Education Institute for

Equipment & Process Design

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Rupture Disk

Rupture Disk

Rupture disk devices are non-reclosing PRDs used to protect vessels, piping, and other pressure-containing components from excessive pressure and/or vacuum. Rupture disks are used in single and multiple relief device installations. They are also used as redundant PRDs. With no moving parts, rupture disks are simple, reliable, and faster acting than other PRDs. Rupture disks react quickly enough to relieve some types of pressure spikes. Because of their lightweight, rupture disks can be made from high alloy and corrosion resistant materials that are not practical in PRVs.

Rupture disks can be specified for systems with vapor (gas) or liquid pressure-relief requirements. Also, rupture disk designs are available for highly viscous fluids. The use of rupture disk devices in liquid service should be carefully evaluated to ensure that the design of the disk is suitable for liquid service. The user should consult the manufacturer for information regarding liquid service applications.

Rupture disk devices often have different opening characteristics as a function of the fluid state against the disk at the time of bursting. To account for the resulting differences in the resistance to flow,certified *K*r values are stated in terms of *K*rg (gas), *K*rl (liquid), or *K*rgl (gas or liquid). In application, use the following guidelines.

1.When the fluid initiating rupture (in contact with rupture disk) is compressible, rupture disks rated with *K*rg or *K*rgl should be used.

2.When the fluid initiating rupture (in contact with rupture disk) is incompressible, rupture disks rated with *K*rl or *K*rgl should be used.

The rupture disk is also a temperature-sensitive device. Burst pressures can vary significantly with the temperature of the rupture disk device. This temperature may be different from the normal fluid operating temperature. As the temperature at the disk increases, the burst pressure usually decreases.

Since the effect of temperature depends on the rupture disk design and material, the manufacturer should be consulted for specific applications. For these reasons, the rupture disk shall be specified at the pressure and temperature the disk is expected to burst.

Application of Rupture Disks

Rupture disks can be used in any application requiring overpressure protection where a non-reclosing device is suitable. This includes single, multiple, and fire applications as specified in UG-134 of the ASME *Code*.

Rupture Disk Device at the Inlet of a Pressure-relief Valve

Rupture disks are used upstream of PRVs to seal the system to meet emissions standards, to provide corrosion protection for the valve, and to reduce valve maintenance.

When a rupture disk device is installed at the inlet of a PRV, the devices are considered to be close coupled, and the specified burst pressure and set pressure should be the same nominal value. When installed in liquid service, it is especially important for the disk and valve to be close coupled to reduce shock loading on the valve

The space between the rupture disk and the PRV shall have a free vent, pressure gauge, Try-cock, or suitable telltale indicator as required in UG-127 of the ASME *Code.* Users are warned that a rupture disk will not burst in tolerance if backpressure builds up in a non-vented space between the disk and the PRV, which will occur should leakage develop in the rupture disk due to corrosion or other cause.

Rupture Disk Device at the Outlet of a Pressure-relief Valve

A rupture disk device may be installed on the outlet of a PRV to protect the valve from atmospheric or downstream fluids. Consideration should be given to the valve design so that it will open at its proper pressure setting regardless of any backpressure that may accumulate between the valve and rupture disk.

Types of Rupture Disks

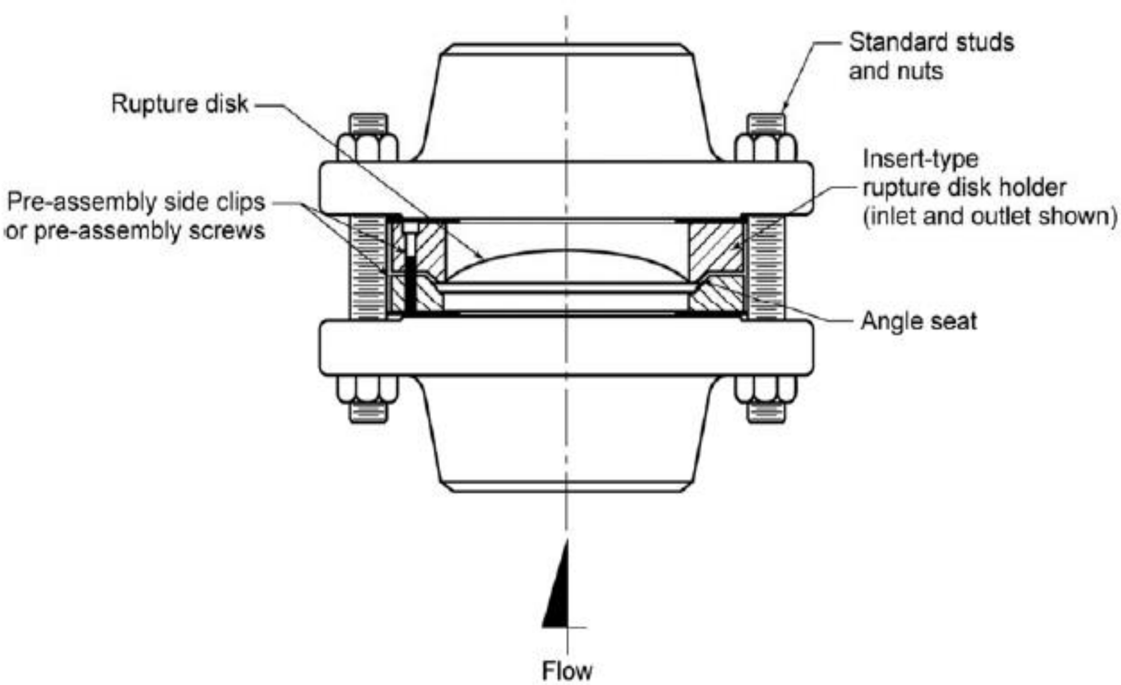
There are three major rupture disk types

1. Forward-acting, tension-loaded
2. Reverse-acting, compression-loaded;
3. Graphite, shear-loaded.

Forward-acting Solid Metal Rupture Disks

A forward-acting rupture disk is a formed (domed), solid metal disk designed to burst at a rated pressure applied to the concave side (see Figure 21). This rupture disk typically has an angular seat design and provides a satisfactory service life when operating pressures are up to 70 % of the marked burst pressure of the disk (70 % operating ratio). Consult the manufacturer for the actual recommended operating ratio for the specific disk under consideration. If vacuum or backpressure conditions are present, the disk can be furnished with a support to prevent reverse flexing. These disks have a random opening pattern and are considered fragmenting designs that are not suitable for installation upstream of a PRV

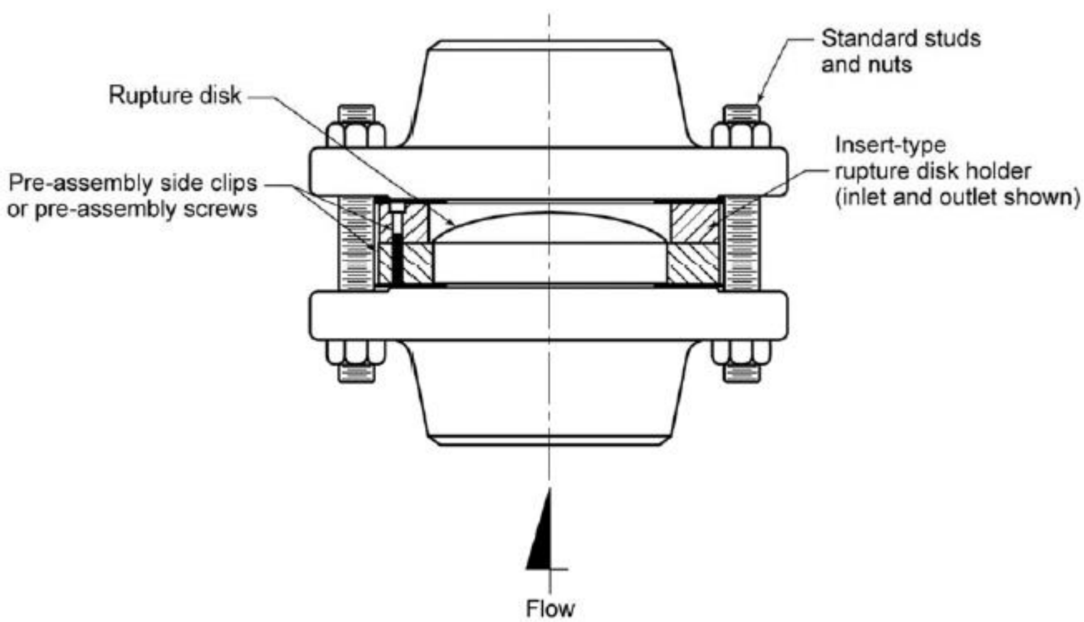
Correct Installation



Forward-acting Scored Rupture Disks

The scored forward-acting rupture disk is a formed (domed) disk designed to burst along scored lines at a rated pressure applied to the concave side (see Figure 22). Some designs provide satisfactory service life when operating pressures are up to 85 % to 90 % of the marked burst pressure of the disk (85 % to 90 % operating ratio). Most designs withstand vacuum conditions without a vacuum support. If backpressure conditions are present, the disk can be furnished with a support to prevent reverse flexing. Because the score lines control the opening pattern, this type of disk can be manufactured to be nonfragmenting and is acceptable for installation upstream of a PRV. The scored, forward-acting rupture disk is manufactured from thicker material than nonscored designs with the same burst pressure, and it provides additional resistance to mechanical damage.

Correct Installation



A forward-acting composite rupture disk

A forward-acting composite rupture disk is a flat or domed multipiece construction disk (see Figure 23). The domed composite rupture disk is designed to burst at a rated pressure applied to the concave side. The flat composite rupture disk may be designed to burst at a rated pressure in either or both directions. Some designs are nonfragmenting and acceptable for use upstream of a PRV. A flat composite rupture disk is available for the protection of low-pressure vessels or the isolation of equipment such as exhaust headers or the outlet side of a PRV. This disk usually comes complete with gaskets and is designed to be installed between companion flanges rather than within a specific rupture disk holder. Flat composite rupture disks generally provide satisfactory service life when operating pressures are 50 % or less of the marked burst pressure (50 % operating ratio). The slits and tabs in the top section provide a predetermined opening pattern for the rupture disk. If vacuum or backpressure conditions are present, composite disks can be furnished with a support to prevent reverse flexing (see Figure 23). A domed, composite rupture disk generally provides satisfactory service life when the operating pressure is 80 % or less of the marked burst pressure (80 % operating ratio).

A flat composite rupture disk is available for the protection of low-pressure vessels or the isolation of equipment such as exhaust headers or the outlet side of a PRV. This disk usually comes complete with gaskets and is designed to be installed between companion flanges rather than within a specific rupture disk holder. Flat composite rupture disks generally provide satisfactory service life when operating pressures are 50 % or less of the marked burst pressure (50 % operating ratio).

Reverse-acting Rupture Disks

A reverse-acting rupture disk typically is a formed (domed) solid metal disk designed to reverse and burst at a rated pressure applied on the convex side. Reverse-acting rupture disks are designed to open by such methods as shear knife blades, tooth rings, or scored lines Reverse-acting rupture disks may be manufactured as non-fragmenting and are suitable for installation upstream of PRVs. These disks provide satisfactory service life when operating pressures are 90 % or less of marked burst pressure (90 % operating ratio). Some types of reverse-buckling disks are designed to be exposed to pressures up to 95 % of the marked burst pressure. Consult the manufacturer for the actual recommended operating ratio for the specific disk under consideration. Because a reverse acting rupture disk is operated with pressure applied on the convex side, thicker disk materials may be used, thereby lessening the effects of corrosion, eliminating the need for vacuum support, and providing longer service life under pressure/vacuum cycling conditions and pressure fluctuations

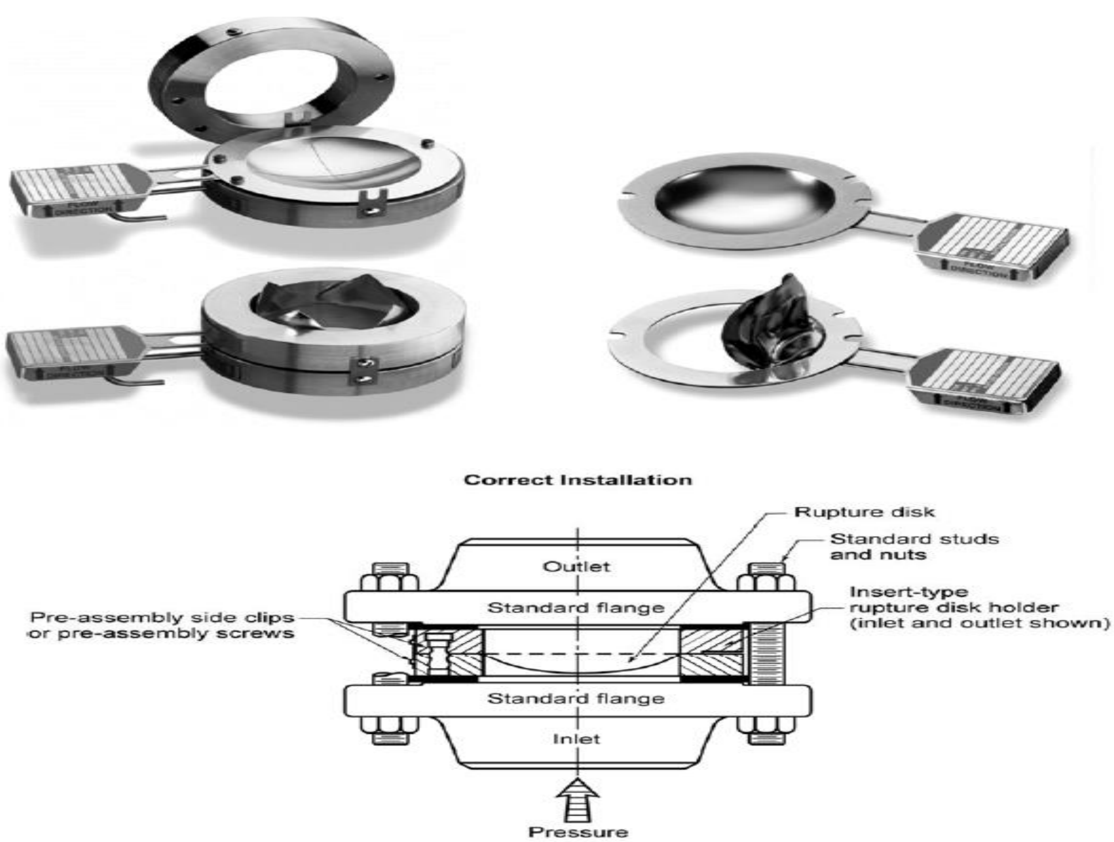


Figure 25—Reverse-acting Scored Rupture Disk

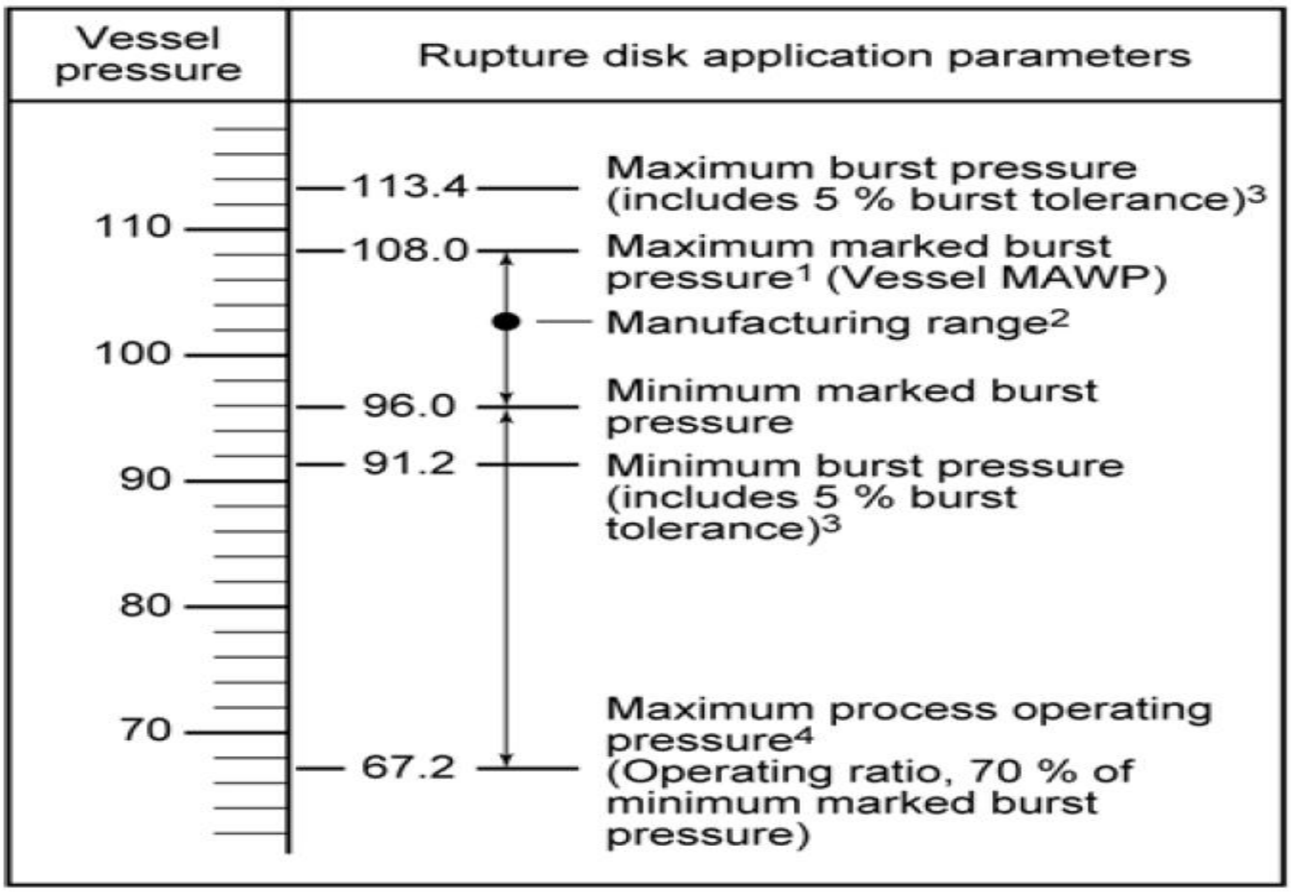
Graphite Rupture Disks

Graphite rupture disks are typically machined from a bar of fine graphite that has been impregnated with a sealing compound to seal the porosity of the graphite matrix (see Figure 26). The disk operates on a pressure differential across the center diaphragm or web portion of the disk. Graphite rupture disks provide a satisfactory service life when operating pressures are up to 80 % of the marked burst pressure (80 % operating ratio) and can be used in both liquid and vapor service.

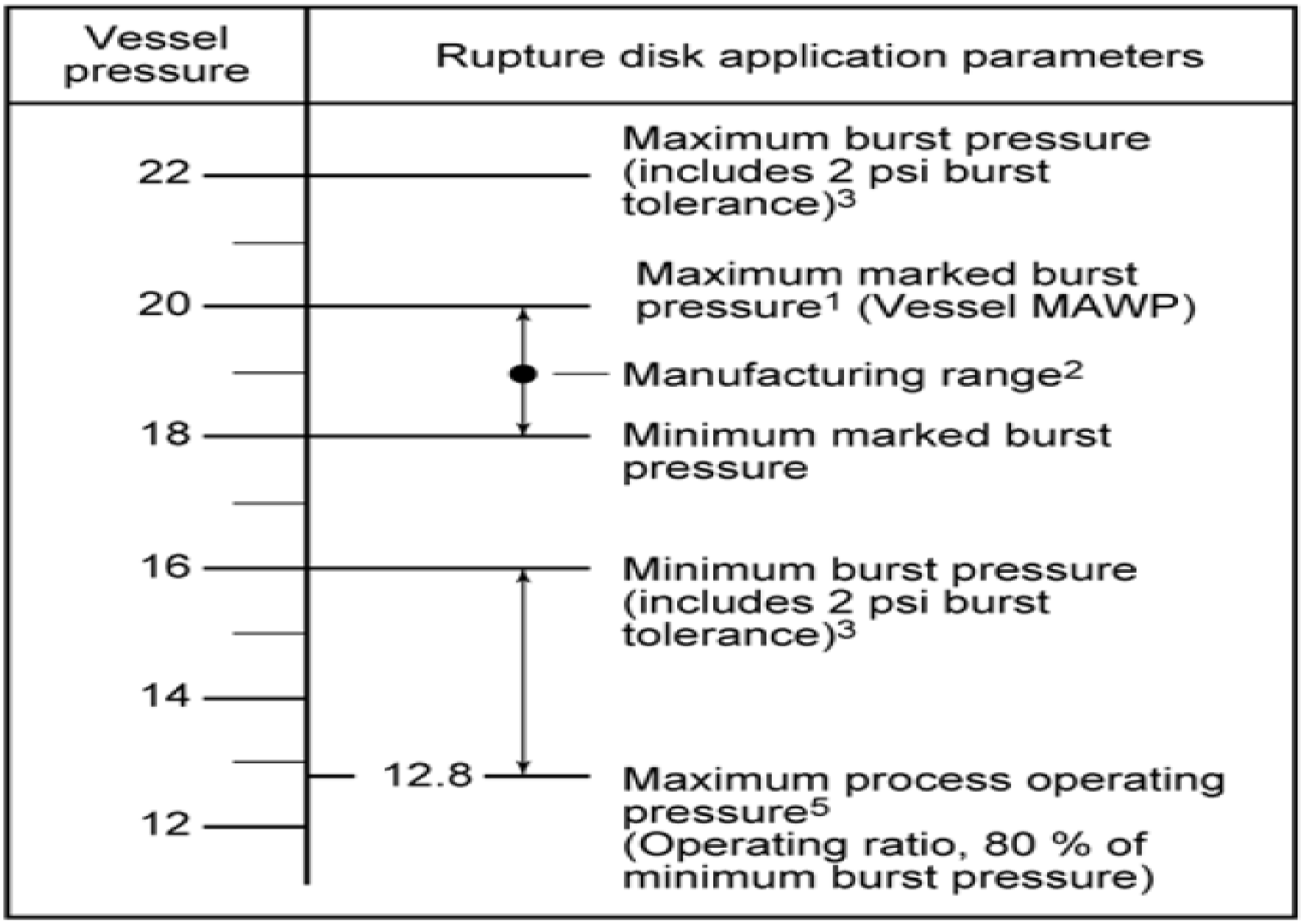
If vacuum or backpressure conditions are present, the disk can be furnished with a support to prevent reverse flexing. These disks have a random opening pattern and are considered fragmenting designs that are not suitable for installation upstream of a PRV. A metallic ring called armoring is often added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

Rupture Disk Selection

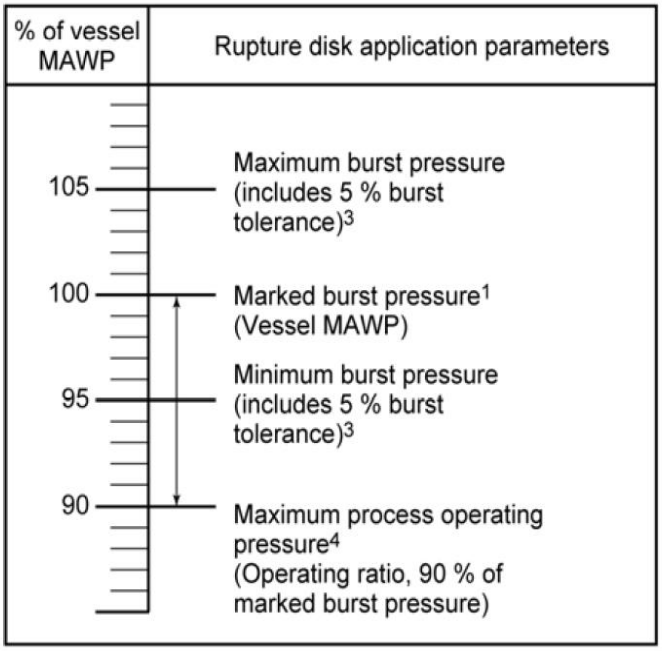
the user is cautioned to make sure that the upper limit of the manufacturing design range does not exceed the MAWP of the equipment being protected.



A. Example of a rupture disk with a specified burst pressure of 100 psig, manufacturing range of +8/-4 %, burst tolerance of ±5 %, and a 70 % operating ratio.



C. Example of a rupture disk with a specified burst pressure of 20 psig, manufacturing range of +0/-10 %, burst tolerance of ± 2 psig, and an 80 % operating ratio.



B. Example of a rupture disk with a specified burst pressure of 100 psig, zero manufacturing range, burst tolerance of ±5 %, and a 90 % operating ratio.

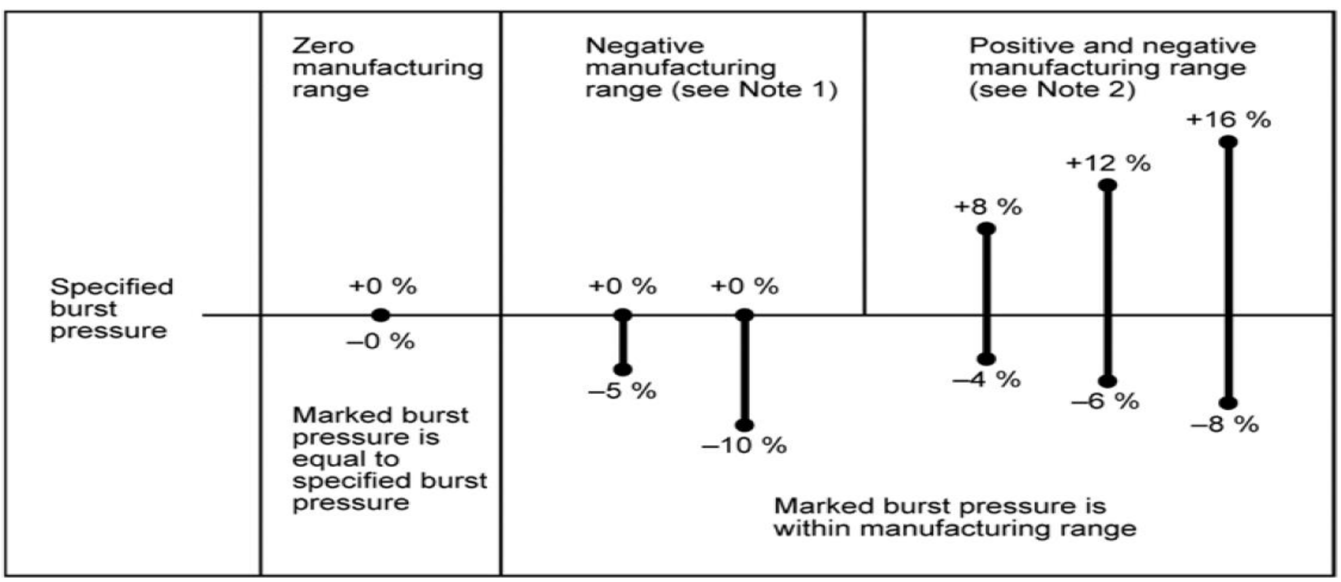
NOTE 1 See Figure 19 for limits on marked burst pressure.

NOTE 2 Marked burst pressure may be any pressure within the manufacturing range, see Figure 28.

NOTE 3 For marked burst pressures above 40 psig, the burst tolerance is ±5 %. For marked burst pressures at 40 psig and below, the burst tolerance is ±2 psi.

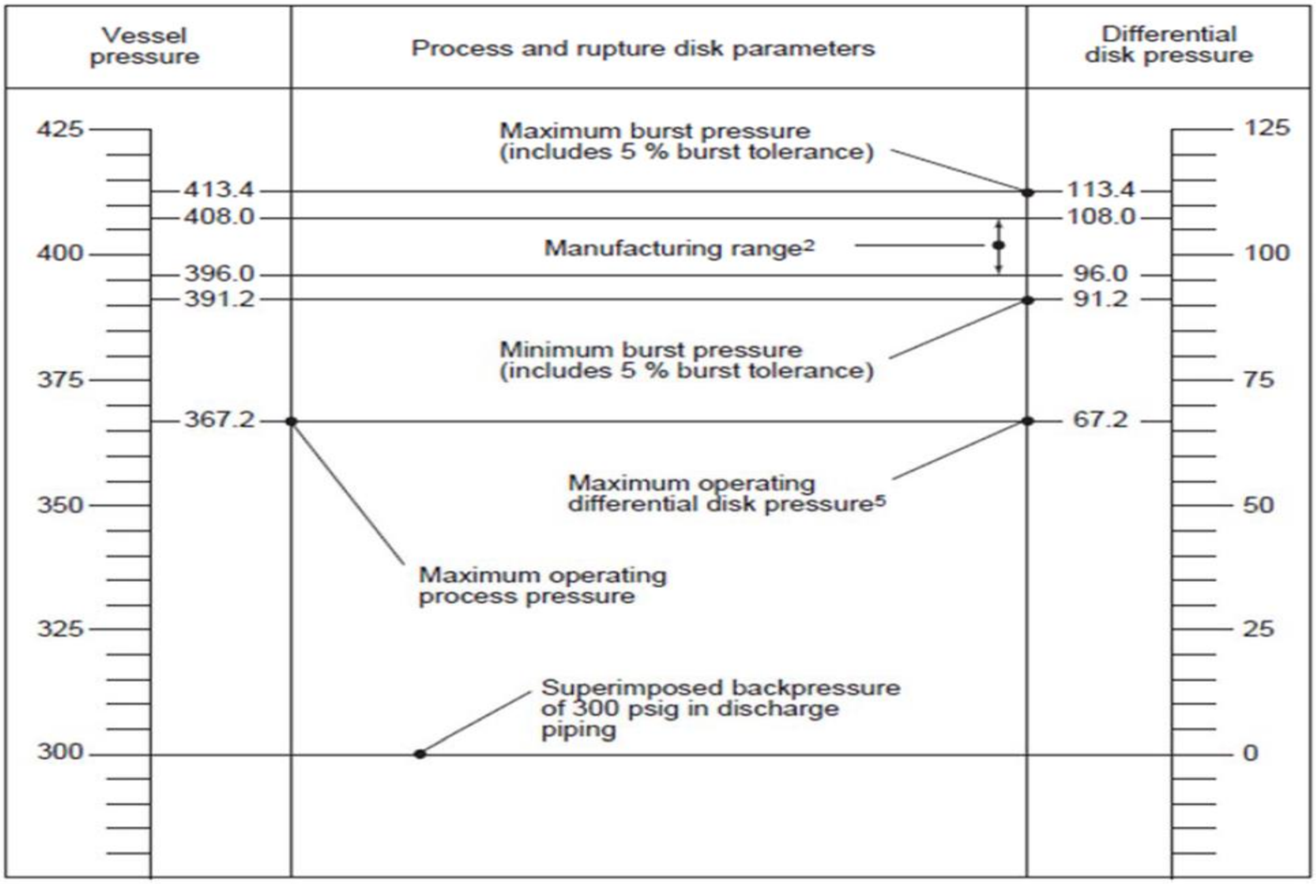
NOTE 4 For marked burst pressures above 40 psig, the maximum process operating pressure is calculated by multiplying the minimum marked burst pressure by the operating ratio.

NOTE 5 For marked burst pressures at 40 psig and below, the maximum process operating pressure is calculated by subtracting the burst tolerance from the minimum marked burst pressure, then multiplying the difference by the operating ratio.



NOTE 1 The marked burst pressure will not exceed the specified burst pressure.

NOTE 2 Positive manufacturing range may result in a marked burst pressure exceeding the specified burst pressure.


Vessel pressure
Process and rupture disk parameters
Differential disk pressure
425
400
375
350
325
300
413.4
408.0
396.0
391.2
367.2
Maximum burst pressure (includes 5 % burst tolerance)
Manufacturing range2
Minimum burst pressure (includes 5 % burst tolerance)
Maximum operating differential disk pressure5
Maximum operating process pressure
Superimposed backpressure of 300 psig in discharge piping
113.4
108.0
96.0
91.2
67.2
125
100
75
50
25
0

Selection Procedure

NOTE 1 This figure is an example of a rupture disk with a:

a) specified burst pressure of 100 psi;
b) manufacturing range of +8/−4 %;
c) burst pressure tolerance of ± 5 %;
d) operating ratio of 70 % (0.7 × 96.0 psi = 67.2 psi);
e) superimposed backpressure of 300 psig;
f) vessel MAWP equal to or greater than 408 psig.

NOTE 2 The disk used in this figure is intended to be identical with the disk in Figure 27A. The disks are interchangeable. The disk in this figure (and in Figure 27A) may be marked anywhere in the manufacturing range, from 96 psi to 108 psi.

NOTE 3 The superimposed backpressure in this example is larger than normally encountered to amplify the difference between vessel pressure and differential pressure across the rupture disk.

NOTE 4 The differential disk pressure is equal to the vessel pressure minus the superimposed backpressure.

NOTE 5 The user is cautioned not to exceed the maximum operating differential disk pressure throughout the process cycle, including start-up and shutdown.

Sizing Procedure

a) Step 1—Determine required information:

— MAWP = 100 psig;

— P_1 = relieving pressure = 110 % = 124.7 psia;

— T_1 = relieving temperature = 200 °F + 460 °F = 660 °R;

— Z_1 = relieving compressibility = 1.0;

— M = molecular weight = 20;

— P_2 = backpressure = 14.7 psia.

b) Step 2—Determine overall piping resistance factor, K, from Table E.1.

c) Step 3—Determine Y_{sonic} and $\frac{dP_{sonic}}{P_1}$ based on total system K.

The charts on page A-22 of Crane 410 [16] can be used to obtain Y_{sonic} and $\frac{dP_{sonic}}{P_1}$. From the chart where, k (C_p/C_v) = 1.4, the following values are determined:

$$Y_{sonic} = 0.653$$

$$\frac{dP_{sonic}}{P_1} = 0.70$$

As an alternate to the chart method, curve fit equations for obtaining Y_{sonic} and $\frac{dP_{sonic}}{P_1}$ have been provided as Equation (E.1) through Equation (E.4).

For $\frac{dP_{sonic}}{P_1}$:

If $1.2 < K \leq 10$, then $\frac{dP_{sonic}}{P_1} = 0.1107\ln(K) + 0.5352$ (E.1)

If $10 < K \leq 100$, then $\frac{dP_{sonic}}{P_1} = 0.0609\ln(K) + 0.6513$ (E.2)

For Y_{sonic}:

If $1.2 < K \leq 20$, then $Y_{sonic} = 0.0434\ln(K) + 0.5889$ (E.3)

If $20 < K \leq 100$, then $Y_{sonic} = 0.710$ (E.4)

Based on $K = 4.04$:

$$\frac{dP_{sonic}}{P_1} = 0.69$$

$$Y_{sonic} = 0.65$$

d) Step 4—Compare $\frac{dP_{sonic}}{P_1}$ to $\frac{dP_{actual}}{P_1}$.

$$\frac{dP_{actual}}{P_1} = \frac{(124.7 - 14.7)}{124.7} = 0.88$$

Since $\frac{dP_{sonic}}{P_1} < \frac{dP_{actual}}{P_1}$, the flow will be sonic (critical).

Use Y_{sonic} and $\frac{dP_{sonic}}{P_1}$ and skip to Step 6 (if subsonic, proceed to Step 5).

e) Step 5—Evaluate Y_{actual} (subsonic cases only).

Using the Crane 410—Chart A-22 Method to obtain Y_{actual}:

1) at $\frac{dP_{actual}}{P_1}$ and K determine Y_{actual} from Chart A-22;

2) use $\frac{dP_{actual}}{P_1}$ and Y_{actual} in Step 6.

Using the Curve Fit Method for obtaining Y_{actual}:

1) calculate Y_{actual} from the Equation (E.5):

$$Y_{actual} = 1 - \frac{(1 - Y_{sonic})}{dP_{sonic}/P_1}\left(\frac{dP_{actual}}{P_1}\right) \quad (E.5)$$

2) use $\frac{dP_{actual}}{P_1}$ and Y_{actual} in Step 6 in place of $\frac{dP_{sonic}}{P_1}$ and Y_{sonic}.

f) Step 6—Calculate capacity based on Crane 410—Equation (3-20):

$$W = 0.9\left(1891 \times Y \times d^2 \sqrt{\frac{dP}{K \times V_1}}\right) \quad (E.6)$$

g) Step 7—Using the Chart Method values and Equation (E.6):

1) $Y = Y_{sonic} = 0.65$;

2) d = pipe ID (in.) = 3.068 in.;

3) $dP = \left(\frac{dP_{sonic}}{P_1}\right)(P_1) = 87.3$ psi;

4) K = overall resistance = 4.04;

5) V_1 = vapor specific volume = 2.84 ft³/lb (obtained using ideal gas law and compressibility).

6) $W = 0.9\left(1891 \times 0.65 \times 3.068^2 \sqrt{\frac{87.3}{4.04 \times 2.84}}\right) = 28{,}700$ lb/h.

h) Step 8—Using the Curve Fit Method values from Figure E.2 and Equation (E.6):

1) $Y = Y_{sonic} = 0.65$;

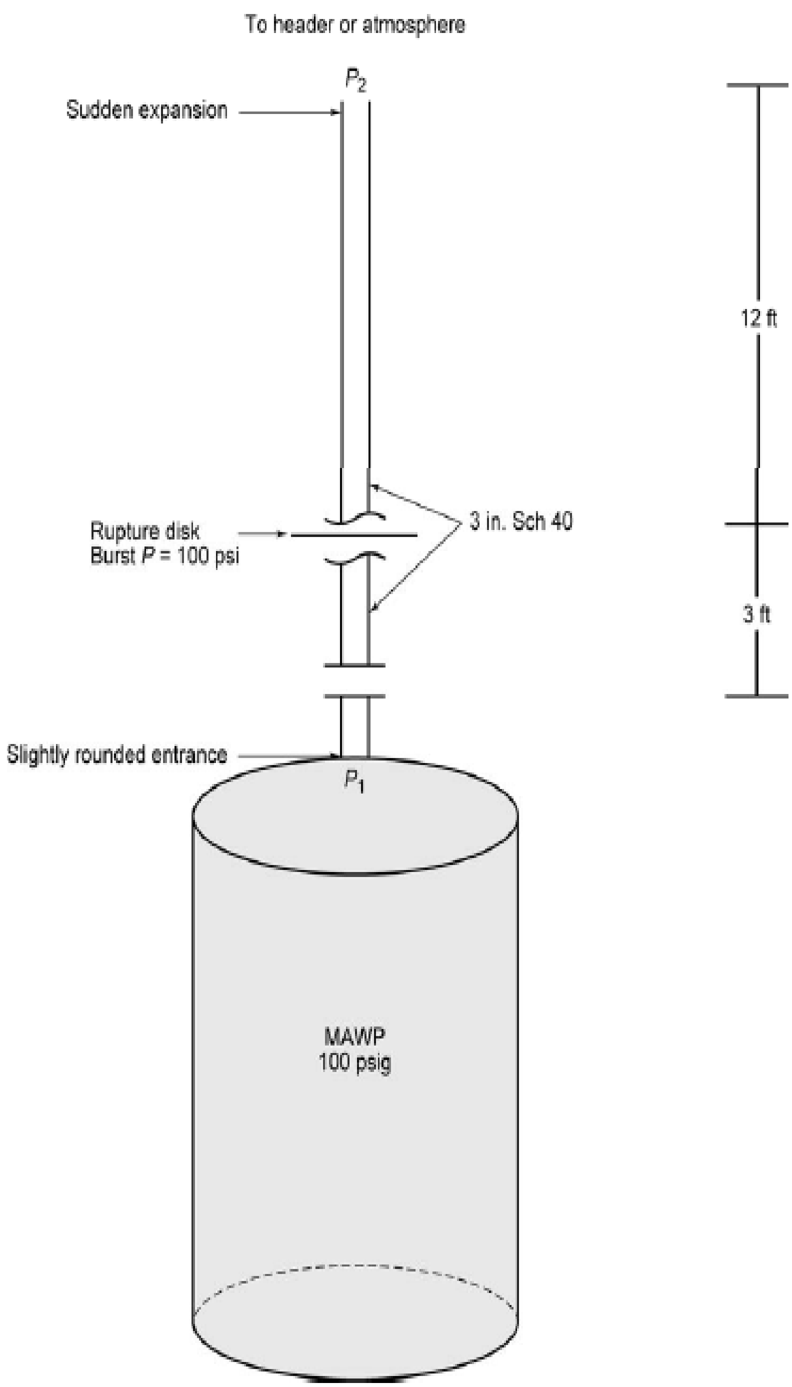
2) d = Pipe ID (in.) = 3.068 in.;

3) $dP = (dP_{sonic}/P_1)(P_1) = 86.0$ psi;

4) K = Overall resistance = 4.04;

5) V_1 = vapor specific volume = 2.84 ft³/lb (obtained using ideal gas law and compressibility).

6) $W = 0.9\left(1891 \times 0.65 \times 3.068^2 \sqrt{\dfrac{86.0}{4.04 \times 2.84}}\right) = 28{,}508$ lb/h.


To header or atmosphere
P_2
Sudden expansion
12 ft
Rupture disk
Burst P = 100 psi
3 in. Sch 40
3 ft
Slightly rounded entrance
P_1
MAWP
100 psig