Crosby Valve Inc.

Technical Document No. TP-V300
Effective: May 1997

Crosby®
Pressure Relief Valve Engineering Handbook

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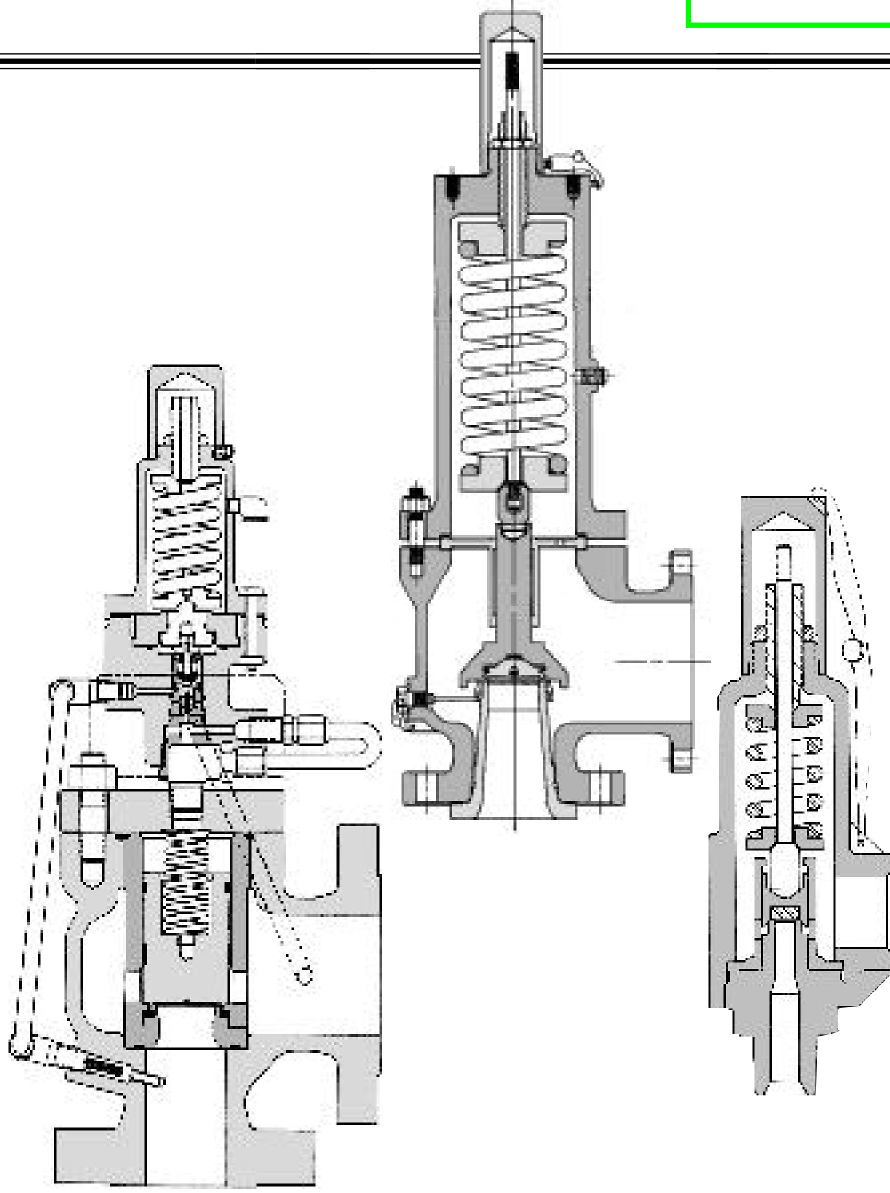

Notes:

CROSBY®
Pressure Relief Valve
ENGINEERING HANDBOOK

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*United States Customary System

CROSBY

Crosby® Engineering Handbook

Technical Publication No. TP-V300

Chapter I

Introduction

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The Crosby® Pressure Relief Valve Engineering Handbook contains important technical information relating to pressure relief valves.

The primary purpose of a pressure relief valve is protection of life and property by venting fluid from an overpressurized vessel. Information contained in this handbook applies to the overpressure protection of pressure vessels, lines and systems.

Reference is made to the ASME Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels. The information in this handbook is NOT to be used for the application of overpressure protection to power boilers and nuclear power plant components which are addressed in the ASME Boiler and Pressure Vessel Code, Section I, Power Boilers, and Section III, Nuclear Power Plant Components, respectively.

Proper sizing, selection, manufacture, assembly, test, installation and maintenance of a pressure relief valve are all critical to obtaining maximum protection.

This handbook has been designed to provide a service to Crosby's customers by presenting reference data and technical recommendations based on our many years of experience in sizing, selecting, testing, installing and operating pressure relief valves. Sufficient data is supplied so to properly size and select Crosby pressure relief valves for specific applications. Information covering terminology, standards, codes, basic design, sizing and selection information, including examples, are presented in an easy to use format.

Some of the material in this handbook is reprinted or excerpted from publications developed by associations or committees in which Crosby has participated. The information contained in the manual is offered as a guide. Those who use the information are reminded of the limitations of such a publication and that there is no substitute for qualified engineering analysis.

Crosby pressure relief valves are manufactured in accordance with a controlled Quality Assurance Program which meets or exceeds ASME Code Quality Control Program requirements. Capacities are certified by the National Board of Boiler and Pressure Vessel Inspectors. These features are assured by the presence of an ASME Code Symbol Stamp and the letters NB on each valve nameplate. Crosby's valves are designed, manufactured and tested in accordance with a quality management system approved to the International Standard Organization's ISO 9000 Quality Standard Series requirements. With proper sizing and selection, the user can thus be assured that Crosby products are of the highest quality and technical standards in the world of pressure relief technology.

When in doubt as to the proper application of any particular data, the user is advised to contact the nearest Crosby Regional Office or Representative. Crosby has a large staff of highly trained people strategically located throughout the world who should be contacted when a question arises. Refer to Crosby's Worldwide Directory for an up-to-date contact listing.

Crosby's Computer Aided Valve Sizing Program - "*CROSBY-SIZE*"

Crosby has designed a computer sizing program, *CROSBY-SIZE*, to provide maximum service to our customers by presenting recommendations based on Crosby's many years of experience. Use of this program allows an accurate determination of such parameters as orifice size, maximum flow and predicted sound level.

The program is a powerful tool, yet easy to use. Its many features include quick and accurate calculations, user selected units, selection of valve size and style, valve data storage, printed reports, specification sheets and dimensional drawings.

Program control via pop-up windows, function keys, extensive on-line help facilities, easy to read formatted screens, immediate flagging of errors, easy editing of displayed inputs and other features combine to make the program easy to understand and operate.

It is assumed that the user of *CROSBY-SIZE* has a basic understanding of relief valve sizing calculations. The user is responsible for correct determination of service conditions and the suitability of this program for a specific application.

CROSBY-SIZE and Crosby's Engineering Handbook are useful tools in sizing pressure relief valves. Should additional clarification be required, contact Crosby.

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Chapter 2

Design Fundamentals

Introduction

A pressure relief valve is a safety device designed to protect a pressurized vessel or system during an overpressure event. An overpressure event refers to any condition which would cause pressure in a vessel or system to increase beyond the specified design pressure or maximum allowable working pressure (MAWP).

Since pressure relief valves are safety devices, there are many Codes and Standards written to control their design and application. The purpose of this discussion is to familiarize you with the various parameters involved in the design of a pressure relief valve and provide a brief introduction to some of the Codes and Standards which govern the design and use of pressure relief valves. Excerpts of various applicable Codes and Standards are included in other sections of this handbook.

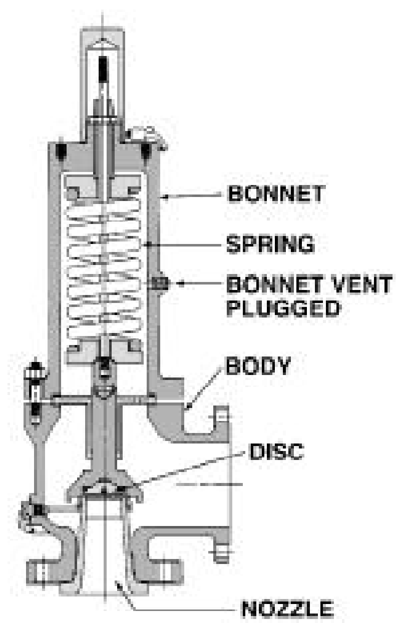
Many electronic, pneumatic and hydraulic systems exist today to control fluid system variables, such as pressure, temperature and flow. Each of these systems requires a power source of some type, such as electricity or compressed air in order to operate. A pressure relief valve must be capable of operating at all times, especially during a period of power failure when system controls are nonfunctional. The sole source of power for the pressure relief valve, therefore, is the process fluid.

Once a condition occurs that causes the pressure in a system or vessel to increase to a dangerous level, the pressure relief valve may be the only device remaining to prevent a catastrophic failure. Since reliability is directly related to the complexity of the device, it is important that the design of the pressure relief valve be as simple as possible.

The pressure relief valve must open at a predetermined set pressure, flow a rated capacity at a specified overpressure, and close when the system pressure has returned to a safe level. Pressure relief valves must be designed with materials compatible with many process fluids from simple air and water to the most corrosive media. They must also be designed to operate in a consistently smooth and stable manner on a variety of fluids and fluid phases. These design parameters lead to the wide array of Crosby products available in the market today and provide the challenge for future product development.

Spring Loaded Design

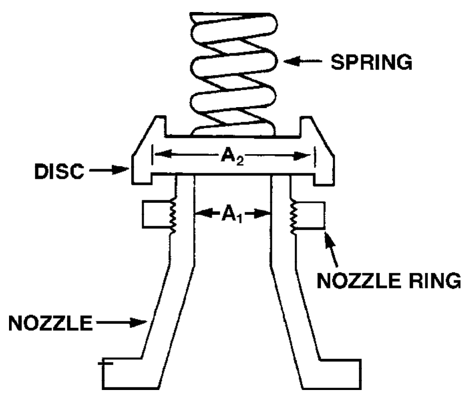
The basic spring loaded pressure relief valve has been developed to meet the need for a simple, reliable, system actuated device to provide overpressure protection. Figure F2-1 shows the construction of a spring loaded pressure relief valve. The valve consists of a valve inlet or nozzle mounted on the pressurized system, a disc held against the nozzle to prevent flow under normal system operating conditions, a spring to hold the disc closed, and a body/bonnet to contain the operating elements. The spring load is adjustable to vary the pressure at which the valve will open.



Crosby Style JOS Spring Loaded Pressure Relief Valve
Figure F2-1

Figure F2-2 is a simple sketch showing the disc held in the closed position by the spring. When system pressure reaches the desired opening pressure, the force of pressure acting over Area A_1 equals the force of the spring, and the disc will lift and allow fluid to flow out through the valve. When pressure in the system returns to a safe level, the valve will return to the closed position.

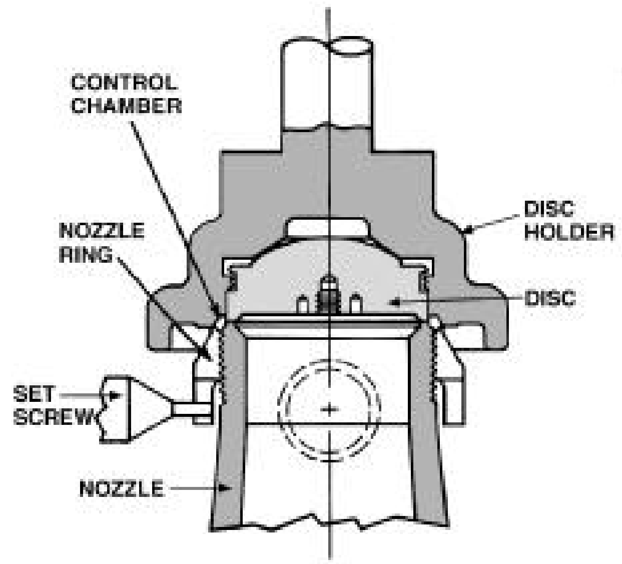
When a pressure relief valve begins to lift, the spring force increases. Thus system pressure must increase if lift is to continue. For this reason pressure relief valves are allowed an overpressure allowance to reach full lift. This allowable overpressure is generally 10% for valves on unfired systems. This margin is relatively small and some means must be provided to assist in the lift effort.



Trim Areas Diagram
Figure F2-2

Most pressure relief valves, therefore, have a secondary control chamber or huddling chamber to enhance lift. A typical configuration is shown in Figure F2-3. As the disc begins to lift, fluid enters the control chamber exposing a larger area A_2 of the disc (Figure F2-2) to system pressure. This causes an incremental change in force which overcompensates for the increase in spring force and causes the valve to open at a rapid rate. At the same time, the direction of the fluid flow is reversed and the momentum effect resulting from the change in flow direction further enhances lift. These effects combine to allow the valve to achieve maximum lift and maximum flow within the allowable overpressure limits. Because of the larger disc area A_2 (Figure F2-2) exposed to system pressure after the valve achieves lift, the valve will not close until system pressure has been reduced to some level below the set pressure. The design of the control chamber determines where the closing point will occur.

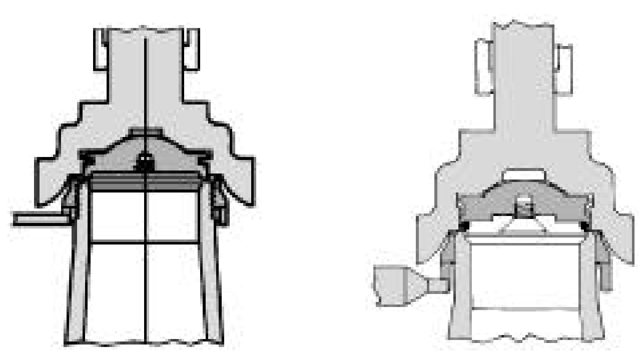
The difference between the set pressure and the closing point pressure is called blowdown and is usually expressed as a percentage of set pressure.



Crosby Style JOS Pressure Relief Valve Trim
Figure F2-3

The design of the control or huddling chamber involves a series of design tradeoffs. If the design maximizes lift effort then blowdown will be long. If the design objective is to minimize blowdown, then the lift effort will be diminished. Many pressure relief valves are, therefore, equipped with a nozzle ring which can be adjusted to vary the geometry of the control chamber to meet a particular system operating requirement (Figures F2-2 and F2-3).

Liquid Trim Designs
For liquid applications, Crosby offers a unique, patented liquid trim design designated as Style JLT-JOS or JLT-JBS. See Figure F2-4 showing liquid trim available in metal or soft seated valves. These designs provide stable non-chattering valve performance and high capacity at 10% overpressure.



Metal Seat **O-Ring Soft Seat**
Crosby Styles JLT-JOS and JLT-JBS
Figure F2-4

Materials of Construction

Compatibility with the process fluid is achieved by careful selection of materials of construction. Materials must be chosen with sufficient strength to withstand the pressure and temperature of the system fluid. Materials must also resist chemical attack by the process fluid and the local environment to ensure valve function is not impaired over long periods of exposure. Bearing properties are carefully evaluated for parts with guiding surfaces. The ability to achieve a fine finish on the seating surfaces of the disc and nozzle is required for tight shut off. Rates of expansion caused by temperature of mating parts is another design factor.

Back Pressure Considerations

Pressure relief valves on clean non-toxic, non-corrosive systems may be vented directly to atmosphere. Pressure relief valves on corrosive, toxic or valuable recoverable fluids are vented into closed systems. Valves that vent to the atmosphere, either directly or through short vent stacks, are not subjected to elevated back pressure conditions. For valves installed in a closed system, or when a long vent pipe is used, there is a possibility of developing high back pressure. The back pressure on a pressure relief valve must always be evaluated and its effect on valve performance and relieving capacity must be considered.

A review of the force balance on the disc (Figure F2-2 on page 2-2) shows that the force of fluid pressure acting on the inlet side of the disc will be balanced by the force of the spring plus whatever pressure exists on the outlet side of the valve. If pressure in the valve outlet varies while the valve is closed, the valve set pressure will change. If back pressure varies while the valve is open and flowing, valve lift and flow rate through the valve can be affected. Care must be taken in the design and application of pressure relief valves to compensate for these variations.

Conventional Valves

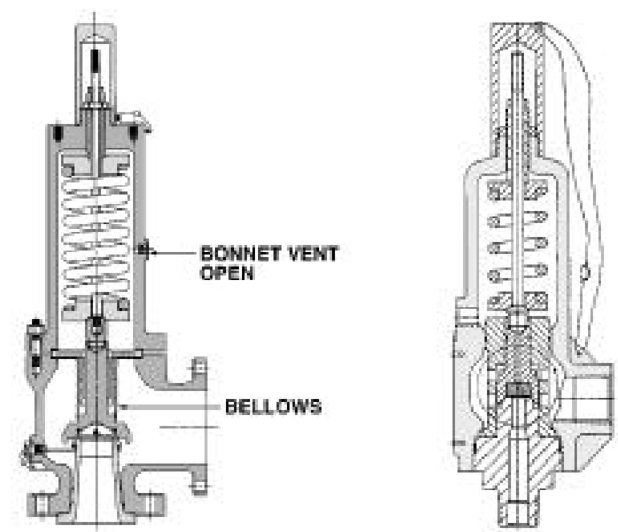
Back pressure which may occur in the downstream system while the valve is closed is called superimposed back pressure. This back pressure may be a result of the valve outlet being connected to a normally pressurized system or may be caused by other pressure relief valves venting into a common header. Compensation for superimposed back pressure which is constant may be provided by reducing the spring force. Under this condition the force of the spring plus back pressure acting on the disc would equal the force of the inlet set pressure acting to open the disc. It must be remembered, however, that the value of the set pressure will vary directly with any change in back pressure.

Balanced Bellows Valves and Balanced Piston Valves

When superimposed back pressure is variable, a balanced bellows or balanced piston design is recommended. Typical balanced bellows and piston style valves are shown in Figure F2-5. The bellows or piston is designed with an effective pressure area equal to the seat area of the disc. The bonnet is vented to ensure that the pressure area of the bellows or piston will always be exposed to atmospheric pressure and to provide a telltale sign should the bellows or piston begin to leak. Variations in back pressure, therefore, will have no effect on set pressure. Back pressure may, however, affect flow.

Back pressure, which may occur 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 through the downstream piping system. Built up back pressure will not affect the valve opening pressure, but may have an effect on valve lift and flow. On applications of 10% overpressure, balanced bellows or balanced piston designs are recommended when built-up back pressure is expected to exceed 10% of the cold differential test pressure (CDTP).

In addition to offsetting the effects of variable back pressure, the bellows or piston acts to seal process fluid from escaping to atmosphere and isolates the spring, bonnet and guiding surfaces from contacting the process fluid. This is especially important for corrosive services.



Crosby Style JBS **Crosby Series BP**

Balanced Pressure Relief Valves
Figure F2-5

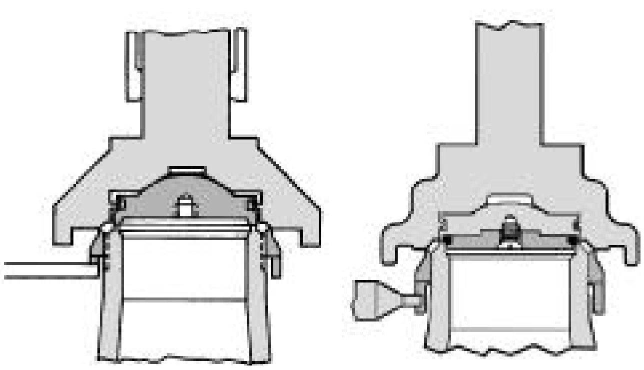
Nozzle Type

The inlet construction of pressure relief valves is either a full nozzle as used in Styles JOS, JBS and JLT, Series 800/900 OMNI-TRIM® and Series BP, or semi nozzle as used in Styles JPV/JPVM. In a full nozzle valve, only the nozzle and disc are exposed to the fluid media when the valve is closed. In a semi nozzle valve, the nozzle, disc, and part of the valve body are exposed to the inlet fluid when the valve is closed.

Seat Leakage

Another important consideration in the design of a pressure relief valve is the ability to maintain tight shut off. Pressure relief valves are required to remain on systems for long periods of time under widely varying conditions of pressure and temperature. Seat leakage will result in continuous loss of system fluid and may cause progressive damage to the valve seating surfaces. Extreme leakage could result in premature opening of the valve. Allowable seat leakage limits for pressure relief valves are many orders of magnitude more stringent than required for other types of valves.

These extremes of tightness are achieved by close control of part alignment, optically flat seating surfaces, and careful selection of materials for each application. A diligent maintenance schedule must be carried out in the field to maintain the leak tight integrity of the valve, particularly on a system where the pressure relief valve is cycled often. For additional tightness, where system conditions permit, soft seat or elastomer seat construction may be employed (see Figure F2-6). Most manufacturers recommend that system operating pressures not exceed 90% of set pressure to achieve and maintain proper seat tightness integrity.

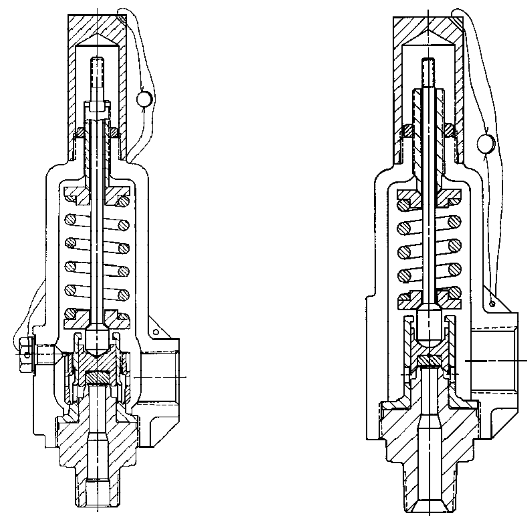


Metal Seat **O-Ring Soft Seat**
Crosby Styles JOS and JBS
Figure F2-6

Screwed Connection Valves

For applications requiring smaller sizes (0.074 to 0.503 sq. in. orifices), maximum versatility and premium performance, Crosby offers Series 800 Adjustable Blowdown, Series 900 Fixed Blowdown OMNI-TRIM® and Series BP (Balanced Piston) pressure relief valves. See Figure F2-7 for these screwed connection valves which also can be furnished with welding end or flanged connections. See Figure F2-5 for Series BP valve.

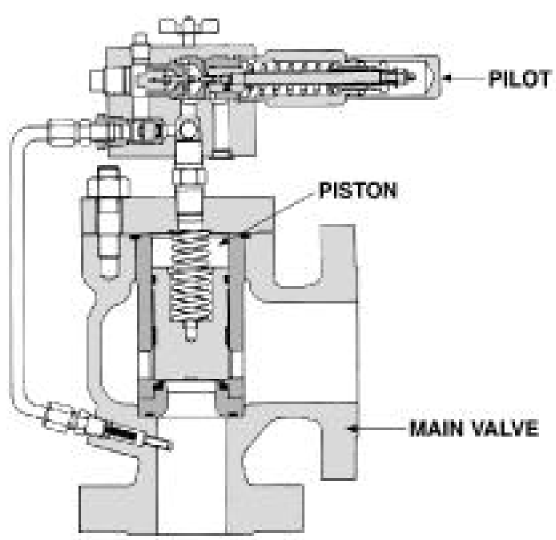
Series 900 pressure relief valve trim is unique with a single trim configuration used to provide smooth stable operation on gas, vapor, liquid and steam applications.



Adjustable Blowdown **Fixed Blowdown**
Crosby Series 800 **Crosby Series 900**
(Compressible Fluids Only)
Figure F2-7

Pilot Operated Designs

A second type of pressure relief valve which offers advantages in selected applications is the pilot operated pressure relief valve. Crosby Snap Acting Style JPV is shown in Figure F2-8.

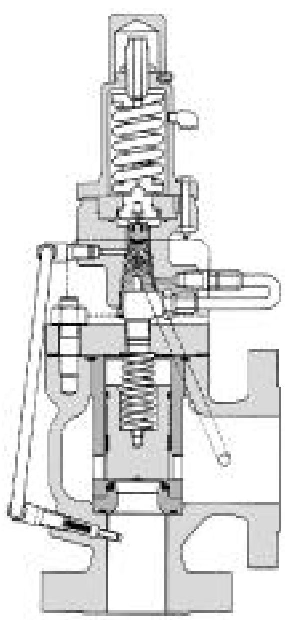


Crosby Snap Acting Style JPV
Pilot Operated Pressure Relief Valve
Figure F2-8

Pilot operated pressure relief valves consist of a main valve with piston or diaphragm operated disc and a pilot. Under normal operating conditions the pilot allows system pressure into the piston chamber. Since the piston area is greater than the disc seat area, the disc is held closed. When the set pressure is reached, the pilot actuates to shut off system fluid to the piston chamber and simultaneously vents the piston chamber. This causes the disc to open.

The pilot operated pressure relief valve has several advantages. As the system pressure increases, the force holding the disc in the 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. Pilots are generally designed with a separate control for set pressure and blowdown. Valves can be set to open fully at the set pressure and close with a very short blowdown. Modulating pilot valve designs, as shown in Figure F2-9, control the main valve such that minor overpressure conditions are controlled without fully opening the main valve. This limits fluid loss and system shock. Another advantage of pilot operated pressure relief valves is the reduced cost of larger valve sizes. The large spring and associated envelope is replaced by a small pilot, thus reducing the mass and cost of the valve.

Pilot operated pressure relief valves are supplied with filters to protect against foreign matter and are generally recommended for relatively clean service.



Crosby Modulating Style JPVM
Pilot Operated Pressure Relief Valve
Figure F2-9

Codes, Standards and Recommended Practices

Many Codes and Standards are published throughout the world which address the design and application of pressure relief valves. The most widely used and recognized of these is the ASME Boiler and Pressure Vessel Code, commonly called the ASME Code.

Most Codes and Standards are voluntary, which means that they are available for use by manufacturers and users and may be written into purchasing and construction specifications. The ASME Code is unique in the United States and Canada, having been adopted by the majority of state and provincial legislatures and mandated by law.

The ASME Code provides rules for the design and construction of pressure vessels. Various sections of the Code cover fired vessels, nuclear vessels, unfired vessels and additional subjects, such as welding and nondestructive examination. Vessels manufactured in accordance with the ASME Code are required to have overpressure protection. The type and design of allowable overpressure protection devices is spelled out in detail in the Code.

Certain sizes and types of vessels are specifically excluded from the scope of the ASME Code. For example, vessels with operating pressure not exceeding 15 psig are excluded from the scope of Section VIII.

A manufacturer, in order to comply with ASME Code requirements, must first prepare a Quality Assurance Program and submit to periodic on-site inspections by ASME. Completion of this task qualifies the manufacturer and allows him to apply an ASME Code stamp to approved products. Each product, however, must go through a specific qualification process.

The product inspection agency for ASME is the National Board of Boiler and Pressure Vessel Inspectors commonly referred to as The National Board. Before a pressure relief valve can be sold with an ASME Code stamp, a group of valves, generally a quantity of nine, must be subjected to a flow test conducted in accordance with rules in the ASME Code. From this testing a flow coefficient is determined and submitted to the National Board. Once the results of the tests are approved, the flow coefficient is published by the National Board to be used for valve sizing. Thereafter, a sample of valves must be submitted to the National Board on a periodic basis for flow verification. Any major changes in the valve design require that the certification be repeated. All testing is conducted in laboratories which are certified and inspected by the National Board.

The ASME requirement for capacity certification once applied to valves on compressible fluid service only. In January 1985, the ASME rules were expanded to include valves for liquid service at 10% overpressure, as well as gas, steam and vapor services.

The ASME Code also provides specific rules governing the application of overpressure protection, determination of and allowable tolerance on set pressure, allowable overpressure, required blowdown, application of multiple valves, sizing for fire, requirements for materials of construction, and rules for installation.

The most widely used pressure relief valve voluntary standards in the United States are published by the American Petroleum Institute (API). These Standards provide recommended practices for pressure relief valve construction, sizing, installation and maintenance. The API, more than any other body, has worked to standardize the ratings and sizes of pressure relief valves, including pressure/temperature limits and center-to-face dimensions.

API developed a series of inlet, orifice, outlet combinations for various flanged valve pressure classes which are utilized throughout the petroleum and hydrocarbon processing industry. These standard sizes are characterized by a series of fourteen standard letter orifices ranging from D through T. Each letter refers to a specific effective orifice area. As an example, the effective area of a J orifice valve is 1.287 square inches. This orifice area is used in standard API formulations to calculate valve flow rate. The manufacturer is not required to produce a valve with a bore area equal to the effective area. Rather, he is obliged to produce a valve which will have a flow rate equal to or greater than that determined by the API formulation.

Many other Standards are published which deal with the application and design of pressure relief valves particular to a specific industry. Additional Codes and Standards are written by various bodies throughout the world.

Sizing Pressure Relief Valves

The first step in applying overpressure protection to a vessel or system is to determine the set pressure, back pressure, allowable overpressure, and required relieving capacity. Set pressure and allowable overpressure can be determined by reference to the operating pressures of the system and the Code under which the system or vessel will be built and inspected.

A more difficult task is determining the required relieving capacity. The pressure relief valve must relieve a sufficient amount of fluid to ensure that pressure in the vessel or system never exceeds the specified overpressure. This means that all possible sources and causes of overpressure must be evaluated. Some examples could be failure of a stop valve to close, control system failure, fire, pump failure, uncontrolled chemical reaction, vessel isolation, and many more. The worst case combination of these factors is used to determine the required capacity.

Total rated relieving capacity of the selected valve (or valves if multiple valves are used) must be greater than the required capacity determined from the worst case system failure analysis.

Summary

The purpose of this discussion has been to provide an introduction to some of the considerations employed when designing pressure relief valves and to the Codes and Standards employed in this industry to maintain a high level of product quality and reliability. More specific information may be found by referencing the ASME Code, various published Standards, and by consulting literature published by the pressure relief valve manufacturers.

It is important to remember that a pressure relief valve is a safety device employed to protect pressure vessels or systems from catastrophic failure. With this in mind, the application of pressure relief valves should be assigned only to fully trained personnel and be in strict compliance with rules provided by the governing Codes and Standards.

Chapter 3

Terminology

HOME

This chapter contains common and standardized terminology related to pressure relief devices and is in accordance with, and adapted from, ANSI/ASME Performance Test Code PTC-25.3-1988, Appendix I and other accepted practices.

Terminology for Pressure Relief Devices

A. General

A.1 Pressure Relief Devices

A pressure relief device is a device designed to prevent internal fluid pressure from rising above a predetermined maximum pressure in a pressure vessel exposed to emergency or abnormal conditions.

A.2 Flow Capacity Testing

Testing of a pressure relief device to determine its operating characteristics including measured relieving capacity.

A.3 In-Service Testing

Testing of a pressure relief device while protecting the system on which it is installed to determine some or all of its operating characteristics using system pressure solely or in conjunction with an auxiliary lift device or other pressure source.

A.4 Bench Testing

Testing of a pressure relief device on a pressurized system to determine set pressure and seat tightness.

B. Types of Devices

B.1 Reclosing Pressure Relief Devices

***(a) Pressure Relief Valve*.** 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 the further flow of fluid after normal conditions have been restored. It is characterized by rapid opening pop action or by opening generally proportional to the increase in pressure over the opening pressure. It may be used for either compressible or incompressible fluids, depending on design, adjustment, or application.

(b) Safety Valve. A safety valve is a pressure relief valve actuated by inlet static pressure and characterized by rapid opening or pop action. (It is normally used for steam and air services.)

(1) Low-Lift Safety Valve. A low-lift safety valve is a safety valve in which the disc lifts automatically such that the actual discharge area is determined by the position of the disc.

(2) Full-Lift Safety Valve. A full-lift safety valve is a safety valve in which the disc lifts automatically such that the actual discharge area is not determined by the position of the disc.

(c) Relief Valve. A relief valve is a pressure relief device actuated by inlet static pressure 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 discharge system application and is primarily used for liquid service.

***(d) Safety Relief Valve*.** 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 may be used either for liquid or compressible fluid.

(1) Conventional Safety Relief Valve. A conventional safety relief valve is a pressure relief valve which has its spring housing vented to the discharge side of the valve. The operational characteristics (opening pressure, closing pressure, and relieving capacity) are directly affected by changes of the back pressure on the valve.

(2) Balanced Safety Relief Valve. A balanced safety relief valve is a pressure relief valve which incorporates means of minimizing the effect of back pressure on the operational characteristics (opening pressure, closing pressure, and relieving capacity).

***(e) Pilot-Operated Pressure Relief Valve*.** 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.

(f) Power-Actuated Pressure Relief Valve. 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.

(*g) Temperature-Actuated Pressure Relief Valve.* 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.

(h) Vacuum Relief Valve. A vacuum relief valve is a pressure relief device designed to admit fluid to prevent an excessive internal vacuum; it is designed to reclose and prevent further flow of fluid after normal conditions have been restored.

B.2 *Non-Reclosing Pressure Relief Devices*. A non-reclosing pressure relief device is a pressure relief device designed to remain open after operation. A manual resetting means may be provided.

(a) Rupture Disc Device*.* A rupture disc device is a non-reclosing pressure relief device actuated by inlet static pressure and designed to function by the bursting of a pressure containing disc.

(b) Breaking Pin Device. A breaking pin device is a non-reclosing 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.

C. Parts of Pressure Relief Devices

approach channel - the passage through which the fluid must pass to reach the operating parts of a pressure relief device

breaking pin - the load-carrying element of a breaking pin device

breaking pin housing - the structure which encloses the breaking pin mechanism

discharge channel - the passage through which the fluid must pass between the operating parts of a pressure relief device and its outlet

disc - the pressure containing movable element of a pressure relief valve which effects closure

huddling chamber - the annular pressure chamber located beyond the valve seat for the purpose of generating a popping characteristic

lifting device - a device for manually opening a pressure relief valve by the application of external force to lessen the spring loading which holds the valve closed

lifting lever - see *lifting device*

nozzle - a pressure containing element which constitutes the inlet flow passage and includes the fixed portion of the seat closure

pilot valve - an auxiliary valve which actuates a major relieving device (Crosby sometimes calls pilot actuator)

pressure containing member (of a pressure relief device) - a part which is in actual contact with the pressure media in the protected vessel

pressure retaining member (of a pressure relief device) - a part which is stressed due to its function in holding one or more pressure containing members in position

rupture disc- the pressure containing and pressure sensitive element of a rupture disc device

rupture disc holder - the structure which encloses and clamps the rupture disc in position

seat - the pressure containing contact between the fixed and moving portions of the pressure containing elements of a valve

vacuum support - an auxiliary element of a rupture disc device designed to prevent rupture or deformation of the disc due to vacuum or back pressure

D. Pressure Relief Valve Dimensional Characteristics

actual discharge area - the measured minimum net area which determines the flow through a valve.

bore area - the minimum cross-sectional flow area of a nozzle

bore diameter - the minimum diameter of a nozzle

curtain area - the area of the cylindrical or conical discharge opening between the seating surfaces created by the lift of the disc above the seat

developed lift - the actual travel of the disc from closed position to the position reached when the valve is at flow-rating pressure

discharge area - see *actual discharge area*

effective discharge area - a nominal or computed area of flow through a pressure relief valve, differing from the actual discharge area, for use in recognized flow formulas to determine the capacity of a pressure relief valve

inlet size - the nominal pipe size of the inlet of a pressure relief valve, unless otherwise designated

lift - the actual travel of the disc away from closed position when a valve is relieving

nozzle area, nozzle throat area - see *bore area*

nozzle diameter - see *bore diameter*

orifice area - see *effective discharge area*

outlet size - the nominal pipe size of the outlet of a pressure relief valve, unless otherwise designated

rated lift - the design lift at which a valve attains its rated relieving capacity

seat angle - the angle between the axis of a valve and the seating surface. A flat-seated valve has a seat angle of 90 degrees.

seat area - the area determined by the seat diameter

seat diameter - the smallest diameter of contact between the fixed and moving portions of the pressure containing elements of a valve

seat flow area - see *curtain area*

throat area - see *bore area*

throat diameter - see *bore diameter*

E. Operational Characteristics of Pressure Relief Devices

back pressure - the static pressure existing at the outlet of a pressure relief device due to pressure in the discharge system

blowdown - the difference between actual popping pressure of a pressure relief valve and actual reseating pressure expressed as a percentage of set pressure or in pressure units

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 pressure - the value of inlet static pressure at which a breaking pin or shear pin device functions

built-up back pressure - pressure existing at the outlet of a pressure relief device caused by the flow through that particular device into a discharge system

burst pressure - the value of inlet static pressure at which a rupture disc device functions

chatter - abnormal rapid reciprocating motion of the movable parts of a pressure relief valve in which the disc contacts the seat

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

coefficient of discharge - the ratio of the measured relieving capacity to the theoretical relieving capacity

cold differential test pressure - 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

cracking pressure - see *opening pressure*

flow capacity - see *measured relieving capacity*

flow-rating pressure - the inlet static pressure at which the relieving capacity of a pressure relief device is measured

flutter - abnormal, rapid reciprocating motion of the movable parts of a pressure relief valve in which the disc does not contact the seat

leak pressure - see *start-to-leak pressure*

leak test pressure - the specified inlet static pressure at which a quantitative seat leakage test is performed in accordance with a standard procedure

marked breaking pressure - the value of pressure marked on a breaking pin device or its nameplate

marked burst pressure - the value of pressure marked on the rupture disc device or its nameplate or on the tag of the rupture disc and indicates the burst pressure at the coincident disc temperature

marked pressure - the value or values of pressure marked on a pressure relief device

marked relieving capacity - see *rated relieving capacity*

measured relieving capacity - the relieving capacity of a pressure relief device measured at the flow-rating pressure, expressed in gravimetric or volumetric units

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 - a pressure increase over the set pressure of a pressure relief valve, usually expressed as a percentage of set pressure

popping pressure - the value of increasing inlet static pressure at which the disc moves in the opening direction at a faster rate as compared with corresponding movement at higher or lower pressures. It applies only to safety or safety relief valves on compressible-fluid service.

primary pressure - the pressure at the inlet in a safety, safety relief, or relief valve

rated relieving capacity - that portion of 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

reference conditions - those conditions of a test medium which are specified by either an applicable standard or an agreement between the parties to the test, which may be used for uniform reporting of measured flow test results

relieving pressure - set pressure plus overpressure

resealing pressure - the value of decreasing inlet static pressure at which no further leakage is detected after closing. The method of detection may be a specified water seal on the outlet or other means appropriate for this application.

reseating pressure - see *closing pressure*

seal-off pressure - see *resealing pressure*

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 - the value of increasing inlet static pressure at which a pressure relief valve displays one of the operational characteristics as defined under opening pressure, popping pressure, or start-to-leak pressure

simmer - the audible or visible escape of fluid between the seat and disc at an inlet static pressure below the popping pressure and at no measurable capacity. It applies to safety or safety relief valves on compressible-fluid service.

specified burst pressure (of a rupture disc device) - the value of increasing inlet static pressure, at a specified temperature, at which a rupture disc is designed to function

start-to-discharge pressure - see *opening pressure*

start-to-leak pressure - the value of increasing inlet static pressure at which the first bubble occurs when a pressure relief valve is tested by means of air under a specified water seal on the outlet

superimposed back pressure - the static pressure existing at the outlet of a pressure relief device at the time the device is required to operate. It is the result of pressure in the discharge system from other sources.

test pressure - see *relieving pressure*

theoretical relieving capacity - the computed capacity expressed in gravimetric or volumetric units of a theoretically perfect nozzle having a minimum cross-sectional flow area equal to the actual discharge area of a pressure relief valve or relief area of a non-reclosing pressure relief device

vapor-tight pressure - see *resealing pressure*

variable back pressure - a superimposed back pressure that will vary with time

warn - see *simmer*

CEN Definitions

accumulation - a pressure increase over the set pressure of a pressure relief valve, usually expressed as a percentage of the set pressure.

pilot-operated safety valve - safety valve, the operation of which is initiated and controlled by the fluid discharged from a pilot valve which is itself a direct-loaded safety valve.

supplementary loaded safety valve - safety valve which has, until the pressure at the inlet to the safety valve reaches the set pressure, an additional force which increases the sealing force. This additional force (supplementary load), which may be provided by means of an extraneous power source, is reliably released when the pressure at the inlet of the safety valve reaches the set pressure. The amount of supplementary loading is so arranged that if such supplementary is not released, the safety valve attains its certified discharge capacity at a pressure not greater than 10% above the allowable pressure.

Chapter 4

Codes and Standards

HOME

American Petroleum Institute (API)

ANSI/API Recommended Practice 520 Part I, Sizing and Selection. This API design manual is widely used for sizing of relief valves on both liquid and gas filled vessels: (a) liquid vessels - paragraphs 5 and 6, and (b) gas filled vessels - Appendix D-3. This RP covers only vessels above 15 psig.

ANSI/API Recommended Practice 520 Part II, Installation. This includes: (a) recommended piping practices, (b) calculation formula for reactive force on valve (2.4), and (c) precautions on preinstallation handling and dirt.

ANSI/API Recommended Practice 521, Guide for Pressure Relief and Depressuring Systems. An excellent document on everything from causes of overpressure through flare stacks.

ANSI/API Recommended Practice 526, Flanged Steel Relief Valves. Gives industry standards as to dimensions, pressure-temperature ratings, maximum set pressures, body materials.

ANSI/API Recommended Practice 527, Seat Tightness of Pressure Relief Valves. Permissible leakage rate of conventional and bellows valves and testing procedure.

API Guide for Inspection of Refinery Equipment, Chapter XVI Pressure Relieving Devices. Gives: (a) guide for inspection and record keeping, and (b) frequency of inspection, Paragraph 1602.03.

American Society of Mechanical Engineers (ASME)

ASME B31.1. Power Piping - Code 1995 Edition

Reference sections:

Chapter II, Part 3, Paragraph 107.8 Safety and relief valves including general information, safety and relief valves on boiler external piping, safety relief valves on non boiler external piping, and non mandatory appendices on valve installations.

Chapter II, Part 6, Paragraph 122.6 - Pressure Relief Piping

American National Standards Institute (ANSI)

ASME/ANSI B16.5. Pipe flanges and flanged fittings. This standard provides allowable materials, pressure temperature limits and flange dimensions for standard ANSI flanges.

ASME/ANSI B16.34. Valves - Flanged, Threaded and Welding End. Standard covers pressure, temperature ratings, dimensions, tolerances, materials, nondestructive examination requirements, testing and marking for cast, forged and manufactured flanged, threaded and welding end valves. **(End connection dimensions and tolerances are applicable only.)**

ANSI B31.8. Gas Transmission and Distribution Systems. Portions of this large document pertain to pressure relief and its limitations.

Manufacturers Standardizations Society Standard Practices (MSS-SP)

SP-25. (Not applicable to pressure relief valves.) Standard marking system for valves, fittings, flanges and unions. Refer to UG-129 of ASME Section VIII for marking information for pressure relief valves.

SP-55. Quality standards for steel castings for valves, flanges and fittings and other piping components.

SP-61. (Not applicable to pressure relief valves.) Pressure testing of steel valves **(refer to API Recommended Practice 527 for commercial seat tightness tests).**

Other Standards to be considered:

See pages 4-2 and 4-3.

Codes and Standards

Regulatory Body	Codes and Standards
Allami Energerhkai es Energiabiztonsagtechnikai Felugyelet (AEEF) (State Authority for Energy, Management and Safety) Budapest VIII Koztarsasag ter 7, Hungary	Safety Valves 22/1969/VI.12 (mod) 29/1960/VI.7 (orig)
American National Standards Institute 1430 Broadway New York, NY 10018	B16.34 Steel Valves, Flanged and Buttwelded Ends B16.5 Steel Pipe Flanges and Flanged Fittings B31.1 Power Piping B31.3 Chemical Plant and Petroleum Refinery Piping B31.4 Liquid Petroleum Transportation Piping Systems B95.1 Terminology for Pressure Relief Devices ANSI/ASME PTC 25.3 Performance Test Code, Safety and Relief Valves
American Petroleum Institute 2101 L Street Northwest Washington, DC 20037	API RP 510 Pressure Vessel Inspection Code API RP 520 Recommended Practice for the Design and Installation of Pressure Relieving Systems in Refineries: Part 1 - Design; Part II - Installation API RP 521 Guide for Pressure Relief and Depressuring Systems API Standard 526 Flanged Steel Safety Relief Valves API Standard 527 Commercial Seat Tightness of Safety Relief Valves with Metal to Metal Seats API Standard 2000 Venting Atmospheric and Low Pressure StorageTanks API Guide for Inspection of Refinery Equipment Chapter XVI - Pressure Relieving Devices
The American Society of Mechanical Engineers United Engineering Center 345 East 47th Street New York, NY 10017	Boiler and Pressure Vessel Code Section I - Power Boilers Section II - Materials Section IV - Heating Boilers Section VII - Care of Power Boilers Section VIII - Pressure Vessels Section IX - Welding and Brazing Qualifications
Association Francaise de Normalisation Tour Europe Cedex 7 F-92049 Paris La Defence, France	NFE 29-410 to 420
Australian Standards Association No. 1 The Crescent Homebush New South Wales 2140, Australia	AS1271 Safety Valves, Other Valves, Liquid Level Gages and Other Fittings for Boilers and Unfired Pressure Vessels 1990 Edition AS1210 Unfired Pressure Vessels (EAA Unfired Pressure Vessel Code) 1989 Edition AS1200 Pressure Equipment 1994 Edition
British Standards Institute 389 Chiswick High Road London W4 4AL, England	BS6759 Parts 1, 2 and 3 Safety Valves
Canadian Standards Association 178 Rexdale Boulevard Toronto, Ontario M9W 1R3	CSA Z299.2.85 (R1991) - Quality Assurance Program - Category 1 CSA Z299.3.85 (R1991) - Quality Assurance Program - Category 3 CSA Z299.4.85 (R1991) - Quality Assurance Program - Category 4
Chlorine Institute Inc. 2001 L Street, NW Washington, DC 20036	Pamphlet 39 Type 1-1/2" JQ Pamphlet 41 Type 4" JQ
CC NASTHOL Shenogina Street 123007 Moscow, Russia	GOST R Certification System

Codes and Standards (Cont.)

Regulatory Body	Codes and Standards
Deutsche Institut Fur Normung Burggrafenstrasse 6 D-10787 Berlin, Germany	DIN 50049 Materials Testing Certificates
Comite Europeen de Normalisation (Europeon Committee for Standardisation) rue de Stassart 36 B-1050 Brussels, Belgium	CEN Standards for Safety Valves Pressure Equipment Directive
Heat Exchange Institute, Inc. 1300 Sumner Avenue Cleveland, OH 44115	HEI Standards for Closed Feedwater Heaters
International Organisation for Standardisation Case Postale 56 CH-1211 Geneve 20, Switzerland	ISO-9000 Quality System ISO-4126 Safety Valves - General Requirements
I.S.C.I.R. Central Bucuresti Frumoasa nr. 26, Romania	Romanian Pressure Vessel Standard
Japanese Industrial Standard Committee Japanese Standards Association 1-24, Akasaka 4-chome, Minato-ku Tokyo 107 Japan	JIS B8210 Spring Loaded Safety Valves for Steam Boilers and Pressure Vessels.
Manufacturers' Standardization Society of the Valve and Fitting Industry 1815 North Fort Myer Drive Arlington, VA 22209	SP-6 Finishes of Contact Faces of Connecting End Flanges SP-9 MSS Spot Facing Standard SP-55 Quality Standard for Steel Castings
Ministerie Van Sociale Zaken En Werkgelegenheid Directoraat Generaal Van De Arbeid Dienst Voor Het Stoomwezen 2517 KL Gravenhage - Eisenhowerlaan 102 Holland	Stoomwezen Specification A1301
National Association of Corrosion Engineers P.O. Box 1499 Houston, TX 77001	NACE MR0175
National Board of Boiler and Pressure Vessel inspectors 1055 Crupper Avenue Columbus, OH 43229	NB-25 National Board Inspectors Code NB-65 National Board Authorization to Repair ASME and National Board Stamped Safety Valves and Relief Valves
National Fire Protection Association Batterymarch Park Quincy, MA 02269	NFPA 30 Flammable and Combustible Liquids Code
Schweizerisher Verein fur Druckbehalteruberwachung (SVDB) Postfach 35 8030 Zurich, Switzerland	Specifications 602 - Safety Valves for Boilers and Pressure Vessels
Den Norske Trykkbeholderkomite (TBK) Norsk Verkstedsindustris Standardiseringssentral Oscarsgate 20, Oslo, Norway	TBK General Rules for Pressure Vessels
Verband der Technischen Uberwachungs-Vereine e. V (TUV) Kurfurstenstrafe 56 4300 Essen 1, Germany	TRD 421 AD-Merkblatt A2

Crosby® Engineering Handbook
Technical Publication No. TP-V300

Chapter 5

Valve Sizing and Selection

U.S.C.S. Units (United States Customary System)

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Introduction

This section of the Crosby Pressure Relief Valve Engineering Handbook is designed to assist the user in the sizing and selection of pressure relief valves when system parameters are expressed in U.S.C.S. units. Please refer to Chapter 6 for sizing using metric unit formulations.

The basic formulae and capacity correction factors contained in this handbook have been developed at Crosby and by others within the industry and reflect current state-of-the-art pressure relief valve sizing technology. Typical valve sizing examples have been included to assist in understanding how specific formulae are applied. Useful technical data is included for easy reference.

This handbook is limited to spring loaded and pilot operated pressure relief valves. Formulations in this chapter are in U.S.C.S. Units and are consistent with the requirements of ASME Section VIII and API Recommended Practice 520.

Sizing formulae in this handbook are used to calculate the required effective area for a pressure relief valve that will flow the required volume of system fluid at anticipated relieving conditions. The appropriate valve size and style may then be selected having a nominal effective area equal to or greater than the calculated required effective area. Effective areas for Crosby pressure relief valves are shown on pages 7-30 and 7-31 along with a cross reference to the applicable product catalogs, styles or series. Crosby uses "effective" areas in these formulae consistent with API RP520.

Crosby pressure relief valves are manufactured and tested in accordance with requirements of the ASME Boiler and Pressure Vessel Code. Relieving capacities have been certified, as required, by The National Board of Boiler and Pressure Vessel Inspectors.

Pressure relief valves must be selected by those who have complete knowledge of the pressure relieving requirements of the system to be protected and the environmental conditions particular to that installation. Selection should not be based on arbitrarily assumed conditions or incomplete information. Valve selection and sizing is the responsibility of the system engineer and the user of the equipment to be protected.

NOTE: Crosby offers a computer program, *CROSBY-SIZE*, for sizing pressure relief valves. See page 1-1 for additional information or contact your local Crosby Representative.

REQUIRED SIZING DATA

The following is a suggested list of service conditions which must be provided in order to properly size and select a pressure relief valve.

1. Fluid Properties:	
a. Fluid and State	
b. Molecular Weight	
c. Viscosity	
d. Specific Gravity **Liquid (referred to water)** **Gas (referred to air)**	
e. Ratio of Specific Heats (k)	
f. Compressibility Factor (Z)	
2. Operating Conditions:	
a. Operating Pressure (psig maximum)	
b. Operating Temperature (°F maximum) **c. Max. Allowable Working Pressure (psig)**	
3. Relieving Conditions:	
a. Required Relieving Capacity **Gas or Vapor (lb/hr)** **Gas or Vapor (scfm)** **Liquid (gpm)**	
b. Set Pressure (psig)	
c. Allowable Overpressure %	
d. Superimposed Back Pressure (psig) **(specify constant or variable)**	
e. Built-Up Back Pressure (psig)	
f. Relieving Temperature (°F)	

Gas and Vapor Sizing

10% Overpressure (lb/hr)

The following formula is used for sizing valves for gases and vapor (except steam) when required flow is expressed as a mass flow rate, pounds per hour. Correction factors are included to account for the effects of back pressure, compressibility and subcritical flow conditions. For steam application use the formula on page 5-6.

$$A = \frac{W\sqrt{TZ}}{C\,K\,P_1\,K_b\sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square inches.
- C = Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at standard conditions (see Table T7-7 on page 7-26), or if ratio of specific heats value is known, see page 7-9. Use C = 315 if value is unknown.
- K = Effective coefficient of discharge, K = 0.975
- K_b = Capacity correction factor due to back pressure. For standard valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows or Series BP valves with superimposed or variable back pressure see Figure F7-2 on page 7-5. For pilot operated valves see discussion on page 7-4.
- M = Molecular weight of the gas or vapor obtained from standard tables or Table T7-7 on page 7-26.
- P_1 = Relieving pressure, pounds per square inch absolute. This is the set pressure (psig) + overpressure (psi) + atmospheric pressure (psia).
- T = Absolute temperature of the fluid at the valve inlet, degrees Rankine (°F + 460).
- W = Required relieving capacity, pounds per hour.
- Z = Compressibility factor (see Figure F7-1 on page 7-2). Use Z = 1.0 if value is unknown.

EXAMPLE #1

Atmospheric Back Pressure

Fluid:	Natural Gas
Required Capacity:	5900 lb/hr
Set Pressure	210 psig
Overpressure:	10%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	120F
Molecular Weight:	19.0

$$A = \frac{W\sqrt{TZ}}{C\;K\;P_1\,K_b\sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square inches
- W = 5900 lb/hr
- T = 120F + 460 = 580R
- Z = Compressibility Factor, use Z = 1.0
- P_1 = Absolute relieving pressure 210 + 21 + 14.7 = 245.7 psia
- C = 344 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
- M = 19.0 (Table T7-7 on page 7-26)

$$A = \frac{5900\sqrt{580\,(1)}}{(344)\,(0.975)\,(245.7)\,(1)\sqrt{19}} = 0.396 \text{ sq.in.}$$

A "G" orifice valve with an effective area of 0.503 square inches is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No.310, select a 1-1/2G2-1/2 Style JOS-15 with Type J cap. Standard materials of construction are satisfactory for this application (natural gas).

EXAMPLE #2

Superimposed Constant Back Pressure

In the preceding example, any change in service conditions would necessitate recalculation of the required orifice area. For example, rather than atmospheric back pressure, consider that there is a superimposed constant back pressure of 195 psig.

Since the superimposed back pressure is constant, a conventional valve may be used.

To find the value of the capacity correction factor K_b, use Table T7-1 on page 7-3.

$$\frac{P_b}{P_1} = \text{Back Pressure Percentage}$$

$$= \frac{\text{Back Pressure (psia)}}{\text{Relieving Pressure (psia)}} \times 100$$

$$\frac{(195 \text{ psig} + 14.7 \text{ psi})}{(210 \text{ psig} + 21 \text{ psig} + 14.7 \text{ psi})} \times 100 = 85.3\%$$

Gas and Vapor Sizing
10% Overpressure (Cont.)

Interpolating from Table T7-1 on page 7-3, $K_b = 0.76$

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}} = \frac{5900 \sqrt{580\ (1)}}{(344)\ (0.975)\ (245.7)(.76) \sqrt{19}}$$

$$= 0.520 \text{ sq. in.}$$

A Crosby "H" orifice valve with an effective area of 0.785 square inches is the smallest standard valve orifice that will flow the required relieving capacity. Since the back pressure is constant a conventional Style JOS valve can be used. From Crosby Catalog No.310, select a 1-1/2H3 Style JOS-15 with Type J cap. For the production test this valve would be adjusted to open at 15 psig. This is called the cold differential test pressure (CDTP) and is equal to the set pressure minus superimposed constant back pressure. The opening pressure under service conditions, however, would equal the sum of the cold differential test pressure plus the superimposed constant back pressure (210 psig = 15 psig + 195 psig). The proper valve spring for this particular application would be the spring specified for a CDTP of 15 psig.

EXAMPLE #3
Set Pressure Below 30 psig

When a pressure relief valve is to be used with a set pressure below 30 psig, the ASME Boiler and Pressure Vessel Code, Section VIII, specifies a maximum allowable overpressure of 3 psi.

Fluid:	Air (UV Stamp Required)
Required Capacity:	500 lb/hr
Inlet Relieving Temp.:	70F
Set Pressure:	20 psig
Overpressure:	3 psi

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

- W = 500 lb/hr
- T = 70F + 460 = 530R
- Z = Compressibility Factor, use Z = 1.0
- P_1 = Absolute relieving pressure = 20 psig + 3 psi + 14.7 psia = 37.7 psia
- C = 356 from Table T7-7 on page 7-26.
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
- M = 28.97 from Table T7-7 on page 7-26.

$$A = \frac{500 \sqrt{530(1)}}{(356)\ (0.975)\ (37.7)\ (1) \sqrt{28.97}} = 0.163 \text{ sq.in.}$$

From Catalog No. 902, select a 1" x 1-1/2" Crosby Series 900 valve with a No.7, 0.196 sq.in. orifice, Type D lifting lever and standard materials. Therefore, Model Number is 972103M-D.

EXAMPLE #4
Variable Superimposed Back Pressure

When a pressure relief valve is exposed to a variable back pressure the set pressure of the valve may be effected unless either a balanced bellows or series BP style valve is selected.

Fluid:	Air (UV Stamp Required)
Required Capacity:	280 lb/hr
Inlet Relieving Temp.:	140 deg F
Set Pressure:	58 psig
Back Pressure:	0-20.3 psig
Overpressure:	10%

A BP-Omni threaded valve is preferred for this application.

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

- W = 280 lb/hr
- T = 140F + 460 = 600R
- Z = Compressibility Factor = 1.0
- P_1 = Absolute relieving pressure = 58 + 5.8 + 14.7 = 78.5 psia
- C = 356 from Table T7-7 on page 7-26.
- K = 0.975
- K_b = Capacity correction factor from Table F7-2 for BP Omni on page 7-5 = 0.650.
- M = 28.97 from Table T7-7 on page 7-26.

$$A = \frac{280 \sqrt{600(1)}}{(356)\ (0.975)\ (78.5)\ (0.65) \sqrt{28.97}}$$

$$= 0.072 \text{ sq.in.}$$

From Catalog No. 905, select a 3/4" x 1" Series BP with a 0.074 sq. in. orifice, type D lifting lever and standard material. Therefore the Model No. is BP51701M-D.

Gas and Vapor Sizing

10% Overpressure (scfm)

The following formula is used for sizing valves for gases and vapor (except steam) when required flow is expressed as a volumetric flow rate, scfm. Correction factors are included to account for the effects of backpressure, compressibility and subcritical flow.

$$A = \frac{SCFM \sqrt{TGZ}}{1.175\ C\ K\ P_1 K_b}$$

Where:

- A = Minimum required effective discharge area, square inches.
- C = Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at standard conditions (see Table T7-7 on page 7-26) or if ratio of specific heats value is known, see page 7-9. Use C = 315 if value is unknown.
- K = Effective coefficient of discharge, K = 0.975
- G = Specific gravity of the gas or vapor.
- K_b = Capacity correction factor due to back pressure. For standard valves with superimposed constant back pressure exceeding critical see Table T7-1 on page 7-3. For bellows or Series BP valves with superimposed or variable back pressure see Figure F7-2 on page 7-5. For pilot valves see discussion on page 7-4.
- P_1 = Relieving pressure, pounds per square inch absolute. This is the set pressure (psig) + overpressure (psi) + atmospheric pressure (psia).
- T = Absolute temperature of the fluid at the valve inlet, degrees Rankine (°F + 460).
- SCFM = Required relieving capacity, standard cubic feet per minute (scfm).
- Z = Compressibility factor (see Figure F7-1 on page 7-2). Use Z = 1.0 if value is unknown.

EXAMPLE #1

Built-up Variable Back Pressure

Fluid:	Ethylene Gas
Required Capacity:	12,000 scfm
Set Pressure:	170 psig
Overpressure:	10%
Back Pressure:	0-75 psig
Inlet Relieving Temp.:	200F
Specific Gravity:	0.968
Special Requirement:	Bolted cap requested

$$A = \frac{SCFM \sqrt{TGZ}}{1.175\ C\ K\ P_1 K_b}$$

Where:

- A = Minimum required effective discharge area, square inches
- SCFM = 12,000 standard cubic feet per minute
- T = 200F + 460 = 660R
- G = 0.968 relative to air
- Z = Compressibility factor, use Z = 1.0
- P_1 = Absolute relieving pressure 170 psig + 17 psi +14.7 psia = 201.7 psia
- C = 341 (from Table T7-7 on page 7-26.)
- K = 0.975
- K_b = Capacity correction factor for bellows style valves from Figure F7-2 on page 7-5.

$$\frac{\text{Back Pressure}}{\text{Set Pressure}} \times 100 = \frac{75}{170} \times 100 = 44.1\%, K_b = 0.899$$

$$A = \frac{12000 \sqrt{660(.968)(1)}}{1.175(341)\ (0.975)\ (201.7)\ (0.899)} = 4.282 \text{ sq.in.}$$

Standard Valve

An "N" orifice valve with an effective area of 4.34 square inches is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No.310, select a 4N6 JBS-15 with a Type L cap. Standard materials of construction are satisfactory for this application (Ethylene).

Pilot Valve

Note that Crosby Style JPV Pilot Operated Valve may also be selected for this application. Since pilot operated valve performance is unaffected by back pressure,* the flow correction factor K_b is not applicable except when subcritical flow is encountered. Thus in the example above, the K_b correction factor (0.899) should not be applied if a pilot operated valve is to be selected.

$$A = \frac{12000 \sqrt{660(.968)\ (1)}}{1.175\ (341)\ (0.975)\ (201.7)} = 3.849 \text{ sq.in.}$$

From Crosby Catalog No. 318, select a 4N6 JPV-15.

* For Style JPVM, up to 70% back pressure is permissible with exhaust connected to outlet of main valve. Above 70% the exhaust should vent to a suitable low pressure location.

Steam Sizing

10% Overpressure (lb/hr)

The following formula is used for sizing valves for steam service at 10% overpressure. This formula is based on the empirical Napier formula for steam flow. Correction factors are included to account for the effects of superheat, back pressure and subcritical flow. An additional correction factor K_n is required by ASME when relieving pressure (P_1) is above 1500 psia.

$$A = \frac{W}{51.5\ K\ P_1 K_{sh} K_n K_b}$$

Where:

- A = Minimum required effective discharge area, square inches
- W = Required relieving capacity, pounds per hour
- K = Effective coefficient of discharge, K = 0.975
- P_1 = Relieving pressure, pounds per square inch absolute. This is the set pressure (psig) + overpressure (psi) + atmospheric pressure (psia).
- K_{sh} = Capacity correction factor due to the degree of superheat in the steam. For saturated steam use K_{sh} = 1.00. See Table T7-2 on page 7-8 for other values.
- K_n = Capacity correction factor for dry saturated steam at set pressures above 1500 psia and up to 3200 psia. See Figure F7-4 on page 7-6.
- K_b = Capacity correction factor due to back pressure. For conventional valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows valves with superimposed or variable back pressure see Figure F7-2 on page 7-5. For pilot valves, see discussion on page 7-4.

EXAMPLE #1

Saturated Steam (lb/hr)

Required Capacity:	21,500 lb/hr saturated steam
Set Pressure:	225 psig
Overpressure:	10%
Relieving Pressure:	P_1 = 225 psig + 22.5 psi +14.7 psi = 262.2 psia
Back Pressure:	Atmospheric

$$A = \frac{W}{51.5\ K\ P_1 K_{sh} K_n\ K_b}$$

$$A = \frac{21{,}500}{(51.5)\ (0.975)\ (262.2)\ (1)\ (1)\ (1)} = 1.633 \text{ sq.in.}$$

A "K" orifice valve with an effective area of 1.838 square inches is the smallest standard size valve that will flow the required capacity. From Crosby Catalog No.310, select a 3K4 JOS-15 valve with a Type C lifting lever. Standard materials of construction are satisfactory for this saturated steam application.

EXAMPLE #2

Superheated Steam (lb/hr)

Required Capacity:	108,500 lb/hr superheated steam
Relieving Temp.:	750F
Set Pressure:	532 psig
Relieving Pressure:	P_1=532 psig +53.2 psi +14.7 psi = 599.9 psia
Back Pressure:	Atmospheric
From page 7-8:	Capacity Correction Factor, K_{sh} = 0.844

$$A = \frac{108{,}500}{(51.5)\ (0.975)\ (599.9)\ (.844)\ (1)\ (1)} = 4.268 \text{ sq.in.}$$

An "N" orifice valve with an effective area of 4.34 square inches is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No.310, select a 4N6 JOS-46 valve with a Type C lifting lever and alloy steel spring. Standard materials of construction are satisfactory for this superheated steam application.

EXAMPLE #3

Saturated Steam at a Relieving Pressure Greater than 1500 psig

Required Capacity:	88,000 lb/hr saturated steam
Set Pressure:	2750 psig
Overpressure:	10%
Back Pressure:	Atmospheric
Special Requirement:	Open Bonnet
Relieving Pressure:	P_1 =2750 psig + 275 psi + 14.7 psi = 3039.7 psia
From Figure F7-4 on page 7-6:	Capacity Correction Factor, K_n = 1.155

$$A = \frac{W}{51.5\ K\ P_1 K_{sh} K_n K_b}$$

$$A = \frac{88{,}000}{51.5\ (0.975)\ (3039.7)\ (1)\ (1.155)\ (1)}$$

$$A = 0.499 \text{ sq. in.}$$

A "G" orifice valve with an effective area of 0.503 square inches is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No.310, select a 2G3 JOS-76 valve with a Type C lifting lever and alloy steel spring. Standard materials of construction are satisfactory for this saturated steam application.

Liquid Sizing

Spring Loaded Valves

Styles JLT-JOS, JLT-JBS, Series 900 and Series BP

The following formula has been developed for valve Styles JLT-JOS, JLT-JBS, Series 900 and Series BP pressure relief valves using valve capacities certified by the National Board of Boiler and Pressure Vessel Inspectors in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section VIII. This formula applies to, and is to be used exclusively for, sizing Crosby Styles JLT, Series 900 and Series BP pressure relief valves for liquid service applications. Valve sizing using this formulation is not permitted for overpressures less than 10%.

$$A = \frac{GPM \sqrt{G}}{28.14\, K_w K_v \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square inches.
- G = Specific gravity of the liquid at flowing conditions.
- GPM = Required relieving capacity, U.S. gallons per minute at flowing temperature.
- ΔP = Differential pressure (psi). This is the set pressure (psig) + overpressure (psi) - back pressure (psig). Pressures expressed, psi.
- K_v = Flow correction factor due to viscosity of the fluid at flowing conditions (see page 7-7).
- K_w = Capacity correction factor due to back pressure on bellows or Series BP valves on liquid service. Refer to Figure F7-3 on page 7-5.

Note: See page 7-25 for information on two phase flow.

EXAMPLE #1
Liquid, gpm

Fluid:	Sodium Trisulfate
Relieving Capacity:	125 gpm
Set Pressure:	100 psig
Overpressure:	10%
Back Pressure:	0-30 psig (built-up)
Relieving Temperature:	60F
Specific Gravity:	1.23

$$A = \frac{GPM \sqrt{G}}{28.14\, K_v K_w \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square inches
- GPM = 125 gallons per minute
- G = 1.23
- K_w = .866 (Figure F7-3 on page 7-5)
- K_v = 1.0 for non-viscous fluid
- ΔP = 100 psig + 10 psi - 30 psig = 80 psi

$$A = \frac{125 \sqrt{1.23}}{28.14(1)(.866)\sqrt{80}} = 0.636 \text{ sq. in.}$$

An "H" orifice valve with an effective area of 0.785 square inches is the smallest standard size valve that will flow the required relieving capacity. Since the built-up back pressure exceeds 10% a bellows style valve, Style JBS, is required. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 1-1/2H3 Style JLT-JBS-15 valve with a Type J cap.

EXAMPLE #2
Liquid, gpm

Fluid:	Castor Oil
Relieving Cap:	100 gpm
Set Pressure:	210 psig
Overpressure:	10%
Back Pressure:	35 psig (constant)
Relieving Temperature:	60F
Specific Gravity:	0.96

$$A = \frac{GPM \sqrt{G}}{28.14\, K_w K_v \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square inches
- GPM = 100 gallons per minute
- G = 0.96
- K_w = 1.0 (Page 7-5)
- K_v = 1.0 for non-viscous fluid
- ΔP = 210 psig + 21 psi - 35 psig = 196 psi

$$A = \frac{100 \sqrt{0.96}}{28.14\,(1)(1)\sqrt{196}} = 0.249 \text{ sq.in.}$$

A number "8" orifice with an effective area of 0.307 sq.in. is the smallest Series 900 OMNI-TRIM valve that will flow the required relieving capacity. Since the back pressure is constant a conventional Style JOS or Series 900 valve can be used. Therefore, from Crosby Catalog No. 902, select a 981105M-A.

Liquid Sizing
Pilot Operated Valves
Style JPVM

Crosby Style JPVM Pilot Operated Pressure Relief Valves may be used on liquid service. The coefficient of discharge for these valves has been certified at 10% overpressure in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section VIII. Capacities are certified by the National Board of Boiler and Pressure Vessel Inspectors. The following formula is to be used exclusively for Crosby Style JPVM valve.

Note: A Style JPVM on liquid service provides 30% greater capacity than spring loaded type valves with liquid trim. This can permit use of a much smaller valve than would otherwise be required.

$$A = \frac{GPM \sqrt{G}}{36.81 (K_v) \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square inches.
- G = Specific gravity of the liquid at flowing conditions.
- GPM = Required relieving capacity, U.S. gallons per minute at flowing temperature
- ΔP = Differential pressure (psi). This is the set pressure (psig) + overpressure (psi) - back pressure (psig).
- K_v = Flow correction factor due to viscosity of the fluid at flowing conditions (see page 7-7). Note: For optimum operation, fluid viscosity should be no greater than 300 SSU, and in this case K_v = 1.0 may be used.

Note: See page 7-25 for information on two phase flow.

EXAMPLE #1
Liquid, GPM
Crosby Style JPVM Valve

Fluid:	Sodium Trisulfate
Relieving Cap:	125 GPM
Set Pressure:	100 psig
Overpressure:	10%
Back Pressure:	0-30 psig (built-up)
Relieving Temperature:	60F
Specific Gravity:	1.23

$$A = \frac{GPM \sqrt{G}}{36.81 (K_v) \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square inches
- GPM = 125 gallons per minute
- G = 1.23
- K_v = 1.0 for non-viscous fluid
- ΔP = 100 psig + 10 psi - 30 psig = 80 psi

$$A = \frac{125 \sqrt{1.23}}{36.81 (1.0) \sqrt{80}} = 0.421 \text{ sq.in.}$$

A "G" orifice valve with an effective area of 0.503 square inches is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 318, standard materials were selected. Therefore, Model Number is 1-1/2G3 Style JPVM-15.

Multiple Valve Sizing

When multiple pressure relief valves are used, one valve shall be set at or below the Maximum Allowable Working Pressure, MAWP, and the remaining valve(s) may be set up to 5% over the MAWP. When sizing for multiple valve applications, the total required area is calculated on an overpressure of 16% or 4 psi, whichever is greater.

When exposure to fire is a consideration, please reference liquid relief valve sizing under fire conditions (see page 7-17).

Example #1

Reference Example #1, page 5-3, except that this is a multiple valve application:

MAWP:	210 psig
Fluid:	Natural Gas
Required Capacity:	5900 lb/hr
Set Pressure:	210 psig
Overpressure:	16%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	120F
Molecular Weight:	19.0

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1\ K_b \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square inches
- W = 5900 lb/hr
- T = 120 + 460 = 580R
- Z = Compressibility factor, use Z = 1.0
- P_1 = (210)(1.16) + 14.7 = 258.3 psia
- C = 344 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
- M = 19.0 (Table T7-7 on page 7-26)

$$A = \frac{(5900)\ \sqrt{(580)(1)}}{(344)(0.975)(258.3)(1)\ \sqrt{19.0}}$$

$$A = 0.376 \text{ sq. in.}$$

Therefore, two "E" orifice valves with a total area of .392 square inches are selected to meet the required flow for this multiple valve application: one valve set at MAWP equals 210 psig, and one set at 105% of MAWP equals 220.5 psig. The effective area of each "E" orifice valve is .196 square inches. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 1E2 JOS-15-J.

Example #2

Fluid:	Air
Required Capacity:	150000 lb/hr
Set Pressure:	200 psig
Overpressure:	16%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	150F

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1\ K_b \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square inches
- W = 150000 lb/hr
- T = 150 + 460 = 610R
- Z = Compressibility factor, use Z = 1.0
- P_1 = Absolute relieving pressure 200 + 32 + 14.7 = 246.7 psia
- C = 356 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. For standard valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows valves with superimposed variable back pressure see Figure F7-2 on page 7-5. Use K_b = 1.0 for atmospheric back pressure.
- M = 28.97 (Table T7-7 on page 7-26)

$$A = \frac{(150000)\ \sqrt{(610)(1)}}{(356)(0.975)(246.7)(1)\ \sqrt{28.97}}$$

$$A = 8.038 \text{ sq. in.}$$

Total required orifice area is 8.038 square inches. Valves selected are "N" orifice with an effective area of 4.340 square inches each. Total area of two "N" orifice valves equals 8.680 square inches. On multiple valve applications, only one valve needs to be set at or below MAWP. All additional valves may be set up to and including 105% of MAWP. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 4N6 JOS-15-J.

Combination Devices

The rated relieving capacity of a pressure relief valve in combination with a rupture disc is equal to the capacity of the pressure relief valve multiplied by a combination capacity factor to account for any flow losses attributed to the rupture disc.

Combination capacity factors that have been determined by test and are acceptable to use are compiled by The National Board of Boiler and Pressure Vessel Inspectors in the Pressure Relief Device Certifications publication, NB-18. This publication lists the combination capacity factors to be used with specific rupture device and relief valve by manufacturer rupture device/ valve models.

When a combination capacity factor that has been determined by test for the specific rupture disc and relief valve combination is not available, a combination capacity factor of 0.9 may be used.

Example #1

Gas/Vapor Mass Flow (lb/hr)
(See page 5-3)

Fluid:	Natural Gas
Required Capacity:	7400 lb/hr
Set Pressure:	210 psig
Overpressure:	10%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	120F
Molecular Weight:	19.0

$$A = \frac{W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square inches
- W = 7400 lb/hr
- T = 120F + 460 = 580R
- Z = Compressibility factor, use Z = 1.0
- P_1 = (210)(1.10) + 14.7 = 245.7 psia
- C = 344 (Table T7-7, page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure
- M =19.0 (Table T7-7, page 7-26)

$$A = \frac{(7400)\ \sqrt{(580)(1)}}{(344)(0.975)(245.7)(1)\ \sqrt{19.0}}$$

$$A = 0.496 \text{ sq. in.}$$

A standard application would require a G orifice Style JOS valve with an effective orifice area of 0.503 square inches. However, this application requires a rupture disc. Since a specific rupture disc has not been specified, a rupture disc combination factor of 0.9 could be used. The minimum required effective discharge area must be scaled up by dividing it by the combination factor.

$$\text{Required Area} = (A) / (F_{comb})$$
$$= (.496) / (0.9)$$
$$= 0.551 \text{ sq. in.}$$

Therefore, this application with rupture disc requires an H orifice Style JOS valve of standard materials with an effective area of 0.785 square inches, an increase of one valve size. However, in this example, if using a specific rupture disc having a combination factor (F_{comb}) when used with Crosby valves that is 0.986 or higher, a larger valve size may not be necessary. (See The National Board of Boiler and Pressure Vessel Inspectors NB-18, "Pressure Relief Device Certifications" - Section IV.)

Crosby® Engineering Handbook
Technical Publication No. TP-V300

Chapter 6

Valve Sizing and Selection
Metric Units

HOME

Introduction

This section is provided to assist in calculating the required effective area of a pressure relief valve that will flow the required volume of system fluid at anticipated relieving conditions when system parameters are expressed in metric units. The appropriate valve size and style may then be selected having a nominal effective area equal to or greater than the calculated required effective area. Detailed explanations and illustrative examples for sizing using U.S.C.S. Units may also be found in Chapter 5.

Effective areas for Crosby pressure relief valves are shown on pages 7-30 and 7-31 along with a cross reference to the applicable product catalogs, styles or series. Crosby uses "effective" areas in these formulae consistent with API RP520.

The basic formulae and capacity correction factors contained in this handbook have been developed at Crosby and by others within the industry and reflect current state-of-the-art pressure relief valve sizing technology. Typical valve sizing examples have been included to assist in understanding how specific formulae are applied. Useful technical data is included for easy reference.

Crosby pressure relief valves are manufactured and tested in accordance with requirements of the ASME Boiler and Pressure Vessel Code. Relieving capacities have been certified, as required, by The National Board of Boiler and Pressure Vessel Inspectors.

Pressure relief valves must be selected by those who have complete knowledge of the pressure relieving requirements of the system to be protected and the environmental conditions particular to that installation. Selection should not be based on arbitrarily assumed conditions nor incomplete information. Valve selection and sizing is the responsibility of the system engineer and the user of the equipment to be protected.

NOTE: Crosby offers a computer program, *CROSBY-SIZE*, for sizing pressure relief valves. See page 1-1 for additional information or contact your local Crosby Representative.

REQUIRED SIZING DATA

The following is a suggested list of service conditions which must be provided in order to properly size and select a pressure relief valve.

1. Fluid Properties:	
a. Fluid and State	
b. Molecular Weight	
c. Viscosity	
d. Specific Gravity **Liquid (referred to water)** **Gas (referred to air)**	
e. Ratio of Specific Heats (k)	
f. Compressibility Factor (Z)	
2. Operating Conditions:	
a. Operating Pressure (kPag maximum)	
b. Operating Temperature (°C maximum) **c. Max. Allowable Working Pressure (kPag)**	
3. Relieving Conditions:	
a. Required Relieving Capacity **Gas or Vapor (kg/hr)** **Gas or Vapor (Sm^3/min)** **Liquid (liter/minute)**	
b. Set Pressure (kPag)	
c. Allowable Overpressure %	
d. Superimposed Back Pressure (kPag) **(specify constant or variable)**	
e. Built-Up Back Pressure (kPag)	
f. Relieving Temperature (°C)	

Gas and Vapor Sizing

10% Overpressure (kg/hr)

The following formula is used for sizing valves for gases and vapor (except steam) when required flow is expressed as a mass flow rate, kilograms per hour. Correction factors are included to account for the effects of back pressure, compressibility and subcritical flow conditions. For steam applications use the formula on page 6-6.

$$A = \frac{13160 W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square millimeters.
- C = Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at standard conditions (seeTable T7-7 on page 7-26). Use C = 315 if value is unkown.
- K = Effective coefficient of discharge. K = 0.975
- K_b = Capacity correction factor due to back pressure. For standard valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows or Series BP valves with superimposed or variable back pressure see Figure F7-2 on page 7-5. For pilot operated valves see discussion on page 7-4.
- M = Molecular weight of the gas or vapor obtained from standard tables or Table T7-7 on page 7-26.
- P_1 = Relieving pressure, kiloPascals absolute. This is the set pressure (kPa) + overpressure (kPa) + atmospheric pressure (kPaa).
- T = Absolute temperature of the fluid at the valve inlet, degrees Kelvin (˚C + 273).
- W = Required relieving capacity, kilograms per hour.
- Z = Compressibility factor (see Figure F7-1 on page 7-2). Use Z = 1.0 if value is unknown.

EXAMPLE #1

Atmospheric Back Pressure

Fluid:	Natural Gas
Required Capacity:	2675 kg/hr
Set Pressure:	1450 kPag
Overpressure:	10%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	50C
Molecular Weight:	19.0

$$A = \frac{13160\ W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square millimeters
- W = 2675 kg/hr
- T = 50 + 273 = 323K
- Z = Compressibility Factor, use Z = 1.0
- P1 = Absolute relieving pressure 1450 + 145 + 101 = 1696 kPaa
- C = 344 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure
- M = 19 (Table T7-7 on page 7-26)

$$A = \frac{13160\ (2675) \sqrt{(323)(1.0)}}{(344)\ (0.975)\ (1696)\ (1.0) \sqrt{19}} = 255 \text{ sq.mm}$$

A "G" orifice valve with an effective area of 325 square millimeters is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 310, select a 1-1/2 G 2-1/2 Style JOS-15 with Type J cap. Standard materials of construction are satisfactory for this application (natural gas).

EXAMPLE #2

Superimposed Constant Back Pressure

In the preceding example, any change in service conditions would necessitate recalculation of the required orifice area. For example, rather than atmospheric back pressure, consider that there is a superimposed constant back pressure of 1345 kPag.

Since the superimposed back pressure is constant, a conventional valve may be used.

To find the value of the capacity correction factor K_b, use Table T7-1 on page 7-3.

$$\frac{P_b}{P_1} = \text{Back Pressure Percentage}$$

$$= \frac{\text{Back Pressure (kPag)}}{\text{Relieving Pressure (kPag)}} \times 100$$

$$\frac{(1345 \text{ kPag} + 101 \text{ kPa})}{(1450 \text{ kPag} + 145 \text{ kPag} + 101 \text{ kPa})} \times 100 = 85.3\%$$

Gas and Vapor Sizing
10% Overpressure (kg/hr) (Continued)

Interpolating from Table T7-1 on page 7-3, $K_b = 0.76$

$$A = \frac{13160\, W \sqrt{TZ}}{C\, K P_1 K_b \sqrt{M}} = \frac{13160\,(2675)\sqrt{323\ (1)}}{344\,(0.975)\,(1696)\,(0.76)\sqrt{19}}$$

$$= 335 \text{ sq.mm}$$

A Crosby "H" orifice valve with an effective area of 506 square millimeters is the smallest standard valve orifice that will flow the required relieving capacity. Since the back pressure is constant a conventional Style JOS valve can be used. From Crosby Catalog No. 310, select a 1-1/2 H 3 Style JOS-15 with Type J cap. For the production test this valve would be adjusted to open at 105 kPag. This is called the cold differential test pressure (CDTP) and is equal to the set pressure minus superimposed constant back pressure. The opening pressure under service conditions, however, would equal the sum of the cold differential test pressure plus the superimposed constant back pressure (1450 kPag = 105 kPag + 1345 kPag). The proper valve spring for this particular application would be the spring specified for a CDTP of 105 kPag.

EXAMPLE #3
Set Pressure Below 30 psig (207 kPag)

When a pressure relief valve is to be used with a set pressure below 30 psig (207 kPag), the ASME Boiler and Pressure Vessel Code, Section VIII, specifies a maximum allowable overpressure of 3 psi (20.7 kPa).

Fluid:	Air (UV Stamp Required)
Required Capacity:	227 kg/hr
Inlet Relieving Temperature:	21C
Set Pressure:	138 kPag
Overpressure:	20.7 kPa (3 psi)

$$A = \frac{13160\, W \sqrt{TZ}}{C\, K P_1 K_b \sqrt{M}}$$

Where:

W = 227 kg/hr
T = 21C + 273 = 294K
Z = Compressibility Factor, use Z = 1.0
P_1 = Absolute relieving pressure = 138 kPag + 20.7 kPa + 101 kPaa = 259.7 kPaa
C = 356 (Table T7-7 on page 7-26)
K = 0.975
K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
M = 28.97 (Table T7-7 on page 7-26)

$$A = \frac{13160\,(227)\sqrt{294\ (1)}}{356\,(0.975)\,(259.7)\,(1)\sqrt{28.97}} = 106 \text{ sq.mm}$$

From Crosby Catalog No. 902, select a 1" x 1-1/2" Crosby Series 900 valve with a No. 7, 126 sq.mm orifice, Type D lifting lever and standard materials. Therefore, Model Number is 972103M-D.

EXAMPLE #4
Variable Superimposed Back Pressure

When a pressure relief valve is exposed to a variable back pressure the set pressure of the valve may be effected unless either a balanced bellows or series BP style valve is selected.

Fluid:	Air (UV Stamp Required)
Required Capacity:	127 Kg/hr
Inlet Relieving Temp.:	60 deg C
Set Pressure:	400 kPag
Back Pressure:	0-140 kPag
Overpressure:	10%

A BP-Omni threaded valve is preferred for this application.

$$A = \frac{13160\, W \sqrt{TZ}}{C\ K\ P_1 K_b \sqrt{M}}$$

Where:

W = 127 Kg/hr
T = 60C + 273 = 333 K
Z = Compressibility Factor = 1.0
P_1 = Absolute relieving pressure = 400 + 400 + 101 = 541
C = 356 from Table T7-7 on page 7-26.
K = 0.975
K_b = Capacity correction factor from Table F7-2 for BP Omni on page 7-5 = 0.650.
M = 28.97 from Table T7-7 on page 7-26.

$$A = \frac{(13160)\,(127)\sqrt{(333)\,(1.0)}}{(356)\,(0.975)\,(541.)\,(0.65)\sqrt{28.97}}$$
$$= 46.42 \text{ sq. mm}$$

From Catalog No. 905, select a 3/4" x 1" Series BP with a 47.74 sq. mm orifice, type D lifting lever and standard material. Therefore the Model No. is BP51701M-D.

Gas and Vapor Sizing

10% Overpressure (Sm³/min)

The following formula is used for sizing valves for gases and vapor (except steam) when required flow is expressed as a volumetric flow rate in sm³/min. Correction factors are included to account for the effects of back pressure, compressibility and subcritical flow.

$$A = \frac{179400\ Q\ \sqrt{TGZ}}{C\ K\ P_1 K_b}$$

Where:

- A = Minimum required effective discharge area, square millimeters.
- C = Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at standard conditions (see Table T7-7 on page 7-26). Use C = 315 if value is unknown.
- K = Effective coefficient of discharge. K = 0.975
- G = Specific gravity of the gas or vapor.
- K_b = Capacity correction factor due to back pressure. Standard valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows or Series BP valves with superimposed or variable back pressure, see Figure F7-2 on page 7-5. For pilot valves see discussion on page 7-4.
- P_1 = Relieving pressure, kiloPascals absolute. This is the set pressure (kPa) + overpressure (kPa) + atmospheric pressure (kPaa).
- T = Absolute temperature of the fluid at the inlet, degrees Kelvin (˚C + 273).
- Q = Required relieving capacity, standard cubic meters per minute (sm³/min).
- Z = Compressibility factor (see Figure F7-1 on page 7-2). Use Z = 1.0 if value is unknown.

EXAMPLE

Built-up Variable Back Pressure

Fluid:	Ethylene Gas
Required Capacity:	326 Sm³/min
Set Pressure:	1170 kPag
Overpressure:	10%
Back Pressure:	0- 520 kPag
Inlet Relieving Temperature:	93C
Specific Gravity:	0.968
Special Requirement:	Bolted cap requested

$$A = \frac{179400\ Q\ \sqrt{TGZ}}{C\ K\ P_1 K_b}$$

Where:

- A = Minimum required effective discharge area, square millimeters
- Q = 326 Sm³/min
- T = 93C + 273 = 366 K
- G = 0.968 relative to air
- Z = Compressibility factor, use Z = 1.0
- P_1 = Absolute relieving pressure 1170 kPag + 117 kPa + 101 kPaa = 1388 kPaa
- C = 341 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor for bellows style valves from Figure F7-2 on page 7-5.

$$\frac{\text{Back Pressure}}{\text{Set Pressure}} \times 100 = \frac{520}{1170} \times 100 = 44.4\%,\ K_b = 0.896$$

$$A = \frac{179400\ (326)\ \sqrt{(366)\ (0.968)\ (1)}}{(341)\ (0.975)\ (1388)\ (0.896)} = 2{,}662\ \text{sq.mm}$$

Standard Valve

An "N" orifice valve with an effective area of 2800 square millimeters is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 310, select a 4N6 JBS-15 with a Type L cap. Standard materials of construction are satisfactory for this application (Ethylene).

Pilot Valve

Note that Crosby Style JPV Pilot Operated Valves may also be selected for this application. Since pilot operated valve performance is unaffected by back pressure*, the flow correction factor K_b is not applicable except when subcritical flow is encountered. Thus in the example above, the K_b correction factor (0.896) should not be applied if a pilot operated valve is to be selected.

$$A = \frac{179400\ (326)\ \sqrt{(366)\ (0.968)\ (1)}}{(341)\ (0.975)\ (1388)} = 2386\ \text{sq.mm}$$

From Crosby Catalog No. 318, select a 4N6 JPV-15.

*For Style JPVM, up to 70% back pressure is permissible with exhaust connected to outlet of main valve. Above 70% the exhaust should vent to a suitable low pressure location.

Steam Sizing

10% Overpressure (kg/hr)

The following formula is used for sizing valves for steam service at 10% overpressure. This formula is based on the empirical Napier formula for steam flow. Correction factors are included to account for the effects of superheat, back pressure and subcritical flow. An additional correction factor K_n is required by ASME when relieving pressure (P_1) is above 10,340 kPaa.

$$A = \frac{190.4\ W}{K\ P_1 K_{sh} K_n K_b}$$

Where:

- A = Minimum required effective discharge area, square millimeters.
- W = Required relieving capacity, kilograms per hour.
- K = Effective coefficient of discharge. K = 0.975
- P_1 = Relieving pressure, kiloPascals absolute. This is the set pressure (kPaa) + overpressure (kPa) + atmospheric pressure (kPaa).
- K_{sh} = Capacity correction factor due to the degree of superheat in the steam. For saturated steam use K_{sh} = 1.00. See Table T7-2 on page 7-8 for other values.
- K_n = Capacity correction factor for dry saturated steam at set pressures above 10346 kPaa and up to 22,060 kPaa. See Figure F7-4 on page 7-6.
- K_b = Capacity correction factor due to back pressure. For conventional valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows valves with superimposed or variable back pressure see Figure F7-2 on page 7-5. For pilot valves, see discussion on page 7-4.

EXAMPLE #1

Saturated Steam (kg/hr)

Required Capacity:	9750 kg/hr saturated steam
Set Pressure:	1550 kPag
Overpressure:	10%
Relieving Pressure:	P_1= 1550 kPag + 155 kPa + 101 kPa = 1806 kPaa
Back Pressure:	Atmospheric

$$A = \frac{190.4W}{K\ P_1\ K_{sh}\ K_n\ K_b}$$

$$A = \frac{190.4\ (9750)}{0.975\ (1806)\ (1)\ (1)\ (1)} = 1054 \text{ sq.mm}$$

A "K" orifice valve with an effective area of 1186 square millimeters is the smallest standard size valve that will flow the required capacity. From Crosby Catalog No.310, select a 3K4 Style JOS-15 valve with a Type C lifting lever. Standard materials of construction are satisfactory for this saturated steam application.

EXAMPLE #2

Superheated Steam (kg/hr)

Required Capacity:	49,200 kg/hr superheated steam
Relieving Temperature:	400C
Set Pressure:	3670 kPag
Relieving Pressure:	P_1=3670 kPag + 367 kPa + 101 kPa = 4138 kPaa
Back Pressure:	Atmospheric
From page 7-8:	Capacity Correction Factor, K_{sh} = 0.844

$$A = \frac{(190.4)\ (49,200)}{0.975\ (4138)\ (0.844)\ (1)\ (1)} = 2751 \text{ sq.mm}$$

An "N" orifice valve with an effective area of 2800 square millimeters is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 310, select a 4N6 Style JOS-46 valve with a Type C lifting lever and alloy steel spring. Standard materials of construction are satisfactory for this superheated steam application.

EXAMPLE #3

Saturated Steam at a Relieving Pressure Greater than 1500 psig(103 Barg)

Required Capacity:	39,900 kg/hr saturated steam
Set Pressure:	18,960 kPag
Overpressure:	10%
Back Pressure:	Atmospheric
Special Requirement:	Open Bonnet
Relieving Pressure:	P_1 = 18,960 kPag + 1896 kPa + 101 kPa = 20957 kPaa
From Figure F7-4 on page 7-6:	Capacity Correction Factor, K_n=1.154

$$A = \frac{190.4\ W}{K\ P_1\ K_{sh}\ K_n\ K_b}$$

$$A = \frac{190.4\ (39,900)}{0.975\ (20957)\ (1)\ (1.154)\ (1)}$$

$$A = 322 \text{ sq.mm}$$

A "G" orifice valve with an effective area of 325 square millimeters is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 310, select a 2G3 Style JOS-H-76 valve with a Type C lifting lever and alloy steel spring. Standard materials of construction are satisfactory for this saturated steam application.

Liquid Sizing

Spring Loaded Valves
Styles JLT-JOS, JLT-JBS, Series 900 and Series BP

The following formula has been developed for valve Styles JLT-JOS, JLT-JBS, Series 900 and Series BP pressure relief valves using valve capacities certified by the National Board of Boiler and Pressure Vessel Inspectors in accordance with the rules of ASME Boiler and Pressure Vessel Code Section VIII. This formula applies to, and is to be used exclusively for sizing Styles JLT, Series 900 and Series BP pressure relief valves for liquid service applications.

Valve sizing using this formulation is not permitted for overpressures less than 10%.

$$A = \frac{15.9Q\sqrt{G}}{K_w K_v \sqrt{\Delta P}}$$

Where:
- A = Minimum required effective discharge area, square millimeters.
- G = Specific gravity of the liquid at flowing conditions.
- Q = Required relieving capacity, liters per minute at flowing temperature.
- ΔP = Differential pressure (kPa). This is set pressure (kPag) + overpressure (kPa) - back pressure (kPag).
- K_v = Flow correction factor due to viscosity of the fluid at flowing conditions (see page 7-7).
- K_w = Capacity correction factor due to back pressure on bellows or Series BP valves on liquid service. Refer to Figure F7-3 on page 7-5.

Note: See page 7-25 for information on two phase flow.

EXAMPLE #1
Liquid, liters/minute

Fluid:	Sodium Trisulfate
Relieving Capacity:	475 liters/minute
Set Pressure:	690 kPag
Overpressure:	10%
Back Pressure:	0 - 207 kPag (built-up)
Relieving Temperature:	16C
Specific Gravity:	1.23

$$A = \frac{15.9\,Q\,\sqrt{G}}{K_w K_v \sqrt{\Delta P}}$$

Where:
- A = Minimum required effective discharge area, square millimeters
- Q = 475 liters/minute
- G = 1.23
- K_w = .866 (Figure F7-3 on page 7-5)
- K_v = 1.0 for non-viscous fluid
- ΔP = 690 kPag + 69 kPa - 207 kPag = 552 kPa

$$A = \frac{15.9\,(475)\sqrt{1.23}}{(0.866)\,(1)\sqrt{552}} = 412 \text{ sq.mm}$$

An "H" orifice valve with an effective area of 506 square millimeters is the smallest standard size valve that will flow the required relieving capacity. Since the built-up back pressure exceeds 10% a bellows style valve, Style JBS, is required. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 1-1/2H3 Style JLT-JBS-15 valve with a Type J Cap.

EXAMPLE #2
Liquid, liters/minute

Fluid:	Castor Oil
Relieving Capacity:	380 liters/minute
Set Pressure:	1450 kPag
Overpressure:	10%
Back Pressure:	240 kPag (constant)
Relieving Temperature:	15C
Specific Gravity:	0.96

$$A = \frac{15.9\,Q\,\sqrt{G}}{K_w K_v \sqrt{\Delta P}}$$

Where:
- A = Minimum required effective discharge area, square millimeters
- Q = 380 liters/minute
- G = 0.96
- K_w = 1.0 from page 7-5
- K_v = 1.0 for non-viscous fluid
- ΔP = 1450 kPag + 145 kPa - 240 kPag = 1355 kPa

$$A = \frac{15.9\,(380)\sqrt{0.96}}{(1)\,(1)\sqrt{1355}} = 160.8 \text{ sq.mm}$$

A number 8 orifice with an effective area of 198 sq.mm is the smallest Series 900 OMNI-TRIM valve that will flow the required relieving capacity. Since the back pressure is constant a conventional Style JOS or Series 900 valve can be used. Therefore, from Crosby Catalog No. 902 select a Series 900 OMNI-TRIM 981105M-A.

Liquid Sizing
Pilot Operated Valves
STYLE JPVM

Crosby Style JPVM Pilot Operated Pressure Relief Valves may be used on liquid service. The coefficient of discharge for these valves has been certified at 10% overpressure in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section VIII. Capacities are certified by the National Board of Boiler and Pressure Vessel Inspectors. The following formula is to be used exclusively for Crosby Style JPVM valve.

Note: Style JPVM on liquid service provides 30% greater capacity than spring loaded valves with liquid trim. This can permit use of a much smaller valve than would otherwise be required.

$$A = \frac{12.16Q\sqrt{G}}{K_v \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square millimeters.
- G = Specific gravity of the liquid at flowing conditions.
- Q = Required relieving capacity, liters per minute at flowing temperature.
- ΔP = Differential pressure (kPa). This is the set pressure (kPag) + overpressure (kPa) - back pressure (kPag).
- K_v = Flow correction factor due to viscosity of the fluid flowing conditions (see page 7-7).
  Note: For optimum operation, fluid viscosity should be no greater than 300 SSU, and in this case K_v = 1.0 may be used.

Note: See page 7-25 for information on two phase flow.

EXAMPLE
Liquid, liters/minute
Crosby Style JPVM Valve

Fluid:	Sodium Trisulfate
Relieving Cap:	475 liters/minute
Set Pressure:	690 kPag
Overpressure:	10%
Back Pressure:	0 - 207 kPag (built-up)
Relieving Temperature:	16C
Specific Gravity:	1.23

$$A = \frac{12.16\,Q\sqrt{G}}{K_v \sqrt{\Delta P}}$$

Where:

- A = Minimum required effective discharge area, square millimeters
- Q = 475 liters/minute
- G = 1.23
- K_v = 1.0 for non-viscous fluid
- ΔP = 690 kPag + 69 kPa - 207 kPag = 552 kPa

$$A = \frac{12.16\,(475)\sqrt{1.23}}{(1)\sqrt{552}} = 273 \text{ sq.mm}$$

A "G" orifice valve with an effective area of 325 square millimeters is the smallest standard size valve that will flow the required relieving capacity. From Crosby Catalog No. 318, standard materials were selected. Therefore, Model Number is 1-1/2G3 Style JPVM-15.

Multiple Valve Sizing

When multiple pressure relief valves are used, one valve shall be set at or below the Maximum Allowable Working Pressure, MAWP, and the remaining may be set up to 5% over the MAWP. When sizing for multiple valve applications, the total required area is calculated on an overpressure of 16% or 27.58 kPa, whichever is greater.

When exposure to fire is a consideration, please reference liquid relief valve sizing under fire conditions (see page 7-17).

Example #1

Reference Example #1, page 6-3, except that this is a multiple valve application:

MAWP:	1450 kPag
Fluid:	Natural Gas
Required Capacity:	2675 kg/hr
Set Pressure:	1450 kPag
Overpressure:	16%
Back Pressure:	Atmospheric
Relieving Temperature:	50C
Molecular Weight:	19.0

$$A = \frac{13160\ W\ \sqrt{TZ}}{C\ K\ P_1\ K_b\ \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square millimeters
- W = 2675 kg/hr
- T = 50C + 273 = 323 K
- Z = Compressibility Factor, use Z = 1.0
- P_1 = 1450 (1.16) + 101 = 1783 kPaa
- C = 344 (Table T7-7, page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
- M = 19 (Table T7-7 page 7-26)

$$A = \frac{13160\ (2675)\ \sqrt{(323)\ (1)}}{(344)\ (0.975)\ (1783)\ (1.0)\ \sqrt{19}} = 242.7 \text{ sq.mm}$$

Therefore, two "E" orifice valves with a total area of 242.7 square mm are selected to meet the required flow for this multiple valve application: one valve set at MAWP equals 1450 kPag, and one set at 105% of MAWP equals 1522 kPag. The effective area of each "E" orifice valve is 126 square mm. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 1E2 JOS-15-J.

Example #2

Fluid:	Air
Required Capacity:	68038.9 kg/hr
Set Pressure:	1379 kPag
Overpressure:	16%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	66C

$$A = \frac{W\ \sqrt{TZ}}{C\ K\ P_1\ K_b\ \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square mm
- W = 68038.9
- T = 66C + 273C = 339 K
- Z = Compressibility factor, use Z = 1.0
- P_1 = Absolute relieving pressure 1379 kPag + 220 kPag + 101 = 170 kPa
- C = 356 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. For standard valves with superimposed (constant) back pressure exceeding critical see Table T7-1 on page 7-3. For bellows valves with superimposed variable back pressure see Figure F7-2 on page 7-5. Use K_b = 1.0 for atmospheric back pressure.
- M = 28.97 (Table T7-7 on page 7-26)

$$A = \frac{13160\ (68038.9)\ \sqrt{339\ (1)}}{(356)(0.975)(1701)(1)\ \sqrt{28.97}}$$

A = 5188 sq. mm.

Total required orifice area is 5188 square mm. Valves selected are "N" orifice with an effective area of 2800 square mm each. Total area of two "N" orifice valves equals 5600 square mm. On multiple valve applications, only one valve needs to be set at or below MAWP. All additional valves may be set up to and including 105% of MAWP. From Crosby Catalog No. 310, standard materials were selected. Therefore, Model Number is 4N6 JOS-15-J.

Combination Devices

The rated relieving capacity of a pressure relief valve in combination with a rupture disc is equal to the capacity of the pressure relief valve multiplied by a combination capacity factor to account for any flow losses attributed to the rupture disc.

Combination capacity factors that have been determined by test and are acceptable to use are compiled by the National Board of Boiler and Pressure Vessel Inspectors in the Pressure Relief Device Certifications publication NB-18. This publication lists the combination capacity factors to be used with specific rupture device and relief valve by manufacturer rupture device/valve models.

When a combination capacity factor that has been determined by test for the specific rupture disc and relief valve combination is not available, a combination capacity factor of 0.9 may be used.

Example #1

Gas/Vapor Mass Flow (kg/hr)
(See page 6-3)

Fluid:	Natural Gas
Required Capacity:	3350 kg/hr
Set Pressure:	1450 kPag
Overpressure:	10%
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	50C
Molecular Weight:	19.0

$$A = \frac{13160\ W\ \sqrt{TZ}}{C\ K\ P_1\ K_b\ \sqrt{M}}$$

Where:

- A = Minimum required effective discharge area, square millimeters
- W = 3350 kg/hr
- T = 50C + 273 = 323 K
- Z = Compressibility Factor, use Z = 1.0
- P_1 = 1450 kPag + 145 kPa + 101 kPaa = 1696 kPaa
- C = 344 (Table T7-7 on page 7-26)
- K = 0.975
- K_b = Capacity correction factor due to back pressure. Use K_b = 1.0 for atmospheric back pressure.
- M = 19.0 (Table T7-7 on page 7-26)

$$A = \frac{13160\ (3350)\ \sqrt{(323)\ (1)}}{(344)(0.975)(1696)(1.0)\ \sqrt{19}} = 319.9 \text{ sq.mm}$$

A standard application would require a "G" orifice, Style JOS valve with an effective orifice area of 325 square millimeters. However, this application requires a rupture disc. Since a specific rupture disc has not been specified, a rupture disc combination factor of 0.9 could be used.

The minimum required effective discharge area must be scaled up by dividing it by the combination factor.

$$\text{Required Area} = (A) / (F_{comb}) = (319.9) / (0.9) = 355.4 \text{ sq.mm}$$

Therefore, this application with rupture disc requires an "H" orifice Style JOS valve of standard materials with an effective area of 506 square millimeters, an increase of one valve size. However, in this example, if using a specific rupture disc having a combination factor (F_{comb}), when used with Crosby valves that is 0.986 or higher, a larger valve size may not be necessary. (See The National Board of Boiler and Pressure Vessel Inspectors NB-18, "Pressure Relief Device Certifications" - Section IV.)

Crosby® Engineering Handbook
Technical Publication No. TP-V300

Chapter 7

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Engineering Support Information

HOME

The following data with charts and tables are included in this chapter:

Compressibility Factor, Z

The gas and vapor formulae of this handbook are based on perfect gas laws. Many real gases and vapors, however, deviate from a perfect gas. The compressibility factor Z is used to compensate for the deviations of real gases from the ideal gas.

The compressibility factor may be determined from Figure F7-1 below by first calculating the reduced pressure and the reduced temperature of the gas. The reduced temperature is equal to the ratio of the actual absolute inlet gas temperature to the absolute critical temperature of the gas.

$$T_R = \frac{T}{T_c}$$

Where:
T_R = Reduced temperature
T = Inlet fluid temperature, °F + 460 (°C + 273)
T_c = Critical temperature, °F + 460 (°C + 273)

The reduced pressure is equal to the ratio of the actual absolute inlet pressure to the critical pressure of the gas.

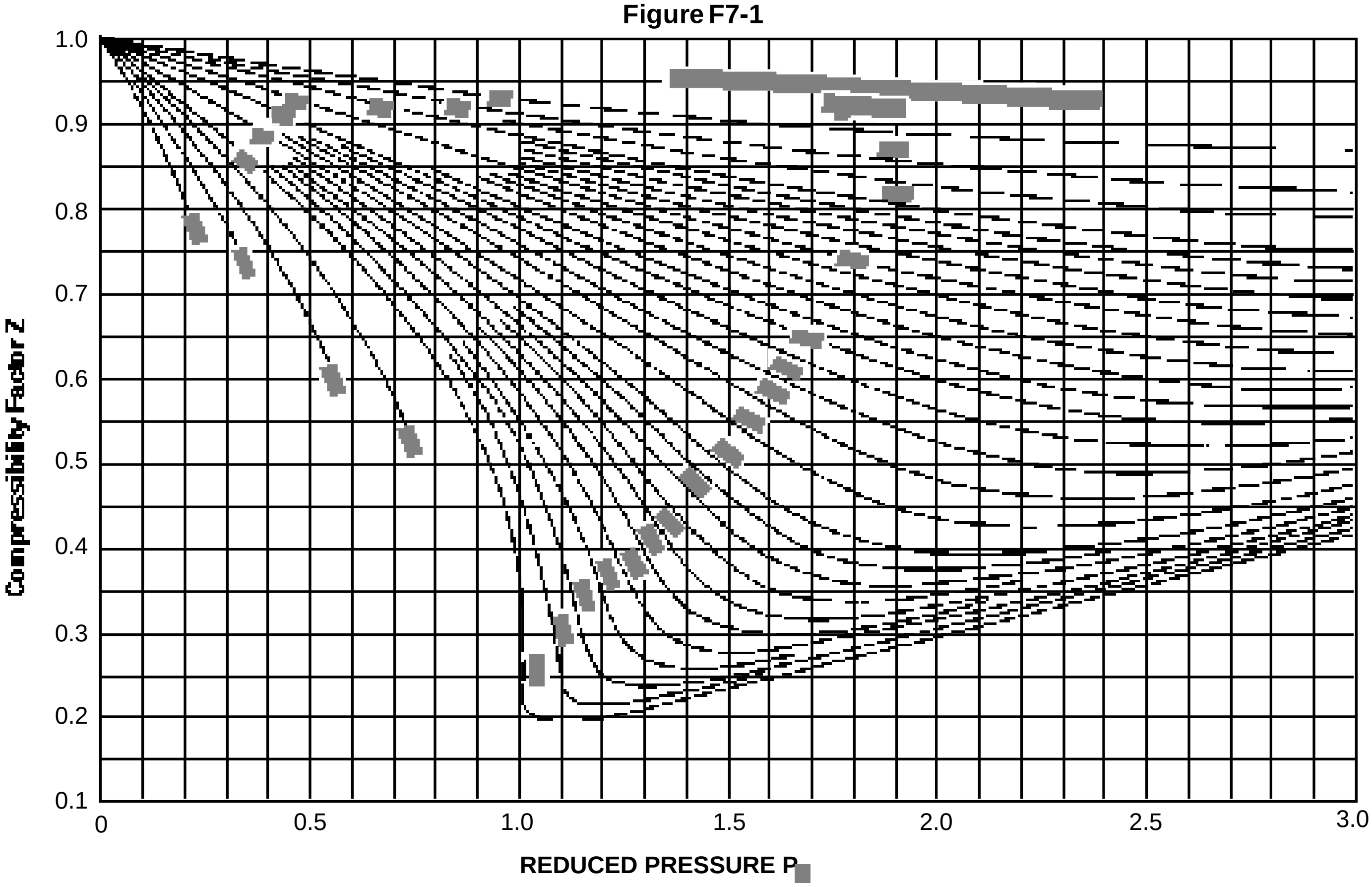
$$P_R = \frac{P}{P_c}$$

Where:
P_R = Reduced pressure
P = Relieving pressure (set pressure + overpressure + atmospheric pressure), psia (kPaa)
P_c = Critical pressure, psia (kPaa)

Enter the chart at the value of reduced pressure, move vertically to the appropriate line of constant reduced temperature. From this point, move horizontally to the left to read the value of Z.

In the event the compressibility factor for a gas or vapor cannot be determined, a conservative value of Z = 1 is commonly used.

Figure F7-1



CAPACITY CORRECTION FACTORS

Back Pressure

Back pressure is the pressure existing at the outlet of a pressure relief valve due to pressure in the discharge system or as a result of flashing in the valve body. Without proper consideration of the effects of back pressure the valve may experience (1) a change in set pressure, (2) a change in closing pressure, (3) a decrease in relieving capacity, and (4) dynamic instability.

In process applications there are two general back pressure conditions:

1. *Built-up* back pressure is the additional pressure at the outlet of the pressure relief valve resulting from the resistance of the discharge system and piping or as a result of flashing in the valve body.
2. *Superimposed* back pressure is the static pressure existing at the outlet of a pressure relief valve at the time the valve is required to operate. It is the result of pressure in the discharge system from other sources.

The effect of back pressure on a pressure relief valve depends upon a combination of several coexisting conditions:

1. Back pressure condition - constant vs. variable
2. Valve position - closed vs. open and relieving
3. Fluid phase - gases or vapors vs. liquids
4. Valve construction - balanced bellows or balanced piston vs. conventional

For gases and vapors including steam, the capacity is unaffected provided the back pressure is less than the critical pressure of the flowing media. Under these conditions no correction factor is required.

Conventional Valves
Style JOS and Series 800/900

Valve Closed

1. ***Superimposed Constant Back Pressure***
 The effect of constant back pressure on a conventional pressure relief valve, before the valve opens, is to increase the pressure at which the valve opens by an amount equal to the back pressure. For this condition the spring setting (cold differential test pressure) is based on the set pressure minus the back pressure.

2. ***Superimposed Variable Back Pressure***
 When the superimposed back pressure is variable, the pressure at which the valve opens will change as the back pressure changes. This variation may cause the opening pressure to vary beyond allowable limits. For this reason a balanced valve is generally recommended for applications with superimposed variable back pressure. However, if the superimposed variable back pressure is low and the resulting variation in the opening pressure of the valve can be tolerated, then a conventional valve may be used.

Valve Open and Relieving

1. ***Built-Up Back Pressure***
 The effect of built-up back pressure on a conventional pressure relief valve that is open and relieving is to rapidly reduce the lifting forces which hold the valve open. The back pressure under such conditons must be limited to no greater than 10% of the set pressure or cold differential test pressure whichever is lower. Back pressure in excess of this requires specification of a balanced style valve.

2. ***Superimposed Back Pressure***
 A flow correction factor may be required in calculating the required valve size.

 Gases and Vapors
 If back pressure on the valve exceeds the critical pressure (55% of the absolute relieving pressure), the Flow Correction Factor K_b must be applied (see Table T7-1). If the back pressure is less than critical pressure, no correction factor is required: $K_b = 1.00$.

 Liquids
 Conventional valves in back pressure service on liquids require no correction factor, when using the accepted capacity formula: $K_w = 1$.

Table T7-1

Correction Factor for Vapors and Gases, K_b for Conventional Valves with Constant Back Pressure and Styles JPV/JPVM Pilot Valves with Back Pressures Exceeding Critical Pressure*

$$P_b / P_1 = \text{Back Pressure Percentage} = \frac{\text{Back Pressure (absolute)}}{\text{Relieving Pressure (absolute)}} \times 100$$

P_b / P_1	K_b	P_b / P_1	K_b	P_b / P_1	K_b
55	1.00	72	0.93	86	0.75
60	0.995	74	0.91	88	0.70
62	0.99	76	0.89	90	0.65
64	0.98	78	0.87	92	0.58
66	0.97	80	0.85	94	0.49
68	0.96	82	0.81	96	0.39
70	0.95	84	0.78		

* Critical pressure is generally taken as 55% of accumulated inlet pressure, absolute

Capacity Correction Factors
Back Pressure (continued)

Balanced Valves
Style JBS, Series BP

Valve Closed

1. ***Superimposed Constant or Variable Back Pressure*** Since the effective area of the bellows or piston is equivalent to the seat area, the set pressure of the valve is unaffected by back pressure. Therefore, whether the back pressure is constant or variable, balanced valves will open within the allowable set pressure tolerances of the ASME Code.

Valve Open and Relieving

1. ***Built-up or Superimposed Constant or Variable Back Pressure*** The effect of back pressure on a balanced pressure relief valve that is open and relieving is to gradually reduce the lifting forces. The effect on the relieving capacity of the valve by this performance characteristic must be taken into consideration. A flow correction factor for the maximum expected back pressure must be used in calculating the required valve size.

Back Pressure Correction Factors

Gases and Vapors

The capacity correction factor, K_b shown in Figures F7-2A and F7-2B should be used to compensate for the effect of back pressure on a Style JBS or Series BP valve.

Liquids

The capacity correction factor K_w shown in Figures F7-3A and F7-3B should be used to compensate for the effect of back pressure on a Style JBS or Series BP valve.

Note: K_b and K_w = 1.00 if back pressure conditions do not apply. For back pressure applications exceeding Figure F7-2 and F7-3 limits, consult with your local Crosby representative for additional sizing information.

Pilot Operated Valves
Style JPV (Snap-Acting)

Back pressure has no effect on the set pressure or flow capacity of Style JPV Pilot Operated Pressure Relief Valves except when flow is subcritical (ratio of absolute back pressure to absolute relieving pressure exceeds 55%). In this case the flow correction factor K_b (see Table T7-1 on page 7-3) must be applied. If the ratio of absolute back pressure to absolute relieving pressure is less than 55%, no correction factor is required: K_b = 1.00.

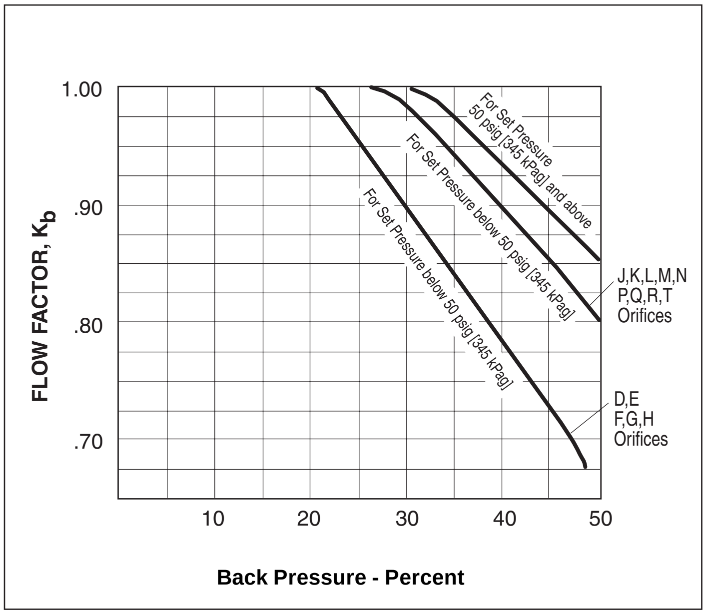
Pilot Operated Valves
Style JPVM (Modulating)

The JPVM pilot exhaust is normally vented to the main valve outlet. Set pressure and operability are unaffected by back pressure up to 70% of set pressure, provided that a backflow preventer is used whenever back pressure is expected to exceed inlet pressure during operation (consult the Factory for back pressure greater than 70% of set pressure).

The capacity of Style JPVM is affected, however, when flow is subcritical (ratio of absolute back pressure to absolute relieving pressure exceeds 55%). In this case the flow correction factor K_b (see Table T7-1) must be applied. If the ratio of absolute back pressure to absolute relieving pressure is less than 55%, no correction factor is required: K_b = 1.00.

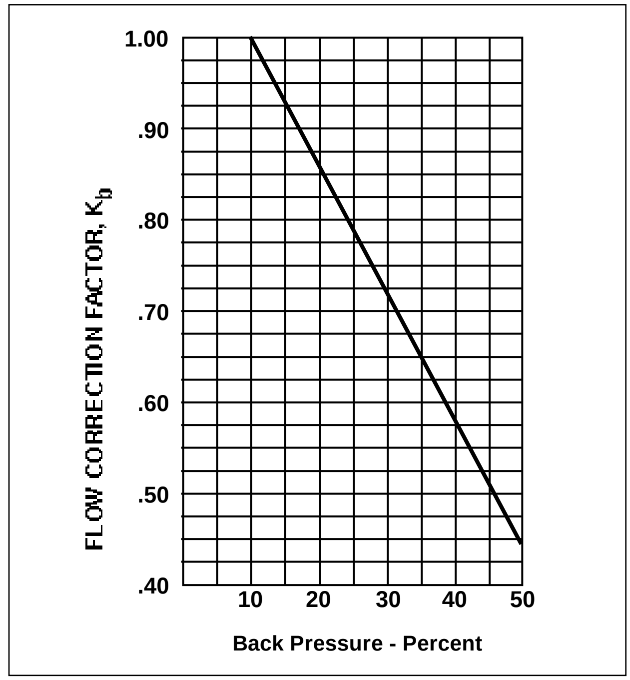
Correction Factor for Vapors and Gases, K_b

Figure F7-2A
Style JBS Valves - 10% Overpressure



$$\frac{\text{Back Pressure (gage)}}{\text{Set Pressure (gage)}} \times 100$$

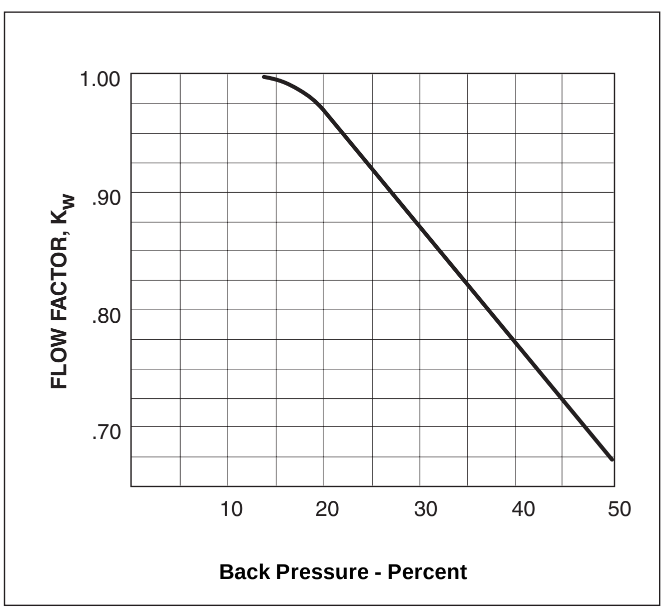
Figure F7-2B
Series BP Valves - 10% Overpressure



$$\frac{\text{Back Pressure (gage)}}{\text{Set Pressure (gage)}} \times 100$$

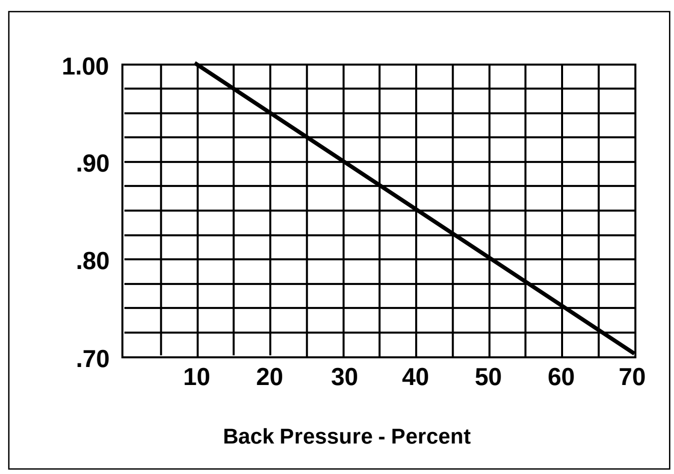
Correction Factor for Liquids, K_w

Figure F7-3A
Style JLT-JBS Valves - 10% Overpressure and Above



$$\frac{\text{Back Pressure (gage)}}{\text{Set Pressure (gage)}} \times 100$$

Figure F7-3B
Series BP Valves - 10% Overpressure



$$\frac{\text{Back Pressure (gage)}}{\text{Set Pressure (gage)}} \times 100$$

Capacity Correction Factor for High Pressure Steam, K_n

The high pressure steam correction factor K_n is used when steam pressure P_1 is greater than 1500 psia (10340 kPaa) and up to 3200 psia (22060 kPaa). This factor has been adopted by ASME to account for the deviation between steam flow as determined by Napier's Equation and actual saturated steam flow at high pressures. K_n may be calculated by the following equation or may be taken from Figure F7-4, below.

U.S.C.S Units:

$$K_n = \frac{0.1906P_1 - 1000}{0.2292P_1 - 1061}$$

Metric Units:

$$K_n = \frac{0.02763P_1' - 1000}{0.03324P_1' - 1061}$$

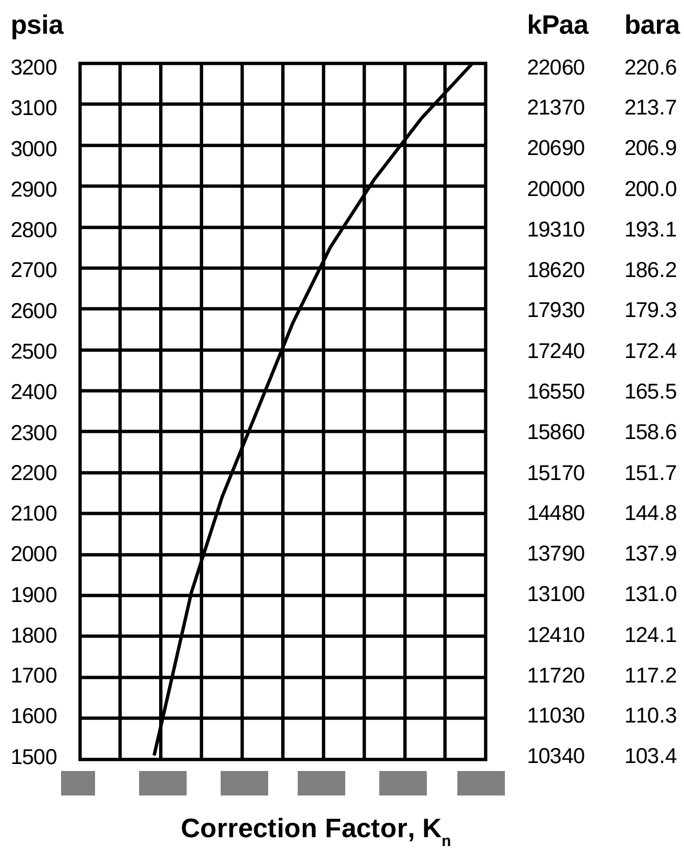
Where:

K_n = High pressure steam correction factor

P_1 = Relieving pressure, psia. This is the set pressure + overpressure + atmospheric pressure.

P_1' = Relieving pressure, kPaa

Figure F7-4
Correction Factor for High Pressure Steam, K_n



Capacity Correction Factor for Viscosity, K_v

When a relief valve is sized for viscous liquid service, it is suggested that it be sized first as for nonviscous-type application in order to obtain a preliminary required effective discharge area, A. From Crosby's standard effective orifice sizes select the next larger orifice size and calculate the Reynolds' number, R, per the following formula:

U.S.C.S. Units:

$$R = \frac{GPM(2800G)}{\mu \sqrt{A}} \qquad R = \frac{12700\,GPM}{U \sqrt{A}}$$

Metric Units:

$$R = \frac{Q(18800)G}{\mu \sqrt{A'}} \qquad R = \frac{85225Q}{U \sqrt{A'}}$$

Where:

GPM = Flow rate at the flowing temperature, U.S. gallons per minute.

G = Specific gravity of the liquid at the flowing temperature referred to water = 1.00 at 70F (21C).

A = Effective discharge area, square inches (from manufacturers' standard orifice areas).

U = Viscosity at the flowing temperature, Saybolt Universal Seconds (SSU).

μ = Absolute viscosity at the flowing temperature, centipoises.

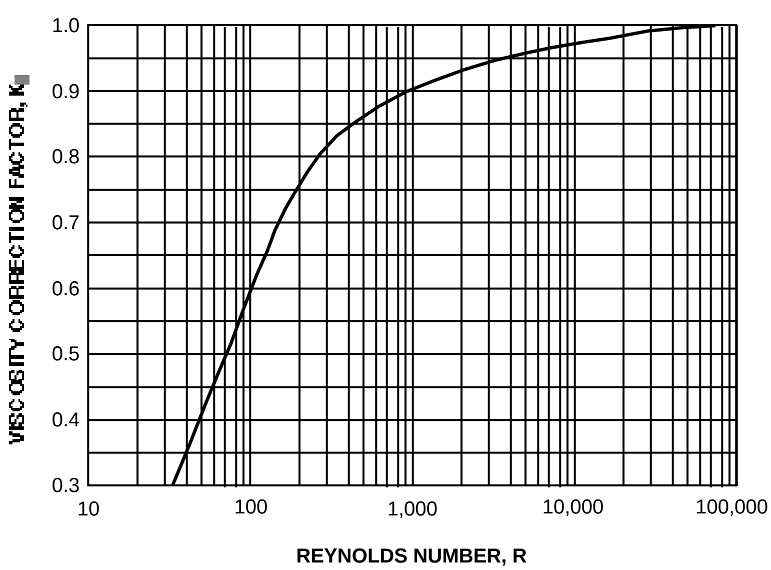
Q = Flow rate at the flowing temperature, liters per minute.

A' = Effective discharge area, sq. mm.

After the value of R is determined, the factor K_v is obtained from the graph. Factor K_v is applied to correct the "preliminary required discharge area." If the corrected area exceeds the "chosen effective orifice area," the above calculations should be repeated using the next larger effective orifice size as the required effective orifice area of the valve selected cannot be less than the calculated required effective area.

Figure F7-5

Correction Factor for Viscosity, K_v



Capacity Correction Factor for Superheat, K_{sh}

The steam sizing formulae on page 5-6 and 6-6 are based on the flow of dry saturated steam. To size for superheated steam, the superheat correction factor is used to correct the calculated saturated steam flow to superheated steam flow. For saturated steam K_{sh} = 1.0. When the steam is superheated, enter Table T7-2 at the required relieving pressure and read the superheat correction factor under the total steam temperature column.

Table T7-2

RELIEVING* PRESSURE			TOTAL TEMPERATURE SUPERHEATED STEAM													
			400F	450F	500F	550F	600F	650F	700F	750F	800F	850F	900F	950F	1000F	1050F
psia	bara	kPaa	(204C)	(232C)	(260C)	(288C)	(316C)	(343C)	(371C)	(399C)	(427C)	(454C)	(482C)	(510C)	(538C)	(566C)
50	3.4	340	.987	.957	.930	.905	.882	.861	.841	.823	.805	.789	.774	.759	.745	.732
100	6.9	690	.998	.963	.935	.909	.885	.864	.843	.825	.807	.790	.775	.760	.746	.733
150	10.3	1030	.984	.970	.940	.913	.888	.866	.846	.826	.808	.792	.776	.761	.747	.733
200	13.8	1380	.979	.977	.945	.917	.892	.869	.848	.828	.810	.793	.777	.762	.748	.734
250	17.2	1720		.972	.951	.921	.895	.871	.850	.830	.812	.794	.778	.763	.749	.735
300	20.7	2070		.968	.957	.926	.898	.874	.852	.832	.813	.796	.780	.764	.750	.736
350	24.1	2410		.968	.963	.930	.902	.877	.854	.834	.815	.797	.781	.765	.750	.736
400	27.6	2760			.963	.935	.906	.880	.857	.836	.816	.798	.782	.766	.751	.737
450	31.0	3100			.961	.940	.909	.883	.859	.838	.818	.800	.783	.767	.752	.738
500	34.5	3450			.961	.946	.914	.886	.862	.840	.820	.801	.784	.768	.753	.739
550	37.9	3790			.962	.952	.918	.889	.864	.842	.822	.803	.785	.769	.754	.740
600	41.4	4140			.964	.958	.922	.892	.867	.844	.823	.804	.787	.770	.755	.740
650	44.8	4480			.968	.958	.927	.896	.869	.846	.825	.806	.788	.771	.756	.741
700	48.3	4830				.958	.931	.899	.872	.848	.827	.807	.789	.772	.757	.742
750	51.7	5170				.958	.936	.903	.875	.850	.828	.809	.790	.774	.758	.743
800	55.2	5520				.960	.942	.906	.878	.852	.830	.810	.792	.774	.759	.744
850	58.6	5860				.962	.947	.910	.880	.855	.832	.812	.793	.776	.760	.744
900	62.1	6210				.965	.953	.914	.883	.857	.834	.813	.794	.777	.760	.745
950	65.5	6550				.969	.958	.918	.886	.860	.836	.815	.796	.778	.761	.746
1000	69.0	6900				.974	.959	.923	.890	.862	.838	.816	.797	.779	.762	.747
1050	72.4	7240					.960	.927	.893	.864	.840	.818	.798	.780	.763	.748
1100	75.8	7580					.962	.931	.896	.867	.842	.820	.800	.781	.764	.749
1150	79.3	7930					.964	.936	.899	.870	.844	.821	.801	.782	.765	.749
1200	82.7	8270					.966	.941	.903	.872	.846	.823	.802	.784	.766	.750
1250	86.2	8620					.969	.946	.906	.875	.848	.825	.804	.785	.767	.751
1300	89.6	8960					.973	.952	.910	.878	.850	.826	.805	.786	.768	.752
1350	93.1	9310					.977	.958	.914	.880	.852	.828	.807	.787	.769	.753
1400	96.5	9650					.982	.963	.918	.883	.854	.830	.808	.788	.770	.754
1450	100.0	10000					.987	.968	.922	.886	.857	.832	.809	.790	.771	.754
1500	103.4	10340					.993	.970	.926	.889	.859	.833	.811	.791	.772	.755
1550	106.9	10690						.972	.930	.892	.861	.835	.812	.792	.773	.756
1600	110.3	11030						.973	.934	.894	.863	.836	.813	.792	.774	.756
1650	113.8	11380						.973	.936	.895	.863	.836	.812	.791	.772	.755
1700	117.2	11720						.973	.938	.895	.863	.835	.811	.790	.771	.754
1750	120.7	12070						.974	.940	.896	.862	.835	.810	.789	.770	.752
1800	124.1	12410						.975	.942	.897	.862	.834	.810	.788	.768	.751
1850	127.6	12760						.976	.944	.897	.852	.833	.809	.787	.767	.749
1900	131.0	13100						.977	.946	.898	.862	.832	.807	.785	.766	.748
1950	134.5	13450						.979	.949	.898	.861	.832	.806	.784	.764	.746
2000	137.9	13790						.982	.952	.899	.861	.831	.805	.782	.762	.744
2050	141.3	14130						.985	.954	.899	.860	.830	.804	.781	.761	.742
2100	144.8	14480						.988	.956	.900	.860	.828	.802	.779	.759	.740
2150	148.2	14820							.956	.900	.859	.827	.801	.778	.757	.738
2200	151.7	15170							.955	.901	.859	.826	.799	.776	.755	.736
2250	155.1	15510							.954	.901	.858	.825	.797	.774	.753	.734
2300	158.6	15860							.953	.901	.857	.823	.795	.772	.751	.732
2350	162.0	16200							.952	.902	.856	.822	.794	.769	.748	.729
2400	165.5	16550							.952	.902	.855	.820	.791	.767	.746	.727
2450	168.9	16890							.951	.902	.854	.818	.789	.765	.743	.724
2500	172.4	17240							.951	.902	.852	.816	.787	.762	.740	.721
2550	175.8	17580							.951	.902	.851	.814	.784	.759	.738	.718
2660	179.3	17930							.951	.903	.849	.812	.782	.756	.735	.715
2650	182.7	18270							.952	.903	.848	.809	.779	.754	.731	.712
2700	186.2	18620							.952	.903	.846	.807	.776	.750	.728	.708
2750	189.6	18960							.953	.903	.844	.804	.773	.747	.724	.705
2800	193.1	19310							.956	.903	.842	.801	.769	.743	.721	.701
2850	196.5	19650							.959	.902	.839	.798	.766	.739	.717	.697
2900	200.0	20000							.963	.902	.836	.794	.762	.735	.713	.693
2950	203.4	20340								.902	.834	.790	.758	.731	.708	.688
3000	206.9	20690								.901	.831	.786	.753	.726	.704	.684

*Relieving pressure is the valve set pressure plus the overpressure plus the atmospheric pressure (14.7 psia, 1.014 bara or 101.4 kPaa.)

Ratio of Specific Heats, k, and Coefficient, C

The following formula equates the ratio of specific heats to the coefficient, C, used in sizing methods for gases and vapors. Figure F7-6 and Table T7-3 provide the calculated solution to this formula.

$$C = 520 \sqrt{(k)[2/(k+1)]^{(k+1)/(k-1)}}$$

Where:

k = Ratio of specific heats

Figure F7-6

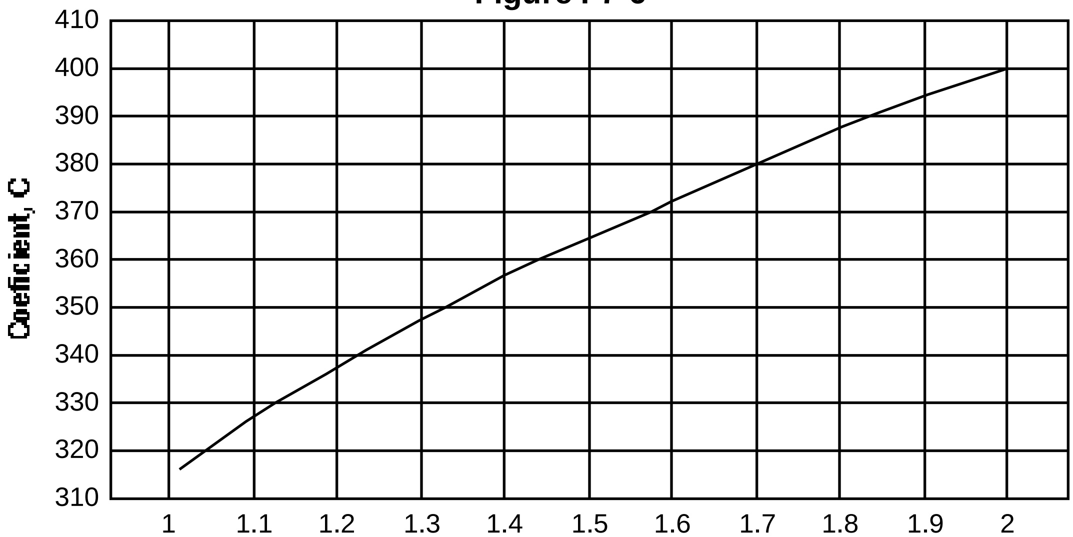


Table T7-3

k	C	k	C	k	C	k	C	k	C
1.01	317	1.21	338	1.41	357	1.61	373	1.81	388
1.02	318	1.22	339	1.42	358	1.62	374	1.82	389
1.03	319	1.23	340	1.43	359	1.63	375	1.83	389
1.04	320	1.24	341	1.44	360	1.64	376	1.84	390
1.05	321	1.25	342	1.45	360	1.65	376	1.85	391
1.06	322	1.26	343	1.46	361	1.66	377	1.86	391
1.07	323	1.27	344	1.47	362	1.67	378	1.87	392
1.08	325	1.28	345	1.48	363	1.68	379	1.88	393
1.09	326	1.29	346	1.49	364	1.69	379	1.89	393
1.10	327	1.30	347	1.50	365	1.70	380	1.90	394
1.11	328	1.31	348	1.51	365	1.71	381	1.91	395
1.12	329	1.32	349	1.52	366	1.72	382	1.92	395
1.13	330	1.33	350	1.53	367	1.73	382	1.93	396
1.14	331	1.34	351	1.54	368	1.74	383	1.94	397
1.15	332	1.35	352	1.55	369	1.75	384	1.95	397
1.16	333	1.36	353	1.56	369	1.76	384	1.96	398
1.17	334	1.37	353	1.57	370	1.77	385	1.97	398
1.18	335	1.38	354	1.58	371	1.78	386	1.98	399
1.19	336	1.39	355	1.59	372	1.79	386	1.99	400
1.20	337	1.40	356	1.60	373	1.80	387	2.00	400

Noise Level Calculations

The following formulae are used for calculating noise level of gases, vapors and steam as a result of the discharge of a pressure relief valve. The expressed formulae are derived from API Recommended Practice 521. Table T7-4 on page 7-11 lists relative noise levels.

$$L_{100} = L + 10\ LOG_{10}\ (0.29354\ \ W\ \ k\ \ T/M)$$

Where:

L_{100} = Sound level at 100 feet from the point of discharge in decibels.

L = Noise intensity measured as the sound pressure level at 100 feet from the discharge. Reference Figure F7-7 on page 7-11.

W = Maximum relieving capacity, pounds per hour.

k = Ratio of specific heats of the fluid. Reference Table T7-7 on page 7-26. (For steam, k = 1.3 if unknown.)

T = Absolute temperature of the fluid at the valve inlet, degrees Rankine (˚F + 460).

M = Molecular weight of the gas or vapor obtained from standard tables or Table T7-7 on page 7-26. (For steam, M = 18)

When the noise level is required at a distance of other than 100 feet, the following equation shall be used:

$$L_p = L_{100} - 20\ LOG_{10}\ (r/100)$$

Where:

L_p = Sound level at a distance, r, from the point of discharge in decibels.

r = Distance from the point of discharge, feet.

Example #1

Gas/Vapor Mass Flow (lb/hr)

Fluid:	Natural Gas
Set Pressure:	210 psig
Overpressure:	10%
Back Pressure:	50 psig
Inlet Relieving Temperature:	120F
Molecular Weight:	19.0 (page 7-26)
Compressibility:	1
Selected Area:	0.503 square inches
Noise to be calculated at:	500 feet

Although the required capacity has been given, the noise level of the valve should be calculated on the total flow through the selected valve at the specified overpressure. Therefore the rated flow must first be calculated. The following formula is a rearrangement of the area calculation formula for gas and vapor in mass flow units (lb/hr). Reference page 5-3.

P_1 = Absolute relieving pressure
210 + 21 + 14.7 = 245.7 psia

K_b = 1.0

C = 344 from Table T7-7 on page 7-26.

K = 0.975

$W = A\ P_1\ C\ K\ K_b\ \sqrt{M}\ /\ \sqrt{TZ}$

$W = (0.503)(245.7)(344)(0.975)(1)(\sqrt{19})/\sqrt{(580)(1)}$

W = 7502 lb/hr

T = 120F + 46F = 580R

P_b = 50 psig

Continuing with the noise level calculation:

$$L_{100} = L + 10\ LOG_{10}\ (0.29354\ \ W\ \ k\ \ T/M)$$

Where:

PR = Absolute relieving pressure/absolute back pressure
= $P_1\ (P_b + 14.7)$ = 245.7/(50 + 14.7) = 3.8

L = 54.5 (Figure F7-7, page 7-11.)

k = 1.27 (Table T7-7, page 7-26.)

W = 7502 lb/hr

M = 19

T = 120F + 460F = 580R

L_{100}=54.5+ 10 LOG_{10} [(0.29354)(7502)(1.27)(580)/(19)]

L_{100}=103.8 decibels

At a distance of 500 feet:

$$L_p = L_{100} - 20\ \ LOG_{10}\ \ (r/100)$$

Where:

r = 500 feet

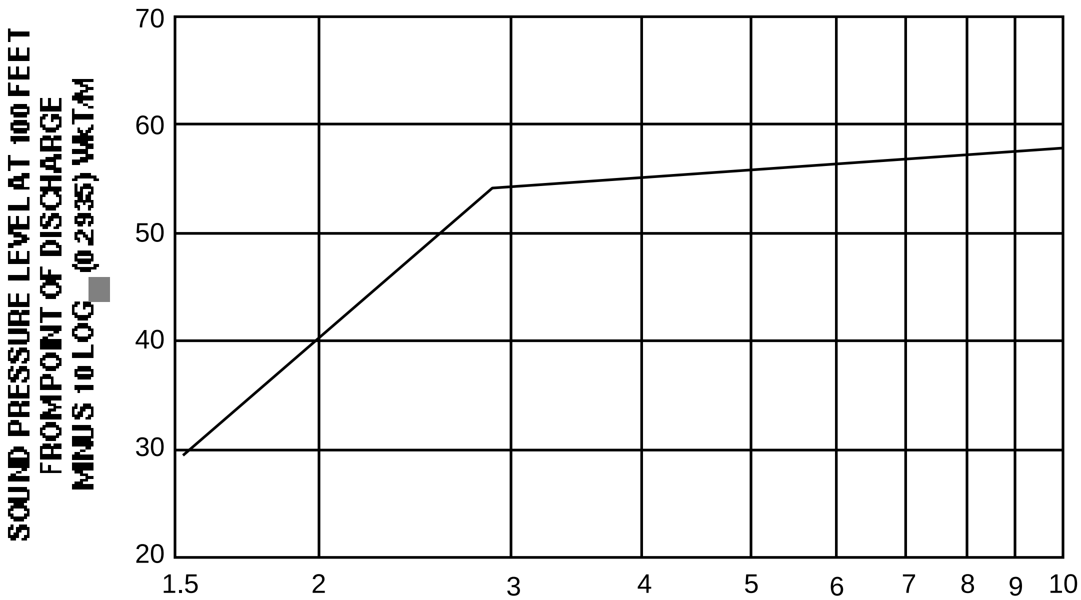
$$L_p\ \ =\ \ 103.8 - 20\ LOG_{10}\ (500/100)$$

$$L_p\ \ =\ \ 89.9\ \text{decibels}$$

Noise Intensity

(At 100 feet from the Discharge)

Figure F7-7



PRESSURE RATIO, PR

$$\frac{\textbf{Absolute Relieving Pressure}}{\textbf{Absolute Back Pressure}}$$

Table T7-4

Relative Noise Levels			
130	Decibels	-	Jet Aircraft on Takeoff
120	Decibels	-	Threshold of Feeling
110	Decibels	-	Elevated Train
100	Decibels	-	Loud Highway
90	Decibels	-	Loud Truck
80	Decibels	-	Plant Site
70	Decibels	-	Vacuum cleaner
60	Decibels	-	Conversation
50	Decibels	-	Offices

Reaction Forces

The following formulae are used for the calculation of reaction forces for a pressure relief valve discharging gas, vapor or steam directly to atmosphere without discharge piping. The expressed formulae produce results consistent with the API Recommended Practice 520 for gas and vapor and ANSI/ASME B31.1 for steam.

Gas/Vapor:

$$F = \frac{C\ K\ A\ P_1 \sqrt{[k/(k+1)]}}{332.7} + F_g$$

$$F_g = \left(\frac{K\ A\ P_1\ K_r}{1.383\ A_o} - P_a\right) A_o$$

If F_g is less than or equal to 0.0 use $F_g = 0.0$.

Steam:

$$F = \frac{A\ P_1}{1.335} + F_s$$

$$F_s = \left(\frac{A\ P_1}{1.886\ A_o} - P_a\right) A_o\ K_n$$

If F_s is less than or equal to 0.0 use $F_s = 0.0$.

Where:

- F = Total reaction force at the point of discharge to atmosphere, pounds force.
- F_g = Component of reaction force due to static pressure at the valve outlet for gas/vapor applications, pounds force.
- F_s = Component of reaction force due to static pressure at the valve outlet for steam applications, pounds force.
- C = Coefficient determined from an expression of the ratio of specific heats of the gas or vapor at standard conditions. (Reference Table T7-7 on page 7-26).
- K = Effective coefficient of discharge. $K = 0.975$.
- A = Effective discharge area, square inches.
- A_o = Outlet cross-sectional area, square inches.
- P_1 = Relieving pressure, pounds per square inch, absolute. This is set pressure (psig) + overpressure (psi) + atmospheric pressure (psia).
- P_a = Atmospheric pressure (psia).
- k = Ratio of specific heats of the fluid. Reference Table T7-7 on page 7-26.
- K_n = High pressure steam correction factor. Reference page 7-6.
- K_r = Correction for ratios of specific heats of other than 1.4. (Reference Table T7-5 on page 7-13).

Example #1

Gas/Vapor Mass Flow (lb/hr)
Reference Example #1, page 5-3.

Fluid:	Natural Gas
Required Capacity:	5900 lb/hr
Set Pressure:	210 psig
Overpressure:	10%
Relieving Pressure:	245.7 psia
Ratio of Specific Heats:	1.27 (Table T7-7 on page 7-26)
Coefficient, C:	344 (Table T7-7 on page 7-26)
Calculated Area:	0.397 square inches
Valve Selected:	1-1/2 G 2-1/2
Selected Area:	0.503 square inches

Calculate F_g:

$$F_g = \left(\frac{K\ A\ P_1\ K_r}{1.383\ A_o} - P_a\right) A_o$$

Where:

$K = 0.975$
$A = 0.503$ (Effective area of selected valve)
$P_1 = 245.7$ psia
$K_r = 1.04$ (Table T7-5 on page 7-13)
$P_a = 14.7$ psia
$A_o = (2\text{-}1/2)^2\ (\pi/4) = 4.909$ square inches

$$F_g = \left[\frac{(0.975)(0.503)(245.7)(1.04)}{(1.383)(4.909)} - 14.7\right](4.909)$$

$F_g = 18.5$ lb.

Calculate Reaction Force, F:

$$F = \frac{C\ K\ A\ P_1 \sqrt{[k/(k+1)]}}{332.7} + F_g$$

Where:

$C = 344$
$k = 1.27$

$$F = \frac{(344)(0.975)(0.503)(245.7)\sqrt{[1.27/(1.27+1)]}}{332.7} + 18.5$$

$F = 111.6$ lb.

Reaction Forces

Correction for Ratio of Specific Heats

(The correction for the ratio of specific heats, K_r, is to be used for the gas and vapor reaction force formula only and should not be used to modify the graphical results. For values outside the range of this table, please consult your local Crosby representative.)

Table T7-5

k	K_r
1.01	1.15
1.05	1.13
1.10	1.11
1.15	1.09
1.20	1.07
1.25	1.05
1.30	1.03
1.35	1.02
1.40	1.00
1.45	0.98
1.50	0.97
1.55	0.95
1.60	0.94
1.65	0.93
1.70	0.91
1.75	0.90
1.80	0.89
1.85	0.87
1.90	0.86
1.95	0.85
2.00	0.84

Graphical Results:

The graphs on the following pages present the reaction force for Series 800, 900 and Series BP, Styles JOS and JBS and Styles JPV/JPVM pressure relief valves. These graphs cover the standard outlet sizes as referenced in Crosby Catalogs Nos. 902, 905, 310 and 318.

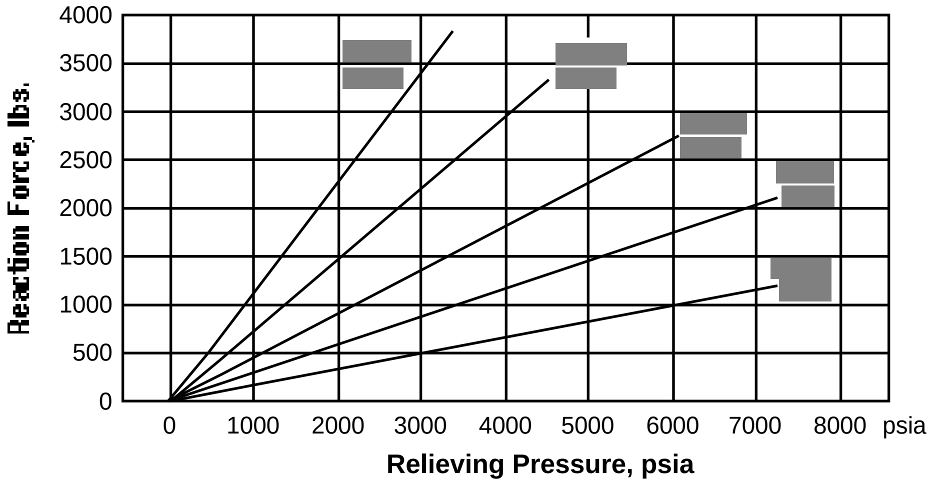
The graphical reaction force results for gas and vapor have been calculated with a ratio of specific heat of 1.4. For values of ratio of specific heat or other than 1.4, please refer to the formulae provided.

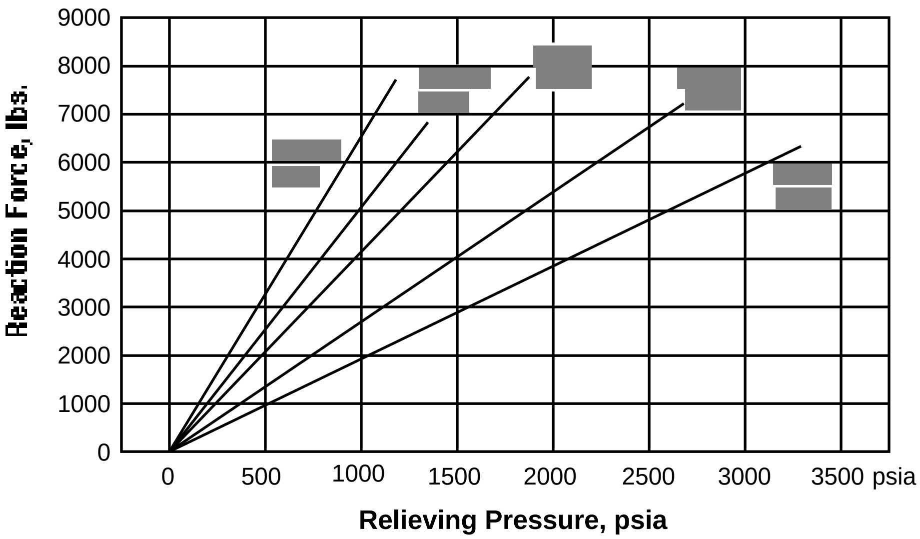
Determination of outlet reaction forces is the responsibility of the designer of the vessel and/or piping. Crosby publishes this information as technical advice or assistance and assumes no obligation or liability for the advice or assistance provided or the results obtained. All such advice or assistance is given and accepted at buyer's risk.

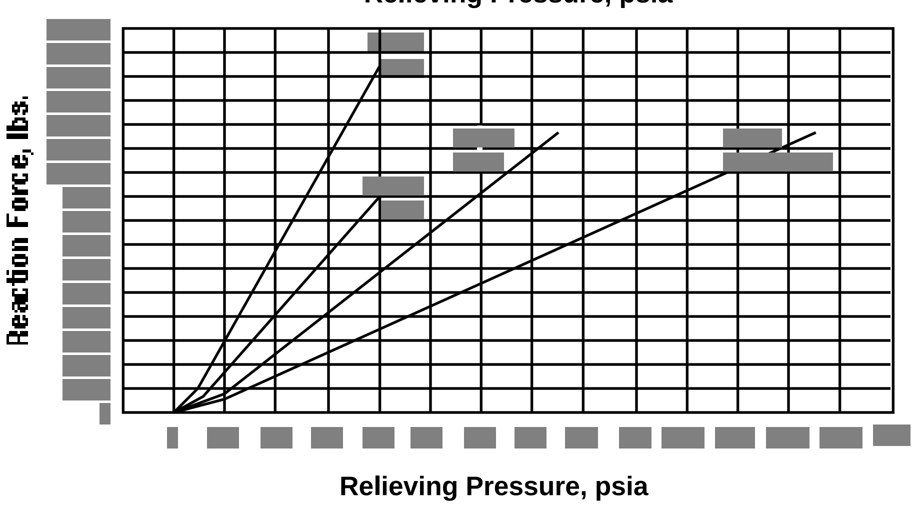
Reaction Forces

Styles JOS/JBS and JPV/JPVM

Figure F7-8
Gases and Vapors (k = 1.4)



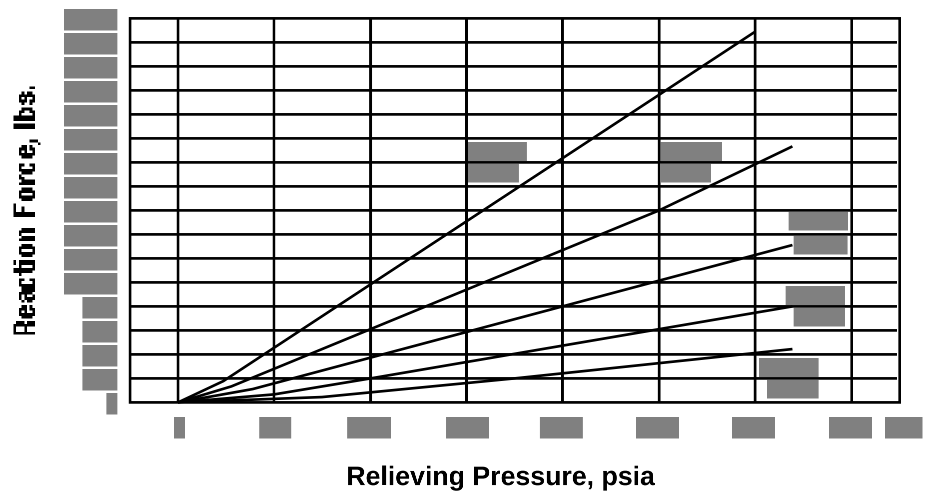


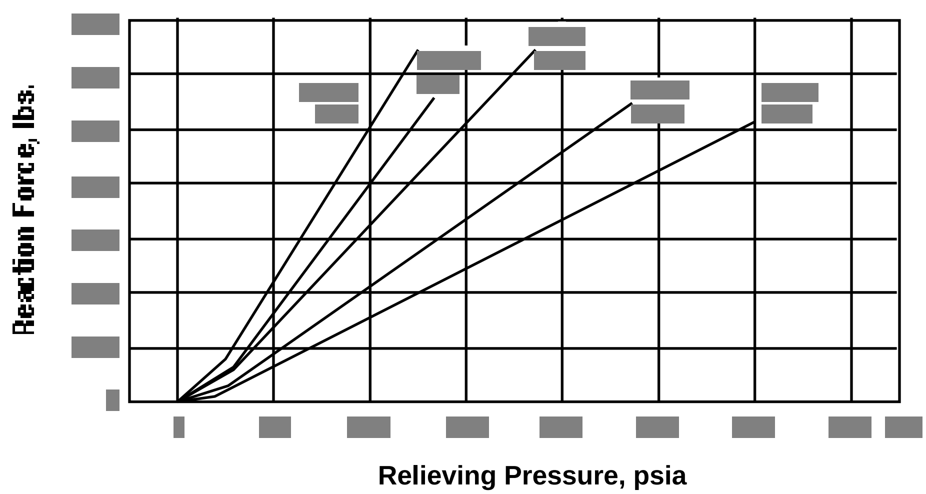


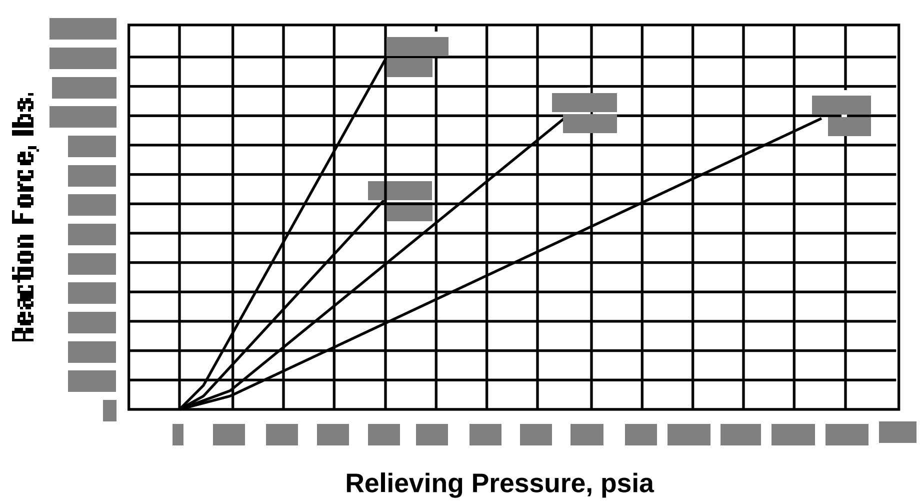
Reaction Forces

Styles JOS/JBS and JPV/JPVM

Figure F7-9
Steam







Reaction Forces

Series 800, 900 and Series BP

Figure F7-10
Gases and Vapors (k = 1.4)

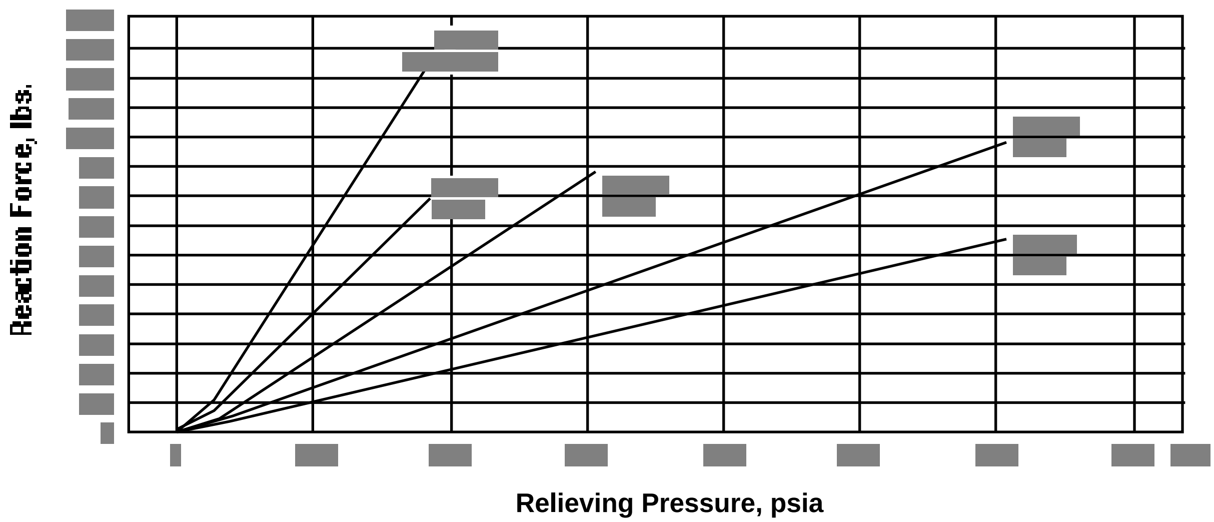
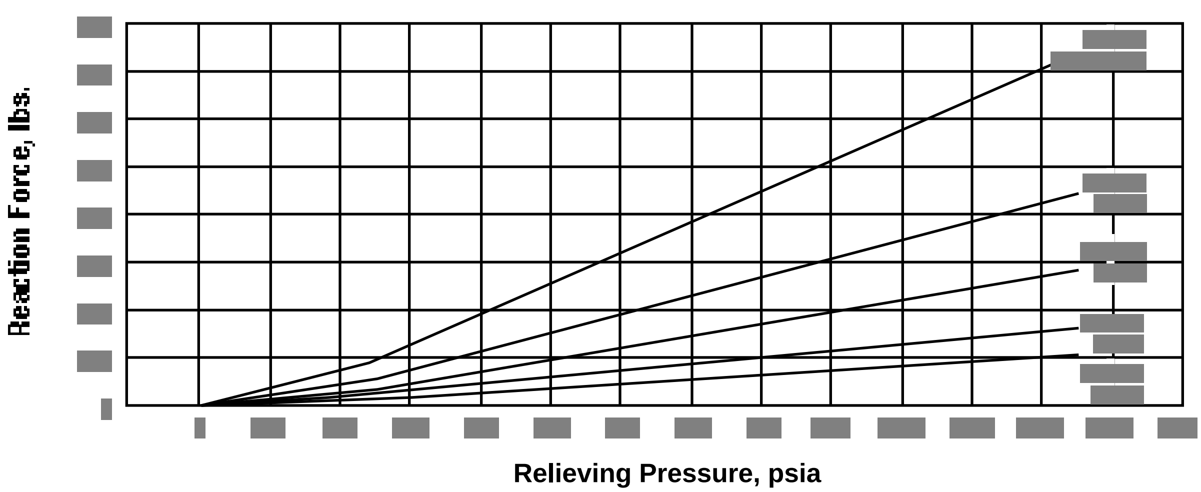


Figure F7-11
Steam



Fire Conditions
Sizing for Vaporizing Liquids
(Wetted Vessels)
U.S.C.S. Units

The following method may be used for calculating the required orifice area for pressure relief valves on vessels containing liquids that are exposed to fire. Reference API Recommended Practice 520.

Step 1. Determine the total wetted surface area.

Reference section on wetted area calculation beginning on page 7-19

Step 2. Determine the total heat absorption.

When prompt fire-fighting efforts and adequate drainage exist:

$$Q = 21{,}000\, F\, (A_{wet})^{0.82}$$

When prompt fire-fighting efforts and adequate drainage **do not** exist:

$$Q = 34{,}500\, F\, (A_{wet})^{0.82}$$

Where:

Q = Total heat absorption to the *wetted* surface, BTU per hour.
F = Environmental factor. Reference Table T7-6 on page 7-18.
A_{wet} = Total wetted surface area in square feet. Reference page 7-19.

Step 3. Determine the rate of vapor or gas vaporized from the liquid.

$$W = Q / H_{vap}$$

Where:

W = Mass flow, lbs/hr.
Q = Total heat absorption to the *wetted* surface, BTU per hour.
H_{vap} = Latent heat of vaporization, BTU/lb.

Step 4. Calculate the minimum required relieving area.

If the valve is used as a supplemental device for vessels which may be exposed to fire, an overpressure of 21% may be used. However, allowable overpressure may vary according to local regulations. Specific application requirements should be referenced for the allowable overpressure.

The minimum required relieving area can now be calculated using the equations on page 5-3 for gas and vapor relief valve sizing, lbs/hr.

Fire Conditions
Sizing for Vaporizing Liquids (Continued)
(Wetted Vessels)
U.S.C.S. Units

Table T7-6
Environmental Factor

Equipment Type	Factor F[1]
Bare Vessel	1.0
Insulated Vessel[2] (These arbitrary insulation conductance values are shown as examples and are in BTU's per hour per square foot per degree Fahrenheit):	
4	0.3
2	0.15
1	0.075
0.67	0.05
0.50	0.0376
0.40	0.03
0.33	0.026
Water application facilities, on bare vessels[3]	1.0
Depressurizing and emptying facilities[4]	1.0

Notes:

(1) These are suggested values assumed for the conditions in API Recommended Practice 520, Paragraph D.5.1. When these conditions do not exist, engineering judgement should be exercised either in selecting a higher factor or in means of protecting vessels from fire exposure in API Recommended Practice 520, Paragraph D.8.

(2) Insulation shall resist dislodgement by fire hose streams. Reference API Recommended Practice 520, Table D-3 for further explanation.

(3) Reference API Recommended Practice 520, Paragraph D.8.3.3.

(4) Reference API Recommended Practice 520, Paragraph D.8.2.

Fire Conditions
Sizing for Vaporizing Liquids (Continued)
(Wetted Vessels)
U.S.C.S. Units

Wetted Area Calculation

The following formulae are used to determine the wetted surface area of a vessel. They use the logic as stated in API Recommended Practice 520, Table D-2 Wetted Surface Area of a Vessel Based on Fire Heat Absorbed.

Wetted Surface Area A_{wet} in square feet:

Sphere:

$$A_{wet} = \pi \, (E_s)(D)$$

Horizontal Cylinder with flat ends:

$$A_{wet} = [\pi (D)(B) / 180] \, (L + \frac{D}{2}) - (\frac{D}{2} - E) \sin(B)$$

Horizontal Cylinder with spherical ends:

$$A_{wet} = \pi \, (D) \{ E + [(L - D)(B)] / 180 \}$$

Vertical Cylinder with flat ends:

If E < L then: $A_{wet} = \pi (D) \, (\frac{D}{4} + E)$

If E = L then: $A_{wet} = \pi (D) \, (\frac{D}{2} + E)$

Vertical Cylinder with spherical ends:

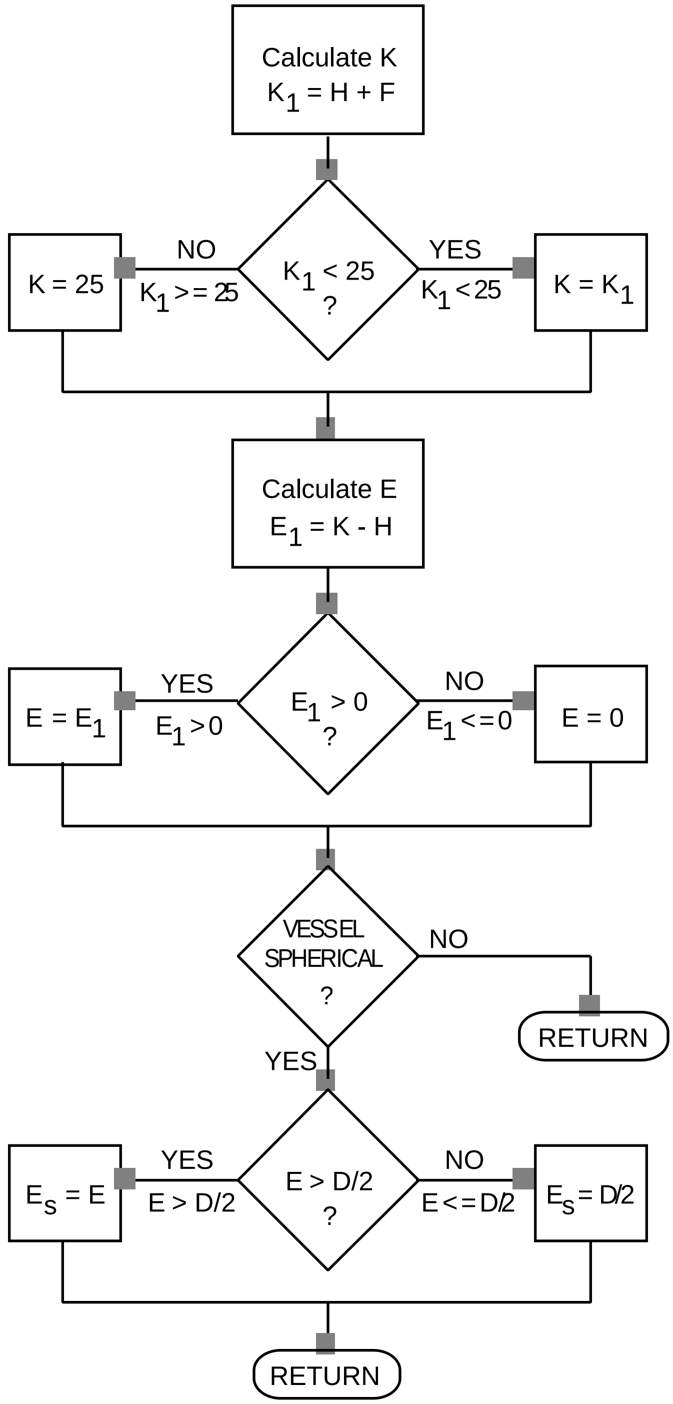
$$A_{wet} = \pi \, (E)(D)$$

Where:

A_{wet} = Wetted area, square feet.
E = Effective liquid level, feet, up to 25 feet from the flame source. Reference Figure F7-12 on page 7-20.
E_s = Effective spherical liquid level, feet, up to a maximum horizontal diameter or up to a height of 25 feet, whichever is greater. Reference Figure F7-12 on page 7-20.
D = Vessel diameter, feet. Reference Figure F7-13 on page 7-21.
B = Effective liquid level angle, degrees.
= $\cos^{-1} [1 - (2)(E) / (D)]$
L = Vessel end-to-end length, feet. Reference Figure F7-13 on page 7-21.

Fire Conditions
Sizing for Vaporizing Liquids (Continued)
(Wetted Vessels)
(U.S.C.S. Units)

Figure F7-12
Logic Diagram
Effective Liquid Level

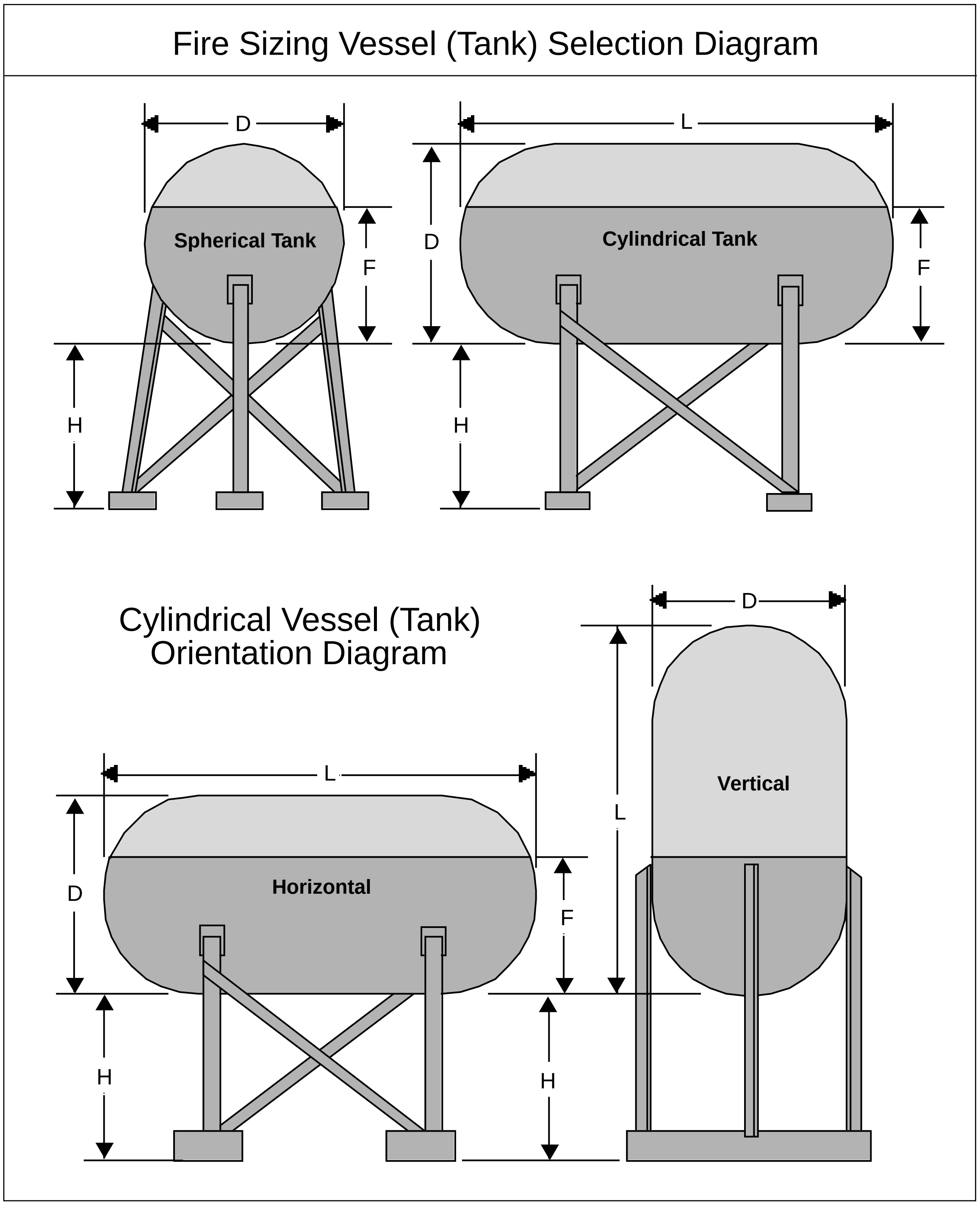


Where:

K	=	Effective total height of liquid surface, feet.
K_1	=	Total height of liquid surface, feet.
H	=	Vessel elevation, feet.
F	=	Liquid depth in vessel, feet.
E	=	Effective liquid level, feet.
E_1	=	Initial liquid level, feet.
E_s	=	Effective spherical liquid level, feet.

Fire Conditions
Sizing for Vaporizing Liquids (Continued)

Figure F7-13



Fire Conditions
Sizing for Vaporizing Liquids (Continued)
(Wetted Vessels)
U.S.C.S. Units

Example #1

This example is for the overpressure protection of a vessel, using a supplemental relief valve, where an additional hazard can be created by exposure of the pressure vessel to fire.

Fluid Data

Fluid:	Benzene
Required Capacity:	5000 lb/hr
Set Pressure:	200 psig
Back Pressure:	Atmospheric
Inlet Relieving Temperature:	100F
Molecular Weight:	78.11
Latent Heat:	172 BTU/lb

Vessel Data

Diameter: (D)	15 feet
Length: (L)	30 feet
Elevation: (H)	15 feet
Maximum Fluid Level (F):	147 inches (12.25 feet)
Type:	Cylindrical with spherical ends. Prompt fire-fighting efforts and adequate drainage exist.
Placement:	Horizontal
Insulation:	None

Step 1. Determine the total wetted surface area.

$$A_{wet} = \pi (D) \{ E + [(L - D) (B)] / 180 \}$$

Where:

D = 15 feet
H = 15 feet
F = 147 inches = 12.25 feet
E = From logic diagram Figure F7-12 on page 7-20.
$K_1 = (H + F) = (15 + 12.25) = 27.25$ feet
$K_1 > 25$; therefore $K = 25$
$E_1 = (K - H) = (25 - 15) = 10$ feet
$E_1 > 0$; therefore $E = E_1 = 10$ feet
L = 30 feet
B = $\cos^{-1} [1 - (2) (E) / (D)]$
$\cos^{-1} [1 - (2) (10) / (15)] = 109.5$ degrees

$$A_{wet} = \pi (15) \{ 10 + [(30 - 15) (109.5)] / 180 \}$$
$$A_{wet} = 901 \text{ square feet}$$

Fire Conditions
Sizing for Vaporizing Liquids (Continued)
(Wetted Vessels)
U.S.C.S. Units

Example #1 (continued)

Step 2. Determine the total heat absorption.

$$Q = 21{,}000\,F\,A_{wet}^{\,0.82}$$

Where:

F = 1.0 (Bare vessel. Reference Table T7-6 on page 7-18)
A_{wet} = 901 square feet

$$Q = 21{,}000\,(1.0)\,(901)^{0.82}$$
$$Q = 5{,}560{,}000 \text{ BTU per hour}$$

Step 3. Determine the fluid mass flow converted to gas from the liquid.

$$W = Q / H_{vap}$$

Where:

Q = 5,560,000 BTU per hour
H_{vap} = 172 BTU/lb

$$W = (5{,}560{,}000) / (172)$$
$$W = 32{,}330 \text{ lb/hr}$$

Step 4. Calculate the minimum required relieving area (see page 5-3).

$$A = \frac{W\sqrt{TZ}}{C\;K\;P_1\,K_b\sqrt{M}}$$

Where:

W = 32,330 lb/hr
T = (100°F + 460) = 560°R
Z = 1.0
P_1 = (200) (1.21) + 14.7 = 256.7 psia
21% overpressure allowed because "fire only"
C = 329 (Page 7-26)
K = 0.975
K_b = 1
M = 78.11 (Page 7-26)

$$A = \frac{32330\sqrt{(560)(1)}}{(329)(0.975)(256.7)(1)\sqrt{78.11}}$$

$$A = 1.051 \text{ sq.in.}$$

Fire Conditions
Sizing for Vessels Containing Gases and Vapors Only
(Unwetted Vessels)
U.S.C.S. Units

The following method may be used for calculating the required orifice area for pressure relief valves on vessels containing gases that are exposed to fire. Reference API Recommended Practice 520, Fifth Edition.

$$A = \frac{F'A'}{\sqrt{P_1}}$$

Where:

- A = Minimum required effective discharge area, square inches.
- A' = Exposed surface area of the vessel, square feet.
- P_1 = Relieving pressure, pounds per square inch, absolute (set pressure [psig] + overpressure [psi] + atmospheric pressure [psia]).

$$F' = \frac{0.1406}{C\,K} \frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}}$$

The recommended minimum value of F' is 0.01. When the minimum value is unknown, F' = 0.045 should be used.

- T_w = Vessel wall temperature, degrees Rankine. The API recommended maximum wall temperature is 1100F for carbon steel vessels only.
- T_1 = Gas temperature at the upstream pressure, degrees Rankine as determined by the following relationship.

$$T_1 = \frac{P_1 T_n}{P_n}$$

- T_n = Normal operating gas temperature, degrees Rankine.
- P_n = Normal operating gas pressure, pounds per square inch, absolute (normal operating gas pressure [psig] + atmospheric pressure [psia]).
- C = Coefficient from page 7-9 or 7-26.
- K = Effective coefficient of discharge.

EXAMPLE #1

This example is for the calculation of the required effective discharge area for an unwetted vessel.

Fluid:	Air
Set Pressure:	100 psig
Exposed Surface Area of the Vessel: (A')	200 square feet
Normal Operating Gas Temperature:	125F
Normal Operating Gas Pressure:	80 psig
Wall Temperature:	1100F

Step 1 - Determine the gas temperature at the upstream pressure.

$$T_1 = \frac{P_1 T_n}{P_n}$$

Where:

P_1 = (100 psig) (1.1) + 14.7 = 124.7 psia
T_n = 125F + 460 = 585R
P_n = 80 psig + 14.7 = 94.7 psia
T_1 = (124.7) (585) / 94.7
T_1 = 770.3R

Step 2 - Determine F'.

$$F' = \frac{0.1406}{C\,K} \frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}}$$

Where:

T_w = 1100F + 460 = 1560R
C = 356 (from Table T7-7 on page 7-26)
K = 0.975

$$F' = \frac{0.1406}{(356)(0.975)} \frac{(1560 - 770.3)^{1.25}}{770.3^{0.6506}}$$

F' = 0.022

Step 3 - Calculate the minimum required effective discharge area.

$$A = F' A' / \sqrt{P_1}$$

Where:

A' = 200 square feet
A = $(0.022)(200) / \sqrt{124.7}$
A = 0.402 sq. in.

A "G" orifice valve with an effective area of 0.503 would be required to relieve the flow caused by fire on this unwetted vessel.

Two-Phase and Flashing Flow

Two-phase flow describes a condition whereby a flow stream contains fluid in the liquid phase and in the gas or vapor phase. Flashing flow occurs when, as a result of a decrease in pressure, all or a portion of a liquid flow changes to vapor. It is possible for both flowing conditions, two-phase and flashing, to occur simultaneously within the same application.

This handbook provides techniques which may be used for calculating the required effective orifice area for a pressure relief valve application. These formulae, provided for liquid, gas, vapor and steam applications, however, may not be suitable for determining the required effective orifice area on two-phase and flashing flow applications.

Recent work by DIERS (Design Institute for Emergency Relief Systems) and others, regarding the calculation of pressure relief valve required orifice areas on flashing and two-phase flow, has demonstrated the complexity of this subject. What is apparent from this work is that no single universally accepted calculation method will handle all applications. Some methods give accurate results over certain ranges of fluid quality, temperature and pressure. Complex mixtures require special consideration. Inlet and outlet conditions must be considered in more detail than for single component, non-flashing applications. It is necessary, therefore, that those who are responsible for the selection of pressure relief valves for two-phase and flashing applications be knowledgeable and up-to-date on current two-phase flow technology, and knowledgeable of the total system on which the pressure relief valve will be used. A number of the DIERS techniques may be found in a publication entitled, "International Symposium on Runaway Reactions and Pressure Relief Design, Aug. 2-4, 1995" available from the American Institute of Chemical Engineers, 345 East 47th Street., NY, NY 10017.

The following guidelines should be considered when sizing for two-phase and flashing flow.

1. The increase in body bowl pressure due to flashing must be estimated and considered along with the expected built-up back pressure.

2. A back pressure balanced pressure relief valve such as a balanced bellows Crosby Style JBS or a pilot operated Crosby Style JPVM may be necessary when the increase in body bowl pressure, due to flashing flow conditions, is excessive or cannot be predicted with certainty.

3. If the mass of the two-phase mixture at the valve inlet is 50% liquid or more, a liquid service valve construction is recommended. If the vapor content of the two-phase mixture is greater than 50% (mass) then a valve designed for compressible fluid service is recommended.

Typical Properties of Gases

Table T7-7

Gas or Vapor	Molecular Weight M	Ratio of Specific Heats k (14.7 psia)	Coefficient C*	Specific Gravity	Critical Pressure psia	Critical Temp.(˚R) (˚F+460)
Acetylene	26.04	1.25	342	0.899	890	555
Air	28.97	1.40	356	1.000	547	240
Ammonia	17.03	1.30	347	0.588	1638	730
Argon	39.94	1.66	377	1.379	706	272
Benzene	78.11	1.12	329	2.696	700	1011
N-Butane	58.12	1.18	335	2.006	551	766
Iso-Butane	58.12	1.19	336	2.006	529	735
Carbon Dioxide	44.01	1.29	346	1.519	1072	548
Carbon Disulphide	76.13	1.21	338	2.628	1147	994
Carbon Monoxide	28.01	1.40	356	0.967	507	240
Chlorine	70.90	1.35	352	2.447	1118	751
Cyclohexane	84.16	1.08	325	2.905	591	997
Ethane	30.07	1.19	336	1.038	708	550
Ethyl Alcohol	46.07	1.13	330	1.590	926	925
Ethyl Chloride	64.52	1.19	336	2.227	766	829
Ethylene	28.03	1.24	341	0.968	731	509
Freon 11	137.37	1.14	331	4.742	654	848
Freon 12	120.92	1.14	331	4.174	612	694
Freon 22	86.48	1.18	335	2.985	737	665
Freon 114	170.93	1.09	326	5.900	495	754
Helium	4.02	1.66	377	0.139	33	10
N-Heptane	100.20	1.05	321	3.459	397	973
Hexane	86.17	1.06	322	2.974	437	914
Hydrochloric Acid	36.47	1.41	357	1.259	1198	584
Hydrogen	2.02	1.41	357	0.070	188	60
Hydrogen Chloride	36.47	1.41	357	1.259	1205	585
Hydrogen Sulphide	34.08	1.32	349	1.176	1306	672
Methane	16.04	1.31	348	0.554	673	344
Methyl Alcohol	32.04	1.20	337	1.106	1154	924
Methyl Butane	72.15	1.08	325	2.491	490	829
Methyl Chloride	50.49	1.20	337	1.743	968	749
Natural Gas (Typical)	19.00	1.27	344	0.656	671	375
Nitric Oxide	30.00	1.40	356	1.036	956	323
Nitrogen	28.02	1.40	356	0.967	493	227
Nitrous Oxide	44.02	1.31	348	1.520	1054	557
N-Octane	114.22	1.05	321	3.943	362	1025
Oxygen	32.00	1.40	356	1.105	737	279
N-Pentane	72.15	1.08	325	2.491	490	846
Iso-Pentane	72.15	1.08	325	2.491	490	829
Propane	44.09	1.13	330	1.522	617	666
Sulfur Dioxide	64.04	1.27	344	2.211	1141	775
Toluene	92.13	1.09	326	3.180	611	1069

*If "C" is not known then use C = 315
If the ratio of specific heats " k" is known, reference page 7-9 to calculate "C".

Water
Saturation Pressure/Temperature
(psia/kpaa/bara) / (˚F/˚C)

Table T7-8

Pressure			Temperature	
psia	kPaa	bara	deg F	deg C
14.7	101	1.01	212.0	100.0
15	103	1.03	213.3	100.7
20	138	1.38	228.0	108.9
25	172	1.72	240.1	115.6
30	207	2.07	250.3	121.3
35	241	2.41	259.3	126.3
40	276	2.76	267.3	130.7
45	310	3.10	274.4	134.7
50	345	3.45	281.0	138.3
55	379	3.79	287.1	141.7
60	414	4.14	292.7	144.8
65	448	4.48	298.0	147.8
70	483	4.83	302.9	150.5
75	517	5.17	307.6	153.1
80	552	5.52	312.0	155.6
85	586	5.86	316.3	157.9
90	621	6.21	320.3	160.2
95	655	6.55	324.1	162.3
100	690	6.90	327.8	165.3
105	724	7.24	331.4	166.3
110	758	7.58	334.8	168.2
115	793	7.93	338.1	170.1
120	827	8.27	341.3	171.8
125	862	8.62	344.4	173.6
130	896	8.96	347.3	175.2
135	931	9.31	350.2	176.8
140	965	9.65	353.0	178.3
145	1000	10.0	355.8	179.9
150	1034	10.3	358.4	181.3
160	1103	11.0	363.6	184.2
170	1172	11.7	368.4	186.9
180	1241	12.4	373.1	189.5
190	1310	13.1	377.5	191.9
200	1379	13.8	381.8	194.3
210	1448	14.5	385.9	196.6
220	1517	15.2	389.9	198.8

Pressure			Temperature	
psia	kPaa	bara	deg F	deg C
230	1586	15.9	393.7	200.9
240	1655	16.5	397.4	203.0
250	1724	17.2	401.0	205.0
260	1793	17.9	404.4	206.9
270	1862	18.6	407.8	208.8
280	1931	19.3	411.1	210.6
290	2000	20.0	414.3	212.4
300	2069	20.7	417.4	214.1
320	2206	22.1	423.3	217.4
340	2344	23.4	429.0	220.6
360	2482	24.8	434.9	223.8
380	2620	26.2	439.6	226.4
400	2758	27.6	444.6	229.2
420	2896	29.0	449.4	231.9
440	3034	30.3	454.0	23.4
460	3172	31.7	458.5	236.9
480	3310	33.1	462.8	239.3
500	3448	34.5	467.0	241.7
520	3585	35.9	471.1	243.9
540	3723	37.2	475.0	246.1
560	3861	38.6	478.8	248.2
580	3999	40.0	482.6	250.3
600	4137	41.4	486.2	252.3
620	4275	42.7	489.7	254.3
640	4413	44.1	493.2	256.2
660	4551	45.5	496.6	258.1
680	4689	46.9	499.9	259.9
700	4827	48.3	503.1	261.7
720	4964	49.6	506.2	263.4
740	5102	51.0	509.3	265.2
760	5240	52.4	512.3	266.8
780	5378	53.8	515.3	268.5
800	5516	55.2	518.2	270.1
820	5654	56.5	521.1	271.7
840	5792	57.9	523.9	273.3
860	5930	59.3	526.6	274.8

Pressure			Temperature	
psia	kPaa	bara	deg F	deg C
880	6068	60.7	529.3	276.3
900	6206	62.1	532.0	277.8
920	6343	63.4	534.6	279.2
940	6481	64.8	537.1	280.6
960	6619	66.2	539.7	282.1
980	6757	67.6	542.1	283.4
1000	6895	69.0	544.6	284.8
1050	7240	72.4	550.5	288.1
1100	7585	75.8	556.3	291.3
1150	7929	79.3	561.8	294.3
1200	8274	82.7	567.2	297.3
1250	8619	86.2	572.4	300.2
1300	8964	89.6	577.4	303.0
1350	9308	93.1	582.3	305.7
1400	9653	96.5	587.1	308.4
1450	9998	100.0	591.7	310.9
1500	10343	103.4	596.2	313.4
1600	11032	110.3	604.9	318.3
1700	11721	117.2	613.1	322.8
1800	12411	124.1	621.0	327.2
1900	13101	131.0	628.6	331.4
2000	13790	137.9	635.8	335.4
2100	14479	144.8	642.8	339.3
2200	15169	151.7	649.6	343.1
2300	15859	158.6	655.9	346.6
2400	16548	165.5	662.1	350.1
2500	17238	172.4	668.1	353.4
2600	17927	179.3	673.9	356.6
2700	18617	186.2	679.5	359.7
2800	19306	193.1	685.0	362.8
2900	19996	200.0	690.2	365.7
3000	20685	206.9	695.3	368.5
3100	21375	213.7	700.3	371.3
3200	22064	220.6	705.1	373.9
3208	22119	221.2	705.5	374.2

ANSI Flange Dimensions

Table T7-9

ANSI Class 150

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	3.50	3.88	4.25	5.00	6.00	7.00	7.50	9.00	11.00	13.50	16.00
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness, min.	0.44	0.50	0.56	0.69	0.75	0.88	0.94	0.94	1.00	1.12	1.19
Bolt circle diameter	2.38	2.75	3.12	3.88	4.75	5.50	6.00	7.50	9.50	11.75	14.25
Number of bolts	4	4	4	4	4	4	4	8	8	8	12
Bolt hole diameter	0.62	0.62	0.62	0.62	0.75	0.75	0.75	0.75	0.88	0.88	1.00

ANSI Class 300

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	3.75	4.62	4.88	6.12	6.50	7.50	8.25	10.00	12.50	15.00	17.50
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness, min.	0.56	0.62	0.69	0.81	0.88	1.00	1.12	1.25	1.44	1.62	1.88
Bolt circle diameter	2.62	3.25	3.50	4.50	5.00	5.88	6.62	7.88	10.62	13.00	15.25
Number of bolts	4	4	4	4	8	8	8	8	12	12	16
Bolt hole diameter	0.62	0.75	0.75	0.88	0.75	0.88	0.88	0.88	0.88	1.00	1.12

ANSI Class 600

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	3.75	4.62	4.88	6.12	6.50	7.50	8.25	10.75	14.00	16.50	20.00
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness, min.	0.56	0.62	0.69	0.88	1.00	1.12	1.25	1.50	1.88	2.19	2.50
Bolt circle diameter	2.62	3.25	3.50	4.50	5.00	5.88	6.62	8.50	11.50	13.75	17.00
Number of bolts	4	4	4	4	8	8	8	8	12	12	16
Bolt hole diameter	0.62	0.75	0.75	0.88	0.75	0.88	0.88	1.00	1.12	1.25	1.38

ANSI Class 900

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	4.75	5.12	5.88	7.00	8.50	9.62	9.50	11.50	15.00	18.50	21.50
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness, min.	0.88	1.00	1.12	1.25	1.50	1.62	1.50	1.75	2.19	2.50	2.75
Bolt circle diameter	3.25	3.50	4.00	4.88	6.50	7.50	7.50	9.25	12.50	15.50	18.50
Number of bolts	4	4	4	4	8	8	8	8	12	12	16
Bolt hole diameter	0.88	0.88	1.00	1.12	1.00	1.12	1.00	1.25	1.25	1.50	1.50

ANSI Class 1500

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	4.75	5.12	5.88	7.00	8.50	9.62	10.50	12.25	15.50	19.00	23.00
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness,min.	0.88	1.00	1.12	1.25	1.50	1.62	1.88	2.12	3.25	3.62	4.25
Bolt circle diameter	3.25	3.50	4.00	4.88	6.50	7.50	8.00	9.50	12.50	15.50	19.00
Number of bolts	4	4	4	4	8	8	8	8	12	12	12
Bolt hole diameter	0.88	0.88	1.00	1.12	1.00	1.12	1.25	1.38	1.50	1.75	2.00

ANSI Class 2500

Nominal Pipe Size	1/2	3/4	1	1-1/2	2	2-1/2	3	4	6	8	10
Flange diameter	5.25	5.50	6.25	8.00	9.25	10.50	12.00	14.00	19.00	21.75	26.50
Raised face diameter	1.38	1.69	2.00	2.88	3.62	4.12	5.00	6.19	8.50	10.62	12.75
Flange thickness,min.	1.19	1.25	1.38	1.75	2.00	2.25	2.62	3.00	4.25	5.00	6.50
Bolt circle diameter	3.50	3.75	4.25	5.75	6.75	7.75	9.00	10.75	14.50	17.25	21.25
Number of bolts	4	4	4	4	8	8	8	8	8	12	12
Bolt hole diameter	0.88	0.88	1.00	1.25	1.12	1.25	1.38	1.62	2.12	2.12	2.62

Equivalents and Conversion Factors

Table T7-10

This table may be used in two ways:
(1) *Multiply* the unit under column A by the figure under column B, the result is the unit under column C.
(2) *Divide* the unit under column C by the figure under column B, the result is then the unit under column A.

A MULTIPLY	B BY	C TO OBTAIN
Atmospheres	14.70	Pounds per square inch
Atmospheres	1.033	Kilograms per sq. cm
Atmospheres	29.92	Inches of mercury
Atmospheres	760.0	Millimeters of mercury
Atmospheres	407.5	Inches of water
Atmospheres	33.96	Feet of water
Atmospheres	1.013	Bars
Atmospheres	101.3	KiloPascals
Barrels	42.00	Gallons (U.S.)
Bars	14.50	Pounds per square inch
Bars	1.020	Kilograms per sq. cm
Bars	100.0	KiloPascals
Centimeters	0.3937	Inches
Centimeters	0.03281	Feet
Centimeters	0.010	Meters
Centimeters	0.01094	Yards
Cubic centimeters	0.06102	Cubic inches
Cubic feet	7.481	Gallons
Cubic feet	0.1781	Barrels
Cubic feet per minute	0.02832	Cubic meters per minute
Cubic feet per second	448.8	Gallons per minute
Cubic inches	16.39	Cubic centimeters
Cubic inches	0.004329	Gallons
Cubic meters	264.2	Gallons
Cubic meters per hour	4.403	Gallons per minute
Cubic meters per minute	35.31	Cubic feet per minute
Standard cubic feet per min.	60.00	Standard cubic ft. per hr
Standard cubic feet per min.	1440.	Standard cubic ft. per day
Standard cubic feet per min.	0.02716	Nm^3/min. (0°C, 1 Bara)
Standard cubic feet per min.	1.630	Nm^3/hr. (0°C, 1 Bara)
Standard cubic feet per min.	39.11	Nm^3/day (0°C, 1 Bara)
Standard cubic feet per min.	0.02832	Sm^3/min.
Standard cubic feet per min.	1.699	Sm^3/hr.
Standard cubic feet per min.	40.78	Sm^3/day
Feet	0.3048	Meters
Feet	0.3333	Yards
Feet	30.48	Centimeters
Feet of water (68°F)	0.8812	Inches of mercury (0°C)
Feet of water (68°F)	0.4328	Pounds per square inch
Gallons(U.S.)	3785.	Cubic centimeters
Gallons(U.S.)	0.1337	Cubic feet
Gallons(U.S.)	231.0	Cubic inches
Gallons(Imperial)	277.4	Cubic inches
Gallons(U.S.)	0.8327	Gallons (Imperial)
Gallons(U.S.)	3.785	Liters
Gallons of water (60°F)	8.337	Pounds
Gallons of liquid per minute	500 x Sp. Gr.	Pounds per hour liquid
Gallons per minute	0.002228	Cubic feet per second
Gallons per minute (60°F)	227.0 x SG	Kilograms per hour
Gallons per minute	.06309	Liters per second
Gallons per minute	3.785	Liters per minute
Gallons per minute	.2271	M^3/hr.
Grams	.03527	Ounces
Inches	2.540	Centimeters
Inches	0.08333	Feet
Inches	0.0254	Meters
Inches	0.02778	Yards
Inches of mercury (0°C)	1.135	Feet of water (68°F)
Inches of mercury (0°C)	0.4912	Pounds per square inch
Inches of mercury (0°C)	0.03342	Atmospheres
Inches of mercury (0°C)	0.03453	Kilograms per sq. cm
Inches of water (68°F)	0.03607	Pounds per sq. in.
Inches of water (68°F)	0.07343	Inches of mercury (0°C)
Kilograms	2.205	Pounds
Kilograms	0.001102	Short tons (2000 lbs.)
Kilograms	35.27	Ounces
Kilograms per minute	132.3	Pounds per hour
Kilograms per sq. cm	14.22	Pounds per sq. in.
Kilograms per sq. cm	0.9678	Atmospheres
Kilograms per sq. cm	28.96	Inches of mercury
Kilograms per cubic meter	0.0624	Pounds per cubic foot
KiloPascals	0.1450	Pounds per sq. in.
KiloPascals	0.0100	Bars
KiloPascals	0.01020	Kilograms per sq. cm
Liters	0.03531	Cubic feet
Liters	1000.	Cubic centimeters
Liters	0.2642	Gallons
Liters per hour	0.004403	Gallons per minute
Meters	3.281	Feet
Meters	1.094	Yards
Meters	100.0	Centimeters
Meters	39.37	Inches
Pounds	0.1199	Gallons H_2O @ 60F (U.S.)
Pounds	453.6	Grams
Pounds	0.0005	Short tons (2000 lbs.)
Pounds	0.4536	Kilograms
Pounds	0.0004536	Metric tons
Pounds	16.00	Ounces
Pounds per hour	6.324/M.W.	SCFM
Pounds per hour	.4536	Kilograms per hour
Pounds per hour liquid	0.002/Sp.Gr.	Gallons per minute liquid (at 60F)
Pounds per sq. inch	27.73	Inches of water (68°F)
Pounds per sq. inch	2.311	Feet of water (68°F)
Pounds per sq. inch	2.036	Inches of mercury (0°C)
Pounds per sq. inch	0.07031	Kilograms per sq. cm
Pounds per sq. inch	0.0680	Atmospheres
Pounds per sq. inch	51.71	Millimeters of mercury (0°C)
Pounds per sq. inch	0.7043	Meters of water (68°F)
Pounds per sq. inch	0.06895	Bar
Pounds per sq. inch	6.895	KiloPascals
Specific gravity (of gas or vapors)	28.97	Molecular weight (of gas or vapors)
Square centimeter	0.1550	Square inch
Square inch	6.4516	Square centimeter
Square inch	645.16	Square millimeter
SSU	0.2205 x SG	Centipoise
SSU	0.2162	Centistoke
Water (cubic feet @ 60F)	62.37	Pounds

Temperature:

Centigrade	=	5/9 (Fahrenheit - 32)
Kelvin	=	Centigrade + 273
Fahrenheit	=	9/5 (Centigrade)+32
Fahrenheit	=	Rankine -460
Fahrenheit	=	(9/5 Kelvin) -460

Crosby Spring Loaded Pressure Relief Valve Orifice Areas

Table T7-11

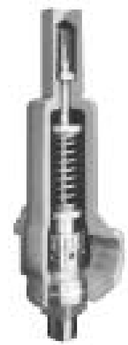

Style JOS

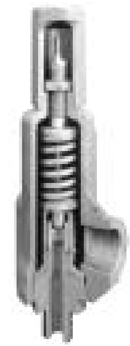

Style JBS

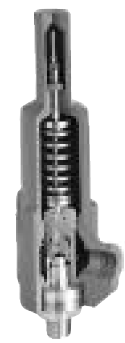

Style JOS-H (with open bonnet)


Style JO


Style JB


Series 800


Series 900 OMNI-TRIM


Series BP

***Indicates available orifices**

Orifice Designation and Effective Area Sq. In. (Sq. mm)	Series BP Fixed Blowdown Balanced Pressure Relief Valve Gas, Vapor, Liquid 3/4" x 1", 1" x 1"	Style JOS,/JBS Closed Bonnet Pressure Relief Valve Gas, Vapor, Steam 1 D 2 to 8 T_2 10	Style JLT-JOS/JBS Closed Bonnet Pressure Relief Valve Liquid 1 D 1 to 8 T_2 10	Style JOS-H Open Bonnet Pressure Relief Valve Steam 1 D 2 to 8 T_2 10	Style JO/JB Closed Bonnet Pressure Relief Valve Gas,Vapor,Steam 10 V 14 to 20 BB_2 24	Series 800 Adjustable Blowdown Pressure Relief Valve Gas,Vapor,Steam 3/4" x 1" to 1-1/2" x 2-1/2"	Series 900 OMNI-TRIM® Fixed Blowdown Pressure Relief Valve Gas,Vapor,Steam, Liquid 1/2" x 1" to 1-1/2" x 2-1/2"
- 0.074 (47.7)	*						*
D 0.110 (71.0)	*	*	*	*		*	*
E 0.196 (126)		*	*	*		*	*
F 0.307 (198)		*	*	*		*	*
G 0.503 (325)		*	*	*		*	*
H 0.785 (506)		*	*	*			
J 1.287 (830)		*	*	*			
K 1.838 (1186)		*	*	*			
L 2.853 (1841)		*	*	*			
M 3.600 (2323)		*	*	*			
N 4.340 (2800)		*	*	*			
P 6.379 (4116)		*	*	*			
Q 11.05 (7129)		*	*	*			
R 16.00 (10323)		*	*	*			
T 26.00 (16774)		*	*	*			
T_2 27.87 (17982)		*	*	*			
V 42.19 (27219)					*		
W 60.75 (39193)					*		
Y 82.68 (53342)					*		
Z 90.95 (58677)					*		
Z_2 108.86 (70232)					*		
AA 136.69 (88187)					*		
BB 168.74 (108864)					*		
BB_2 185.00 (119355)					*		
Crosby Catalog No.		310	310	310	307	902	902

Crosby Pilot Operated Pressure Relief Valve Orifice Areas
Table T7-12

Style JPV/JPF

Style JPVM/JPFM

Style JPVM-D/JPFM-D

***Indicates available orifices**

Orifice Designation and Effective Area Sq.In (Sq.mm)			Style JPV Pilot Operated Pressure Relief Valve Gas, Vapor 1 D 2 to 8 T 10	Style JPVM/JPVM-T Pilot Operated Pressure Relief Valve Gas, Vapor, Steam, Liquid 1 D 2 to 8 T 10	Style JPF/JPF-D Pilot Operated Pressure Relief Valve Full Bore Single or Dual Outlet Gas, Vapor 2" x 3" to 8" x 10"	Style JPFM/JPFM-D Pilot Operated Pressure Relief Valve Full Bore Single or Dual Outlet Gas, Vapor 2" x 3" to 8" x 10"
D	0.110	(71.0)	*	*		
E	0.196	(126)	*	*		
F	0.307	(198)	*	*		
G	0.503	(325)	*	*		
H	0.785	(506)	*	*		
J	1.287	(830)	*	*		
K	1.838	(1186)	*	*		
-	2.461	(1588)			*	*
L	2.853	(1841)	*	*		
M	3.600	(2323)	*	*		
N	4.340	(2800)	*	*		
-	5.546	(3578)			*	*
P	6.379	(4116)	*	*		
-	9.866	(6365)			*	*
Q	11.05	(7129)	*	*		
R	16.00	(10323)	*	*		
-	22.22	(14335)			*	*
T	26.00	(16774)	*	*		
-	39.51	(25490)			*	*
Crosby Catalog No.			318	318	318	318

ASME Section VIII Division 1, 1992 Edition Pressure Relief Devices

HOME

The paragraphs that immediately follow are excerpts from ASME Section VIII, Division 1, 1992 Edition through 1994 Addenda dated December 31, 1994. They are presented to provide the user of this handbook with insight into ASME Code requirements for pressure relief devices. The ASME Code is revised on an annual basis and reissued every three years. Crosby recommends that the proper edition and revision be applied whenever the Code is used.

UG-125 GENERAL

(a) All pressure vessels within the Scope of this Division, irrespective of size or pressure, shall be provided with protective devices in accordance with the requirements of UG-125 through UG-136. It is the responsibility of the user to ensure that the required pressure relief devices are properly installed prior to initial operation. These pressure relief devices need not be supplied by the vessel Manufacturer. Unless otherwise defined in this Division, the definitions relating to pressure relief devices in Appendix I of ASME/ANSI PTC 25.3 Safety and Relief Valves shall apply.

(b) An unfired steam boiler, as defined in U-1(g), shall be equipped with pressure relief devices required by Section I insofar as they are applicable to the service of the particular installation.

(c) All pressure vessels other than unfired steam boilers shall be protected by a pressure relieving device that shall prevent the pressure from rising more than 10% or 3 psi, whichever is greater, above the maximum allowable working pressure except as permitted in (1) and (2) below. (See UG-134 for pressure settings)

(1) When multiple pressure relieving devices are provided and set in accordance with UG-134(a), they shall prevent the pressure from rising more than 16% or 4 psi, whichever is greater, above the maximum allowable working pressure.

(2) Where an additional hazard can be created by exposure of a pressure vessel to fire or other unexpected sources of external heat, supplemental pressure relieving devices shall be installed to protect against excessive pressure. Such supplemental pressure relieving devices shall be capable of preventing the pressure from rising more than 21% above the maximum allowable working pressure. The same pressure relieving devices may be used to satisfy the capacity requirements of (c) or (c)(1) above and this paragraph provided the pressure setting requirements of UG-134(a) are met.

(3) Pressure relief devices, intended primarily for protection against exposure of a pressure vessel to fire or other unexpected sources of external heat installed on vessels having no permanent supply connection and used for storage at ambient temperatures of nonrefrigerated liquefied compressed gases,[40] are excluded from the requirements of (c)(1) and (c)(2) above, provided:

(a) the relief devices are capable of preventing the pressure from rising more than 20% above the maximum allowable working pressure of the vessels;

(b) the set pressure of these devices shall not exceed the maximum allowable working pressure of the vessels;

(c) the vessels have sufficient ullage to avoid a liquid full condition;

(d) the maximum allowable working pressure of the vessels on which these devices are installed is greater than the vapor pressure of the stored liquefied compressed gas at the maximum anticipated temperature[41] that the gas will reach under atmospheric conditions; and

(e) pressure relief valves used to satisfy these provisions also comply with the requirements of UG-129(a)(5), UG-131(c)2, and UG-134(d)(2).

(d) Pressure relieving devices shall be constructed, located, and installed so that they are readily accessible for inspection and repair and so that they cannot be readily rendered inoperative (see Appendix M), and should be selected on the basis of their intended service.

(e) Pressure relief valves or nonreclosing pressure relief devices[42] may be used as protective devices.

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[40] For the purpose of these rules, gases are considered to be substances having a vapor pressure greater than 40 psia at 100°F.

[41] Normally this temperature should not be less than 115°F.

[42] 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. A *nonreclosing pressure* relief device is a pressure relief device designed to remain open after operation.

Nonreclosing pressure relief devices may be used either alone or, if applicable, in combination with safety or safety relief valves on vessels.

NOTE: Use of nonreclosing devices of some types may be advisable on vessels containing substances that may render a safety or safety relief valve inoperative, where a loss of valuable material by leakage should be avoided, or where contamination of the atmosphere by leakage of noxious fluids must be avoided. The use of rupture disk devices may also be advisable when very rapid rates of pressure rise may be encountered.

(f) Vessels that are to operate completely filled with liquid shall be equipped with pressure relief devices designed for liquid service, unless otherwise protected against overpressure.

(g) The protective devices required in (a) above need not be installed directly on a pressure vessel when the source of pressure is external to the vessel and is under such positive control that the pressure in the vessel cannot exceed the maximum allowable working pressure at the operating temperature except as permitted in (c) above (see UG-98).

NOTE: Pressure reducing valves and similar mechanical or electrical control instruments, except for pilot operated valves as permitted in UG-126(b), are not considered as sufficiently positive in action to prevent excess pressures from being developed.

(h) Safety and safety relief valves for steam service shall meet the requirements of UG-131(b).

UG-126 PRESSURE RELIEF VALVES[43]

(a) Safety, safety relief, and relief valves shall be of the direct spring loaded type.

(b) Pilot operated pressure relief valves may be used, provided that the pilot is self-actuated and the main valve will open automatically at not over the set pressure and will discharge its full rated capacity if some essential part of the pilot should fail.

(c) The spring in a safety valve or safety relief valve shall not be set for any pressure more than 5% above or below that for which the valve is marked, unless the setting is within the spring design range established by the valve manufacturer or is determined to be acceptable to the manufacturer. The initial adjustment shall be performed by the manufacturer, his authorized representative, or an assembler, and a valve data tag shall be provided that identifies the 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.

(d) The set pressure tolerances, plus or minus, of pressure relief valves shall not exceed 2 psi for pressures up to and including 70 psi and 3% for pressures above 70 psi.

UG-127 NONRECLOSING PRESSURE RELIEF DEVICES

(a) Rupture Disk Devices[44]

(1) General

(a) Every rupture disk shall have a stamped burst pressure established by rules of (a)(1)(b) below within a manufacturing design range[45] at a specified disk temperature[46] and shall be marked with a lot number. The burst pressure tolerance at the specified disk temperature shall not exceed $\pm$ 2 psi for stamped burst pressure up to and including 40 psi and $\pm$ 5% for stamped burst pressure above 40 psi.

(b) The stamped bursting pressure within the manufacturing design range at the coincident disk temperature shall be derived by one of the following methods. All the tests of disks for a given lot shall be made in a holder of the same form and dimensions as that with which the disk is to be used.

(1) At least two sample rupture disks from each lot of rupture disks, made from the same materials and of the same size as those to be used, shall be burst to verify that the stamped bursting pressure falls within the manufacturing design range at the coincident disk temperature. At least one disk shall be burst at room temperature. The stamped rating at the specified disk temperature shall be the average of the bursts at coincident disk temperature.

(2) At least four sample rupture disks, but not less than 5%, from each lot of rupture disks, made from the same material and of the same size as those to be used, shall be burst at four different temperatures, distributed over the applicable temperature range for which the disks will be used. These data shall be used to establish a curve of bursting pressure versus temperature for the lot of disks. The stamped rating at the coincident disk temperature shall be interpolated from this curve.

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[43] A *safety valve* is a pressure relief valve actuated by inlet static pressure and characterized by rapid opening or pop action. A *relief valve* is a pressure relief valve actuated by inlet static pressure which opens in proportion to the increase in pressure over the opening pressure. 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 application. 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.

[44] 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* is the pressure containing and pressure sensitive element of a rupture disk device. A *rupture disk holder* is the structure which encloses and clamps the rupture disk in position. Rupture disks may be designed in several configurations, such as plain flat, prebulged or reverse buckling, and may be made of either ductile or brittle material; rupture disk material is not required to conform to an ASME specification. The material of the rupture disk holder shall be listed in Section II and be permitted for use in this Division.

[45] The *manufacturing design range* is a range of pressure within which the average burst pressure of test disks must fall to be acceptable for a particular requirement as agreed upon between the rupture disk Manufacturer and the user or his agent. The disk shall be marked at the average burst pressure of all test disks.

[46] The specified disk temperature supplied to the rupture disk Manufacturer shall be the temperature of the disk when the disk is expected to burst.

(3) For prebulged, solid metal disks or graphite disks only, a curve of percentage ratio at temperatures other than ambient may be established as in (2) above, using one size of disk for each lot of material. At least four bursts at four different temperatures shall be used to establish the above curve over the applicable temperature range. At least two disks from each lot of disks, made from this lot of material and of the same size as those to be used, shall be burst at ambient temperature to establish the room temperature rating of the lot of disks.

The percent change of bursting pressure taken from the above curve shall be used to establish the stamped rating at the coincident disk temperature for the lot of disks.

(2) Capacity Rating

(a) The calculated capacity rating of a rupture disk device shall not exceed a value based on the applicable theoretical formula (see UG-131) for the various media multipled by K = coefficient = 0.62. The area A (square inches) in the theoretical formula shall be the minimum net area existing after disk burst.[47]

(b) In lieu of the method of capacity rating in (a) above, a Manufacturer may have the capacity of a given rupture disk device design determined for the K_D coefficient in general accordance with the procedures of UG-131, as applicable.

(3) Application of Rupture Disks

(a) A rupture disk device may be used as the sole pressure relieving device on a vessel.

NOTE: When rupture disk devices are used, it is recommended that the design pressure of the vessel be sufficiently above the intended operating pressure to provide sufficient margin between operating pressure and rupture disk bursting pressure to prevent premature failure of the rupture disk due to fatigue or creep.

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.

(b) A rupture disk device may be installed between a pressure relief valve[48] and the vessel provided:

(1) the combination of the spring loaded safety or safety relief valve and the rupture disk device is ample in capacity to meet the requirements of UG-133(a) and (b);

(2) the stamped capacity of a spring loaded safety or safety relief valve (nozzle type) when installed with a rupture disk device between the inlet of the valve and the vessel shall be multiplied by a factor of 0.90 of the rated relieving capacity of the valve alone, or alternatively, the capacity of such a combination shall be established in accordance with (3) below;

(3) the capacity of the combination of the rupture disk device and the spring loaded safety or safety relief valve may be established in accordance with the appropriate paragraphs of UG-132, Certification of Capacity of Safety and Safety Relief Valves in Combination with Nonreclosing Pressure Relief Devices;

(4) the space between a rupture disk device and a safety or safety relief valve shall be provided with a pressure gage, a try cock, free vent, or suitable telltale indicator. This arrangement permits detection of disk rupture or leakage.[49]

(5) the opening[47] provided through the rupture disk, after burst, is sufficient to permit a flow equal to the capacity of the valve [(2) and (3) above], and there is no chance of interference with proper functioning of the valve; but in no case shall this area be less than the area of the inlet of the valve unless the capacity and functioning of the specific combination of rupture disk and valve have been established by test in accordance with UG-132.

(c) A rupture disk device may be installed on the outlet side[50] of a spring loaded safety relief valve which is opened by direct action of the pressure in the vessel provided:

(1) the valve is so designed that it will not fail to open at its proper pressure setting regardless of any back pressure that can accumulate between the valve disk and the rupture disk. The space between the valve disk and the rupture disk shall be vented or drained to prevent accumulation of pressure due to a small amount of leakage from the valve.[51]

(2) the valve is ample in capacity to meet the requirements of UG-133(a) and (b);

(3) the stamped bursting pressure of the rupture disk at the coincident disk temperature plus any pressure in the outlet piping shall not exceed the design pressure of the outlet portion of the safety or safety relief valve and any pipe or fitting between the valve and the rupture disk device. However, in no case shall the stamped bursting pressure of the rupture disk at the coincident operating temperature plus any pressure in the outlet piping exceed the maximum allowable working pressure of the vessel or the set pressure of the safety or safety relief valve.

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[47] The *minimum net flow area* is the calculated net area after a complete burst of the disk with appropriate allowance for any structual members which may reduce the net flow area through the rupture disk device. The net flow area for sizing purposes shall not exceed the nominal pipe size area of the rupture disk device.

[48] Use of a rupture disk device in combination with a safety or safety relief valve shall be carefully evaluated to ensure that the media being handled and the valve operational characteristics will result in pop action of the valve coincident with the bursting of the rupture disk.

[49] Users are warned that a rupture disk will not burst at its design pressure if back pressure builds up in the space between the disk and the safety or safety relief valve which will occur should leakage develop in the rupture disk due to corrosion or other cause.

[50] This use of a rupture disk device in series with the safety or safety relief valve is permitted to minimize the loss by leakage through the valve of valuable or of noxious or otherwise hazardous materials, and where a rupture disk alone or disk located on the inlet side of the valve is impracticable, or to prevent corrosive gases from a common discharge line from reaching the valve internals.

[51] Users are warned that an ordinary spring loaded safety relief valve will not open at its set pressure if back pressure builds up in the space between the valve and rupture disk. A specially designed valve is required, such as a diaphragm valve or a valve equipped with a bellows above the disk.

(4) the opening provided through the rupture disk device after breakage is sufficient to permit a flow equal to the rated capacity of the attached safety or safety relief valve without exceeding the allowable overpressure;

(5) any piping beyond the rupture disk cannot be obstructed by the rupture disk or fragment;

(6) the contents of the vessel are clean fluids, free from gumming or clogging matter, so that accumulation in the space between the valve inlet and the rupture disk (or in any other outlet that may be provided) will not clog the outlet;

(7) the bonnet of the safety relief valve shall be vented to prevent accumulation of pressure.

(b) Breaking Pin Device[52]

(1) Breaking pin devices shall not be used as single devices but only in combination between the safety or safety relief valve and the vessel.

(2) The space between a breaking pin device and a safety or safety relief valve shall be provided with a pressure gage, a try cock, a free vent, or suitable telltale indicator. This arrangement permits detection of breaking pin device operation or leakage.

(3) Each breaking pin device shall have a rated pressure and temperature at which the pin will break. The breaking pin shall be identified to a lot number and shall be guaranteed by the Manufacturer to break when the rated pressure, within the following tolerances, is applied to the device:

Rated Pressure, psi		
Minimum	Maximum	Tolerance, Plus or Minus, psi
30	150	5
151	272	10
276	375	15

(4) The rated pressure of the breaking pin plus the tolerance in psi shall not exceed 105% of the maximum allowable working pressure of the vessel to which it is applied.

(5) The rated pressure at the coincident operating temperature[53] shall be verified by breaking two or more sample breaking pins from each lot of the same material and the same size as those to be used. The lot size shall not exceed 25. The test shall be made in a device of the same form and pressure dimensions as that in which the breaking pin is to be used.

(c) Spring Loaded Nonreclosing Pressure Relief Device

(1) A spring loaded nonreclosing pressure relief device, pressure actuated by means which permit the spring loaded portion of the device to open at the specified set pressure and remain open until manually reset, may be used provided the design of the spring loaded nonreclosing device is such that if the actuating means fail, the device will achieve full opening at or below its set pressure. Such a device may not be used in combination with any other pressure relief device. The tolerance on opening point shall not exceed ± 5%.

(2) The calculated capacity rating of a spring loaded nonreclosing pressure relief device shall not exceed a value based on the applicable theoretical formula (see UG-131) for the various media, multiplied by: K = coefficient = 0.62.

The area A (square inches) in the theoretical formula shall be the flow area through the minimum opening of the nonreclosing pressure relief device.

(3) In lieu of the method of capacity rating in (2) above, a Manufacturer may have the capacity of a spring loaded nonreclosing pressure relief device design certified in general accordance with the procedures of UG-131, as applicable.

UG-128 LIQUID RELIEF VALVES

Any liquid relief valve used shall be at least NPS 1/2.

UG-129 MARKING

(a) Safety, Safety Relief, Liquid Relief, and Pilot Operated Pressure Relief Valves. Each safety, safety relief, liquid relief, and main valve of a pilot operated pressure relief valve NPS 1/2 and larger shall be plainly marked by the manufacturer or assembler with the required data in such a way that the marking will not be obliterated in service. The marking may be placed on the valve or on a plate or plates that satisfy the requirements of UG-119:

(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;

(5) certified capacity (as applicable):

(a) lb/hr of saturated steam at an overpressure of 10% or 3 psi, whichever is greater for valves certified on steam complying with UG-131(b); or

(b) gal/min of water at 70°F at an overpressure of 10% or 3 psi, whichever is greater for valves certified on water; or

(c) SCFM (standard cubic feet per minute at 60°F and 14.7 psia), or lb/min, of air at an overpressure of 10%

[52] A *breaking pin device* is a nonreclosing 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. A *breaking pin* is the load-carrying element of a breaking pin device. A *breaking pin housing* is the structure which encloses the breaking pin mechanism. The material of the housing shall be listed in Section II and be permitted for use in this Division.

[53] The specified temperature supplied to the breaking pin manufacturer shall be the temperature of the breaking pin when an emergency condition exists and the pin is expected to break.

FIG. UG-129 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD

or 3 psi, whichever is greater. Valves that are capacity certified in accordance with UG-131(c)(2) shall be marked "at 20% overpressure."

(d) In addition to one of the fluids specified above, the Manufacturer may indicate the capacity in other fluids (see Appendix 11).

(6) year built, or alternatively, a coding may be marked on the valve such that the valve Manufacturer or Assembler can identify the year the valve was assembled or tested;

(7) ASME Symbol as shown in Fig. UG-129. The pilot of a pilot operated pressure relief valve shall be plainly marked by the Manufacturer or Assembler showing the name of the Manufacturer, the Manufacturer's design or type number, the set pressure in pounds per square inch, and the year built, or alternatively, a coding that the Manufacturer can use to identify the year built.

On valves smaller than NPS 1/2, the markings may be made on a metal tag attached by wire or adhesive meeting the requirements of UG-119 or other means suitable for the service conditions.

(b) Safety and safety relief valves certified for a steam discharging capacity under the provisions of Section I and bearing the official Code Symbol Stamp of Section I for safety valves may be used on pressure vessels. The rated capacity in terms of other fluids shall be determined by the method of conversion given in Appendix 11. [See UG-131(h).]

(c) Pressure Relief Valves in Combination With Rupture Disk Devices. Pressure relief valves in combination with rupture disk devices shall be marked with the capacity as established in accordance with UG-127(a)(3)(b)(2) (using 0.90 factor) or the combination capacity factor established by test in accordance with UG-132(a) or (b), in addition to the marking of UG-129(a) and (f) below. The marking may be placed on the valve or rupture disk device or on a plate or plates that satisfy the requirements of UG-119 or rupture disk device. The marking shall 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 this marking. This shall be either the vessel user, vessel Manufacturer, rupture disk Manufacturer, or pressure relief valve Manufacturer.

(d) Pressure Relief Valves in Combination With Breaking Pin Devices. Pressure relief valves in combination with breaking pin devices shall be marked in accordance with (a) above. In addition, the rated pressure shall be marked on the breaking pin and the breaking pin housing.

(e) Rupture Disk Devices. Every rupture disk shall be plainly marked by the Manufacturer in such a way that the marking will not be obliterated in service. The rupture disk marking may be placed on the flange of the disk or on a metal tab that satisfies the requirements of UG-119. The marking shall 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 designator at valve inlet);

(6) stamped bursting pressure____psi;

(7) coincident disk temperature____°F

(8) capacity____lb of saturated steam/hr, or____cu ft of air/min (60°F and 14.7 psia).

NOTE: In addition, the Manufacturer may indicate the capacity in other fluids (see Appendix 11).

Items (1), (2), and (5) above shall *also* be marked on the rupture disk holder.

(*f*) *Spring Loaded Nonreclosing Pressure Relief Devices.* Spring loaded nonreclosing pressure relief devices shall be marked in accordance with (a) above except that the Code Symbol Stamp is to be applied only when the capacity has been established and certified in accordance with UG-127(c)(3) and all other requirements of UG-130 have been met.

UG-130 USE OF CODE SYMBOL STAMP

Each pressure relief valve[54] to which the Code Symbol (see Fig. UG-129) will be applied shall have been fabricated or assembled by a Manufacturer or Assembler holding a valid Certificate of Authorization (UG-117) and capacity certified in accordance with the requirements of this Division.

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[54] Vacuum relief valves are not covered by Code Symbol Stamp requirements.

UG-131 CERTIFICATION OF CAPACITY OF PRESSURE RELIEF VALVES

(a) Before the Code Symbol is applied to any pressure relief valve, the valve Manufacturer shall have the capacity of his valves certified in accordance with the provisions of this paragraph.

(b)(1) Capacity certification tests for pressure relief valves for compressible fluids shall be conducted on dry saturated steam, or air, or natural gas. When dry saturated steam is used, the limits for test purposes shall be 98% minimum quality and 20°F maximum superheat. Correction from within these limits may be made to the dry saturated condition. Valves for steam service may be rated as above, but at least one valve of each series shall be tested on steam to demonstrate the steam capacity and performance.

(2) Capacity certification tests for pressure relief valves for incompressible fluids shall be conducted on water at a temperature between 40°F and 125°F.

(c)(1) Capacity certification tests shall be conducted at a pressure which does not exceed the pressure for which the pressure relief valve is set to operate by more than 10% or 3 psi, whichever is greater, except as provided in (c)(2) below. Minimum pressure for capacity certification tests shall be at least 3 psi above set pressure. The reseating pressure shall be noted and recorded.

(2) Capacity certification tests of pressure relief valves for use in accordance with UG-125(c)(3) may be conducted at a pressure not to exceed 120% of the stamped set pressure of the valve.

(3)(a) Pressure relief valves for compressible fluids having an adjustable blowdown construction shall be adjusted prior to testing so that the blowdown does not exceed 5% of the set pressure or 3 psi, whichever is greater.

(b) The blowdown of pressure relief valves for incompressible fluids and pressure relief valves for compressible fluids having nonadjustable blowdown shall be noted and recorded.

(4) Capacity certification of pilot operated pressure relief valves may be based on tests without the pilot valves installed, provided prior to capacity tests it has been demonstrated by test to the satisfaction of the Authorized Observer that the pilot valve will cause the main valve to open fully at a pressure which does not exceed the set pressure by more than 10% or 3 psi, whichever is greater, and that the pilot valve in combination with the main valve will meet all the requirements of this Division.

(d)(1) A capacity certification test is required on a set of three valves for each combination of size, design, and pressure setting. The stamped capacity rating for each combination of design, size, and test pressure shall not exceed 90% of the average capacity of the three valves tested. The capacity for each set of three valves shall fall within a range of ± 5% of the average capacity. Failure to meet this requirement shall be cause to refuse certification of that particular safety valve design.

(2) If a Manufacturer wishes to apply the Code Symbol to a design of pressure relief valves, four valves of each combination of pipe size and orifice size shall be tested. These four valves shall be set at pressures which cover the approximate range of pressures for which the valve will be used or covering the range available at the certified test facility that shall conduct the tests. The capacities based on these four tests shall be as follows.

(a) For compressible fluids, the slope W/P of the actual measured capacity versus the flow pressure for each test point shall be calculated and averaged:

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

All values derived from the testing must fall within ± 5% of the average value:

minimum slope = 0.95 x average slope

maximum slope= 1.05 x average slope

If the values derived from the testing do not fall between the minimum and maximum slope values, the Authorized Observer shall require that additional valves be tested at the rate of two for each valve beyond the maximum and minimum values with a limit of four additional valves.

The relieving capacity to be stamped on the valve shall not exceed 90% of the average slope times the absolute accumulation pressure:

rated slope = 0.90 x average slope

stamped capacity ≤ rated slope (1.10 x set pressure
+ 14.7) or (set pressure + 3 psi
+ 14.7), whichever is greater

For valves certified in accordance with (c)(2) above,

stamped capacity ≤ rated slope (1.20 x set pressure
+ 14.7) or (set pressure + 3 psi
+ 14.7), whichever is greater

(b) For incompressible fluids, the capacities shall be plotted on log - log paper against the differential (inlet

minus discharge pressure) test pressure and a straight line drawn through these four points. If the four points do not establish a straight line, two additional valves shall be tested for each unsatisfactory point, with a limit of two unsatisfactory points. Any point that departs from the straight line by more than 5% should be considered an unsatisfactory point. The relieving capacity shall be determined from this line. The certified capacity shall not exceed 90% of the capacity taken from the line.

(e) Instead of individual capacity certification as provided in (d) above, a coefficient of discharge K may be established for a specific safety valve design according to the following procedure.

(1) For each design, the pressure relief valve manufacturer shall submit for test at least three valves for each of three different sizes (a total of nine valves) together with detailed drawings showing the valve construction. Each valve of a given size shall be set at a different pressure.

(2) Tests shall be made on each pressure or relief valve to determine its capacity-lift, popping and blowdown pressures, and actual capacity in terms of the fluid used in the test. A coefficient K_D shall be established for each test run as follows:

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

where actual flow is determined quantitatively by test, and theoretical flow is calculated by the appropriate formula which follows:

For tests with dry saturated steam,

$$W_T = 51.5AP$$

NOTE: For dry saturated steam pressures over 1500 psig and up to 3200 psig, the value of W_T, calculated by the above equation, shall be corrected by being multiplied by the following factors:

$$\frac{0.1906P - 1000}{0.2292P - 1061}$$

For tests with air,

$$W_T = 356AP\sqrt{\frac{M}{T}}$$

For tests with natural gas,

$$W_T = CAP\sqrt{\frac{M}{ZT}}$$

For tests with water,

$$W_T = 2407A\sqrt{(P - P_d)\,w}$$

where

W_T = theoretical flow, lb/hr
A = actual discharge area through the valve at developed lift, sq.in.
P = (set pressure x 1.10) plus atmospheric pressure, psia, or set pressure plus 3 psi plus atmospheric pressure, whichever is greater
P_d = pressure at discharge from valve, psia
M = molecular weight
T = absolute temperature at inlet, °F + 460°F
C = constant for gas or vapor based on the ratio of specific heats

$$k = c_p/c_v \text{ (see Fig. 11-1)}$$

Z = compressibility factor corresponding to P and T
w = specific weight of water at valve inlet conditions

The average of the coefficients K_D of the nine tests required shall be multiplied by 0.90, and this product shall be taken as the coefficient K of that design. The coefficient of the design shall not be greater than 0.878 (the product of 0.9 x 0.975).

NOTE: All experimentally determined coefficients K_D shall fall within a range of ± 5% of the average K_D found. Failure to meet this requirement shall be cause to refuse certification of that particular valve design.

To convert lb/hr of water to gal/min of water, multiply the capacity in lb/hr by 1/500.

(3) The official relieving capacity of all sizes and pressures of a given design, for which K has been established under the provisions of (e)(2) above, that are manufactured subsequently shall not exceed the value calculated by the appropriate formula in (e)(2) above multiplied by the coefficient K (see Appendix 11).

(4) The coefficient shall not be applied to valves whose beta ratio (ratio of valve throat to inlet diameter) lies outside the range of 0.15 to 0.75, unless tests have demonstrated that the individual coefficient of discharge K_D for valves at the extreme ends of a larger range is within ± 5% of the average coefficient K. For designs where the lift is used to determine the flow area, all valves shall have the same nominal lift-to-seat diameter ratio (L/D).

(f) Tests shall be conducted at a place where the testing facilities, methods, procedures, and person supervising the tests (Authorized Observer) meet the applicable requirements of ASME/ANSI PTC 25.3. The tests shall be made under the supervision of and certified by an Authorized Observer. The testing facilities, methods, procedures, and qualifications of the Authorized Observer shall be subject to the acceptance of the ASME on

recommendation of an ASME Designee. Acceptance of the testing facility is subject to review within each 5 year period.

(g) Capacity test data reports for each valve model, type, and size, signed by the manufacturer and the Authorized Observer witnessing the tests shall be submitted to the ASME Designee for review and acceptance.[55] Where changes are made in the design, capacity certification tests shall be repeated.

(h) For absolute pressures up to 1500 psia, it is permissible to rate safety valves under PG-69.1.2 of Section I with capacity ratings at a flow pressure of 103% of the set pressure, for use on pressure vessels, without further test. In such instances, the capacity rating of the valve may be increased to allow for the flow pressure permitted in (c)(1) and (c)(3) above, namely, 110% of the set pressure, by the multiplier

$$\frac{1.10p + 14.7}{1.03p + 14.7}$$

where

p = set pressure, psig

Such valves shall be marked in accordance with UG-129. This multiplier shall not be used as a divisor to transform test ratings from a higher to a lower flow. For steam pressures above 1500 psig, the above multiplier is not applicable. For steam valves with relieving pressures between 1500 psig and 3200 psig, the capacity shall be determined by using the equation for steam and the correction factor for high pressure steam in (e)(2) above with the permitted absolute relieving pressure (1.10p + 14.7) and the coefficient K for that valve design.

(i) Rating of nozzle type pressure relief valves, i.e., coefficient K_D, greater than 0.90 and nozzle construction, for saturated water shall be according to 11-2.

(j) When changes are made in the design of a pressure relief valve in such a manner as to affect the flow path, lift, or performance characteristics of the valve, new tests in accordance with this Division shall be performed.

UG-132 CERTIFICATION OF CAPACITY OF SAFETY AND SAFETY RELIEF VALVES IN COMBINATION WITH NONRECLOSING PRESSURE RELIEF DEVICES

(*a*) *Capacity of Safety or Safety Relief Valves in Combination With a Rupture Disk Device at the Inlet*

(1) For each combination of safety or safety relief valve design and rupture disk device design, the safety valve manufacturer or the rupture disk device manufacturer may have the capacity of the combination certified as prescribed in (3) and (4) below.

(2) Capacity certification tests shall be conducted on saturated steam, air or natural gas. When saturated steam is used, corrections for moisture content of the steam shall be made.

(3) The valve manufacturer or the rupture disk device manufacturer may submit for tests the smallest rupture disk device size with the equivalent size of safety or safety relief valve that is intended to be used as a combination device. The safety or safety relief valve to be tested shall have the largest orifice used in the particular inlet size.

(4) Tests may be performed in accordance with the following subparagraphs. The rupture disk device and safety or safety relief valve combination to be tested shall be arranged to duplicate the combination assembly design.

(a) The test shall embody the minimum burst pressure of the rupture disk device design which is to be used in combination with safety or safety relief valve design. The stamped bursting pressure shall be between 90% and 100% of the stamped set pressure of the valve.

(b) The test procedure to be used shall be as follows.

The safety or safety relief valve (one valve) shall be tested for capacity as an individual valve, without the rupture disk device at a pressure 10% above the valve set pressure.

The rupture disk device shall then be installed ahead of the safety or safety relief valve and the disk burst to operate the valve. The capacity test shall be performed on the combination at 10% above the valve set pressure duplicating the individual safety or safety relief valve capacity test.

(c) Tests shall be repeated with two additional rupture disks of the same nominal rating for a total of three rupture disks to be tested with the single valve. The results of the test capacity shall fall within a range of 10% of the average capacity of the three tests. Failure to meet this requirement shall be cause to require retest for determination of cause of the discrepancies.

(d) From the results of the tests, a Combination Capacity Factor shall be determined. The Combination Capacity Factor is the ratio of the average capacity determined by the combination tests to the capacity determined on the individual valve.

The Combination Capacity Factor shall be used as a multiplier to make appropriate changes in the ASME rated relieving capacity of the safety or safety relief valve in all sizes of the design. The value of the Combination Capacity Factor shall not be greater than one. The Combination Capacity Factor shall apply only to combinations of the

[55] Valve capacities are published in "Pressure Relief Device Certifications." This publication may be obtained from the National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229.

same design of safety or safety relief valve and the same design of rupture disk device as those tested.

(e) The test laboratory shall submit the test results to the ASME Designee for acceptance of the Combination Capacity Factor.

(b) Optional Testing of Rupture Disk Devices and Safety or Safety Relief Valves

(1) If desired, a valve manufacturer or a rupture disk manufacturer may conduct tests in the same manner as outlined in (a)(4)(c) and (a)(4)(d) above using the next two larger sizes of the design of rupture disk device and safety or safety relief valve to determine a Combination Capacity Factor applicable to larger sizes. If a greater Combination Capacity Factor is established and can be certified, it may be used for all larger sizes of the combination, but shall not be greater than one.

(2) If desired, additional tests may be conducted at higher pressures in accordance with (a)(4)(c) and (a)(4)(d) above to establish a maximum Combination Capacity Factor to be used at all pressures higher than the highest tested, but shall not be greater than one.

(c) Capacity of Breaking Pin Devices in Combination With Safety Relief Valves

(1) Breaking pin devices in combination with safety relief valves shall be capacity tested in compliance with UG-131(d) or UG-131(e) as a combination.

(2) Capacity certification and Code Symbol stamping shall be based on the capacity established in accordance with these paragraphs.

(d) Heat exchangers and similar vessels shall be protected with a relieving device of sufficient capacity to avoid overpressure in case of an internal failure.

(e) The official rated capacity of a pressure relieving safety device shall be that which is stamped on the device and guaranteed by the manufacturer.

(f) The rated pressure relieving capacity of a pressure relief valve for other than steam or air shall be determined by the method of conversion given in Appendix 11.

(g) To prorate the relieving capacity at any relieving pressure greater than 1.10p, as permitted under UG-125, a multiplier may be applied to the official relieving capacity of a pressure relieving device as follows:

$$\frac{P + 14.7}{1.10p + 14.7}$$

where

P = relieving pressure, psig

p = set pressure, psig

For steam pressures above 1500 psig, the above multiplier is not applicable. For steam valves with relieving pressures greater than 1500 psig and less than or equal to 3200 psig, the capacity at relieving pressures greater than 1.10p shall be determined using the equation for steam and the correction factor for high pressure steam in UG-131(e)(2) with the permitted absolute relieving pressure and the coefficient K for that valve design.

UG-133 DETERMINATION OF PRESSURE RELIEVING REQUIREMENTS

(a) Except as permitted in (b) below, the aggregate capacity of the pressure relieving devices connected to any vessel or system of vessels for the release of a liquid, air, steam, or other vapor shall be sufficient to carry off the maximum quantity that can be generated or supplied to the attached equipment without permitting a rise in pressure within the vessel of more than 16% above the maximum allowable working pressure when the pressure relieving devices are blowing.

(b) Protective devices as permitted in UG-125(c)(2), as protection against excessive pressure caused by exposure to fire or other sources of external heat, shall have a relieving capacity sufficient to prevent the pressure from rising more than 21% above the maximum allowable working pressure of the vessel when all pressure relieving devices are blowing.

(c) Vessels connected together by a system of adequate piping not containing valves which can isolate any vessel may be considered as one unit in figuring the required relieving capacity of pressure relieving safety devices to be furnished.

UG-134 PRESSURE SETTING OF PRESSURE RELIEF DEVICES

(a) When a single pressure relieving device is used, it shall be set to operate[56] at a pressure not exceeding the maximum allowable working pressure of the vessel. When the required capacity is provided in more than one pressure relieving device, only one device need be set at or below the maximum allowable working pressure, and the additional devices may be set to open at higher pressures but in no case at a pressure higher than 105% of the maximum allowable working pressure, except as provided in (b) below.

(b) Protective devices permitted in UG-125(c)(2) as protection against excessive pressure caused by exposure to fire or other sources of external heat shall be set to operate at a pressure not in excess of 110% of the maximum allowable working pressure of the vessel. If such a device is used to meet the requirements of both

[56] *Set to operate* means the set pressure of a pressure relief valve or a spring loaded nonreclosing device; the bursting pressure of a rupture disk device; or, the breaking pressure of a breaking pin device.

UG-125(c) and UG-125(c)(2), it shall be set to operate at not over the maximum allowable working pressure.

(c) The pressure at which any device is set to operate shall include the effects of static head and constant back pressure.

(d)(1) The set pressure tolerance for pressure relief valves shall not exceed ± 2 psi for pressures up to and including 70 psi and ± 3% for pressures above 70 psi, except as covered in (d)(2) below.

(2) The set pressure tolerance of pressure relief valves which comply with UG-125(c)(3) shall be within -0%, +10%.

UG-135 INSTALLATION

(a) Pressure relief devices for vapor application shall be connected to the vessel in the vapor space above any contained liquid or to piping connected to the vapor space in the vessel which is to be protected.

(b) The opening through all pipe and fittings between a pressure vessel and its pressure relieving device shall have at least the area of the pressure relieving device inlet, and the flow characteristics of this upstream system shall be such that the pressure drop will not reduce the relieving capacity below that required or adversely affect the proper operation of the pressure relieving device. The opening in the vessel wall shall be designed to provide direct and unobstructed flow between the vessel and its pressure relieving device. (See Appendix M.)

(c) When two or more required pressure relieving devices are placed on one connection, the inlet internal cross-sectional area of this connection shall be either sized to avoid restricting flow to the pressure relief devices or made at least equal to the combined inlet areas of the safety devices connected to it. The flow characteristics of the upstream system shall satisfy the requirements of (b) above. (See Appendix M.)

(d) Pressure relief devices for liquid service application shall be connected below the normal liquid level.

(e) There shall be no intervening stop valves between the vessel and its protective device or devices, or between the protective device or devices and the point of discharge, except:

(1) when these stop valves are so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected relieving devices below the required relieving capacity; or

(2) under conditions set forth in Appendix M.

(f) The safety devices on all vessels shall be so installed that their proper functioning will not be hindered by the nature of the vessel's contents.

(g) Discharge lines from pressure relieving safety devices shall be designed to facilitate drainage or shall be fitted with drains to prevent liquid from lodging in the discharge side of the safety device, and such lines shall lead to a safe place of discharge. The size of the discharge lines shall be such that any pressure that may exist or develop will not reduce the relieving capacity of the relieving devices below that required to properly protect the vessel, or adversely affect the proper operation of the pressure relieving devices. [See UG-136(a)(8) and Appendix M.]

UG-136 MINIMUM REQUIREMENTS FOR PRESSURE RELIEF VALVES

(a) Mechanical Requirements

(1) The design shall incorporate guiding arrangements necessary to ensure consistent operation and tightness.

(2) The spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 0.5% of the free height.

(3) Each pressure relief valve on air, water over 140°F, or steam service shall have a substantial lifting device which when activated will release the seating force on the disk when the valve is subjected to a pressure of at least 75% of the set pressure of the valve. Pilot operated pressure relief valves used on these services shall be provided with either a lifting device as described above or means for connecting and applying pressure to the pilot adequate to verify that the moving parts critical to proper operation are free to move.

(4) The seat of a pressure relief valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

(5) In the design of the body of the valve, consideration shall be given to minimizing the effects of deposits.

(6) Valves having screwed inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damaging operating parts.

(7) Means shall be provided in the design of all valves for use under this Division for sealing all initial adjustments

which can be made without disassembly of the valve. Seals shall be installed by the manufacturer or assembler at the time of initial adjustment. Seals shall be installed in a manner to prevent changing the adjustment without breaking the seal. For valves larger than NPS 1/2, the seal shall serve as a means of identifying the manufacturer or assembler making the initial adjustment.

(8) If the design of a pressure relief valve is such that liquid can collect on the discharge side of the disk, the valve shall be equipped with a drain at the lowest point where liquid can collect (for installation, see UG-135).

(9) For pressure relief valves of the diaphragm type, the space above the diaphragm shall be vented to prevent a buildup of pressure above the diaphragm. Pressure relief valves of the diaphragm type shall be designed so that failure or deterioration of the diaphragm material will not impair the ability of the valve to relieve at the rated capacity.

(b) Material Selections

(1) Cast iron seats and disks are not permitted.

(2) Adjacent sliding surfaces such as guides and disks or disk holders shall both be of corrosion resistant material. Springs of corrosion resistant material or having a corrosion resistant coating are required. The seats and disks of pressure relief valves shall be of suitable material to resist corrosion by the fluid to be contained.

NOTE: The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the manufacturer and the purchaser.

(3) Materials used in bodies and bonnets or yokes shall be listed in Section II and this Division. Carbon and low alloy steel bodies, bonnets, yokes, and bolting (UG-20) subject to in-service temperatures colder than -20˚F shall meet the requirements of UCS-66, unless exempted by the following.

(a) The coincident Ratio defined in Fig. UCS-66.1 is 0.4 or less.

(b) The material(s) is exempted from impact testing per Fig. UCS-66.

(4) Materials used in nozzles, disks, and other parts contained within the external structure of the pressure relief valves shall be one of the following categories.

(a) listed in Section II;

(b) listed in ASTM Specifications;

(c) 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.

(c) Inspection of Manufacturing and/or Assembly of Pressure Relief Valves

(1) A Manufacturer or assembler shall demonstrate to the satisfaction of an ASME designee that his manufacturing, production, and testing facilities and quality control procedures will insure close agreement between the performance of random production samples and the performance of those valves submitted for Capacity Certification.

(2) Manufacturing, assembly, inspection, and test operations including capacity are subject to inspections at any time by an ASME designee.

(3) A Manufacturer or assembler may be granted permission to apply the UV Code Symbol to production pressure relief valves capacity certified in accordance with UG-131 provided the following tests are successfully completed. This permission shall expire on the fifth anniversary of the date it is initially granted. The permission may be extended for 5 year periods if the following tests are successfully repeated within the 6-month period before expiration.

(a) Two sample production pressure relief valves of a size and capacity within the capability of an ASME accepted laboratory shall be selected by an ASME designee.

(b) Operational and capacity tests shall be conducted in the presence of an ASME designee at an ASME accepted laboratory. The valve Manufacturer or assembler shall be notified of the time of the test and may have representatives present to witness the test. Valves having an adjustable blowdown construction shall be adjusted by the Manufacturer or assembler following successful testing for operation but prior to flow testing so that the blowdown does not exceed 7% of the set pressure or 3 psi, whichever is greater. This adjustment may be made on the flow test facility.

(c) Should any valve fail to relieve at or above its certified capacity or should it fail to meet performance requirements of this Division, the test shall be repeated at the rate of two replacement valves, selected in accordance with (c)(3)(a) above, for each valve that failed.

(d) Failure of any of the replacement valves to meet the capacity or the performance requirements of this Division shall be cause for revocation within 60 days of the authorization to use the Code Symbol on that particular type of valve. During this period, the Manufacturer or assembler shall demonstrate the cause of such deficiency and the action taken to guard against future occurrence, and the requirements of (c)(3) above shall apply.

(4) Use of the Code Symbol Stamp by an assembler indicates the use of original, unmodified parts in strict accordance with the instructions of the Manufacturer of the valve.

(5) In addition to the requirements of UG-129, the marking shall include the name of the Manufacturer and the assembler. The Code Symbol Stamp shall be that of the assembler.

Note: Within the requirements of UG-136(c) and (d): A Manufacturer is defined as a person or organization who is completely responsible for design, material selection, capacity certification, manufacture of all component parts, assembly, testing, sealing, and shipping of pressure relief valves certified under this Division. An assembler is defined as a person or organization who purchases or receives from a Manufacturer the necessary component parts or valves and assembles, adjusts, tests, seals, and ships pressure relief valves certified under this Division, at a geographical location other than and using facilities other than those used by the Manufacturer. An assembler may be organizationally independent of a Manufacturer or may be wholly or partly owned by a Manufacturer.

(d) Production Testing by Manufacturers and Assemblers

(1) Each pressure relief valve to which the Code Symbol Stamp is to be applied shall be subjected to the following tests by the Manufacturer or assembler. A Manufacturer or assembler shall have a documented program for the application, calibration, and maintenance of gages and instruments used during these tests.

(2) The primary pressure parts of each valve exceeding NPS 1 inlet size or 300 psi set pressure where the materials used are either cast or welded shall be tested at a pressure of at least 1.5 times the design pressure of the parts. These tests shall be conducted after all machining operations on the parts have been completed. There shall be no visible sign of leakage.

(3) The secondary pressure zone of each closed bonnet valve exceeding NPS 1 inlet size when such valves are designed for discharge to a closed system shall be tested with air or other gas at a pressure of at least 30 psi. There shall be no visible sign of leakage.

(4) Each valve shall be tested to demonstrate its popping or set pressure. Valves marked for steam service or having special internal parts for steam service shall be tested with steam, except that valves beyond the capability of the production steam test facility either because of size or set pressure may be tested on air. Necessary corrections for differentials in popping pressure between steam and air shall be established by the manufacturer and applied to the popping point on air. Valves marked for gas or vapor may be tested with air. Valves marked for liquid service shall be tested with water or other suitable liquid. Test fixtures and test drums where applicable shall be of adequate size and capacity to ensure that valve action is consistent with the stamped set pressure within the tolerances required by UG-134(d).

(5) A seat tightness test shall be conducted at a maximum expected operating pressure, but at a pressure not exceeding the reseating pressure of the valve. When testing with either water or steam, a valve exhibiting no visible signs of leakage shall be considered adequately tight. Leakage tests conducted with air shall be in accordance with industry accepted standards.

(6) Testing time on steam valves shall be sufficient, depending on size and design, to insure that test results are repeatable and representative of field performance.

(e) Design Requirements. At the time of the submission of valves for capacity certification, or testing in accordance with (c)(3) above, the ASME Designee has the authority to review the design for conformity with the requirements of UG-136(a) and UG-136(b) and to reject or require modification of designs which do not conform, prior to capacity testing.

(f) Welding and Other Requirements. All welding, brazing, heat treatment, and nondestructive examination used in the construction of bodies, bonnets, and yokes shall be performed in accordance with the applicable requirements of this Division.

ASME Section VIII, Appendix 11 Division 1, 1992 Edition Capacity Conversions for Safety Valves

11-1

The capacity of a safety or relief valve in terms of a gas or vapor other than the medium for which the valve was officially rated shall be determined by application of the following formulas:

For steam,

$$W_s = 51.5KAP$$

For air,

$$W_a = CKAP \sqrt{\frac{M}{T}}$$

$$C = 356$$

$$M = 28.97$$

$$T = 520 \text{ when } W_a \text{ is the rated capacity}$$

For any gas or vapor,

$$W = CKAP \sqrt{\frac{M}{T}}$$

where

- W_s = rated capacity, lb/hr of steam
- W_a = rated capacity, converted to lb/hr of air at 60°F, inlet temperature
- W = flow of any gas or vapor, lb/hr
- C = constant for gas or vapor which is function of the ratio of specific heats, $k = c_p/c_v$ (see Fig. 11-1)
- K = coefficient of discharge [see UG-131(d) and (e)]
- A = actual discharge area of the safety valve, sq.in.
- P = (set pressure x 1.10) plus atmospheric pressure, psia
- M = molecular weight
- T = absolute temperature at inlet (°F + 460)

These formulas may also be used when the required flow of any gas or vapor is known and it is necessary to compute the rated capacity of steam or air.

Molecular weights of some of the common gases and vapors are given in Table 11-1.

For hydrocarbon vapors, where the actual value of k is not known, the conservative value, k = 1.001 has been commonly used and the formula becomes

$$W = 315KAP \sqrt{\frac{M}{T}}$$

When desired, as in the case of light hydrocarbons, the compressibility factor Z may be included in the formulas for gases and vapors as follows:

$$W = CKAP \sqrt{\frac{M}{ZT}}$$

Example 1

Given: A safety valve bears a certified capacity rating of 3020 lb/hr of steam for a pressure setting of 200 psi.

Problem: What is the relieving capacity of that valve in terms of air at 100°F for the same pressure setting?

Solution:

For steam

$$W_s = 51.5KAP$$

$$3020 = 51.5KAP$$

$$KAP = \frac{3020}{51.5} = 58.5$$

For air

$$W_a = CKAP\sqrt{\frac{M}{T}}$$

$$= 356KAP \sqrt{\frac{28.97}{460 + 100}}$$

$$= (356)(58.5) \sqrt{\frac{28.97}{560}}$$

$$= 4750 \text{ lb/hr}$$

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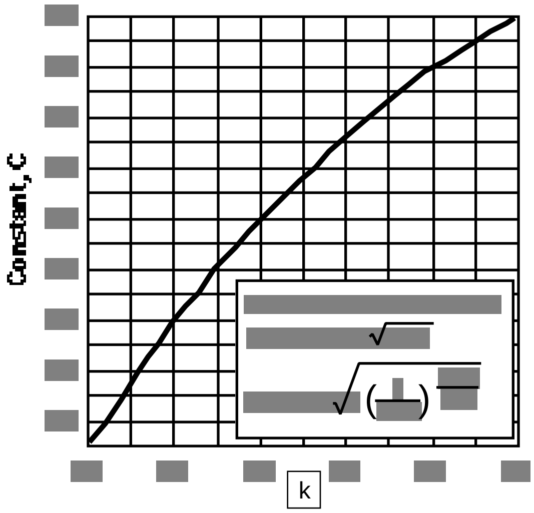
[1] Knowing the official rating capacity of a safety valve which is stamped on the valve, it is possible to determine the overall value of KA in either of the following formulas in cases where the value of these individual terms is not known:

Official Rating in Steam	Official Rating in Air
$KA = \frac{W_s}{51.5P}$	$KA = \frac{W_a}{CP}\sqrt{\frac{T}{M}}$

This value for KA is then substituted in the above formulas to determine the capacity of the safety valve in terms of the new gas or vapor.



k	Constant C	k	Constant C	k	Constant 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	- - -	- - -

Fig.11-1 Constant C for Gas or Vapor Related to Ratio of specific Heats ($k = c_p/c_v$)

Example 2

Given: It is required to relieve 5000 lb/hr of propane from a pressure vessel through a safety valve set to relieve at a pressure of P_s, psi, and with an inlet temperature at 125°F.

Problem: What total capacity in pounds of steam per hour in safety valves must be furnished?

Solution:

For propane,

$$W = CKAP \sqrt{\frac{M}{T}}$$

The value of C is not definitely known. Use the conservative value, C = 315.

$$5000 = 315\,KAP \sqrt{\frac{44.09}{460 + 125}}$$

$$KAP = 57.7$$

For steam,

$$W_s = 51.5\,KAP = (51.5)(57.7)$$

$$= 2970 \text{ lb/hr set to relieve at } P_s\text{, psi}$$

Example 3

Given: It is required to relieve 1000 lb/hr of ammonia from a pressure vessel at 150°F.

Problem: What is the required total capacity in pounds of steam per hour at the same pressure setting?

Solution:

For ammonia,

$$W = CKAP \sqrt{\frac{M}{T}}$$

Manufacturer and user agree to use k = 1.33; from Fig. 11-1, C = 350.

$$1000 = 350\,KAP \sqrt{\frac{17.03}{460 + 150}}$$

$$KAP = 17.10$$

For steam,

$$W_s = 51.5\,KAP = 51.5 \times 17.10$$

$$= 880 \text{ lb/hr}$$

Example 4

Given: A safety valve bearing a certified rating of 10,000 cu ft/min of air at 60°F and 14.7 psia (atmospheric pressure).

Problem: What is the flow capacity of this safety valve in pounds of saturated steam per hour for the same pressure setting?

Solution:

For air: Weight of dry air at 60°F and 14.7 psia is 0.0766 lb/cu ft.

$$W_a = 10,000 \times 0.0766 \times 60 = 45,960 \text{ lb/hr}$$

$$45,960 = 356\,KAP \sqrt{\frac{28.97}{460 + 60}}$$

$$KAP = 546$$

For steam,

$$W_s = 51.5KAP = (51.5)(546)$$

$$= 28{,}200 \text{ lb/hr}$$

NOTE: Before converting the capacity of a safety valve from any gas to steam, the requirements of UG-131(b) must be met.

11-2

(a) Since it is realized that the saturated water capacity is configuration sensitive, the following applies only to those safety valves that have a nozzle type construction (throat to inlet diameter ratio of 0.25 to 0.80 with a continuously contoured change and have exhibited a coefficient K_D in excess of 0.90). No saturated water rating shall apply to other types of construction.

NOTE: The manufacturer, user, and Inspector are all cautioned that for the following rating to apply, the valve shall be continuously subjected to saturated water. If, after initial relief the flow media changes to quality steam, the valve shall be rated as per dry saturated steam. Valves installed on vessels or lines containing steam-water mixture shall be rated on dry saturated steam.

(b) To determine the saturated water capacity of a valve currently rated under UG-131 and meeting the requirements of (a) above, refer to Fig. 11-2. Enter the graph at the set pressure of the valve, move vertically upward to the saturated water line and read horizontally the relieving capacity. This capacity is the theoretical, isentropic value arrived at by assuming equilibrium flow and calculated values for the critical pressure ratio.

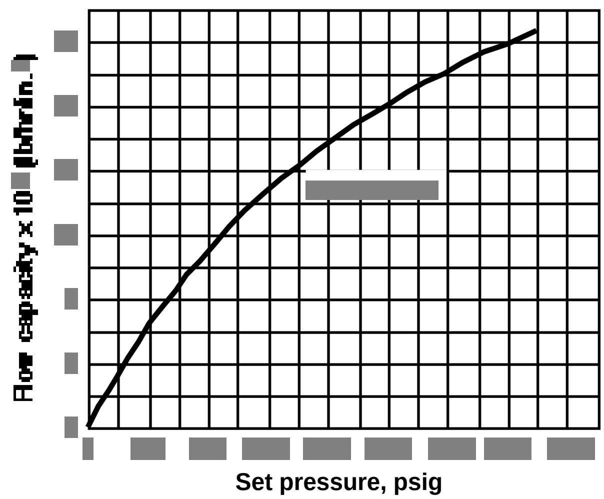


Fig.11-2
Flow Capacity Curve for Rating Nozzle Type Safety Valves on Saturated Water (Based on 10% Overpressure)

Table 11-1
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	**120.9**	**Sulfur Dioxide**	**64.06**

ASME Section VIII, Appendix M Division 1, 1992 Edition Installation and Operation

M-1 INTRODUCTION

(a) The rules in this Appendix are for general information only, because they pertain to the installation and operation of pressure vessels, which are the prerogative and responsibility of the law enforcement authorities in those states and municipalities which have made provision for the enforcement of Section VIII.

(b) It is permissible to use any departures suggested herein from provisions in the mandatory parts of this Division when granted by the authority having legal jurisdiction over the installation of pressure vessels.

M-2 CORROSION

(a) Vessels subject to external corrosion shall be so installed that there is sufficient access to all parts of the exterior to permit proper inspection of the exterior, unless adequate protection against corrosion is provided or unless the vessel is of such size and is so connected that it may readily be removed from its permanent location for inspection.

(b) Vessels having manholes, handholes, or cover plates to permit inspection of the interior shall be so installed that these openings are accessible.

(c) In vertical cylindrical vessels subject to corrosion, to insure complete drainage, the bottom head, if dished, should preferably be concave to pressure.

M-3 MARKING ON THE VESSEL

The marking required by this Division shall be so located that it will be accessible after installation and when installed shall not be covered with insulation or other material that is not readily removable [see UG-116(j)].

M-4 PRESSURE RELIEVING SAFETY DEVICES

The general provisions for the installation of pressure relieving devices are fully covered in UG-135. The following paragraphs contain details in arrangement of stop valves for shutoff control of safety pressure relief devices which are sometimes necessary to the continuous operation of processing equipment of such a complex nature that the shutdown of any part of it is not feasible. There are also rules with regard to the design of inlet and discharge piping to and from safety and relief valves, which can only be general in nature because the design engineer must fit the arrangement and proportions of such a system to the particular requirements in the operation of the equipment involved.

M-5 STOP VALVES BETWEEN PRESSURE RELIEVING DEVICE AND VESSEL

(a) A vessel, in which pressure can be generated because of service conditions, may have a full-area stop valve between it and its pressure relieving device for inspection and repair purposes only. When such a stop valve is provided, it shall be so arranged that it can be locked or sealed open, and it shall not be closed except by an authorized person who shall remain stationed there during that period of the vessel's operation within which the valve remains closed, and who shall again lock or seal the stop valve in the open position before leaving the station.

(b) A vessel or system [see UG-133(c)] for which the pressure originates from an outside source exclusively may have individual pressure relieving devices on each vessel, or connected to any point on the connecting piping, or on any one of the vessels to be protected. Under such an arrangement, there may be a stop valve between any vessel and the pressure relieving devices, and this stop valve need not be locked open, provided it also closes off that vessel from the source of pressure.

M-6 STOP VALVES ON THE DISCHARGE SIDE OF A PRESSURE RELIEVING DEVICE [SEE UG-135(e)]

A full-area stop valve may be placed on the discharge side of a pressure relieving device when its discharge is connected to a common header with other discharge lines from other pressure relieving devices on nearby vessels that are in operation, so that this stop valve when closed will prevent a discharge from any connected operating vessels from backing up beyond the valve so closed. Such a stop valve shall be so arranged that it can be locked or sealed in either the open or closed position, and it shall be locked or sealed in either position only by an authorized person. When it is to be closed while the vessel is in operation, an authorized person shall be present, and he shall remain stationed there; he shall again lock or seal the stop valve in the open position before leaving the station. Under no condition should this valve be closed while the vessel is in operation except when a stop valve on the inlet side of the safety relieving device is installed and is first closed.

M-7 INLET PRESSURE DROP FOR HIGH LIFT, TOP GUIDED SAFETY, SAFETY RELIEF; AND PILOT OPERATED PRESSURE RELIEF VALVES IN COMPRESSIBLE FLUID SERVICE

(a) The nominal pipe size of all piping, valves and fittings, and vessel components between a pressure vessel and its safety, safety relief, or pilot operated pressure relief valves shall be at least as large as the nominal size of the device inlet, and the flow charateristics of the upstream system shall be such that the cumulative total of all nonrecoverable inlet losses shall not exceed 3% of the valve set pressure. The inlet pressure losses will be based on the valve nameplate capacity corrected for the characteristics of the flowing fluid.

(b) When two or more required safety, safety relief, or pilot operated pressure relief valves are placed on one connection, the inlet internal cross-sectional area of this connection shall be either sized to avoid restricting flow to the pressure relief valves or made at least equal to the combined inlet areas of the safety valves connected to it. The flow characteristics of the upstream system shall meet the requirements of (a) above with all valves relieving simultaneously.

M-8 DISCHARGE LINES FROM SAFETY DEVICES

(a) Where it is feasible, the use of a short discharge pipe or vertical riser, connected through long-radius elbows from each individual device, blowing directly to the atmosphere, is recommended. Such discharge pipes shall be at least of the same size as the valve outlet. Where the nature of the discharge permits, telescopic (sometimes called "broken") discharge lines, whereby condensed vapor in the discharge line, or rain, is collected in a drip pan and piped to a drain, are recommended.[1]

(b) When discharge lines are long, or where outlets of two or more valves having set pressures within a comparable range are connected into a common line, the effect of the back pressure that may be developed therein when certain valves operate must be considered [see UG-135(g)]. The sizing of any section of a common-discharge header downstream from each of the two or more pressure relieving devices that may reasonably be expected to discharge simultaneously shall be based on the total of their outlet areas, with due allowance for the pressure drop in all downstream sections. Use of specially designed valves suitable for use on high or variable back pressure service should be considered.

(c) The flow characteristics of the discharge system of high lift, top guided safety, safety relief, or pilot operated pressure relief valves in compressible fluid service shall be such that the static pressure developed at the discharge flange of a conventional direct spring loaded valve will not exceed 10% of the set pressure when flowing at stamp capacity. Other valve types exhibit various degrees of tolerance to back pressure and the manufacturer's recommendation should be followed.

(d) All discharge lines shall be run as direct as is practicable to the point of final release for disposal. For the longer lines, due consideration shall be given to the advantage of long-radius elbows, avoidance of closeup fittings, and the minimizing of excessive line strains by expansion joints and well-known means of support to minimize line-sway and vibration under operating conditions.

(e) Provisions should be made in all cases for adequate drainage of discharge lines.

NOTE: It is recognized that no simple rule can be applied generally to fit the many installation requirements, which vary from simple short lines that discharge directly to the atmosphere to the extensive manifold discharge piping systems where the quantity and rate of the product to be disposed of requires piping to a distant safe place.

M-9 PRESSURE DROP, NONRECLOSING PRESSURE RELIEF DEVICES

Piping, valves and fittings, and vessel components comprising part of a nonreclosing device pressure relieving system shall be sized to prevent the vessel pressure from rising above the allowable overpressure.

M-10 GENERAL ADVISORY INFORMATION ON THE CHARACTERISTICS OF SAFETY RELIEF VALVES DISCHARGING INTO A COMMON HEADER

Because of the wide variety of types and kinds of safety relief valves, it is not considered advisable to attempt a description in this Appendix of the effects produced by discharging them into a common header.

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[1] This construction has the further advantage of not transmitting discharge-pipe strains to the valve. In these types of installation, the back pressure effect will be negligible, and no undue influence upon normal valve operation can result.

Several different types of valves may conceivably be connected into the same discharge header and the effect of back pressure on each type may be radically different. Data compiled by the manufacturers of each type of valve used should be consulted for information relative to its performance under the conditions anticipated.

M-11 PRESSURE DIFFERENTIALS FOR PRESSURE RELIEF VALVES

Due to the variety of service conditions and the various designs of safety and safety relief valves, only general guidance can be given regarding the differential between the set pressure of the valve (see UG-134) and the operating pressure of the vessel. Operating difficulty will be minimized by providing an adequate differential for the application. The following is general advisory information on the characteristics of the intended service and of the safety or safety relief valves that may bear on the proper pressure differential selection for a given application. These considerations should be reviewed early in the system design since they may dictate the MAWP of the system.

(a) Consideration of the Process Characteristics in the Establishment of the Operating Margin to Be Provided. To minimize operational problems, it is imperative that the user consider not only normal operating conditions of fluids, pressures, and temperatures, but also start-up and shutdown conditions, process upsets, anticipated ambient conditions, instrument response times, pressure surges due to quick closing valves, etc. When such conditions are not considered, the pressure relieving device may become, in effect, a pressure controller, a duty for which it is not designed. Additional consideration should be given to hazard and pollution associated with the release of the fluid. Larger differentials may be appropriate for fluids which are toxic, corrosive, or exceptionally valuable.

(b) Consideration of Safety Relief Valve Characteristics.

The blowdown characteristic and capability is the first consideration in selecting a compatible valve and operating margin. After a self-actuated release of pressure, the valve must be capable of reclosing above the normal operating pressure. For example, if the valve is set at 100 psig with a 7% blowdown, it will close at 93 psig. The operating pressure must be maintained below 93 psig in order to prevent leakage or flow from a partially open valve. Users should exercise caution regarding the blowdown adjustment of large spring-loaded valves. Test facilities, whether owned by Manufacturers, repair houses, or users, may not have sufficient capacity to accurately verify the blowdown setting. The settings cannot be considered accurate unless made in the field on the actual installation.

Pilot-operated valves represent a special case from the standpoints of both blowdown and tightness. The pilot portion of some pilot-operating valves can be set at blowdowns as short as 2%. This characteristic is not, however, reflected in the operation of the main valve in all cases. The main valve can vary considerably from the pilot depending on the location of the two components in the system. If the pilot is installed remotely from the main valve, significant time and pressure lags can occur, but reseating of the pilot assures reseating of the main valve. The pressure drop in the connecting piping between the pilot and the main valve must not be excessive; otherwise, the operation of the main valve will be adversely affected.

The tightness of the main valve portion of these combinations is considerably improved above that of conventional valves by pressure loading the main disk or by the use of soft seats or both.

Despite the apparent advantages of pilot-operated valves, users should be aware that they should not be employed in abrasive or dirty service, in applications where coking, polymerization, or corrosion of the wetted pilot parts can occur, or where freezing or condensation of the lading fluid at ambient temperatures is possible. For all applications the valve Manufacturer should be consulted prior to selecting a valve of this type.

Tightness capability is another factor affecting valve selection, whether spring loaded or pilot operated. It varies somewhat depending on whether metal or resilient seats are specified, and also on such factors as corrosion or temperature. The required tightness and test method should be specified to comply at a pressure no lower than the normal operating pressure of the process. A recommended procedure and acceptance standard is given in ANSI B146.1. It should also be remembered that any degree of tightness obtained should not be considered permanent. Service operation of a valve almost invariably reduces the degree of tightness.

Application of special designs such as O-rings or resilient seats should be reviewed with the valve Manufacturer.

The anticipated behavior of the valves includes allowance for a plus-or-minus tolerance on set pressure which varies with the pressure level. Installation conditions, such as back pressure, variations, and vibrations, influence selection of special types and an increase in differential pressure.

(c) General Recommendations. The following pressure differentials are recommended unless the safety or safety relief valve has been designed or tested in a specific or similar service and a smaller differential has been recommended by the Manufacturer.

A minimum difference of 5 psi is recommended for set pressures to 70 psi. In this category, the set pressure tolerance is $\pm$ 2 psi [UG-134(d)(1)], and the differential to the leak test pressure is 10% or 5 psi, whichever is greater.

A minimum differential of 10% is recommended for set pressures from 71 psi to 1000 psi. In this category, the set pressure tolerance is $\pm$ 3% and the differential to the leak test pressure is 10%.

A minimum differential of 7% is recommended for set pressures above 1000 psi. In this category, the set pressure tolerance is $\pm$ 3% and the differential to the leak test pressure should be 5%. Valves having small seat sizes will require additional maintenance when the pressure differential approaches these recommendations.

M-12 INSTALLATION OF SAFETY AND SAFETY RELIEF VALVES

Spring loaded safety and safety relief valves normally should be installed in the upright position with the spindle vertical. Where space or piping configuration preclude such an installation, the valve may be installed in other than the vertical position provided that:

(a) the valve design is satisfactory for such position;

(b) the media is such that material will not accumulate at the inlet of the valve; and

(c) drainage of the discharge side of the valve body and discharge piping is adequate.

M-13 REACTION FORCES AND EXTERNALLY APPLIED LOADS

(a) Reaction Thrust. The discharge of a pressure relief valve imposes reactive flow forces on the valve and associated piping. The design of the installation may require computation of the bending moments and stresses in the piping and vessel nozzle. There are momentum effects and pressure effects at steady state flow as well as transient dynamic loads caused by opening.

(b) External Loads. Mechanical forces may be applied to the valve by discharge piping as a result of thermal expansion, movement away from anchors, and weight of any unsupported piping. The resultant bending moments on a closed pressure relief valve may cause valve leakage and excessive stress in inlet piping. The design of the installation should consider these possibilities.

M-14 SIZING OF PRESSURE RELIEF DEVICES FOR FIRE CONDITIONS

(a) Excessive pressure may develop in pressure vessels by vaporization of the liquid contents and/or expansion of vapor content due to heat influx from the surroundings, particularly from a fire. Pressure relief systems for fire conditions are usually intended to release only the quantity of product necessary to lower the pressure to a predetermined safe level, without releasing an excessive quantity. This control is especially important in situations where release of the contents generates a hazard because of flammability or toxicity. Under fire conditions, consideration must also be given to the possibility that the safe pressure level for the vessel will be reduced due to heating of the vessel material, with a corresponding loss of strength.

(b) Several formulas have evolved over the years for calculating the pressure relief capacity required under fire conditions. The major differences involve heat flux rates. There is no single formula yet developed which takes into account all of the many factors which could be considered in making this determination. When fire conditions are a consideration in the design of a pressure vessel, the following references which provide recommendations for specific installations may be used:

API RP 520, Recommended Practice for the Design and Installation of Pressure-Relieving Systems in Refineries, Part I - Design, 1976, American Petroleum Institute, Washington, DC

API Standard 2000, Venting Atmospheric and Low-Pressure Storage Tanks (nonrefrigerated and refrigerated), 1973, American Petroleum Institute, Washington, DC

AAR Standard M-1002, Specifications for Tank Cars, 1978, Association of American Railroads, Washington, DC

Safety Relief Device Standards: S-1.1, Cylinders for Compressed Gases; S-1.2, Cargo and Portable Tanks; and S-1.3, Compressed Gas Storage Containers. Compressed Gas Association, New York

NFPA Code Nos. 30, 59, and 59A, National Fire Protection Association, Boston, MA

Pressure-Relieving Systems for Marine Cargo Bulk Liquid Containers, 1973, National Academy of Sciences, Washington, DC

Bulletin E-2, How to Size Safety Relief Devices, Phillips Petroleum Company, Bartlesville, OK

A Study of Available Fire Test Data as Related to Tank Car Safety Device Relieving Capacity Formulas, 1971, Phillips Petroleum Company, Bartlesville, OK

M-15 PRESSURE INDICATING DEVICE

If a pressure indicating device is provided to determine the vessel pressure at or near the set pressure of the relief device, one should be selected that spans the set pressure of the relief device and is graduated with an upper limit that is neither less than 1.25 times the set pressure of the relief device nor more than twice the maximum allowable working pressure of the vessel. Additional devices may be installed if desired.

Ordering Information

HOME

The primary purpose of Crosby Pressure Relief Valves is to protect lives and property. In order to select the proper valve for your application, a Pressure Relief Valve Specification Sheet should be completed (see sample on following page). Details of the process fluid and conditions are especially important. If there is any doubt as to selection or application of valves or parts, please contact your local Crosby Sales Office or Representative for assistance. It is the responsibility of the Purchaser to determine suitability of final equipment selection.

Spare Parts

To order parts, the following information should be included:

1. Quantity
2. Part name, i.e. (nozzle seat)
3. Size, style and valve assembly number
4. Valve nameplate data including serial number
5. Original purchase order number (if assembly number has been destroyed)

Springs

To order valve springs, the required valve set pressure must also be specified in addition to the required spare parts information.

Replacement Valves

To replace a valve in service, the valve nameplate data plus previous order number should be specified. A copy of the Pressure Relief Valve Specification Sheet ensures that all pertinent data will be provided.

WARRANTY

Crosby Valve Inc., Crosby Valve and Engineering Company, Limited, Crosby Services International Ltd., Crosby Valve Pte. Ltd., Crosby Valve Ltd. or Crosby Valve Sales and Service Corporation (collectively "Crosby") hereby warrants that the goods delivered under contract will be free from defect in material and workmanship for a period of 18 months from shipment or 12 months from installation, whichever is earlier. Within this period, any of our products claimed defective may be returned to our factory after written notification to and authorization by us, and if found to be defective after examination by us, the products will be repaired or replaced free of charge, F.O.B. our factory. Such defects shall be exclusive of the effects of corrosion, erosion, normal wear or improper handling or storage.

Crosby makes no representation, warranty or guarantee, express or implied, with regard to our products except as specifically stated. When in doubt as to the proper application of any particular product, you are invited to contact your nearest CROSBY office or representative. We cannot otherwise be responsible for the selection of unsuitable equipment. Suitability of the material and product for the use contemplated by the buyer shall be the sole responsibility of the buyer.

Except as specifically set forth above and for warranty of title, CROSBY MAKES NO WARRANTY, EXPRESS OR IMPLIED, OF ANY KIND INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

In no event will CROSBY be liable for incidental or consequential damages.

WARNING

The Product is a safety related component intended for use in critical applications. The improper application, installation or maintenance of the Product or the use of parts or components not manufactured by Crosby may result in a failure of the Product. The advice of a qualified engineer should be sought prior to any use of the Product.

Any installation, maintenance, adjustment, repair or test performed on the Product must be done in accordance with the requirements of all applicable Codes and Standards.

The information, specifications and technical data (the "Specifications") contained in this document are subject to change without notice. Crosby does not warrant that the Specifications are current and assumes no responsibility for the use or misuse thereof. The Purchaser should verify that there have been no changes to the Specifications prior to use.

CROSBY

Pressure Relief Valve Specification Sheet

Sheet No. ____________
Req. No. ____________
Job No. ____________
Date ____________

Sheet ______ of ______

GENERAL	01	Tag Number	
	02	Service	
	03	Line/Vessel Number	
	04	Full/Semi Nozzle	
	05	Safety/Relief	
	06	Conventional/Bellows/Pilot Operated	
	07	Quantity	
CONNECTIONS	08	Size: Inlet/Orifice/Outlet	
	09	Flange Rating	
	10	Flange Faces	
	*11	Body/Bonnet/Top Plate	
MATERIALS	*12	Nozzle	
	*13	Disc	
	*14	Guide	
	*15	Spring	
	*16	Resilient Seals	
	17	Cap Type	
	17A	Lever	
	17B	Test Gag	
OPTIONS	18	Field Test Connection	
	19	Pilot Supply Filter	
	20	Test Button or Lever	
	21	Back Flow Preventer	
	22	Remote Pressure Pickup	
	23	Other	
BASIS	24	Code	
	25	Fire	
	26	Rupture Disc	
	27		
INPUT DATA	28	Fluid and State	
	29	Required Capacity	
	30	Molecular Weight / Specific Gravity	
	31	Set Pressure	
	31A	Operating Pressure	
	32	Operating Temperature	
	32A	Flowing Temperature	
	33	Back Pressure - S/V	
	34	-	
	35	- Total	
	36	Allowable Overpressure	
	37	Overpressure Factor	
	38	Compressibility Factor	
	39	Latent Heat of Vaporization	
	40	Ratio of Specific Heat	
	41	Operating Viscosity	
CALCULATED VALUES	42		
	43		
	44	Calculated Area	
	45	Selected Area	
	46	Orifice Designation	
	47	Manufacturer	
	48	Model Number	
COMMENTS	49		
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	52		
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* Note: For catalog materials other than Crosby standard, please consult the Factory for pressure/temperature limits.

Crosby Products

- Pressure Relief Valves for Air, Steam, Vapor and Liquid Service - Spring Loaded and Pilot Operated
- Safety Valves for Fossil and Nuclear Power Plants
- Pressure/Vacuum Relief Valves for Sanitary, Beverage, Food and Pharmaceutical Industries
- Valves for Chlorine, Bromine, Fluorine, and other Corrosive Services
- Valve Test Benches and Silencers
- Comprehensive Test Facilities for Air, Steam and Water
- Valve Field Service, Repair and Reconditioning, and Training
- Set Pressure Verification Device (SPVD) and Valve Position Indication (VPI) Systems
- QuickCross™ Change Over Valve
- BlockBody™ Valves for Pressures and Temperatures Beyond Catalog Limits

Crosby Full Spectrum Services

Valve Repair

Crosby's valve repair centers in Wrentham, Massachusetts, and in England, Scotland, Singapore, Brazil and India, are staffed by highly trained technicians to refurbish and test your valves, providing round-the-clock repair of safety valves during power plant shutdown and fast routine repair of process safety relief and relief valves. In addition, Crosby has Pressure Management Centers℠ and Designated Repair Centers worldwide - for the location of the center nearest you, consult your local Crosby representative or Crosby's Worldwide Directory.

Field Service

Crosby operates an excellent field service organization capable of adjusting, setting and maintaining Crosby valves worldwide. Service Engineers are located throughout our worldwide operations for fast response to our customers' needs. Service Engineers are factory trained and have extensive experience in servicing safety valves. It is strongly recommended that on new installations a Crosby Service Engineer be present for assembly and testing of safety valves. Field Service Engineers are coordinated through the Wrentham, Massachusetts office. Contact: Field Service Department, Service Manager, Crosby Valve Inc., 43 Kendrick Street, Wrentham, Massachusetts 02093. Tel: (508)384-3121. Fax:(508)384-8675

Parts

Crosby will help you establish the right mix of on-site spares with Crosby's own distribution and manufacturing support.

Training

Crosby offers intensive factory or on-site training seminars to improve maintenance and application skills.

Testing

Crosby has the capability to evaluate pressure relief valve operability either in the field or at various Crosby facilities. Special qualification programs may also be conducted in our laboratories.

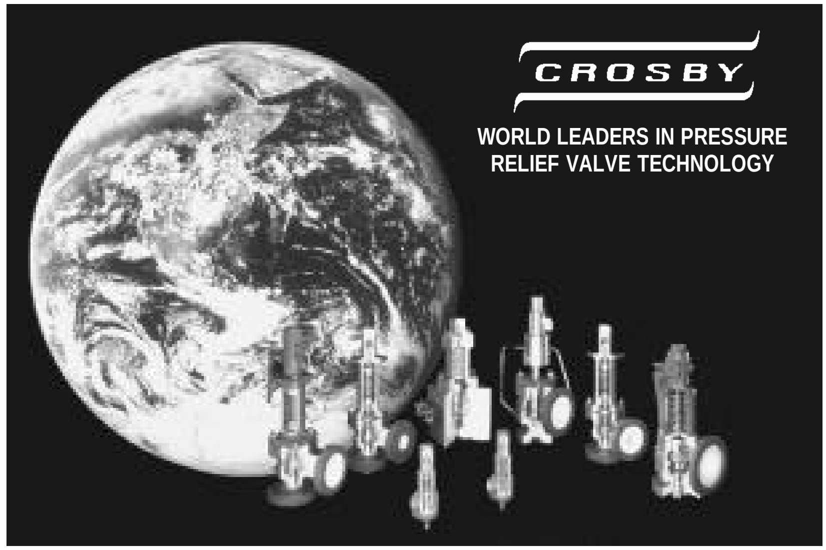
Contract Management

Crosby will combine a group of services to satisfy your special maintenance needs.

CROSBY
FULL-SPECTRUM
SERVICES

Notes:

Crosby Valve Inc. is a leading worldwide supplier of pressure relieving products and related accessories and services, focusing on the chemical, hydorcarbon processing, refining, power and transportation industries. Since 1874 Crosby has been a leader in all aspects of design, manufacture, quality assurance and customer service, earning its reputation for excellence in the field of overpressure protection.



In 1992, Crosby Valve became the first U.S. manufacturer of pressure relief valves to obtain ISO 9001 certification for the design, manufacture, repair and service of pressure relief valves. The Certificate of Approval was issued by Lloyd's Register of Quality Assurance after an intensive assessment of Crosby's operating procedures and facilities at Wrentham, Massachusetts. ISO 9002 certification was achieved by Crosby's Market Harborough, England facility in 1991 and Aberdeen, Scotland facility in 1992. These Certifications of Approval confirm Crosby's conformance to the International Standard Organization's ISO 9000 Quality Standard series requirements and equip Crosby with the verified capability to satisfy international demands for quality assurance. In 1994 Crosby further achieved Vd TÜV compliance for Styles JOS, JBS, JLT and Series 900 OMNI-TRIM safety valves designed, manufactured and tested in accordance with the requirements of AD-Merkblatt A2 and TRD-421.

Crosby Valve is pledged to ongoing consistent quality improvement. With its worldwide network of facilities, and experienced and dedicated people, Crosby is committed to continue offering the best products and services, and to maintain Crosby as the premier international pressure relief valve supplier in the industry.

5/97-HR
US 4M Printed in USA