Rupture Disks for Process Engineers
(From the Process Design Engineer's Perspective)
Part 3: How Do We Set the Burst Pressure

Part 1 of this series on rupture disks for Process Engineers covered *why* you use a rupture disk and *when* you might want to use this device. Part 2 discussed *how to size the rupture disk*. In this part, I will cover how to set the burst pressure. Subsequent parts will include temperature and backpressure affects, the Relief Valve/Rupture Disk combination, how to specify the rupture disk and some discussion on the type of rupture disks you can purchase. Before I begin, let me point out that most of what is included in this series of articles can be found in API RP520[1] and API RP521[2], and ASME Section VIII, Division 1[3]. Much of what is found in these documents can also be found in vendor literature.

Problem

1. What is the maximum allowable specified burst pressure?
2. What should the expected stamped (rated) burst pressure of the rupture disk be?
3. At what pressure(s) can we expect the delivered rupture disk to *actually* burst at?
4. What is the maximum allowable operating pressure in the vessel?

All these questions must be considered in order to properly set the burst pressure of a rupture disk.

What is the maximum allowable specified burst pressure?

Burst Pressure

What do we mean by burst pressure? This is the pressure at which the rupture disk will open or burst. It is analogous to the set pressure of a relief valve and is specified by the process engineer.

Design Pressure

To find the maximum allowable specified burst pressure, the process engineer first needs to define a vessel design pressure. The design pressure is an arbitrary value above the vessel maximum operating pressure. One guideline used by many process design engineers is to increase the maximum operating pressure by 25 psig or 10% whichever is greater. For example, if the maximum operating pressure is 70 psig, then 25 psig should be added to arrive at the design pressure since 10% is only 7 psig. The design pressure would then be set at a nice round 100 psig. Other criteria to determine design pressure may be used but I recommend that the margins never be less than what I described above (the reason will become apparent later).

Maximum Allowable Working Pressure (MAWP)

The next step is to determine the Maximum Allowable Working Pressure (MAWP) of the vessel. A vessel specification stating design pressure, the coincident design temperature and other parameters is sent to the manufacturer. The manufacturer performs a series of calculations utilizing these parameters, amongst others, to determine material thickness for use in vessel fabrication. A standard material thickness (greater than or equal to what was calculated) is chosen. With the actual material thickness known, the true MAWP is calculated. The vessel design documents are then stamped (certified) at this pressure in accordance with code. However, for one reason or another, the MAWP calculation is not always done and the vendor will just stamp the vessel at the specified design pressure.

The maximum allowable specified burst pressure

So, what is the *maximum* allowable specified burst pressure? Theoretically it is the MAWP. However, rupture disks are typically specified during basic engineering, which is performed way before the vessel is mechanically designed. This, combine with the fact that the true MAWP may never really be known (as mentioned above), the maximum allowable specified burst pressure will more typically be the vessel's design pressure.

Note *if* the rupture disk is to be used in conjunction with another relief device to fulfill the total required relieving capacity, the maximum allowable specified burst pressure *could* be 5% or even 10% greater than the design pressure (or MAWP). See ASME Section VIII, Division 1 paragraphs UG-125 and UG-134.

Also note that the *specified* burst pressure can be lower than the maximum allowable. Indeed, this is often the case if the rupture disk is used to protect reactor vessels against over pressure due to run-away reactions.

What should the expected stamped (rated) burst pressure of the rupture disk be?

What do we mean by "stamped or rated" burst pressure? Per code, the rupture disk vendor must provide a tag containing, amongst other things, the rated or what is typically called the stamped burst pressure. This is a guaranteed value so the user knows (within an allowable tolerance; more on this later) the exact bursting pressure of the rupture disk. Also this stamped burst pressure must never exceed the design pressure (or MAWP); except for the special case mentioned above.

So, the rupture disk vendor stamps the disk with the burst pressure specified by the process engineer? Not necessarily!

Manufacturing Range (MR)

A Rupture disk is made out of a sheet of material, e.g. stainless steel, high alloys, ceramics, etc. Like all things in this world, this sheet of material is not perfect. To quantify the inaccuracies in sheet material *thickness*, the vendor uses what is called the Manufacturing Range (MR).

The MR is expressed as ±% of the *specified* burst pressure. It determines the highest pressure above the *specified* burst pressure or the lowest pressure below the *specified* burst pressure that the disk can be stamped at. This is shown graphically in Figure 1.

Figure 1

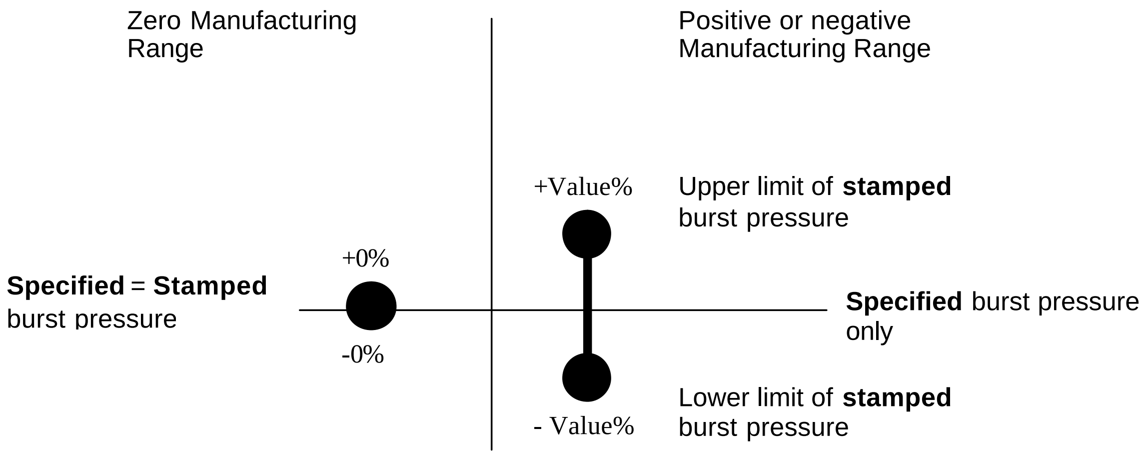


Figure 1 shows the two extremes, a MR of ± 0% and a MR of ± some value%. Note that other combinations may be used such as + 0% and – some value% or – 0% and + some value%.

Let's look at an example. If the specified burst pressure is 100 psig with a MR of ± 0%, the stamped or rated burst pressure *will be* 100 psig (see Figure 2A). However, if the MR is +5% and – 10%, the disk can be delivered with a stamped burst pressure of 105 psig, 90 psig or anywhere in between (see Figure 2B). That's right, if the MR is anything but ± 0%, the user won't know the stamped burst pressure until the rupture disk is ready for shipment!

Figure 2A

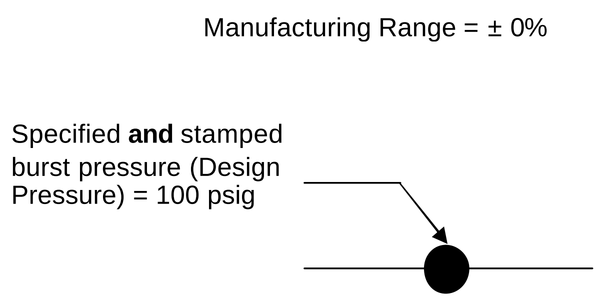
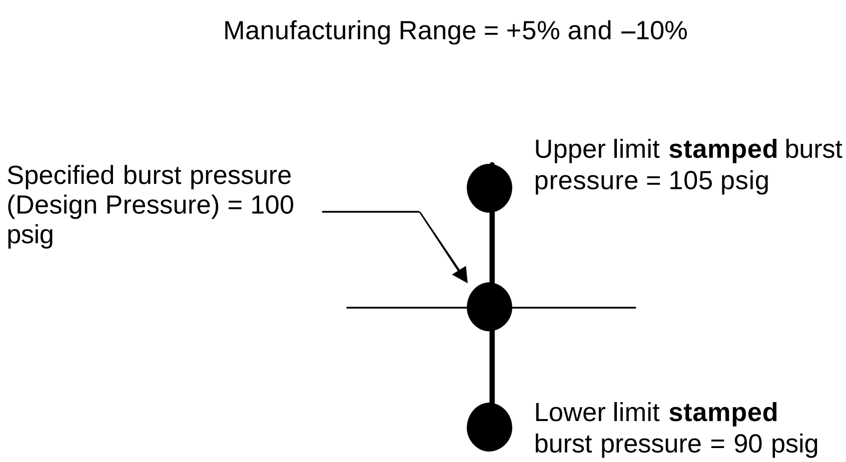


Figure 2B



Do you see anything wrong with this rupture disk as specified?

Remember, the stamped or rated burst pressure must never exceed the vessel's design pressure or MAWP (assumes a single device, no special cases). Since the specified burst pressure *is* the design pressure, this particular rupture disk is not acceptable because the delivered rupture disk may have a stamped burst pressure of 105 psig or 5 psig greater than design!

How can we avoid this problem? There are a number of ways.

The process engineer specifies the Manufacturing Range, not the manufacturer. You can ask for any range within the capability of fabrication including ± 0%. Considering the potential problems, why specify anything other than ± 0%? Cost. A MR of +5% and –10% can save as much as 40% off the cost of a similar rupture disk with a MR of ± 0%. Even if you demand +0% (which you should), you can still realize some cost savings if a stamped burst pressure lower than specified is acceptable (not always a good idea as will be discussed later). Note that code only affects the upper stamped limit, not the lower.

Another way to avoid the potential violation of code and still get a cheaper rupture disk is to specify a burst pressure that will be lower than the vessel design pressure. Thus, when the MR is added the stamped burst pressure will not exceed the design pressure. The maximum allowable specified burst pressure could be determined in the following manner:

$$\mathbf{P_{spec\_max} = (DP) - (+MR/100) \times (P_{spec\_max})}$$

Where DP = Design pressure

So:

$$\mathbf{P_{spec\_max} = (DP) / [1+(+MR)/100]}$$

Since DP = 100 psig and the upper value of MR = +5%,

$$P_{spec\_max} = 100 /[1+(+5/100)] = 100/(1+0.05) = 100/1.05 = 95.2 \text{ psig}$$

This rupture disk would be specified with a burst pressure no higher than 95.2 psig while the stamped burst pressure may be as high as 100 psig.

Note that the standard Manufacturing Range for most manufacturers is ± 0% and this is reflected in the base price you will be quoted.

<u>At what pressure(s) can we expect the delivered rupture disk to *actually* burst at?</u>

Trick question? The answer should be the stamped burst pressure. But again the world isn't perfect.

Burst Tolerance

The Manufacturing Range is applied to the *specified* burst pressure but there is yet another unknown due to imperfections in the material used to fabricate the rupture disk. This is accounted for in the *burst tolerance*. Burst tolerance is applied to the *stamped* burst pressure and is set by code. For stamped burst pressures of 40 psig and lower, the burst tolerance is ± 2 psi. For stamped burst pressures above 40 psig, the burst tolerance is ± 5%.

Let's look at the examples again but apply the burst tolerance. For this discussion, I'm changing the specified burst pressure for the case of a rupture disk with a Manufacturing Range of +5% and –10% to 95.2 psig (see Figure 3B) so the stamped burst pressure can't exceed code.

Figure 3A

Manufacturing Range = ± 0%
Design Pressure = 100 psig

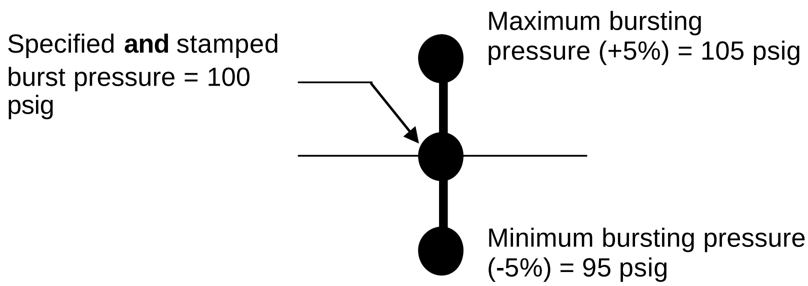
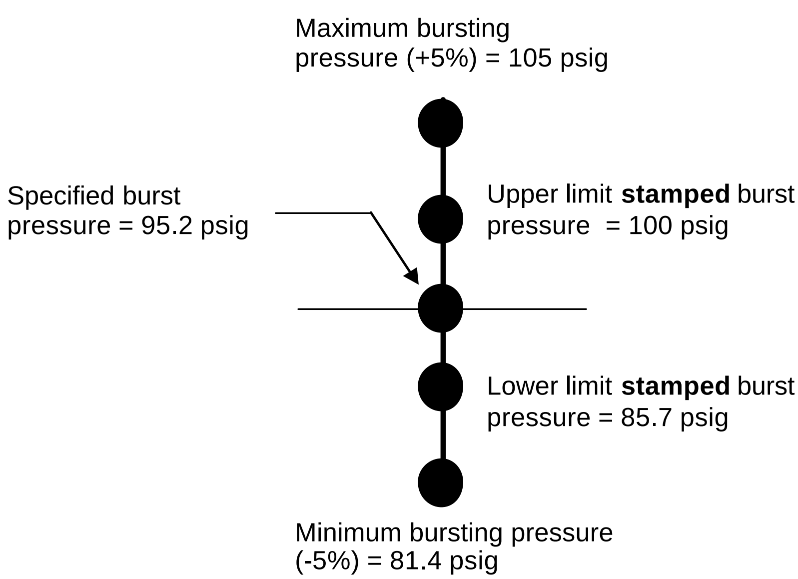


Figure 3B

Manufacturing Range = +5% and –10%
Design Pressure = 100 psig



The important thing to notice is that in both Figures 3A and 3B, the upper limit of the *stamped* burst pressure is equal to the design pressure but the maximum bursting pressure is 105 psig, or 5 psig *over* design pressure. Unlike the *stamped* burst pressure, which by code cannot exceed the design pressure (or MAWP), the maximum expected burst pressure *can if it is caused by the burst tolerance*.

What is the maximum allowable operating pressure in the vessel?

Up to now, the discussions focused on the upper limit of the stamped burst pressure because this is governed by code. But the lower limit is extremely important to consider as well because of the possible affect it has on the maximum allowable operating pressure in the vessel.

Operating Ratio (OR)

The operating ratio is defined as the ratio of the maximum operating pressure to the *lowest stamped* burst pressure. The OR is used to protect against premature bursting of the rupture disk. If the operating pressure is too close to the lowest stamped burst pressure, or the system pressure cycles (pressure rises and falls during operation) too close to the stamped burst pressure, the material will fatigue and can eventually loose its structural integrity. This is a classic reason for premature bursting of a rupture disk.

The manufacturer publishes the Operating Ratio for every rupture disk model they sell. For example, the Continental Disc Corporation's ULTRX rupture disk has an operating ratio of 90%[4]. This means the system pressure can operate to within 90% of the lowest stamped burst pressure without the fear of premature bursting. However, it's always best to operate as far away from the lowest stamped burst pressure as you can to avoid material fatigue.

From Figure 3B above, the lower limit or minimum stamped burst pressure is 85.7 psig:

$$\mathbf{P_{stamped\_min} = (P_{spec}) - ABS\ [(-MR/100)] \times (P_{spec})}$$

Where 'ABS' stands for Absolute Value.

So:

$$\mathbf{P_{stamped\_min} = (P_{spec}) \times \{1 - ABS\ [(-MR/100)]\}}$$

Since P_{spec} = 95.2 psig and the lower value of MR = -10%,

$$P_{stamped\_min} = 95.2 \times \{1 - ABS\ [(-10/100)]\} = 95.2 \times \{1 - ABS\ [(-0.1)]\} = 95.2 \times (1-0.1) = 95.2 \times 0.9 = 85.7 \text{ psig}$$

Therefore based on an OR of 90%, the maximum allowable operating pressure should not be greater than:

$P_{op} = P_{stamped\_min} \times OR = 85.7 \times 0.9 = 77$ psig.

Since our discussions have been based on a maximum operating pressure of 70 psig, this rupture disk is acceptable. But note that this 10% cushion exists only because of the design pressure margin used (25 psig). Had the margin been less, say only 10%, the rupture disk we would want to use would be unacceptable.

How to avoid this problem?

- Set the design pressure appropriately
- Choose a rupture disk with a MR of ± 0%
- Choose a rupture disk with a OR of 90% (they don't really go much higher)

There is one more point to consider. Although I have never seen any mention of checking the maximum allowable operating pressure against the minimum *expected* burst pressure (arrived at by taking into account the burst tolerance), I think it only makes good engineering sense to do so. After all, if the disk can burst at this lower pressure, one certainly does not want to operate too close to it!

Getting back to our question, what is the maximum allowable operating pressure in the vessel? In this case, it is 77 psig.

Summary

- What is the maximum allowable specified burst pressure?
  - Design Pressure or MAWP if the rupture disk is the only relief device

  OR

  - For special cases, 105% (or even 110%) of design pressure or MAWP if the rupture disk is a secondary device

- What should be the expected stamped (rated) burst pressure of the rupture disk?
  - As specified by the process engineer for a Manufacturing Range of ± 0%

  OR

  - As specified by the process engineer but *could be* adjusted per the Manufacturing Range if other than ± 0%

- At what pressure(s) can we expect the delivered rupture disk to *actually* burst at?
  - ± 5% of stamped burst pressure for stamped pressures greater than 40 psig

  OR

  - ± 2 psi for stamped pressures 40 psig and lower

- What is the maximum allowable operating pressure in the vessel?
  - Specified by the process engineer based on operating need but must be checked against the Operating Ratio of the rupture disk
  - I strongly suggest you also check against the minimum expected burst pressure as well.

- Manufacturing Range is applied to the *specified* burst pressure
- Burst Tolerance is applied to the *stamped* burst pressure
- Set the design pressure appropriately
- Choose a rupture disk with a MR of ± 0%
- Choose a rupture disk with a OR of 90%

WARNING!

Don't go running out and specifying a rupture disk just quite yet! We still need to consider the affects of temperature and backpressure and the relief valve-rupture disk combination.

References:

1. **API** (www.api.org) **Recommended Practice 520**, "Sizing, Selection, and Installation of Pressure-Relieving Device in Refineries, Part 1-Sizing and Selection", 7th Edition (January 2000)
2. **API** (www.api.org) **Recommended Practice 521**, "Guide for Pressure-Relieving and Depressuring Systems", 4th Edition (March 1997)
3. **ASME** (www.asme.org) "Boiler and Pressure Vessel Code, Section VIII, Division 1" (1998)
4. **Continental Disc Corporation**, ULTRX® Catalogue 3-2210-3