Rupture Disks for Process Engineers
(From the Process Design Engineer's Perspective)
Part 4: Temperature and Back 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*. Part 3 discussed *how to set* the burst pressure. In this part, I will discuss how temperature and backpressure affects the rupture disk design. Subsequent parts will include 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.

Temperature and Backpressure Considerations

In Part 3, I discussed how to set the burst pressure of the rupture disk. However, the discussion is not complete without considering the affects of temperature and backpressure on the bursting pressure.

Temperature

The rupture disk manufacturer uses both the specified burst pressure *and* the specified temperature when designing and stamping the disk. (In this instance, I use the term design to mean arriving at the correct burst pressure, not mechanical integrity). However, it is more than likely that the temperature of the rupture disk will not be at the specified temperature when it is called into service. Why is this so?

The temperature most commonly specified is that of the relieving fluid coincident with the burst pressure, i.e. relieving conditions. Sounds logical, but remember that the disk is continuously exposed to the process stream for hours, days, weeks or even months before it may ever be needed. Or, the disk may be exposed to ambient conditions.

Therefore, expect the disk temperature to be approximately equal to its environment during normal operation of the system. When a process upset occurs, system pressure rises until it reaches relief (burst). The temperature of the relieving fluid also rises per thermodynamics. However, the time interval between normal system operation and relief is usually so small that the rupture disk's temperature hardly has time to come to equilibrium with the higher process fluid temperature. Therefore the disk can actually be colder than it's specified temperature. The affects?

In general, burst pressure varies inversely with temperature. For some rupture disks, the burst pressure can be as much as 15 psi greater than stamped if the actual temperature is 100^oF *lower* than specified, e.g. a disk specified with a burst pressure of 350 psig at a temperature of 400^oF will actually burst at 365 psig if its temperature is only 300^oF[4]. This doesn't sound like a big difference but if 350 psig were the design pressure (or MAWP) of the vessel, then a burst pressure of 365 psig would be in violation of code (LAW). The opposite is also true. A disk at a temperature hotter than specified when called into service will burst at a pressure lower than stamped. Although this is considered to be the more conservative approach because code can't be violated and there is no risk of catastrophic failure of the vessel, specifying too low of a temperature can lead to the not so desirable action of premature bursting.

The bottom line is that the specified burst temperature must be carefully considered. Specify the lowest temperature at the time the disk is expected to burst. Consider that this might be the normal process operating temperature or even ambient rather than the calculated relieving temperature.

Note that different materials and different types of rupture disks have different sensitivities to temperature. This is an excellent topic of discussion for your rupture disk manufacturer!

Backpressure

A rupture disk is actually a differential pressure device where the specified burst pressure is equal to the difference between the desired upstream pressure (vessel) at the time of rupture disk burst and the downstream pressure (backpressure):

$P_{burst} = P_{vessel} - P_{backpressure}$

Or alternately the desired upstream pressure (vessel) at the time of rupture disk burst is equal to the sum of the specified burst pressure and the downstream pressure (backpressure):

$P_{vessel} = P_{burst} + P_{backpressure}$

Either way, it is apparent that the vessel pressure at the time the rupture disk bursts (commonly called the relief pressure) is directly dependent on backpressure.

When discussing relief systems, three types of backpressure are considered, these being constant, built-up and superimposed.

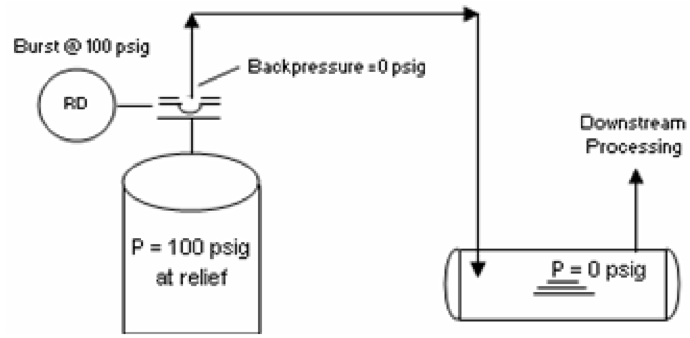

Figure 1A: Single Vessel, Single Rupture Disk Protection, Expected Constant Back pressure = 0 psig

Figure 1A shows a system comprised of a single vessel protected by a single rupture disk with a specified burst pressure of 100 psig. The relief pipe discharges a few inches below the liquid surface in a knockout drum, which is held at a constant 0-psig pressure. Therefore, the rupture disk sees a *constant* (fixed) backpressure of 0 psig. If the vessel were to go into relief, this disk will burst at 100 psig and the vessel relief pressure will be 100 psig (100 + 0 = 100).

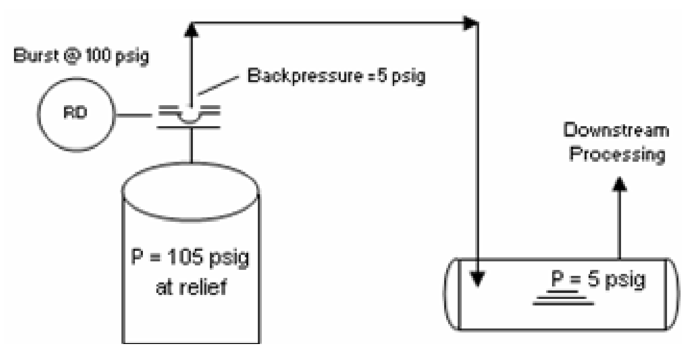

Figure 1B: Single Vessel, Single Rupture Disk Protection, Actual Constant Back pressure > Expected

Figure 1B is the same system however for some reason the pressure in the knockout drum is to be maintained at 5 psig instead of 0 psig. The *constant* (fixed) backpressure against the rupture disk is now 5 psig. If the vessel were to go into relief, the rupture disk would still burst at 100 psig but the vessel relief pressure would now be 105 psig (100 + 5 = 105) rather than the 100 psig expected. This situation could result in a violation of code[3].

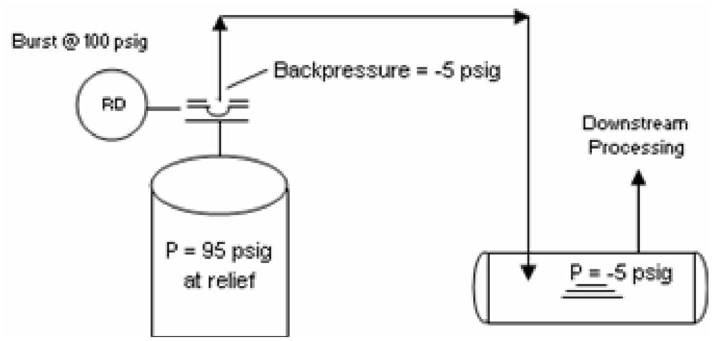

Figure 1C: Single Vessel, Single Rupture Disk Protection, Actual Constant Back pressure < Expected

Figure 1C is again the system however for some reason the pressure in the knockout drum is to be maintained at -5 psig instead of 0 psig. The *constant* (fixed) backpressure against the rupture disk is now -5 psig. If the vessel were to go into relief, the rupture disk would still burst at 100 psig but the vessel relief pressure would now be only 95 psig (100 + (- 5) = 95) rather than the 100 psig expected. There is no particular safety concern here because the vessel can't over pressure. However, the Operating Ratio is affected, which can result in a very premature bursting of the rupture disk.

For the vessel relief pressure to be specified correctly, the rupture disk vendor must be told the constant back pressure so that the rupture disk can be designed accordingly. And, if you truly want the vessel relief pressure to be at a specific value then the "constant" backpressure given to the vendor must be maintained at all times.

The key point is that during design, be aware of the constant backpressure and ensure that the vessel relief pressure will not violate code or affect normal operation.

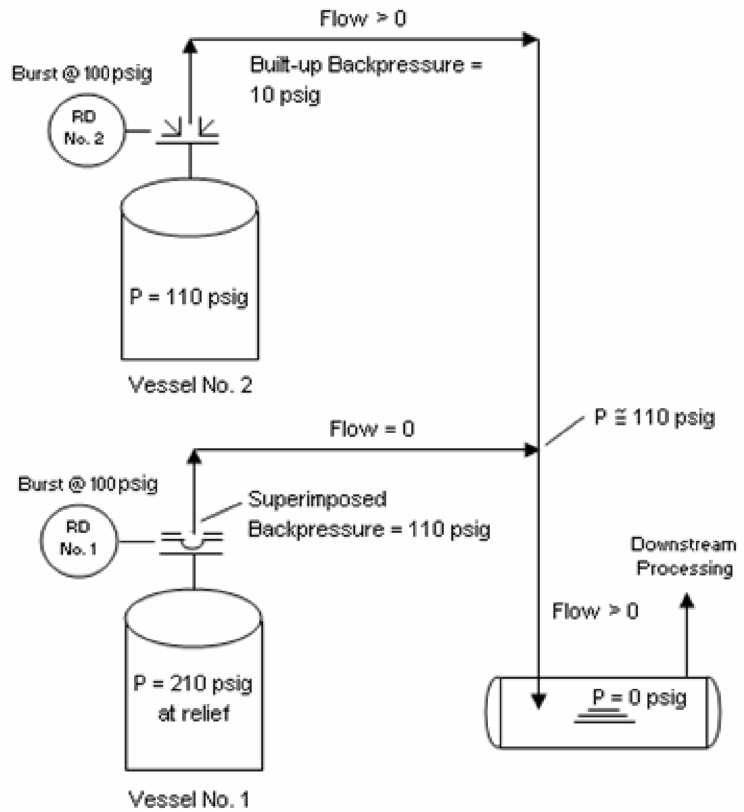

Figure 2A: Two Vessel System – Common Discharge
Built-up and Superimposed Back pressures

Now let's look at the system shown in Figure 2A. A second vessel with a single rupture disk also specified to burst at 100 psig is added in close proximity to the first vessel. The relief piping from the two vessels is tied into a common header before discharging into a knockout drum in the same manner as before, the tie-in occurs near the vessels. At the exact moment Vessel No. 2 goes into relief and its rupture disk bursts, Vessel No. 2's relief pressure is 100 psig due to the constant 0-psig backpressure as described above. After the disk bursts, flow is established causing pressure to build up in the piping system (*built-up* backpressure). The amount of built-up backpressure is dependent on the system pressure drop and possibly even the phenomenon of choked flow. For the purpose of this discussion, assume total built-up backpressure is 10 psig after rupture disk No. 2 bursts and the pressure in Vessel No. 2 is about 110 psig. Because of the proximity of the two discharge pipes and vessels, the pressure near vessel No. 1 will also be at about 110 psig. This pressure, which is exerted or *imposed* onto rupture disk No. 1, is called the *superimposed backpressure* with respect to rupture disk No. 1. If vessel No. 1 were to go into relief shortly afterwards, then for rupture disk No. 1 to burst, the pressure in vessel No. 1 would have to build to about 210 psig (100 + 110)! This is clearly unacceptable!!

One solution to this potentially catastrophic condition is to separate the two relief lines so that one cannot directly affect the other (see Figure 2B below). Of course the answer may very well be that this is not an application for rupture disks but for relief valves! The key point is, avoid combining multiple rupture disk piping into a common relief header.

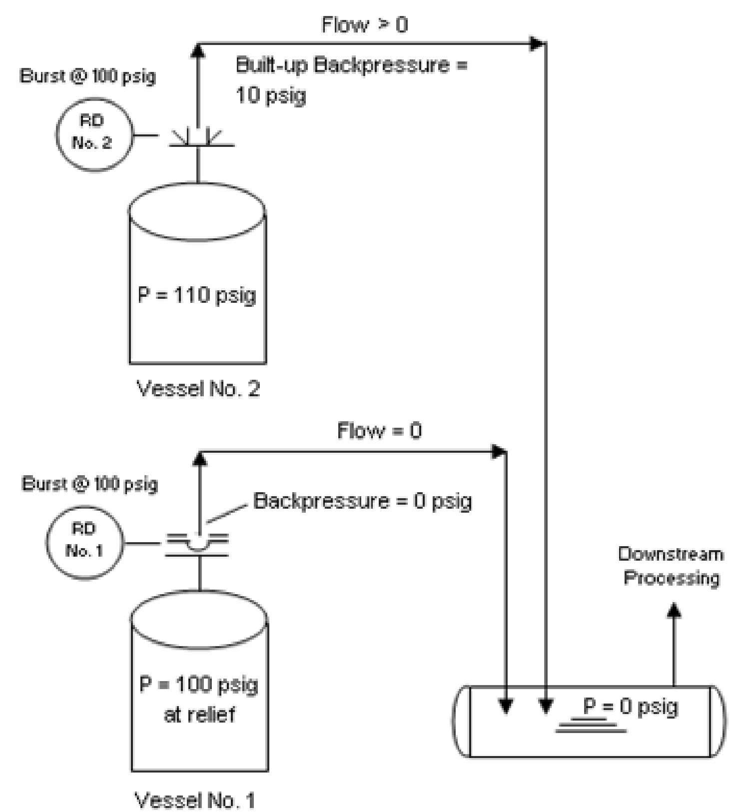

**Figure 2A: Two Vessel System – Separate Discharge Lines
Built-up and Superimposed Back pressures**

Note that built-up backpressure is variable and depends on the relieving rate, which is a function of the relieving scenario. Also, built-up backpressure has no affect on the vessel's *relief* pressure for systems such as those shown in Figure 1 above. Built-up backpressure is the result of fluid flow only and there is no fluid flow before the rupture disk bursts.

Therefore, along with the Manufacturing Range (MR), Operating Ratio (OR) and Burst Tolerance (BT) that were discussed in Part 3, the process design engineer must also strongly consider the backpressure (especially superimposed backpressure) when specifying the rupture disk.

In Summary

- Generally, burst pressure varies inversely with temperature so the specified burst temperature must be carefully considered.
  - Specify the lowest temperature at the time the disk is expected to burst.
  - Different materials and different types of rupture disks have different sensitivities to temperature effects.

- The rupture disk is a differential pressure device.
  - The specified burst pressure is a value equal to the vessel relief pressure minus the backpressure.

  Or

  - The vessel relief pressure equals the specified burst pressure plus the backpressure.

- There are three types of backpressure to consider, these being constant, built-up and superimposed.
  - Constant backpressure is the pressure in the system that does not vary. It is generally a predictable component of the superimposed backpressure.
  - Built-up backpressure is the pressure created in the system as a result of fluid flow. It is a varying component of the superimposed backpressure.
  - Superimposed backpressure is the total pressure exerted (imposed) on the rupture disk by other sources. It is a variable that directly increases or decreases a vessel's relief pressure. It can also interfere with the expected operating ratio of the disk.

- Do not pipe multiple vessel relief systems into a common header; keep the piping separate. However, the individual piping may go to a common disposal system.

- Along with the Manufacturing Range (MR), Operating Ratio (OR) and Burst Tolerance (BT), the process design engineer must also consider backpressure when specifying the rupture disk.

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. **Nazario, F. N.,** "Rupture Discs, A Primer"**,** Chemical Engineering Magazine, June 20, 1988.