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# AN INTRODUCTION TO RUPTURE DISK TECHNOLOGY

## CATALOG 77-1001

## SECTION A

## Introduction

Predicting the failure point of a piece of metal within extremely close tolerances—after disturbing the grain structure by forming the metal into a dome—is phenomenal. The process of transforming a piece of metal into a rupture disk is shown in Figure 1.

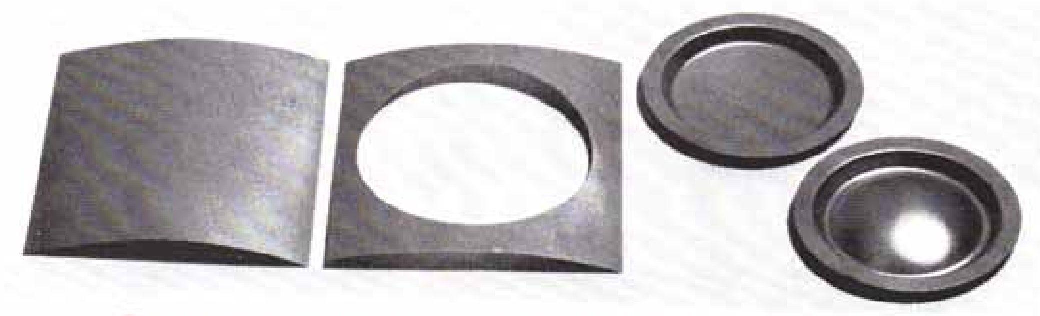


**Figure 1:** Steps in transforming a piece of metal into a rupture disk.

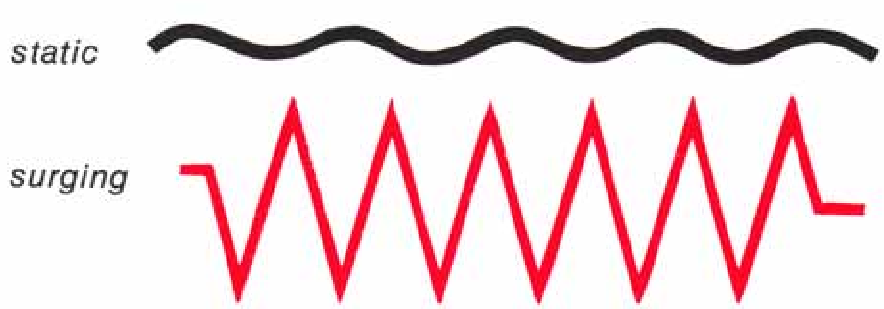
Since 1931, the requirements for rupture disks have varied from a remote pipeline installation to moon modules—and the acceleration of industrial requirements is continually advancing the technology of rupture disks.

A rupture disk is best described as a non-mechanical overpressure relief device that ruptures when its rating is attained.

The high degree of accuracy in a metal rupture disk depends on knowing the behavior of metals. Behavior relates to the performance of a metal over a wide range of temperatures, from elevated to cryogenic; its reaction to tension or compression loading; and its opening characteristics with different types of pressure media—gas and liquid.

Exposure factors and/or conditions to which the disk is subjected are vital and must be considered when a disk is evaluated for use as a designed "weak spot" in the pressure vessel or system. Factors of major importance include:

1. *Pressure margin: the difference between normal operating pressure of a system and pressure rating of disk.*
2. *Disk environment: conditions that will be encountered on both the process and atmospheric sides of disk.*
3. *Type of system pressure: static or surging.*




4. *System operating conditions: pressure (+) or vacuum (-), constant vacuum (-), alternating pressure (+) and vacuum (-).*

5. *Temperature at disk location: usually lower at disk than in liquid phase of vessel. See Figure 2. NOTE: Since disk metal strength is variable with temperature (°F), temperature is to be related with pressure rating.*

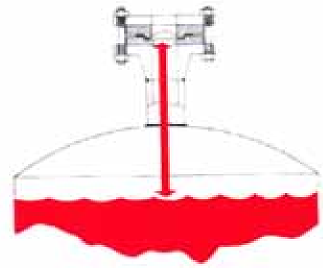


**Figure 2:** Temperature at disk is usually lower than the liquid temperature.

The sizes and types of metals used in the fabrication of rupture disks involve a broad spectrum. Sizes range from ⅛" through 44" (inside diameter). Size selection is usually related to capacity requirement. Ductile metals most commonly used are aluminum, stainless steel, inconel, monel, nickel, silver, platinum, hastelloy, tantalum and titanium. Metal thickness ranges from .001" to .065" and encompasses a pressure span from 1.5 psi to 100,000 psi. Temperature span is from -420° F. to +1000° F.

## Rupture Disks . . . their contribution to the pressure relief system

Excessive overpressure exceeds the desirable or safe operational limits of the pressure system. When this situation occurs, the relief system—consisting of valves, rupture disks, or both— will function and discharge excess pressure to a predetermined safe location.

An important first step involves the selection of relief devices with the assistance of factual data.

The rate of pressure rise is a known factor in many reaction processes and other types of pressure systems. This, together with volume, viscosity and flow characteristics of the process media, provide the data required to size and select the number, types and sizes of relief devices for the flowing media—gas, liquid or steam.

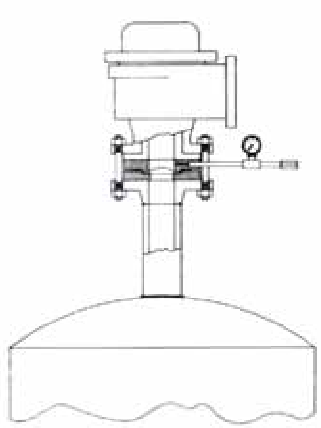


**Figure 3:** Rupture disk installed in series with relief valve.

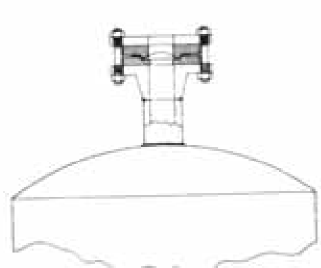


**Figure 4:** Rupture disk installed as sole relief device.

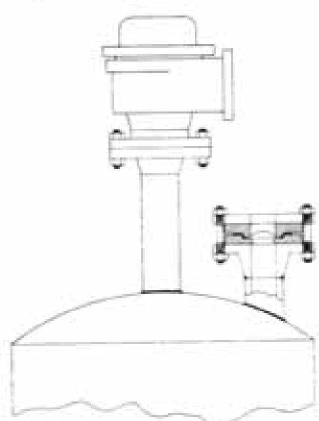


**Figure 5:** Rupture disk and relief valve installed separately.

Three arrangements involving the incorporation of rupture disks into a pressure relief system are shown in Figures 3, 4 and 5.

The in-series valve and disk combination shown in Figure 3 is usually classified as the primary relief device. Capacity is controlled by the valve—provided the design of the rupture disk assembly at valve inlet does not restrict the rate of flow. The rupture disk assembly isolates the valve from process media during normal operation of the system. The rupture disk serves as a barrier to prevent leakage. If process media has a high viscosity and its adherence to mechanical components of the valve could affect valve performance, isolating the valve becomes very important from the standpoint of safety and performance. When overpressure actuates the relief devices, the valve provides a shutoff after blowdown.

The type of product discharged should indicate whether or not the relief system will require maintenance, cleanup or other attention prior to installation of a replacement rupture disk. When this has been accomplished, the relief system should again be ready for on-stream service.

A pressure sensing element is located in the chamber between the valve and rupture disk. See Figure 3. An excess flow valve will bleed off any minute amount of leakage that might be transmitted to the cavity between the valve and disk prior to actuation of the relief system by overpressure.

A good safety practice is the use of a nipple, tee, gauge and excess flow valve. The outlet side of the excess flow valve has a threaded connection. If free venting is not desirable, a discharge line can be installed to permit dispersion of product to a safe location. After the relief system has been operated by overpressure and the relief valve reseats, the prevailing line pressure will force the ball in the excess flow valve to its seat. This permits the line pressure to be indicated on the gauge. After a replacement disk is installed, the chamber between the disk and relief valve is again void of pressure and gauge reading is at zero.

If a closed system is used with pressure gauge, tricock or other type(s) of tell-tale indicator, the relief system is then dependent upon a visual or manual checkoff in order to determine if pressure is present in the chamber between the two relief devices.

Should leakage occur in the disk assembly—attributed to corrosion of the disk metal—and the valve is holding tight, the pressure transmitted as a result of leakage into the closed chamber will cause a differential on the disk. This pressure will add strength to the disk, thereby increasing the rupture pressure of the disk.

**Example:**

The pressure setting of a valve and rupture disk is 100 psi @ 200° C. Normal system pressure is 60 psi @ 200° C. Leakage occurs through disk, pressure is equalized and there is a differential or pressure additive to the disk rating of 60 psi. The leak rate through the disk and rate of pressure rise when overpressure occurs will determine the actual rupture pressure of the disk.

If an unrestricted overpressure relief area is required, the rupture disk assembly shown in Figure 4 may be used in the pressure system. If discharge piping is used, it must be adequately braced and supported. Piping load must not be imposed on the rupture disk. Any friction loss in the vent piping must be considered when sizing the relief area for the rupture disk or relief device.

A primary relief system may consist of one or more rupture disk assemblies, rupture disk/valve combinations or valves. Capacity, pressure rating of disk or valve setting, and maximum accumulation in pressure are frequently associated with the ASME Code. These items may also be associated with other rules and regulations that govern the pressure setting of relief devices used for primary overpressure protection. Since the ASME Code wording on relief devices in a primary classification may be the criteria followed by operators, insurance companies, governing authorities and others, it is desirable to review this and bring it into proper perspective.

In this discussion we refer to Figures 6, 7 and 8.

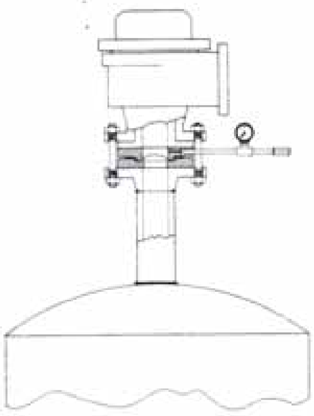


**Figure 6:** Rupture disk installed in series with relief valve.

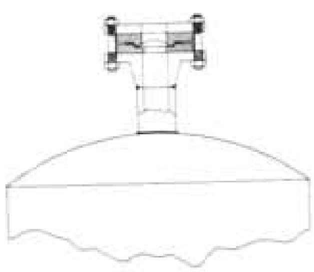


**Figure 7:** Rupture disk installed as sole relief device.

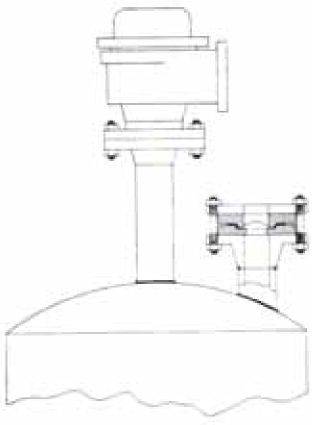


**Figure 8:** Rupture disk and relief valve installed separately.

The disk/valve in series shown in Figure 6, the rupture disk assembly shown in Figure 7 and the valve ONLY shown in Figure 8 all have a primary overpressure relief function. If these installations are to be in compliance with the ASME Code, the pressure rating of the disk and setting of the valve in Figure 6, the pressure rating of the disk in Figure 7 and the setting of the valve in Figure 8 cannot exceed the maximum allowable working pressure (MAWP) or design pressure of the vessel or system. The capacity of one or more primary relief devices should prohibit an accumulation in pressure buildup of no more than ten per cent (10%) above the MAWP. This relates to an unfired pressure system.

Should the vessel or system be in an area where an external source of heat could occur and affect the relief requirements, the use of additional primary relief device(s) is permitted. Here again, the available capacity of one or more relief devices would prohibit the accumulation of pressure buildup exceeding twenty per cent (20%) above the MAWP. The ten per cent (10%) and twenty per cent (20%) allowable pressure buildups could be accomplished with one relief device provided both percentage requirements are met.

Should there be any remote chance that a rapid increase in pressure could occur, causing the relief requirement to exceed the capacity of relief device(s) provided, consideration should be given to providing rupture disks as secondary relief device(s). See Figure 8. Such a rapid increase in pressure might be attributed to an exothermic reaction or to "unknowns." The ASME Code is not involved in this secondary relief classification. Pressure ratings of such disks can be higher than those required for the primary relief device(s). The type or design of disk, operating conditions, and test pressure of the vessel or system are factors to be evaluated when the disk performs a secondary function.

## Location of Rupture Disk in the system layout

*The rupture disk should be positioned in the pressure system so it will have an immediate sensing of an upset from the normal pressure pattern.* This means that an overpressure impulse is immediately transmitted to the disk, an action classified as a straight line function. See Figure 9. A baffle plate installed at the outlet will absorb recoil or kick-back after disk releases overpressure, thereby reducing strain on piping, joints and connections.

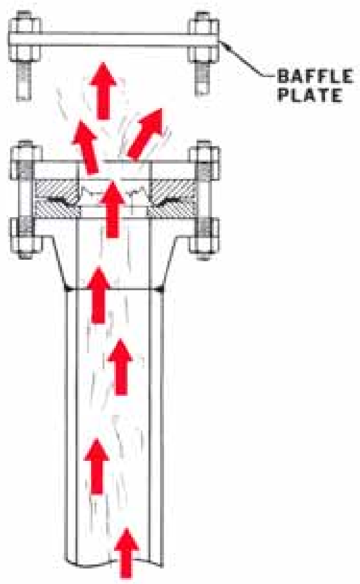



**Figure 9:** Rupture disk installed so overpressure impulse is transmitted directly to disk.

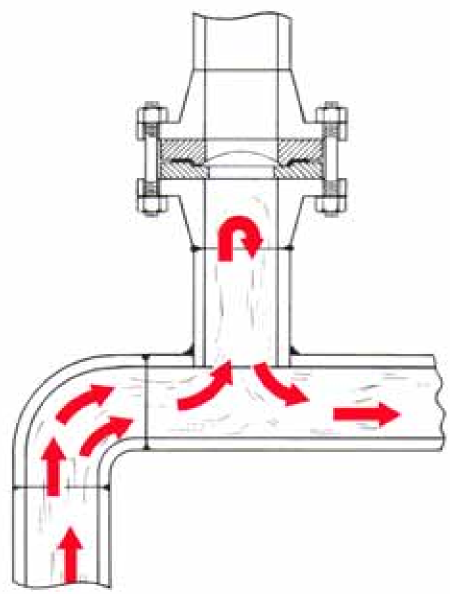


**Figure 10:** Rupture disk installed on downstream side of bend or leg.

A different approach may become necessary when the flow media is a liquid and surging is possible. Locating the disk assembly on a leg or riser as shown in Figure 10 then becomes desirable because it reduces the magnitude of the impulse or surge against the disk. A surge chamber located ahead of the disk assembly is another method used to smooth out the hydraulic stream prior to contact with the disk.

## Importance of exactness in specifications and selection of the rupture disk

We place the rupture disk in an instrument classification of "non-mechanical with a high degree of sensitivity from a functional aspect." Guidelines of the manufacturer should be adhered to when selecting disks for the pressure, temperature and media of the system. We recognize that conformity may not be possible in all areas of selection and application. When a variance or deviation to these guidelines is necessary, the result may be a reduction in the life expectancy of the disk.

A "walk" through the various designs and types of rupture disks in a photo review will explain the plus and minus factors associated with each one.

The "granddaddy" of all metal disks is the solid design shown in Figure 11. This disk design has been around for over sixty years and has maintained a position of leadership because it is available in a greater range of sizes and pressure ratings than are disks in other designs.

**Figure 11:** Solid metal rupture disk, before rupture.

A solid metal disk should retain its initial contour during exposure to the normal system pressure. An overpressure buildup to the rating of the disk will cause a thinning out of the metal. Failure will then take place at the center of the crown. When the flowing media is a gas, the opening pattern will be as shown in Figure 12.

**Figure 12:** Solid metal rupture disk, ruptured with gas as flowing media.

If media to be released is a liquid in a completely hydraulic system, a reduction in the relief area may occur. See Figure 13. This is attributed to the fast pressure drop after the capacity requirement is satisfied. Volume to be discharged may cause the disk to have a larger relief area than the one shown in Figure 13.

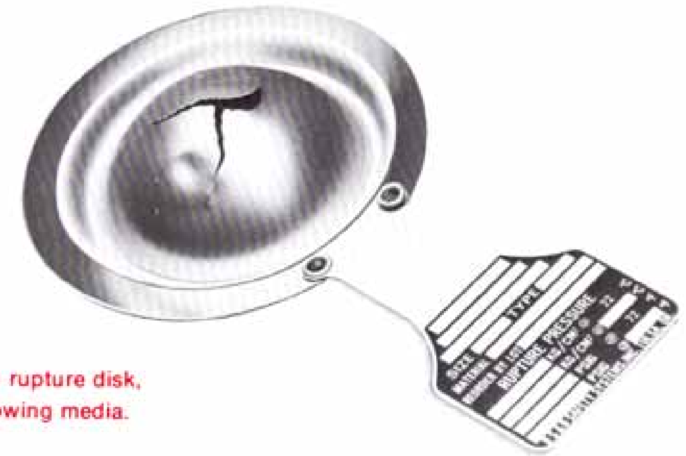


**Figure 13:** Solid metal rupture disk, ruptured with liquid as flowing media.

Facts related to the tolerance or margin in pressure required between the normal system pressure and disk rating cannot be fully explored in this discussion. A more complete review of all disks presented in this discussion is included in the specific product literature available upon request from BS&B.

A composite type disk, which consists of a slotted top section of metal and a seal membrance of metal or plastic, is shown in Figure 14. This design permits the normal system pressure to be closer to the disk rating than is desirable in some metals and pressure ranges of the solid metal disk. The slotted disk is more rugged than the solid design and less susceptible to damage in low pressures.

**Figure 14:** Composite type rupture disk, before rupture.

If the atmospheric environment contains impurities that could attack or corrode the metal top section, a seal or covering of plastic with the required corrosion-resistant properties can be affixed to the metal to function as a corrosion barrier. The plastic—usually Teflon of 5 or 10-mil thickness—may also serve as the isolater in applications where a metal disk could corrode upon exposure to the process media.

Disk designs having system pressure imposed on the concave or dished side may not be of sufficient strength to withstand deformation from the convex or atmospheric side when the vessel or system is on a vacuum cycle. To prohibit deformation of the metal when pressure is greater from the atmospheric side than it is from the process side, a structural member called a vacuum support is mated to the concave contour of the disk. Arrangement of the two components is shown in Figure 15.

**Figure 15:** Solid metal rupture disk with vacuum support.

A major advancement in the technology of rupture disks came about when the concept of disk design involved the exposure of metal to compression loading. In the solid metal and composite disk designs the process media is in contact with the concave side of the disk, putting disk metal under tension. See Figure 16. In the design putting compression loading on the disk metal, process media is in contact with the convex side of the disk. See Figure 17.

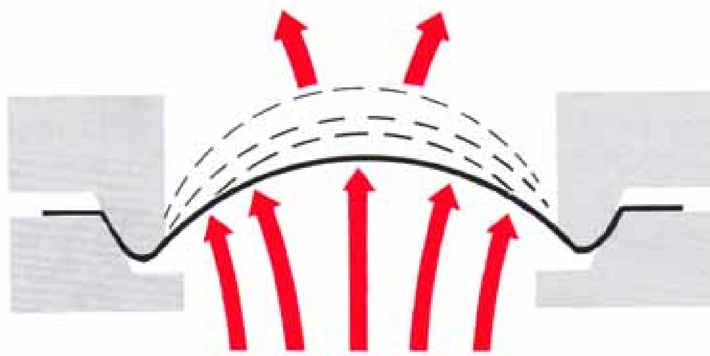


**Figure 16:** Solid metal or composite disk with pressure loading on CONCAVE side of disk, putting disk metal under tension.

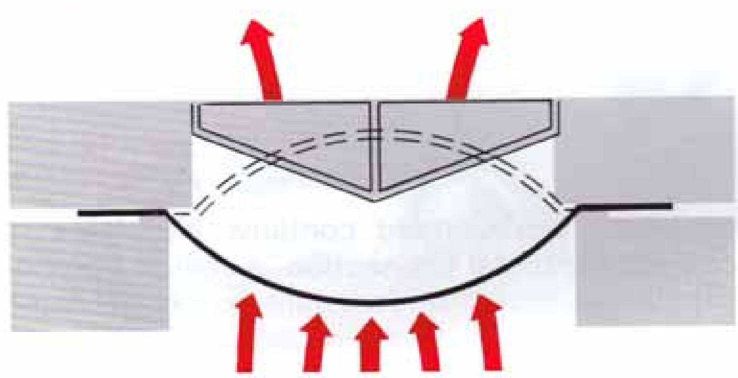


**Figure 17:** Reverse buckling disk with pressure loading on CONVEX side, putting disk metal under compression loading.

This newer design featuring compression loading permits normal system pressure to be ninety per cent of the value or pressure rating of the rupture disk. This is a drastic change in tolerance requirements in comparison with disks where pressure loading is on the concave side and disk metal is under tension.

When pressure rises to the disk rating of the disk under compression loading, the response from the metal is instantaneous. An immediate reversal takes place. There is a rapid snap through. A set of blades located in the outlet holder—highly honed to sharpness—slices the disk metal into four sections of equal size. Shearing or fragmentation of the metal does not occur.

In this design, the disk is sufficiently rigid to withstand back pressure imposed on its concave or atmospheric surface. Since the disk is void of any change to its structure when the system is in a vacuum cycle, pressure from the atmosphere being higher than that within the vessel or system, the need for a support member is eliminated. Figures 18 and 19 show the reverse buckling disk before and after rupture.

**Figure 18:** Reverse buckling disk before rupture with knife blades in outlet flange.

**Figure 19:** Reverse buckling disk after rupture with knife blades in outlet flange.


**Figure 20:** Scored type reverse buckling rupture disk, before rupture.


**Figure 21:** Scored type reverse buckling rupture disk, after rupture.

Further research on disks under compression involves the design shown in Figures 20 and 21. Scoring the metal eliminates the need for knife blades. From the functional aspect, this disk duplicates the design where the blade structure is used to cut and open the disk. Figures 22 and 23 show the complete assembly with unruptured and ruptured disk.


**Figure 22:** Complete rupture disk assembly with scored reverse buckling rupture disk, before rupture.


**Figure 23:** Complete rupture disk assembly with scored reverse buckling rupture disk, after rupture.

## Rupture disk capabilities extend far beyond their function as an overpressure relief device.

A pair of rupture disks can perform as a quick opening valve. See Figure 24. Pressure is applied to the chamber between two disks at one-half the system pressure. When pressure in the chamber is reduced to a pre-established value, an immediate response occurs from the disks. High pressure gas applied to the inlet side of the first disk will activate both disks in an extremely fast reaction rate. Hot gas flowing downstream has exposure to equipment, metals and components being evaluated at high temperature levels. This test simulates exposure conditions (friction) on space vehicles reentering the atmosphere. Figure 25 shows high pressure disks used in a quick opening valve assembly—before and after rupture.

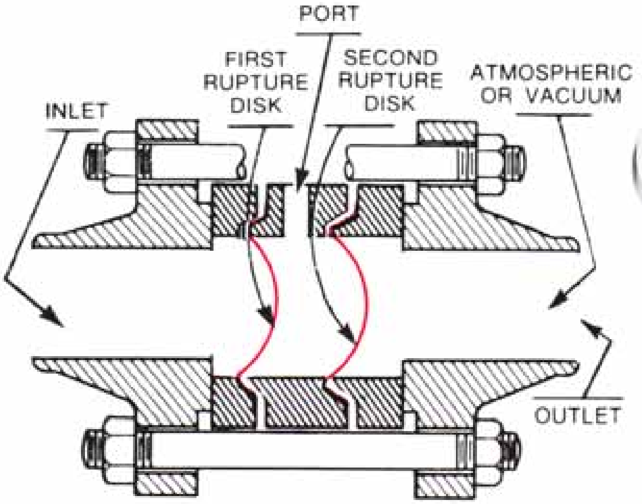



**Figure 24:** Two rupture disks used as quick opening valve.

**Figure 25:** High pressure disks used in quick opening valve assembly, before and after rupture.

Systems may require the pressure relief device to be actuated from either side. Figure 26 shows how a double "D" disk design can fulfill such a requirement.

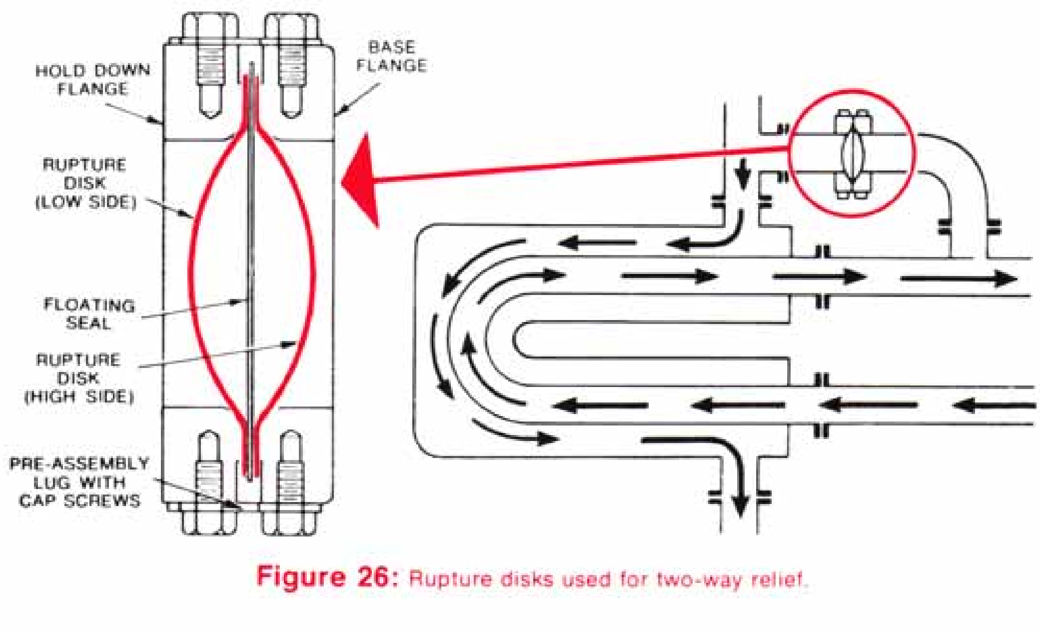



**Figure 26:** Rupture disks used for two-way relief.

Rupture disks are frequently used in high pressure applications. Earlier in this presentation we stated the maximum level was 100,000 psi. The piece of plate shown in Figure 27 has a thickness of 1/4" and when contoured or dished has a pressure rating of 60,000 psi. Accuracy is within a very close tolerance of the predetermined pressure rating.

**Figure 27:** 1/4" plate from which rupture disk with 60,000 psi pressure rating will be formed.

Many designs and types of fittings are used as holders for rupture disks and are fabricated from metal(s) compatible with the process media and atmospheric environment. Typical designs are shown in Figures 28, 29, 30 and 31.

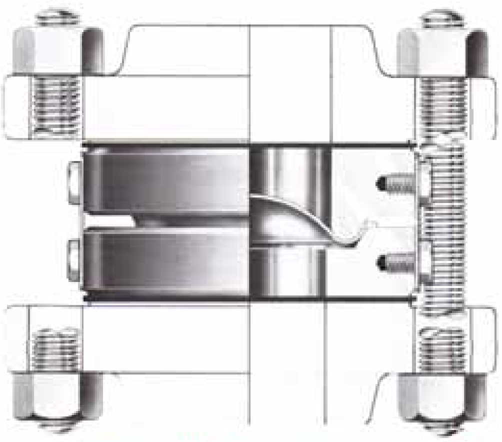


**Figure 28:** Bolted type fitting with "QUICKSERT" preassembly.

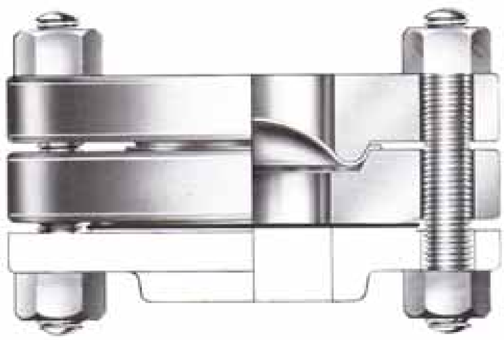


**Figure 29:** Bolted type fitting with flat faced flanges.

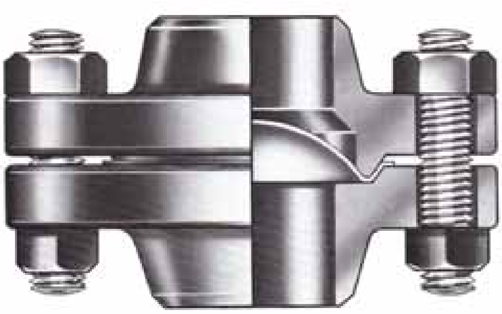


**Figure 30:** Bolted type fitting with welding hub flanges.

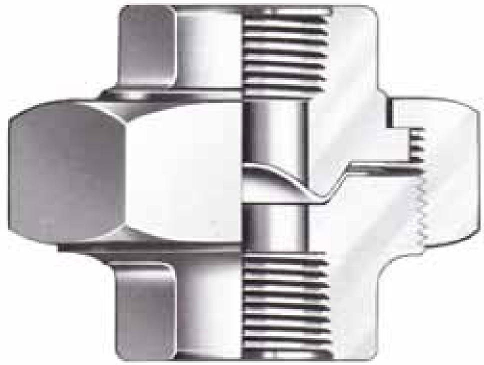


**Figure 31:** Union type fitting.

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