

## Rupture Disks for Process Engineers (From the Process Design Engineer's Perspective) Part 2: How Do We Size It?

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. This part will discuss how to size the rupture disk. Subsequent parts will include how to set the burst pressure, the Relief Valve/Rupture Disk combination, how to specify the device 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<sup>1</sup> and API RP521<sup>2</sup>, and ASME Section VIII, Division 1<sup>3</sup>. Much of what is found in these documents can also be found in vendor literature.

### Sizing

Sizing the rupture disk is a two-part procedure. First, determine how much flow the rupture disk *needs* to pass. Then determine how big it needs to be.

#### **How much flow does it *need* to pass?**

Answering this question is the same as determining the required relieving rate for the system. There is no difference between determining the relieving rate for a rupture disk and a relief valve. They both require a set pressure (burst pressure for rupture disk), an allowable overpressure, an evaluation and calculation of the required relieving rate for each credible scenario and then choosing the flow rate associated with the worst-case scenario. Determining the controlling relieving rate is a paper in of itself and I will not attempt to get into details here.

#### **How Big?**

There are two recognized methods that can be used to answer this question, the Resistance to Flow Method or the Coefficient of Discharge Method.

#### Resistance to Flow Method

The Resistance to Flow Method analyzes the flow capacity of the relief piping. The analysis takes into account frictional losses of the relief piping and all piping components. Calculations are performed using accepted engineering practices for determining fluid flow through piping systems such as the Bernoulli equation for liquids, the Isothermal or adiabatic flow equations for vapor/gas and DIERS methodology for two-phase flow.

Piping component losses may include nozzle entrances and exits, elbows, tees, reducers, valves and *the rupture disk* (note that the rupture disk and its holder are considered a unit).

Let me emphasize that in this method, the rupture disk is considered to be just another piping component, nothing more, and nothing less. Therefore the rupture disk's

contribution to the over all frictional loss in the piping system needs to be determined. This is accomplished by using “Kr”, which is analogous to the K value of other piping components. Kr is determined experimentally in flow laboratories by the manufacturer for their line of products and is certified per ASME Section VIII, Division 1<sup>3</sup>. It is a measure of the flow resistance through the rupture disk and accounts for the holder and the bursting characteristics of the disk.

Below is a list of some models of Continental Disc Corporation rupture disks with their certified Kr values<sup>4</sup>.

Rupture Disk (and holder) Type	Media	Size Range	Kr
ULTRX	Gas, Liquid	1” – 12”	0.62
ULTRX	Gas only	1” – 12”	0.36
MINTRX	Gas, Liquid	1”- 8”	0.75
STARX	Gas, Liquid	1” – 6”	0.38
SANITRX	Gas, Liquid	1 1/2” – 4”	3.18

For comparison, the following is a list of some models of Fike rupture disks with their certified Kr values<sup>5</sup>.

Rupture Disk (and holder) Type	Media	Size Range	Kr
SRX	-	1” – 24”	0.99
SRL	-	1” – 8”	0.38
SRH	-	1 1/2” - 4”	1.88
HO / HOV	-	1” – 24”	2.02
PV, CPV, CP-C, CPV-C	-	1/2” – 24”	3.50

If at the time of sizing the manufacturer and model of the rupture disk are unknown, there are guidelines to help you choose Kr. API RP521<sup>2</sup> recommends using a K of 1.5. However, ASME Section VIII, Division 1<sup>3</sup> states that a Kr of 2.4 *shall* be used. Which one? Remember that ASME is Code (meaning LAW for the most part) and API is a recommended practice. In addition, as can be seen in the tables above, even ASME may not be as conservative as you may think. Therefore, it is in the engineer’s best interest to determine ahead of time the manufacturer and model of the rupture disk that eventually will be purchased. This can be done without knowing the exact size, as Kr is more manufacturer and model specific than size specific (see above tables). If a number of manufacturers are on the allowable purchase list, then at the very least choose the most likely models you would buy from each manufacturer and use the largest Kr from that list. This will be a significantly better guess than just using guidelines.

Once the piping system is laid out and all the fitting types are known, including the rupture disk, the engineer can proceed with the calculations in the following manner (presented here as a suggestion, there are many ways to do it).

1. Known are the two terminal pressures, these being the relieving pressure (upstream) and the downstream pressure (a knock-out pot, atmosphere, etc.).

2. Also known are the fluid properties and required relieving rate (the flow the rupture disk *needs* to pass).
3. Choose a pipe size. This will be the size to use for all components, including the rupture disk.
4. For vapor/gas or two-phase flow, use one of the accepted calculation methods to determine the *maximum* flow through the system. The maximum flow through the system is commonly known as critical flow or choked flow. For liquids, use the Bernoulli equation to calculate the flow that will *balance the system pressure losses*.
5. Per ASME Section VIII, Division 1, multiply this flow by 0.9 to take into account inaccuracies in the system parameters. Compare the adjusted calculated flow to the required relieving rate. If it is greater, then the calculation is basically done. However, the next smaller line size should also be checked to make sure the system is optimized; you want the smallest sized system possible. If the adjusted calculated flow is less than the required relieving rate, the pipe is too small, choose a larger size and repeat the calculations.

Why not just choose a large  $K_r$ ? Isn't that more conservative?

Many times, relief is not to atmosphere but to some downstream collection and treatment system, e.g. knockout drums and flares or thermal oxidizers. These are more often than not specified at a time period in the design that predates the actual purchase of the rupture disk. The flow used to size this equipment will be based on the capacity of your relief system as determined above.

If the rupture disk contributes a significant portion of the frictional losses to the system, a fictitiously large  $K_r$  might result in an oversized piping system. Sounds all right on the surface but once the actual rupture disk is chosen, the calculation must be repeated with the "real"  $K_r$  and this may be a much lower value than originally used. More fluid will flow through the system than previously determined because there will actually be less resistance to flow. The result is that the downstream processing equipment may have been undersized.

The opposite is also true. An initial guess of a fictitiously small  $K_r$  might ultimately result in oversized downstream equipment and the excessive expenditure of a significant amount of money.

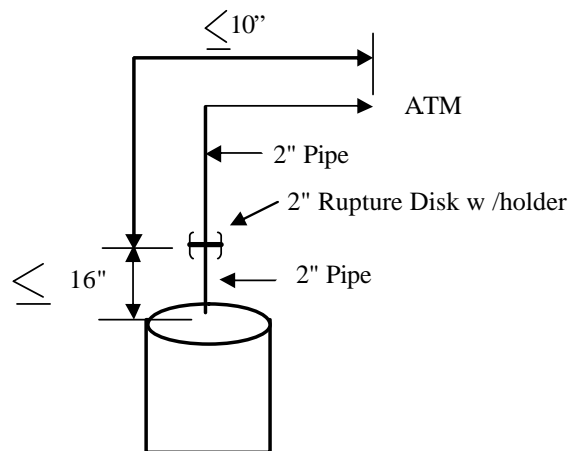
Atmospheric discharge must also be similarly analyzed because the flow capacity determined after rupture disk selection may have a major impact on the emissions reported for permitting if they were based on the initial value of  $K_r$ .

### Coefficient of Discharge Method

The second calculational method is the Coefficient of Discharge Method. The rupture disk is treated as a relief valve with the flow area calculated utilizing relief valve formulas and a fixed coefficient of discharge, 'Kd', of 0.62. This method does NOT directly take into account piping so there are restrictions in its use. These restrictions are known as the "8 & 5 Rule" which states that in order to use this method to size the rupture disk *ALL* of the following four conditions *MUST* be met<sup>3</sup>:

1. The rupture disk must be installed within 8 pipe diameters of the vessel or other overpressure source.
2. The rupture disk discharge pipe must not exceed 5 pipe diameters.
3. The rupture disk must discharge directly to atmosphere.
4. The inlet and outlet piping is at least the same nominal pipe size as the rupture disk.

A sketch of the "8 & 5" rule starting with a 2" nominal sized pipe is shown below.



The flow area calculated with this method is called the Minimum Net Flow Area or MNFA. The MNFA is the rupture disk's minimum cross sectional area required to meet the *needed* flow. This is not the area (and thus the size) you specify. Just like a pipe with a nominal size and an actual inside diameter, the rupture disk has a nominal size and an actual Net Flow Area or NFA. The rupture disk purchased must have a NFA equal to or greater than the MNFA. The manufacturer publishes the NFA for every rupture disk model and size they sell. The NFA also accounts for bursting characteristics of the disk and the holder.

Below is a list of some Continental Disc Corporation rupture disks with their NFA<sup>4</sup>.

Rupture Disk (and holder) Type	Nominal Size, inches	NFA, In <sup>2</sup>
ULTRX	1-1/2"	2.04
ULTRX	3"	7.39
SANITRX	1-1/2"	1.18
SANITRX	3"	5.49

Once the actual NFA of the rupture disk is determined, the calculations must be repeated, basically for the same reasons discussed above for the Resistance to Flow Method.

### **Why I don't like the Coefficient of Discharge Method**

- It's too restrictive! During the basic design phase of a project, actual piping configuration is unknown. You may think you are within the "8 & 5" rule at first but may not be when the final details are worked out. Remember, the "5" means 5 pipe diameters. For a 3" line, that is only a nominal 15". For a 6' vertical vessel with a rupture disk discharge being piped to a drain hub on the floor, the 15" maximum length is exceeded without even thinking.
- Using the Resistance to Flow Method is valid for *all* cases. All sizing calculations can be standardized.
- The  $K_r$  used in the Resistance to Flow Method is obtained by actual flow data for a given model of rupture disk and holder. Its use will provide a much more accurate calculation. The 0.62 coefficient of discharge used in the Coefficient of Discharge Method is very general and independent of rupture disk manufacturer model and type, holder, disk bursting characteristics and flow restrictions of the total relief system.
- Two-phase flow can be a major concern when using this method. The coefficient of discharge was established mainly for true vapors. Its application to liquids is questionable and its application to two-phase flow is totally fictitious. Granted, for the Resistance to Flow Method the  $K_r$  is not particularly applicable to two-phase systems either but one can easily compensate for this in the system calculations. Also, the rupture disk is only a part of an entire piping system and its overall contribution to the system frictional losses may not be greatly significant. Therefore, errors in  $K_r$  may not be very significant. In the Coefficient of Discharge Method, it is the only device considered. If the coefficient of discharge is grossly in error, the MNFA calculated will also be grossly in error.
- The same argument can be made for highly viscous liquid systems such as polymers.

### In Summary

- Obtain the required relieving rate using good sound “what can go wrong” scenario analysis.
- Use the Resistance to Flow Method to calculate the size of the rupture disk (use the Coefficient of Discharge Method if you really must and you fall within the “8 & 5” rule).
- For the Resistance to Flow Method, try to choose the manufacturer and model of rupture disk you intend to purchase ahead of time or at least have a list of acceptable manufacturers and a good idea of the model you intend to use from each.
- For the Resistance to Flow Method use the ASME Kr value of 2.4 if you have no idea who the manufacturer(s) will be at the time of sizing.

### References:

1. **API** ([www.api.org](http://www.api.org)) **Recommended Practice 520**, "Sizing, Selection, and Installation of Pressure-Relieving Device in Refineries, Part 1-Sizing and Selection", 7<sup>th</sup> Edition (January 2000)
2. **API** ([www.api.org](http://www.api.org)) **Recommended Practice 521**, "Guide for Pressure-Relieving and Depressuring Systems", 4<sup>th</sup> Edition (March 1997)
3. **ASME** ([www.asme.org](http://www.asme.org)) "Boiler and Pressure Vessel Code, Section VIII, Division 1" (1998)
4. **Continental Disc Corporation** ([www.contdisc.com](http://www.contdisc.com)), Certiflow<sup>TM</sup> Catalogue 1-1112
5. **Fike** ([www.fike.com](http://www.fike.com)), Technical Bulletin TB8104, December 1999
6. Another good rupture disk manufacturer to investigate would be **Oseco** ([www.oseco.com](http://www.oseco.com)).
  
7. A good reference source for calculating flow through the system for liquids and gas/vapors is **CRANE Technical Paper 410**, “**Flow of Fluids Through Valves, Fittings, and Pipe**”
8. A great source and one that I feel should be the bible on two-phase flow is: **Leung, J.C.** “**Easily Size Relief Device and Piping for Two-Phase Flow**”, **Chemical Engineering Progress**, December, 1996