0.833	0.809	0.787	0.768	0.748	0.729	0.712	0.696	0.68
14.75	...	...	...	0.948	0.898	0.862	0.832	0.808	0.786	0.767	0.747	0.729	0.713	0.704	0.694
15.00	...	...	...	0.948	0.899	0.861	0.832	0.807	0.785	0.766	0.748	0.732	0.717	0.703	0.688
15.25	...	...	...	0.947	0.899	0.861	0.831	0.806	0.784	0.764	0.746	0.73	0.715	0.702	0.687
15.50	...	...	...	0.947	0.899	0.861	0.831	0.806	0.784	0.764	0.746	0.73	0.715	0.702	0.687
15.75	...	...	...	0.946	0.899	0.86	0.829	0.803	0.781	0.761	0.743	0.727	0.712	0.698	0.683
16.00	...	...	...	0.945	0.9	0.859	0.828	0.802	0.779	0.759	0.741	0.725	0.71	0.696	0.681
16.25	...	...	...	0.945	0.9	0.859	0.827	0.801	0.778	0.758	0.74	0.724	0.708	0.694	0.679
16.50	...	...	...	0.945	0.9	0.858	0.826	0.799	0.776	0.756	0.738	0.721	0.706	0.692	0.677
16.75	...	...	...	0.944	0.9	0.857	0.825	0.797	0.774	0.754	0.736	0.719	0.704	0.69	0.675

SUPERHEAT CORRECTION FACTOR, K_{sh} (CONT'D)

Flowing Pressure (MPa)	Superheat Correction Factor, K_{sh} Total Temperature, °C, of Superheated Steam																	
	205	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625
17.00	...	...	...	...	...	...	...	0.944	0.9	0.856	0.823	0.796	0.773	0.752	0.734	0.717	0.702	0.688
17.25	...	...	...	...	...	...	...	0.944	0.9	0.855	0.822	0.794	0.771	0.75	0.732	0.715	0.7	0.686
17.50	...	...	...	...	...	...	...	0.944	0.9	0.854	0.82	0.792	0.769	0.748	0.73	0.713	0.698	0.684
17.75	...	...	...	...	...	...	...	0.944	0.9	0.853	0.819	0.791	0.767	0.746	0.728	0.711	0.696	0.681
18.00	...	...	...	...	...	...	...	0.944	0.901	0.852	0.817	0.789	0.765	0.744	0.725	0.709	0.694	0.679
18.25	...	...	...	...	...	...	...	0.945	0.901	0.851	0.815	0.787	0.763	0.742	0.723	0.706	0.691	0.677
18.50	...	...	...	...	...	...	...	0.945	0.901	0.85	0.814	0.785	0.761	0.739	0.72	0.704	0.689	0.674
18.75	...	...	...	...	...	...	...	0.945	0.901	0.849	0.812	0.783	0.758	0.737	0.718	0.701	0.686	0.671
19.00	...	...	...	...	...	...	...	0.946	0.901	0.847	0.81	0.781	0.756	0.734	0.715	0.698	0.683	0.668
19.25	...	...	...	...	...	...	...	0.948	0.901	0.846	0.808	0.778	0.753	0.732	0.713	0.696	0.681	0.666
19.50	...	...	...	...	...	...	...	0.95	0.9	0.844	0.806	0.776	0.75	0.729	0.71	0.693	0.677	0.663
19.75	...	...	...	...	...	...	...	0.952	0.899	0.842	0.803	0.773	0.748	0.726	0.707	0.69	0.674	0.66
20.00	...	...	...	...	...	...	...	0.899	0.84	0.801	0.77	0.745	0.723	0.704	0.687	0.671	0.657	0.643
20.25	...	...	...	...	...	...	...	0.899	0.839	0.798	0.767	0.742	0.72	0.701	0.683	0.668	0.654	0.64
20.50	...	...	...	...	...	...	...	0.899	0.837	0.795	0.764	0.738	0.717	0.697	0.68	0.665	0.651	0.637
20.75	...	...	...	...	...	...	...	0.898	0.834	0.792	0.761	0.735	0.713	0.694	0.677	0.661	0.647	0.633
21.00	...	...	...	...	...	...	...	0.896	0.832	0.79	0.758	0.732	0.71	0.691	0.674	0.658	0.643	0.629
21.25	...	...	...	...	...	...	...	0.894	0.829	0.787	0.754	0.728	0.706	0.686	0.669	0.654	0.64	0.626
21.50	...	...	...	...	...	...	...	0.892	0.826	0.783	0.75	0.724	0.702	0.682	0.665	0.65	0.636	0.622
21.75	...	...	...	...	...	...	...	0.891	0.823	0.779	0.746	0.72	0.698	0.679	0.661	0.646	0.631	0.617
22.00	...	...	...	...	...	...	...	0.887	0.82	0.776	0.743	0.716	0.694	0.674	0.657	0.641	0.627	0.613

Dimensions of Flanges

ANSI Flanges



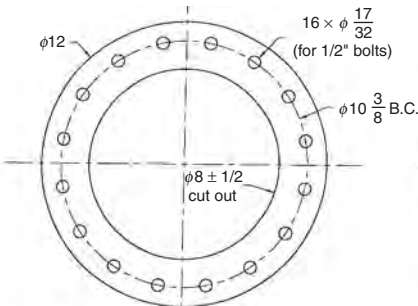
Nominal Pipe Size (In.)	A Outside Diameter of Flange (In.)	B Thickness of Flange (In.)	L Diameter of Raised Face (In.)	Drilling Template			Bolts	
				Number of Holes (In.)	Diameter of Holes (In.)	Diameter of Bolt Circle (In.)	Diameter of Bolt (In.)	Machine Bolt Length (In.)
1/2	3-1/2	7/16	1-3/8	4	5/8	2-3/8	1/2	1-3/4
3/4	3-7/8	1/2	1-11/16	4	5/8	2-3/4	1/2	2
1	4-1/4	9/16	2	4	5/8	3-1/8	1/2	2
1-1/4	4-5/8	5/8	2-1/2	4	5/8	3-1/2	1/2	2-1/4
1-1/2	5	11/16	2-7/8	4	5/8	3-7/8	1/2	2-1/8
2	6	3/4	3-5/8	4	3/4	4-3/4	5/8	2-3/4
2-1/2	7	7/8	4-1/8	4	3/4	5-1/2	5/8	3
3	7-1/2	15/16	5	4	3/4	6	5/8	3
3-1/2	8-1/2	15/16	5-1/2	8	3/4	7	5/8	3
4	9	15/16	6-3/16	8	3/4	7-1/2	5/8	3
5	10	15/16	7-5/16	8	7/8	8-1/2	3/4	3-1/4
6	11	1	8-1/2	8	7/8	9-1/2	3/4	3-1/4
8	13-1/2	1-1/8	10-5/8	8	7/8	11-3/4	3/4	3-1/2
10	16	1-3/16	12-3/4	12	1	14-1/4	7/8	3-1/4
12	19	1-1/4	15	12	1	17	7/8	4
14	21	1-3/8	16-1/4	12	1-1/8	18-3/4	1	4-1/4
16	23-1/2	1-7/16	18-1/2	16	1-1/8	21-1/4	1	4-1/2
18	25	1-9/16	21	16	1-1/8	22-3/4	1-1/8	4-3/4
20	27-1/2	1-11/16	23	20	1-1/4	25	1-1/8	5-1/4
22 *	29-1/2	1-13/16	25-1/4	20	1-3/8	27-1/4	1-1/4	5-1/2
24	32	1-7/8	27-1/4	20	1-3/8	29-1/2	1-1/4	5-3/4
26 *	34-1/4	2	29-1/4	24	1-3/8	31-3/4	1-1/4	6
28 *	36-1/2	2-1/16	31-1/4	28	1-3/8	34	1-1/4	6
30 *	38-3/4	2-1/8	33-3/4	28	1-3/8	36	1-1/4	6-3/4
32 *	41-3/4	2-1/4	35-3/4	28	1-5/8	38-1/2	1-1/2	6-3/4
34 *	43-3/4	2-5/16	37-3/4	32	1-5/8	38-1/2	1-1/2	7
36 *	46	2-3/8	40-1/4	32	1-5/8	42-3/4	1-1/2	7

Materials most commonly used: Forged steel SA 181. Available also in stainless steel and non-ferrous metal.

Flanges bored to dimensions shown unless otherwise specified.

*Flanges for pipe sizes 22, 26, 28, 30, 32, 34 and 36 are not covered by ANSI B16.5.

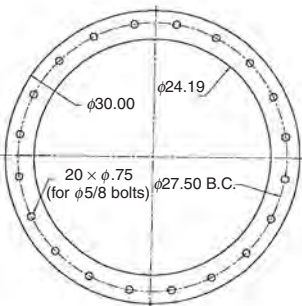
API Flanges



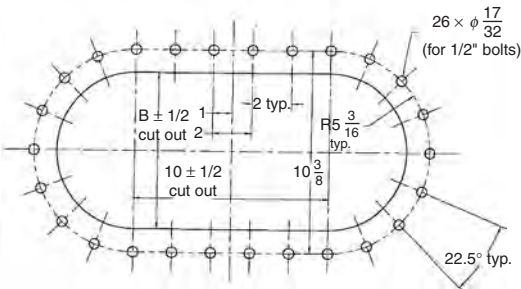
API flange 8" round



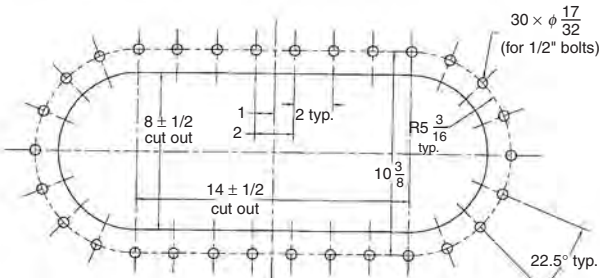
API flange 20" round



API flange 24" round

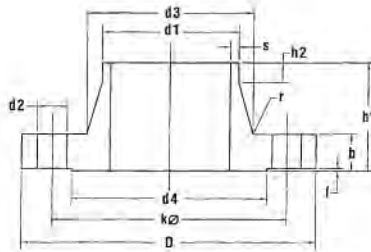


API flange 8 x 18 oblong



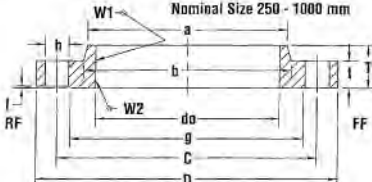
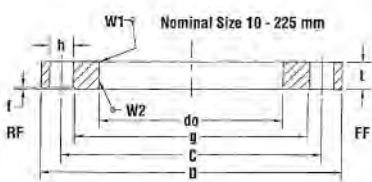
API flange 8 x 22 oblong

DIN Flanges



Paper Size			Flange (mm)				Neck (mm)				Raised Face		Bolts			Weight
Nom. Dia. (mm)	d1		D	b	k	h1	d3	s	r	h2	d4	f	No. of Bolts	Thread	d2	
	ISO Serie 1 Reihe 1	DIN Serie 2 Reihe 2														
25	-	30	115	16	85	38	42	2,6	4	6	68	2	4	M 12	14	1,14
	33,7	-					45									
32	-	38	140	16	100	40	52	2,6	6	6	78	2	4	M 16	18	1,69
	42,4	-					56									
40	-	44,5	150	16	110	42	60	2,6	6	7	88	3	4	M 16	18	1,69
	48,3	-					64									
50	-	57	165	18	125	45	72	2,9	6	8	102	3	4	M 16	18	2,53
	60,3	-					75									
65	76,1	-	185	18	145	45	90	2,9	6	10	122	3	4	M 16	18	3,06
80	88,9	-	200	20	160	50	105	3,2	8	10	138	3	8	M 16	18	3,7
100	-	108	220	20	180	52	125	3,6	8	12	158	3	8	M 16	18	4,62
	114,3	-					131									
125	-	133	250	22	210	55	150	4	8	12	188	3	8	M 16	18	6,3
	139,7	-					156									
150	-	159	285	22	240	55	175	4,5	10	12	212	3	8	M 20	22	7,75
	168,3	-					184									
200	219,1	-	340	24	295	62	235	5,9	10	16	268	3	8	M 20	22	11,3
250	-	267	395	26	350	68	285	6,3	12	16	320	3	12	M 20	22	14,7
	273	-					292									
300	323,9	-	445	26	400	68	344	7,1	12	16	370	4	12	M 20	22	17,4
350	355,6	-	505	26	460	68	385	7,1	12	16	430	4	16	M 20	22	23,6
	-	368														
400	406,4	-	565	26	515	72	440	7,1	12	16	482	4	18	M 24	26	28,6
	-	419														
(450)	457	-	615	28	565	72	488	7,1	12	16	532	4	20	M 24	26	31,5
500	508	-	670	28	620	75	542	7,1	12	16	585	4	20	M 24	26	38,1
600	610	-	780	28	725	80	642	7,1	12	18	685	5	20	M 27	30	44,6

JIS Flanges



Nominal Dia. of Flange (mm)	Outside Dia. of Flange D (mm)	Sectional Dimensions of flange												Nominal Bolt Size	Weight (kg)
		Dia. of Bolt Circle C (mm)	Dia. of Raised Face g (mm)	Inside Dia. of Flange do (mm)	Outside Dia. of Applicable Pipe (mm)	f (mm)	T (mm)	Dia. of Hub		Radius r (mm)	Raised Face (mm)	Hole Dia. h (mm)	Number of Bolt Holes		
								a (mm)	b (mm)						
(10)	75	55	39	17.8	17.3	9	—	—	—	—	1	12	4	M10	0.27
15	80	60	44	22.2	21.7	9	—	—	—	—	1	12	4	M10	0.30
(20)	85	65	49	27.7	27.2	10	—	—	—	—	1	12	4	M10	0.37
25	95	75	59	34.5	34.0	10	—	—	—	—	1	12	4	M10	0.45
(32)	115	90	70	43.2	42.7	12	—	—	—	—	2	15	4	M12	0.78
40	120	95	75	49.1	48.6	12	—	—	—	—	2	15	4	M12	0.83
50	130	105	85	61.1	60.5	14	—	—	—	—	2	15	4	M12	1.07
65	155	130	110	77.1	76.3	14	—	—	—	—	2	15	4	M12	1.49
80	180	145	121	90.0	89.1	14	—	—	—	—	2	19	4	M16	1.99
(90)	190	155	131	102.6	101.6	14	—	—	—	—	2	19	4	M16	2.09
100	200	165	141	115.4	114.3	16	—	—	—	—	2	19	8	M16	2.39
125	235	200	176	141.2	139.8	16	—	—	—	—	2	19	8	M16	3.23
150	265	230	206	166.6	165.2	18	—	—	—	—	2	19	8	M16	4.41
(175)	300	260	232	192.1	190.7	18	—	—	—	—	2	23	8	M20	5.51
200	320	280	252	218.0	216.3	20	—	—	—	—	2	23	8	M20	6.33
(225)	345	305	277	243.7	241.8	20	—	—	—	—	2	23	12	M20	6.64
250	385	345	317	269.5	267.4	22	—	—	—	—	2	2 3	12	M20	9.45
300	430	390	360	321.0	318.5	22	—	—	—	—	3	23	12	M20	10.30
350	480	445	403	358.1	355.6	24	—	—	—	—	3	25	12	M22	14.0
400	540	495	463	409.0	406.4	24	—	—	—	—	3	25	16	M22	16.90
450	605	555	523	460.0	457.2	24	40	495	500	5	3	25	16	M22	24.8
500	655	605	573	511.0	508.0	24	40	548	552	5	3	25	20	M22	26.9
550	720	665	630	562.0	558.8	26	42	597	603	5	3	27	20	M24	34.1
600	770	715	680	613.0	609.6	26	44	648	654	5	3	27	20	M24	37.5
650	825	770	735	664.0	660.4	26	48	702	708	5	3	27	24	M24	42.8
700	875	820	785	715.0	711.2	26	48	751	758	5	3	27	24	M24	45.4

J

Pipe Data

Nominal pipe size, inches	Actual external diameter, inches	Approx. internal diameter, inches	Approx. internal area square inches
3/8	0.675	0.49	0.19
1/2	0.840	0.62	0.30
3/4	1.050	0.82	0.53
1	1.315	1.05	0.86
1-1/4	1.660	1.38	1.50
1-1/2	1.900	1.61	2.04
2	2.375	2.07	3.36
2-1/2	2.875	2.47	4.78
3	3.500	3.07	7.39
3-1/3	4.000	3.55	9.89
4	4.500	4.03	12.73
5	5.563	5.05	19.99
6	6.625	6.07	28.89
8	8.625	8.07	51.15
10	10.750	10.19	81.55
12	12.750	12.09	114.80

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Manufacturer's Data Report Form NV-1*

*From ASME Section III, Div. 1.

FORM NV-1 CERTIFICATE HOLDERS' DATA REPORT FOR PRESSURE OR VACUUM
 RELIEF VALVES*
 As Required by the Provisions of the ASME Code, Section III Division 1

Pg. 1 of 6

1. Manufactured and certified by

(1)

(name and address of NV Certificate Holder)

2. Manufactured for

(2)

(name and address of Purchaser)

3. Location of installation

(3)

(name and address)

4. Valve

(10a)

Orifice size

(6a)

Nom. inlet size

(6b)

Outlet size

(6c)

(model no., series no.)

(in.)

(in.)

(in.)

5. ASME Code, Section III, Division 1:

(11)

(12)

(13)

(14)

(edition)

(addenda date)

(class)

(Code Case no.)

6. Type

(4a)

(4b)

(4c)

(4d)

(4e)

at

(5)

°F

(spring, pilot or power operated)

(set pressure, psig)

(blowdown, psi)

(rated temp.)

(hydro. test, psig, inlet)

7. Identification:

(6)

(7)

(8)

(9)

(10)

(Cert. Holder's serial no.)

(CRN)

(drawing no.)

(Nat'l Bd. no.)

(year built)

8. Control ring settings

(12a)

9. Pressure retaining items:

Serial No. or Identification

Mat'l. Spec., Including Type or Grade

Tensile Strength

Body

(8)

(15)

(16)

Bonnet or Yoke

Support Rods

Nozzle

Disk

Spring Washers

Adjusting Screws

Spindle

Spring

Bolting

Other Items

10. Relieving capacity

(8)

(2)

(6)

overpressure as certified by the National Board

(8)

(date)

(steam or fluid, lb/hr)

(psi)

11. Remarks:

(4e)

CERTIFICATION OF DESIGN

Design Specification certified by

(4)

P.E. State

Reg. no.

Design Report certified by

(5)

P.E. State

Reg. no.

(6)

CERTIFICATE OF COMPLIANCE

We certify that the statements made in this report are correct and that this valve conforms to the rules for construction of the ASME Code, Section III, Division 1.

NV Certificate of Authorization No.

Expires

Date

Name

(NV Certificate Holder)

Signed

(authorization representative)

* Supplemental information in the form of lists, sketches, or drawings may be used provided (1) size is 8½ x 11, (2) information in items 1 through 4 on this Data Report is included on each sheet, (3) each sheet is numbered and the number of sheets is recorded at the top of this form.

FORM NV-1 (Back — Pg. 2 of 6)

Certificate Holder's Serial No.

CERTIFICATE OF INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and the State or Province of and employed by have inspected the valve described in this Data Report on and state that to the best of my knowledge and belief, the Certificate Holder has constructed this valve in accordance with the ASME Code, Section III, Division 1.

By signing this certificate, neither the inspector nor his employer makes any warranty, expressed or implied, concerning the component described in this Data Report. Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date

Signed

Commissions

(7)

(Authorized Nuclear Inspector)

(Nat'l Bd. (incl. endorsements) and state or prov. and no.)



Corrosion Resistance Guide

The following chart may be used as a guide for selecting materials for various applications. The symbols used in the chart are as follows:

A = Excellent resistance

B = Good resistance

C = Fair resistance

N = No recommended

Blank space indicates insufficient data.

**CORROSIVE MEDIA
& CONDITIONS**

MATERIAL USED	GRAY IRON DUCTILE IRON	CARBON STEEL	301SS - 302SS 303SS - 304SS	316SS	416SS - 420SS 403S	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	EPDM	NEOPRENE	VITON
Acetaldehyde	C	B	B	A	N	B		A	N	N	A	N	C	
Acetate Solvents (crude)	N	N	A	A	B	A		A	C	B	B	A	A	B
Acetate Solvents (pure)	N	C	A	A	A	A		A	A	B	A	A	A	B
Acetic Acid (crude)	N	N	B		N	B	B	N	N	N	N	N	N	
Acetic Acid (pure)	N	N	A	A	N	A	B	A	N	N	N	N	N	
Acetic Acid (30%)	N			A	N		B	N	N	N	N	A	A	N
Acetic Acid (vapors)	N	B	N	B	N	N	B	N	N	N	N			B
Acetic Anhydride	C	N	B	A	N	B		A	N	N	B	B	B	N
Acetone	A	B	A	A	A	A		A	N	N	A	A	N	N
Acetylene	A	A	A	A	A	A			C	N	N	A	N	A
Air	A	A	A	A	A	A		A	A	A	A	N	N	A
Alcohols	C	B	A	A	B	A		A	B	B	B	A	C	A
Amines		B	A	A	C	A		A	B		B	C	C	N
Ammonia (Anhydrous)	B	B	A	A	B	A		A	N	A	A	B	C	N
Ammonia Solution	A	B	A	A	B	A			N	N	N		B	
Ammonium Oxalate	N	C	B	B		B			B	C	C			
Ammonium Persulphate	N	N	A	A	B	A		A	N	N	N	A	A	A
Ammonium Phosphate (Mono)	N	N	A	A	B	A		A	N	N	N	A	A	A
Ammonium Phosphate (Di)	B	B	A	A	B	A			C	C	C	A	A	A
Ammonium Phosphate (Tri)	A	A	B	A	B	B			C	C	C	A	A	A
Ammonium Sulphate	N	C	N	B	B	N	B	N	N	N	N	B	A	A
Ammonium Sulfite	C	N	C	B	C	C	N	N	N	N	N	B	B	A
Amyl Acetate	C	C	A	A	B	A			C	N	N	B	N	N
Amyl Alcohol	C	B	B	A	B	B		N	N	N	N	C	N	A
Aniline	C	C	B	A	B	B	B	N	N	N	N	B	N	A
Aniline Dyes	C	C	A	A	B	A		N	N	N	N	B	N	B
Aniline Hydrochloride	N	N	N	C		N	B	N	N	N	N	B	N	
Animal Oil (Lard)	A	A	A	A		A		B	B	B	B			B
Arsenic Acid	N	N	B	A	B	B		N	N	N	N	N	N	B
Asphalt	A	B	A	A	A	A	A	B	B	B	B	N	C	A
Barium Carbonate	B	B	A	A		A		B	B	B	B	C	C	B
Barium Chloride	C	C	C	B		C		C	C	C	B	C	C	B

CORROSIVE MEDIA
& CONDITIONS

MATERIAL USED	GRAY IRON DUCTILE IRON	CARBON STEEL	301SS - 302SS 304SS - 304SS	316SS	416SS - 420SS 440SS	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	EPDM	NEOPRENE	VITON
Barium Cyanide	C	B	A	A	A		A	C	C	C	B	C	B	
Barium Hydroxide	C	C	A	A	A		B	C	C	C	B	C	A	
Barium Nitrate	C	C	A	A	A		N	N	N	N	B	A	A	
Barium Sulphate	C	C	B	A	B		N	N	N	N	B	C	A	
Barium Sulphide	C	C	B	A	B		N	N	N	N	B	C	A	
Battery Acid			A											
Beer (Food)	N	N	A	A	N	A	A	B	B	B	C	C	A	
Beet Sugar Liquor	B	B	A	A	A	A	A	C	C	C	B	C	A	
Black Sulphate Liquor	A	A	A	A	B	A		N	A	N	B	B	A	
Blast Furnace Gas	A	A	A	A	A	A		A	A	A	N	N	A	
Borax (Sodium Borate)	B	B	A	A	A	A	A	C	C	C	A	A	B	
Bordeaux Mixture	A	A	A	A	A	A		A	A	B	B	A	C	
Boric Acid	N	N	B	B	C	B	A	C	C	C	B	C	B	
Bromine (Dry)	N	N	N	N	N	N	B	B	B	B	B	N	C	
Bromine (Wet)	N	N	N	N	N	N	B	N	N	N	N	N	B	
Butane	B	B	A	A	A	A		N	N	N	N	A	A	
Butanol	A	A	A	A	B	A		A	A	A	B	N		
Buttermilk	C	N	A	A	A	A	A	N	A	N	B		A	
Butyl Acetate	C	C	B	A	A	B		A	A	A	N	N	N	
Calcium Bisulphite	N	N	C	B	N	C	N	B	B	B	A	A	B	
Calcium Carbonate	N	N	A	A	A	A		N	N	N				
Calcium Chlorate	C	C	C	C	B	C	A	B	B	B	A	A	B	
Calcium Chloride	C	C	C	B	B	C		C	C	C	A	A	B	
Calcium Hydroxide	C	C	A	A	A	A	A	C	C	C	A	A	B	
Calcium Hypochlorite	N	N	N	N	N	N	C	C	C	C	A	C	B	
Calcium Sulphate	B	B	B	A	A	B		B	B	B	B	C	B	
Cane Sugar Liquors	A	A	A	A	A	A		B	A	A	B	C		
Carbolic Acid	N	N	A	A	A	A	A	C	C	C	B	C	B	
Carbon Dioxide (Dry)	B	B	A	A	A	A	A	A	A	A	B	B	B	
Carbon Dioxide (Wet)	C	C	A	A	A	A	A	C	C	C	B	B		
Carbon Disulphide	B	B	A	A	B	A	A	C	N	N	N	N	B	
Carbon Monoxide	A	B	A	A	A	A		B	B	B	N	N		
Carbon Tetrachloride	N	C	C	C	B	C		A	A	A	B	A	C	
Carbonated Beverages	N	N	A	A	A	A		N	N	N	B	A	A	
Carbonic Acid	N	N	A	A	B	A	A	C	C	C	A	A	B	
Casein			B	B		B								
Castor Oil	A	A	A	A	B	A		A	A	A	B	A	A	
Caustic Soda	B	C	A	A	B			N	N	N	A	C	A	
Caustic Solutions		B		A	B			N	N	N				
Caustic Potash	B	C												
Cellulose Acetate	C		B	B		B	A	A	A	A				
Cellulose Nitrate	B	B	B	B		B	B	B	B	B		B		
China Wood Oil	C	C	A	A	A	A		B	B	B	N		B	
Chloracetic Acid	N	N	N	C		N		N	B	N		N	C	
Chlorbenzol	B	B	C	C		C		A	A	A				

**CORROSIVE MEDIA
& CONDITIONS**

MATERIAL USED	GRAY IRON DUCTILE IRON	CARBON STEEL	301SS - 302SS 304SS - 304SS	316SS	416SS - 420SS 440SS	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	EPDM	NEOPRENE	VITON
Chloramine	A	N	N	C	N			A	A	A				
Chlorex	N	N	N		N			N	N	N				
Chloric Acid	C	C	A	A	A			N	N	N	N	N	A	
Chlorinated Solvents	N	N	N	C	N		C	N	N	N	N	N	A	A
Chlorinated Water	C	B	B	B	B	B	A	B	B	B	A	C	C	A
Chlorine (Dry)	N	N	N	C	N	N	N	N	N	N	C	N	N	C
Chlorine (Wet)							B	N	N	N	N	N	A	A
Chlorosulfonis Acid	N	N	N	B	A	C	B	C	B	B	A	N	A	A
Citric Acid	N	N	B	A	C	B		C	B	B	A	N	A	A
Coconut Oil	A	A	A	A	N	A		N	N	N	C	C	B	
Cod Liver Oil				A							A	A	B	
Coffee			A	A	N	A		N	N	N	A	N	B	
Coke Oven Gas	A	A	A	A	A	A		C	C	C	A	N	A	A
Corn Oil	B	B	A	A		A		N	N	N	C	C	C	A
Cottenseed Oil	B	B	A	A	A	A		N	N	N	C	C	C	A
Creisike	B	B	A	A	A	A	A	C	B	B	N	C	C	B
Cresylic Acid	N	C	A	A	B	A		N	N	N	N	N	N	A
Crude Oil	A	A	A	A	B	A	A	C	C	C	N	N	N	A
Diethylamine	A	A	A	A	A	A		A	A	A	B	C	N	
Dowtherm A or E	N	N	A	A	A	A		B	B	B	N	N	A	
Ethylene Dichloride	N	C	C	C		C		B	B	B	C	N	C	
Ethylene Glycol	B	A	A	A	A	A	A	B	A	A	A	A	A	A
Ethylene Oxide	B	C	A	A	B	A		C	C	C	C	N	B	
Fatty Acids	N	N	B	A		B	A	N	N	N	N	A	B	B
Ferric Chloride	N	N	N	N	N	N	N	N	N	N	N	A	B	B
Ferric Nitrate	N	N	B	A		B	C	N	N	N	A	A	B	B
Ferric Sulphate	N	N	B	A	A	B		N	C	C	A	A	B	B
Ferrous Chloride	N	N	N	N		N		N	N	N	B		B	
Ferrous Sulphate	N	N	B	A	B	B		C	C	C	B		B	
Fish Oils	B	B	A	A		A						B	A	
Flourine	N	A	C	B	C	C		C	C	C	C			
Foamite (Acid)	N	N	C			C		N	N	N		C		
Foamite (Alkaline)	A	A	A	A		A		N	N	N				
Formaldehyde	N	C	A	A	B	A	A	A	A	A	A	C	N	
Formic Acid	N	N	C	A	N	C	N	B	N	N	A	A	A	N
Freon	N	C	C	C	A	C	B	B	B	B	N	N	A	A
Fruit Juices	N	N	A	A	C	A		N	N	N	A	C	A	A
Fuel Oil	B	A	A	A	A	A	A	B	B	B	N	B	B	B
Gallic Acid	N	N	A	A		A		B	B	B		C	B	
Gasoline (Natural)	A	A	A	A	A	A		N	N	N	C	B	A	
Gasoline (Refined)	A	A	A	A	A	A		A	A	A	C	B	A	
Gelatin	N	N	A	A	N	A		N	N	N	A	A	B	
Glucose	B	B	A	A	A	A		A	A	A	A	A	A	A
Glycerine or Glycerol	A	A	A	A	A	A	A	B	A	A	A	A	A	B
Hydraulic Oil (Petro.)	B	B	A	A	B	A		A	A	A	N	B	A	

CORROSIVE MEDIA
& CONDITIONS

MATERIAL USED	GRAY IRON DUCTILE IRON	CARBON STEEL	301SS - 302SS 304SS - 304SS	316SS	416SS - 420SS 440SS	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	ERM	NEOPRENE	VITON
Hydraulic Oil (Synthetic)	A	A	A	A	B	A			A	A	A	B	N	C
Hydrazine				A							B	B		
Hydrobromic Acid	N	N		N	N		N	N	N	N	A	C	N	A
Hydrochloric Acid	N	N	N	N	N	N	N	N	N	N	N	C	N	B
Hydrocyanic A. id	N	C	A	A	A			N	N	N	N	A	N	B
Hydrofluoric Acid	N	N	N	N	N	N		N	N	N	N	A	N	A
Hydrofluosilic Acid	N	N	N	C	B	N	B	N	N	N	N	A	B	B
Hydrogen (Gas)	A	A	A	A	B	A		A	A	A	A	A	A	A
Hydrogen Chloride (Dry)		B	N	C	A	C		A	C	C	C			
Hydrogen Chloride (Wet)		N	N	N		N	N	N	N	N	N			
Hydrogen Fluoride (Dry)		C	N	C	C	N	A	C	B	B	B			
Hydrogen Peroxide	N	N	B	B	A	B	B	N	C	C	C			
Hydrogen Sulphide (Dry)	B	C	B	A	B	B	A	C	N	N	N	A	B	B
Hydrogen Sulphide (Wet)	B	C	B	A	C	B	A	C	N	N	N	A	B	B
Kerosene	B	A	A	A	A	A	A	A	A	A	A	N	C	A
Ketchup	N	N	A	A		A								
Ketones	A	A	A	A		A							N	N
Lacquers & Solvents	C	C	A	A	A	A		B	A	A	N	N	N	N
Lactic Acid	N	N	B	B	C	B	A	C	C	C	A	A	A	A
Lactose				A										
Lard	A	A	A	A		A					N	C		
Lead Acetate	N	N	B	B		B	A	N	N	N	A	A	B	A
Lime-Sulfur	A	A	A	A	B	A		N	C	C	C	C	C	
Lindseed Oil	A	A	A	A	A	A		C	C	C	C	C	A	B
Lubricating Oil (Petro.)	A	A	A	A	A	A		A	A	A	A	N	B	A
Lubricating Oil (Synth.)	A	A	A	A	A	A		A	A	A	A	N	B	A
Magnesium Chloride	N	C	C	B	C	C	A	B	A	A	A	A	A	C
Magnesium Hydroxide	N	B	A	A	A	A		B	A	A	A	A	B	A
Magnesium Nitrate	N	N		A				N	N	N	N			A
Magnesium Sulphate	N	C	A	A	A	A	B	B	A	A	A	A	A	A
Magnesium Sulphite	N	N		A				C	C	C	C	A	A	
Maleic Acid	N	C	C	A		C		B	B	B	B	N	N	A
Mercaptans	A	A	A	A		A		N	N	N	N			
Mercuric Chloride	N	N	N	N	N	N	N	N	N	N	N	A	A	
Mercuric Cyanide	N	N	B	B		B	B	N	N	N	N	B		
Methane	B	A	A	A		A		A	A	A	A	N	B	A
Methanol	B	B	B	B		B	B	B	B	B	B	A	A	N
Methyl Chloride	C	C	B	B	B	B	A	B	B	B	B	C	N	A
Naphtha	B	A	A	A	A	A	A	A	A	A	A	N	N	A
Naphthalene	B	A	A	A	A	A		B	B	B	B	N	N	B
Nickel Chloride	N	N	N	C	N	N	B	N	C	C	C	A	B	B
Nickel Nitrate	N	N	B	B		B		C	C	C	C	A	C	A
Nickel Sulphate	N	N	B	A	C	B		C	B	B	B	A	A	B
Nitrating Acid	N	N	C			C		N	N	N	N			
Nitric Acid (Crude)	N	N	C	B	B	C	N	N	N	N	N	N	N	A

CORROSIVE MEDIA & CONDITIONS	MATERIAL USED													
	GRAY IRON DUCTILE IRON	CARBON STEEL 301SS - 302SS 304SS - 3045SS 316SS	416SS - 420SS 440SS	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	EPDM	NEOPRENE	VITON		
Nitric Acid (Pure)	N	N	N	A	B	A	N	N	N	N	N	A		
Nitrobenzene	B	A	A	A	A	A	B	B	B	N	N	N		
Oxalic Acid	N	N	B	A	C	B	C	B	B	A	B	C		
Oxygen	A	A	A	A	A	A	A	A	A	A	A	A		
Palmitic Acid	C	C	B	A	B	B	A	B	B	B	A	A		
Paraffin Oils	B	B	A	A	A	A	B	B	B	N	A	A		
Petroleum (Sour Crude)	B	B	A	A	B	A	A	C	N	N	N	B	B	
Petroleum (Sweet Crude)	A	A	A	A	A	A	C	N	N	N	N	B	A	
Petroleum Oils (Refined)	A	A	A	A	A	A	A	A	A	N	B	A		
Phenol	N	N	B	B	B	B	A	A	A	B	N	B	A	
Phosphoric Acid	N	N	B	A	C	B	N	N	N	B	B	B		
Potassium Bromide	N	N	C	A	C	C	A	C	C	C	A	C	A	
Potassium Carbonate	B	C	A	A	A	A	C	C	C	C	A	C	A	
Potassium Chlorate	B	B	A	A	A	A	B	B	B	B	A	C	B	
Potassium Chloride	C	N	B	B	C	B	A	N	N	N	A	A	B	
Potassium Cyanide	N	B	B	B	B	B	B	C	B	B	A	A	B	
Potassium Dichromate	C	C	A	A	A	A	C	N	N	N	A	A	B	
Potassium Hydroxide	C	C	C	C	B	C	N	N	N	N	A	B	B	
Potassium Hypochlorite	N	N	C	B	C	C	N	N	N	N				
Potassium Nitrate	B	A	B	B	B	B	A	A	A	A	A	A	B	
Potassium Sulphate	N	N	B	A	B	B	B	A	A	A	A	A	B	
Produce Gas	A	A	A	A	A	A	C	C	C	C	N	B		
Propane	A	B	A	A	A	A	A	A	A	A	N	B	B	
Rosin	B	B	B	B	A	B	B	B	B	B				
Salicylic Acid	N	N	B	A	B	B	B	B	B	B	A	A	B	
Sea (Salt) Water	N	N	A	A	C	A	A	B	C	B	B	A	A	A
Sewage		C		A	B	A	B	B	B	B	B	A	B	A
Shellac	N	N	A	A	A	A	B	A	A		N			
Silver Bromide	N	N	C	B	C	C	N	N						
Silver Chloride	N	N	N	N	N	N	C	N	N	N				
Silver Nitrate	N	N	A	A	A	A	A	N	N	N	A	A		
Sludge, Acid	C	C	C				N	N	N	N				
Soap Solutions (Liquid)	B	A	A	A	C	A	C	C	C	C	A	A	A	
Sodium Acetate	N	N	A	A	C	A	A	B	B	B	A	B	N	
Sodium Aluminate	A	A	A	A	A	A	A	B	B	B	A	C	A	
Sodium Bicarbonate	B	A	B	B	A	B	A	A	A	A	A	A	B	
Sodium Bisulphate	N	N	B	A	A	B	B	N	N	N	B	C	A	
Sodium Bisulphite	N	N	B	A		B		N	N	N	A	A	B	
Sodium Carbonate	A	A	B	B	A	B	B	B	B	A	A	A	B	
Sodium Chlorate	B	A	B	B	B	B	C	C	C	C	B	C	B	
Sodium Chloride	C	C	C	B	C	C	N	C	B	B	A	A		
Sodium Cyanide	C	C	C	B	A	C	B	N	N	N	A	A	B	
Sodium Fluoride	N	N	C	A	C	C	C	C	C	C	A	C	A	
Sodium Hydroxide	C	C	C	C	A	C	N	C	C	C	A	B	N	
Sodium Hypochlorite	N	N	C	B	N	C	C	N	C	C	B	B	A	

CORROSIVE MEDIA
& CONDITIONS

	MATERIAL USED	GRAY IRON DUCTILE IRON	CARBON STEEL	301SS - 302SS 303SS - 304SS	316SS	416SS - 420SS 440SS	17-4 PH	STELLITE	INCONEL	BRASS	BRONZE	COPPER	ERM	NEOPRENE	VITON
Sodium Nitrate	C	B	B	A	A	B		A	C	B	B	B	A	B	A
Sodium Nitrite	B	A	B	B		B			B	B	B	B	A		
Sodium Perborate	C	C	A	A	A	A		A	C	B	B	B	A	B	A
Sodium Peroxide	C	C	A	A	A	A		A	C	B	B	B	A	B	A
Sodium Phosphate (Mono)	N	N	A	A	B	A			C	C	C	C	A	A	A
Sodium Phosphate (Di)	N	N	A	A	B	A			A	A	A	A	A	B	A
Sodium Phosphate (Tri)	C	C	A	A	B	A		A	C	C	C	C	A	B	A
Sodium Silicate	B	B	A	A	B	A		A	C	B	B	B	A	A	A
Sodium Sulphate	B	B	B	A	B	B		B	B	A	A	A	A	A	A
Sodium Sulphide	B	B	C	A	B	C		A	N	N	N	N	A	A	A
Sodium Sulphite	N	C	A	A		A		C	B	B	B	B	A	A	A
Sodium Thiosulphate	N	N	A	B	A	N		B	B	B	B	B	A	A	A
Stannic Chloride	N	N	N	N		N		N	N	N	N	N	B	N	B
Stannous Chloride	N	N	N	A		N		B	N	N	N	N	A	A	A
Steam, 212F	A	A	A	A	B	A	A	A	B	B	B	B	A	N	N
Steam, 600 F	C	C	A	A	B	A	B	A	C	N	N	N	C	N	N
Sulfur	C	C	A	A	A	A		A	C	C	C	C	A	A	B
Sulfur Chloride	N	N	N	C	N	N		B	N	N	N	N	N	N	A
Sulfur Dioxide (Dry)	B	B	A	A	A	A		B	C	A	A	A	A	N	A
Sulfur Dioxide (Wet)	N	N	B	A	N	B		N	N	B	B	B	A	B	
Sulfur Trioxide	B	B	B	B	B	B			B	B	B	B	B	N	C
Sulfuric Acid, 2% & Less	N	N	C	B	N	C	N	B	N	N	N	N	B	B	A
Sulfuric Acid, 2-40%	N	N	N	N	N	N	N	N	B	N	N	N	B	N	A
Sulfuric Acid, 40%	N	N	N	N	N	N	N	N	B	N	N	N	B	N	B
Sulfuric Acid, 93-100%	B	B	B	B	B	B	N	B	N	N	N	N	B	N	B
Sulfurous Acid	N	N	B	B	N	B		C	N	N	N	N	B	B	A
Tannic Acid	C	B	A	A	C	A		B	B	B	B	B	A	C	A
Tar	A	B	A	A	B	A		A	B	A	A	A	N	C	A
Tartaric Acid	N	N	B	A	C	B		A	C	B	B	B	B	B	B
Tung Oil	C	C	A	A	N	A		C	C	C	C	C	N	B	A
Turpentine	B	B	A	A	B	A		A	C	B	B	N	N	N	A
Varnish	C	C	A	A	A	A		A	B	B	B	N	N	N	A
Vegetable Oil		B	A	A	A	A			B	B	B	C	C	C	A
Water (Acid Mine)	N	N	B	B	A	B	B	A	N	C	N	N	B	C	A
Water (Boiler Feed)	B	B	A	A	A	A	A	A	C	C	C	C	A	A	A
Water (Distilled)	N	N	A	A	A	A	A	A	N	N	N	N	A	A	A
Water (Fresh)	A	A	A	A	A	A	A	A	C	B	B	B	A	A	A
Water (Salt)	N	N	N	C	N	N	A	B	C	B	B	B	A	A	A
Wine & Whiskey	N	N	A	A	N	A	A	A	B	B	B	B	A	A	A
Xylene (Xylol)	B	B	A	A	A	A		A	A	A	A	A	N	N	B
Zinc Chloride	N	N	N	C	N	N		B	N	B	B	B	A	A	B
Zinc Sulphate	N	N	A	C	B	A		B	C	B	B	B	A	A	A

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M

Water Saturation Pressure and Temperature

Water **Saturation Pressure/Temperature** **(psia/kpaa/bar) / (°F/°C)**

Table T7-8

Pressure				Temperature		Pressure				Temperature		Pressure				Temperature	
psia	kPaa	bara	deg F	deg C		psia	kPaa	bara	deg F	deg C		psia	kPaa	bara	deg F	deg C	
14.7	101	1.01	212.0	100.0		230	1586	15.9	393.7	200.9		880	6068	60.7	529.3	276.3	
15	103	1.03	213.3	100.7		240	1655	16.5	397.4	203.0		900	6206	62.1	532.0	277.8	
20	138	1.38	228.0	108.9		250	1724	17.2	401.0	205.0		920	6343	63.4	534.6	279.2	
25	172	1.72	240.1	115.6		260	1793	17.9	404.4	206.9		940	6481	64.8	537.1	280.6	
30	207	2.07	250.3	121.3		270	1862	18.6	407.8	208.8		960	6619	66.2	539.7	282.1	
35	241	2.41	259.3	126.3		280	1931	19.3	411.1	210.6		980	6757	67.6	542.1	283.4	
40	276	2.76	267.3	130.7		290	2000	20.0	414.3	212.4		1000	6895	69.0	544.6	284.8	
45	310	3.10	274.4	134.7		300	2069	20.7	417.4	214.1		1050	7240	72.4	550.5	288.1	
50	345	3.45	281.0	138.3		320	2206	22.1	423.3	217.4		1100	7585	75.8	556.3	291.3	
55	379	3.79	287.1	141.7		340	2344	23.4	429.0	220.6		1150	7929	79.3	561.8	294.3	
60	414	4.14	292.7	144.8		360	2482	24.8	434.9	223.8		1200	8274	82.7	567.2	297.3	
65	448	4.48	298.0	147.8		380	2620	26.2	439.6	226.4		1250	8619	86.2	572.4	300.2	
70	483	4.83	302.9	150.5		400	2758	27.6	444.6	229.2		1300	8964	89.6	577.4	303.0	
75	517	5.17	307.6	153.1		420	2896	29.0	449.4	231.9		1350	9308	93.1	582.3	305.7	
80	552	5.52	312.0	155.6		440	3034	30.3	454.0	234.4		1400	9653	96.5	587.1	308.4	
85	586	5.86	316.3	157.9		460	3172	31.7	458.5	236.9		1450	9998	100.0	591.7	310.9	
90	621	6.21	320.3	160.2		480	3310	33.1	462.8	239.3		1500	10343	103.4	596.2	313.4	
95	655	6.55	324.1	162.3		500	3448	34.5	467.0	241.7		1600	11032	110.3	604.9	318.3	
100	690	6.90	327.8	165.3		520	3585	35.9	471.1	243.9		1700	11721	117.2	613.1	322.8	
105	724	7.24	331.4	166.3		540	3723	37.2	475.0	246.1		1800	12411	124.1	621.0	327.2	
110	758	7.58	334.8	168.2		560	3861	38.6	478.8	248.2		1900	13101	131.0	628.6	331.4	
115	793	7.93	338.1	170.1		580	3999	40.0	482.6	250.3		2000	13790	137.9	635.8	335.4	
120	827	8.27	341.3	171.8		600	4137	41.4	486.2	252.3		2100	14479	144.8	642.8	339.3	
125	862	8.62	344.4	173.6		620	4275	42.7	489.7	254.3		2200	15169	151.7	649.6	343.1	
130	896	8.96	347.3	175.2		640	4413	44.1	493.2	256.2		2300	15859	158.6	655.9	346.6	
135	931	9.31	350.2	176.8		660	4551	45.5	496.6	258.1		2400	16548	165.5	662.1	350.1	
140	965	9.65	353.0	178.3		680	4689	46.9	499.9	259.9		2500	17238	172.4	668.1	353.4	
145	1000	10.0	355.8	179.9		700	4827	48.3	503.1	261.7		2600	17927	179.3	673.9	356.6	
150	1034	10.3	358.4	181.3		720	4964	49.6	506.2	263.4		2700	18617	186.2	679.5	359.7	
160	1103	11.0	363.6	184.2		740	5102	51.0	509.3	265.2		2800	19306	193.1	685.0	362.8	
170	1172	11.7	368.4	186.9		760	5240	52.4	512.3	266.8		2900	19996	200.0	690.2	365.7	
180	1241	12.4	373.1	189.5		780	5378	53.8	515.3	268.5		3000	20685	206.9	695.3	368.5	
190	1310	13.1	377.5	191.9		800	5516	55.2	518.2	270.1		3100	21375	213.7	700.3	371.3	
200	1379	13.8	381.8	194.3		820	5654	56.5	521.1	271.7		3200	22064	220.6	705.1	373.9	
210	1448	14.5	385.9	196.6		840	5792	57.9	523.9	273.3		3208	22119	221.2	705.5	374.2	
220	1517	15.2	389.9	198.8		860	5930	59.3	526.6	274.8							

Value of Coefficient C

<i>k</i>	<i>C</i>	<i>k</i>	<i>C</i>	<i>k</i>	<i>C</i>	<i>k</i>	<i>C</i>
1.00	315 ^a	1.30	347	1.60	372	1.90	394
1.01	317	1.31	348	1.61	373	1.91	395
1.02	318	1.32	349	1.62	374	1.92	395
1.03	319	1.33	350	1.63	375	1.93	396
1.04	320	1.34	351	1.64	376	1.94	397
1.05	321	1.35	352	1.65	376	1.95	397
1.06	322	1.36	353	1.66	377	1.96	398
1.07	323	1.37	353	1.67	378	1.97	398
1.08	325	1.38	354	1.68	379	1.98	399
1.09	326	1.39	355	1.69	379	1.99	400
1.10	327	1.40	356	1.70	380	2.00	400
1.11	328	1.41	357	1.71	381	—	—
1.12	329	1.42	358	1.72	382	—	—
1.13	330	1.43	359	1.73	382	—	—
1.14	331	1.44	360	1.74	383	—	—
1.15	332	1.45	360	1.75	384	—	—
1.16	333	1.46	361	1.76	384	—	—
1.17	334	1.47	362	1.77	385	—	—
1.18	335	1.48	363	1.78	386	—	—
1.19	336	1.49	364	1.79	386	—	—
1.20	337	1.50	365	1.80	387	—	—
1.21	338	1.51	365	1.81	388	—	—
1.22	339	1.52	366	1.82	389	—	—
1.23	340	1.53	367	1.83	389	—	—
1.24	341	1.54	368	1.84	390	—	—
1.25	342	1.55	369	1.85	391	—	—
1.26	343	1.56	369	1.86	391	—	—
1.27	344	1.57	370	1.87	392	—	—
1.28	345	1.58	371	1.88	393	—	—
1.29	346	1.59	372	1.89	393	—	—
1.30	347	1.60	373	1.90	394	—	—

^aThe limit of *C*, as *k* approaches 1.00, is 315.

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Unit Conversions

O.1 Flow Rate

1 ft ³ /hr	= 0.02832 m ³ /hr
1 ft ³ /min	= 0.472 Lit/sec
1 ft ³ /sec	= 448.8 gals/min
1 m ³ /hr	= 35.315 ft ³ /hr
	= 264.2 U.S. gals/hr
	= 4.403 gals/min
1 Imperial gal/hr	= 1.2009 U.S. gals/hr
1 lb/hr	= 0.4536 kg/hr
1 kg/min	= 132.3 lb/hr
1 gal/min	= 0.06309 Lit/sec
	= 3.785 Lit//min
	= 0.2271 m ³ /hr
	= 0.002228 ft ³ /sec
1 Lit/hr	= 0.004403 gals/min
1 Lit/sec	= 15.8529 gals/min

O.2 Power and Heat

1 British thermal unit (Btu)	= 778 foot-pounds (ft·lb) = 0.252 kilocalorie (kcal) = 107.6 meter kilogram (mkg) = 1.055×10^3 joules (j)
1 therm·hour	= 100,000 Btu/hour (Btu/h) = 39.3082 brake horsepower (hp) = 2.9873 boiler horsepower (bhp)
1 calorie (cal)	= 3088 (ft·lb) = 3.968 Btu = 4.186 j
1 joule (j)	= 10^7 ergs = 9486×10^{-4} Btu = 0.7736 ft·lb = 1 watt second (W·s)
1 kilowatt (kW)	= 3414 Btu/h = 1000 W = 738 (ft·lb)/s = 1.341 horsepower (hp) = 102 mkg/s
1 kilowatt·hour (kWh)	= 3414 Btu = 860 kcal = 2.665×10^6 (ft·lb) = 3.6×10^6 j
1 megawatt (MW)	= 1000 kilowatts (kW)
1 horsepower (hp)	= 33,000 foot-pounds per minute = 550 ft·lb/s = 0.746 kW = 746 W = 76.0 mkg/s
1 horsepower·hour (hp·h)	= 2545 Btu = 1.98×10^6 ft·lb = 64.17 kcal

1 boiler horsepower (bhp)	= 33,475 Btu/h
	= 34.5 pounds per hour of evaporation from and at 212°F
	= 9.803 kW
	= 10 square feet of boiler heating surface (watertube boiler)
	= 12 square feet of boiler heating surface (firtube boiler)

O.3 Pressure

1 pound per square inch (psi)	= 0.06804 atmosphere (atm)
	= 6.895×10^3 pascals (pa)
	= 0.0703 kg/cm ²
1 kg/cm ²	= 0.9678 atm
	= 14.22 psi
	= 32.81 ft of water
	= 28.96 in of mercury
1 bar	= 0.9869 atm
	= 14.5 psi
	= 1×10^6 dynes/cm ²
1 atmosphere	= 14.696 psi
	= 29.92 inches (in) of mercury
	= 1.0333 kg/cm ²
1 in of water at 62°F	= 0.0361 psi
	= 0.07355 in of mercury
	= 5.20 pounds per square foot (psf)
	= 0.00254 kg/cm ²
1 ft head of water at 62°F	= 0.433 psi
	= 0.0295 atm
	= 0.8826 in of mercury
	= 0.03048 kg/cm ²
1 in of mercury	= 0.491 psi
	= 1.133 ft of water
	= 0.03453 kg/cm ²

O.4 Temperature

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32)/1.8$$

$$^{\circ}\text{R} = ^{\circ}\text{F} + 460$$

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273$$

O.5 Density of Water (at 62°F)

1 cubic foot (ft ³)	= 62.5 lb
	= 7.48 gallons (gal)
1 pound (lb)	= 0.01604 cu ft ³
	= 0.1198 gal
1 gallon (gal)	= 8.33 lb
	= 277.3 cubic inches (in ³)
1 long ton of water	= 36 ft ³

O.6 Length

1 inch (in)	= 2.54 centimeters (cm)
	= 25.4 millimeters (mm)
1 foot (ft)	= 12 in
	= 30.48 cm
1 yard (yd)	= 3 ft
	= 0.914 meter (m)
1 mile (mi)	= 5280 ft
	= 1760 yd
	= 1.609 kilometers (km)
1 meter (m)	= 100 cm
	= 1000 mm
	= 1.094 yd
	= 3.28 ft
	= 39.37 in
1 kilometer (km)	= 1000 m
	= 0.621 mi

O.7 Area

1 square inch (in^2)	$= 6.45 \text{ cm}^2$ $= .006944 \text{ ft}^2$
1 square foot (ft^2)	$= 144 \text{ in}^2$ $= 0.0929 \text{ m}^2$
1 square yard (yd^2)	$= 9 \text{ ft}^2$ $= 0.836 \text{ m}^2$
1 square mile (mi^2)	$= 640 \text{ acres}$ $= 2.590 \text{ km}^2$ $= 3.098 \times 10^6 \text{ yd}^2$ $= 2.590 \times 10^6 \text{ m}^2$
1 acre	$= 43,560 \text{ ft}^2$ $= 4840 \text{ yd}^2$ $= 4.047 \times 10^3 \text{ m}^2$
1 square meter (m^2)	$= 10,000 \text{ cm}^2$ $= 11.196 \text{ yd}^2$ $= 10.76 \text{ ft}^2$
1 square centimeter (cm^2)	$= 100 \text{ mm}^2$ $= 0.155 \text{ in}^2$
1 nautical mile	$= 6080 \text{ ft}$ $= 1.853 \text{ km}$

O.8 Volume

1 cubic inch (in ³)	= 16.39 cm ³ = 0.0005787 ft ³
1 cubic foot (ft ³)	= 1728 in ³ = 28.32 liters (L) = 0.02832 m ³
1 cubic yard (yd ³)	= 27 ft ³ = 0.765 m ³
1 cubic meter (m ³)	= 1000 L = 1.308 yd ³ = 35.31 ft ³
1 imperial gallon	= 277.4 in ³ = 4.55 L
1 U.S. gallon	= 0.833 imperial gal = 3.785 L = 231 in ³
1 liter (l)	= 1000 cm ³ = 0.22 imperial gal = 0.2642 U.S. gal = 61 in ³

O.9 Weight

1 pound (lb)	= 16 ounces (oz)
	= 700 grains (gr)
	= 454 grams (g)
	= 0.454 kg
1 grain (gr)	= 64.8 mg
	= 0.0648 g
	= 0.0023 oz
1 gram (g)	= 1000 mg
	= 0.03527 oz
	= 15.43 gr
1 kilogram (kg)	= 1000 g
	= 2205 lb
1 U.S. short ton	= 2000 lb
	= 907 kg
1 U.S. long ton	= 2240 lb
	= 1016 kg
1 metric ton	= 1000 kg
	= 0.948 U.S. long ton
	= 1.102 U.S. short ton
	= 2205 lb

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