A Structured Method for Proper Selection of Rupture Disks for Safety Relief in Ammonia Plants

Proper selection of a rupture disk is more than performing sizing calculations to make sure it is adequately sized for the emergency event. Criteria such as operating pressure and temperature, material selection, gas or liquid service, etc. must be evaluated to determine the best disk type for the application. The cost of not evaluating such criteria can be significant to operations if the ammonia plant has excessive "nuisance" failures of an improperly specified rupture disk. This paper will present a structured step-by-step method for determining the appropriate rupture disk type for an application.

Jeff Scoville and Alan Wilson
Oseco Inc.

Introduction

IT is common for the process engineer to use either in-house or manufacturer software to size rupture disks for ammonia plant safety. Rupture disks are used to protect ammonia plant piping, heat exchangers, and large equipment such as compressors and pumps. While the criteria for sizing is dependent on the application and conditions (explosive environment, fire conditions, etc.), the conditions are generally well defined and result in a required net flow area to pass a given flow rate at a given pressure and temperature. Sizing is only a small portion of the overall selection process of a rupture disk. Factors such as operating pressure, material selection, etc. have a significant influence on the type of rupture disk selected. Failure to select the correct rupture disk for an application can result in significant plant down time due to "nuisance failures". In a worst case scenario, an improperly specified disk can fail to open during an overpressure event, causing a catastrophic failure. Some of the factors that affect rupture disk selection are outlined in the API Recommended Practice 520[1]. API does a particularly good job of defining the inputs required by the manufacturer in the API "Figure A-1—Rupture Disk Device Specification Sheet". However, while this document is a good tool for collecting data, it does not serve as a selection tool for the novice rupture disk user. The document is intended to transfer information to the manufacturer and does not provide any guidance regarding actual rupture disk selection. It appears that more information regarding proper overpressure device specification is required, as 40% of the equipment in the oil, gas, and chemical industries has at least one pressure relief system deficiency[2]. The purpose of this paper is to address a structured methodology for the selection of a rupture disk for a particular ammonia plant application, regardless of rupture disk manufacturer. A flow chart of the process is included in Figure 1. While additional minor factors may have to be considered for each application, this process should complete 90% of the user's selection "by process of elimination".

FIGURE 1, Rupture Disk Selection Methodology

QUESTION: What is the operating ratio for the application?
____
TASK: Eliminate all rupture disk designs that have a maximum operating ratio below the operating ratio required for the application

QUESTION: What is the phase for the application?
__ Gas or __ Liquid
TASK: Eliminate all rupture disk designs that are "gas only" if this is a liquid application.

QUESTION: Does the application require a special holder?
__ YES _________ TYPE HOLDER or ___ NO
TASK: Eliminate all rupture disk designs that are not available in the the special holder (i.e. sanitary clamp, union, threaded assembly, etc.)

QUESTION: Is rupture disk required to be nonfragmenting?
__ Yes or __ No
TASK: Eliminate all fragmenting rupture disk designs (typically nonscored products)

QUESTION: Does the disk burst pressure fall within the the minimum/maximum charts for the disk design/material?
__ Yes or __ No
TASK: Eliminate all combinations that are outside min/max

QUESTION: Does the disk burst/operating temperature fall within the minimum/maximum charts for the disk design/material?
__ Yes or __ No
TASK: Eliminate all combinations that are outside min/max

QUESTION: Does the disk have to withstand full vacuum?
__ Yes or __ No
TASK: Eliminate all rupture disk designs that cannot withstand full vacuum and/or do not have optional vacuum support

Overview

The purpose of Figure 1 is to provide a structured approach for selecting rupture disks for an applica tion. It is assumed that the user of this chart has already sized a disk for the application. As the user progresses from the top to bottom box, rupture disk designs are eliminated by the question and task listed. The user should have a list of disks suitable for the given application at the end of the process. If all rupture disk designs are eliminated, the appli cation will need to be modified.

Once the reduced list of disks has been determined, less defined "soft" criteria may be used to make the final selection. Soft criteria, including items such as cost, plant history with a particular disk type, main tenance history, etc. can then be used to make a final selection.

This is where the structured approach will realize time and cost savings for the user. The process of elimination should prevent a user from having to evaluate every manufacturer's catalog of disks on all types of criteria. Instead, efforts can be concen trated on the final handful of disks that meet a par ticular criteria. At the same time, more cost effec tive rupture disk designs will not be eliminated by standardizing on a "one size fits all" solution.

It is important to work closely with the rupture disk manufacturer at the end of this process to achieve the best results before making the final purchase.

What is the operating ratio for the application?

The operating ratio is determined by dividing the maximum operating pressure by the burst pressure of the rupture disk. This the most important bench mark for measuring disk performance. Rupture disk manufacturers typically list the recommended oper ating ratio for each type of disk they sell. This ratio is an indicator of the pressure at which that disk can be operated with a reasonable service life. Operating above the manufacturer's recommended maximum operating ratio can reduce the life of the disk sig nificantly due to fatigue. Rupture disks typically have recommended maximum operating ratios from 50 to 90 %, depending on the materials and method of construction.
Disks that are capable of operating around 90% are also called high performance rupture disks. Higher performance disks typically cost more than low performance disks as they are typically of a preci sion-scored design. The manufacturing techniques used on high performance disks are much more labor intensive than low to medium performance designs.

Selecting a disk with a higher than necessary oper ating ratio can be a waste of money, but buying a low cost disk that doesn't perform well will require more frequent change outs and cause reduced produc tion. Applications with pressures that cycle more than a few times a day should not operate too close to the operating ratio. Cyclic or pulsing applications also tend to fatigue disks more quickly. The exact number of pressure cycles that a disk can withstand is dependent on many factors including material thickness, material type, operating temperature, etc. While this is a criteria for many plant applications, it is better addressed under *The final cut – other "soft" criteria*.

The one recommendation that can be made with certainty is that a disk should not be purchased for an application in which it will be exposed to condi tions above the recommended maximum operating ratio. Therefore, any disks that don't meet the operating ratio requirements for this step are imme diately eliminated from consideration.

What is the phase for the application? Gas or liquid?

Many "reverse buckling" disks require a snap-through action to perform correctly. The stored energy in a compressed gas is often used to facilitate this opening. Since liquids are incompressible, the same stored energy is not available. This can mean that a "gas-only" disk may not open at all under liquid conditions and can be a safety hazard.

In some cases, there is a small pocket of gas between the rupture disk and liquid. Depending upon the volume of the gas, a "gas only" disk may be used. The rupture disk manufacturer should be consulted regarding the criteria for gas pocket operation.

Under no circumstances should a "gas-only" disk be used in a liquid-filled application. Therefore, all "gas only" disks are eliminated in this step if the application is liquid.

Does the application require a special holder?

Most rupture disk designs are intended to be used in "insert type" holders that fit between standard ANSI flanges. However, rupture disks are also utilized in many applications where ANSI flanges are not available or a special type of connection is required. These applications include sanitary/food with sanitary clamp fittings, threaded assemblies with NPT connections on each end, union-type assemblies that fit between pipe ends, and welded or soldered units in which the disk is permanently attached to a throw-away holder. It is important to verify from the manufacturer's catalog that the disk type is available in the desired holder. Disks not available in the desired holder are eliminated in this step.

Is the rupture disk required to be non-fragmenting?

The most common reason to specify a non-fragmenting rupture disk is the use of rupture disks upstream of a pressure relief valve. If a disk fragment becomes lodged in a relief valve it can prevent the valve from closing properly and damage the seat of the valve. Non-fragmenting rupture disks may also be specified when there is a chance that personnel or property could be injured or damaged by fragments that result from a burst disk. In some sanitary applications, it is important not to contaminate the process with pieces of rupture disk.

In general, most low to medium performance products are fragmenting. Fragmentation is eliminated by the use of a scored pattern on high performance disks.

Please note that rupture disks should always be vented to a safe area away from personnel, even when nonfragmenting. The high speed flow from a rupture disk can still be dangerous to plant personnel.

If fragmentation is unacceptable for the application, all fragmenting disks will be eliminated in this step.

Does the burst pressure fall within the maximum/minimum charts for the disk design/material?

Most rupture disk manufacturers have a wide selection of standard materials they use to manufacture rupture disks. Some standard materials include 316 stainless steel, nickel, monel, inconel and aluminum. In addition to these you can find specialty disks made from Hastelloy C-276, silver, titanium, tantalum, graphite, Ryton and Teflon. Most manufacturers will furnish you a table listing the various materials available for a given disk design and the applicable minimum and maximum burst pressures (usually at room temperature) for each.

While materials such as Hastelloy C-276 may be desired due to their resistance to corrosion, it may not be possible to reach lower burst pressures in the more exotic materials. This step will eliminate materials that cannot meet the burst pressure requested. In many cases it is iterative as tradeoffs need to be made between corrosion resistance and the target burst pressure.

Does the disk operating/burst temperature fall within the minimum/maximum charts for the disk design/material?

It is important to not only look at the burst temperature, but the maximum operating temperature for the rupture disk. In many cases a peak temperature may occur with little or no pressure on the system and is not listed on the burst condition.

In a similar manner to minimum and maximum burst pressures, most manufacturers list minimum and maximum temperatures for different materials of a given disk design. This step will eliminate materials that cannot meet the temperature requested.

Does the disk have to withstand full vacuum?

Most rupture disks either withstand full vacuum as standard or have an optional vacuum support that may be added to make the disk vacuum resistant. However, there are some low pressure flat and forward acting disks that do not withstand full vacuum and do not have optional vacuum supports. Those disk designs will have to be eliminated when the potential for vacuum exists.

The final cut – other "soft" criteria

Once the final list is established, other soft criteria should be used to evaluate the suitability of a rupture disk design for a given application. At this point, the expertise of the rupture disk manufacturer will be invaluable to make the final decision on which rupture disk design to use in the application. Information such as previous plant history with the rupture disk design in the same or similar applications is also helpful. "Soft" criteria, such as estimated lifetime cost, cycle life, interchangeability, ease of maintenance, etc. may also play a role. The important point is that these types of time-intensive evaluations can now be conducted on a smaller set of disks suited for the application.

A real-world example

In this example we will look at providing a rupture disk to protect the shell side of a shell and tube heat exchanger. The burst pressure is 400 psig @ 100 F and requires a 4" diameter disk (based upon sizing for the application). The customer has informed us that the shell side normally operates at 350 psig and is liquid filled. Based upon compatibility with the process, 316SS is the material choice. There is a possibility of an upset condition in which the shell side sees full vacuum.

We start with a list of all disk types provided in a vendor's catalog. We have listed the first two selection criteria in the two right columns. The operating ratio for the application is 350/400 psig = 87.5%. Any disk with a maximum operating ratio below 87.5% will be crossed out. Any disk that is "gas only" will be crossed out, as this is a liquid application. Disk types CO, FMS, FST, FLCO, GR, and STD are eliminated due to operating ratio. Disk type PCR is eliminated due to the liquid service.

Type	Maximum Operating Ratio	Gas/Liquid
~~CO~~	~~80%~~	~~Gas or Liquid~~
FAS	90%	Gas or Liquid
FASS	90%	Gas or Liquid
~~FMS~~	~~50%~~	~~Gas or Liquid~~
~~FST~~	~~85%~~	~~Gas or Liquid~~
~~FLCO~~	~~50%~~	~~Gas or Liquid~~
~~GR~~	~~60%~~	~~Gas or Liquid~~
~~PCR~~	~~90%~~	~~Gas Only~~
PLR	90%	Gas or Liquid
PSR	90%	Gas or Liquid
PRO	90%	Gas or Liquid
PROS	90%	Gas or Liquid
~~STD~~	~~70%~~	~~Gas or Liquid~~

We then look at the next two selection criteria. The disk is being used between ANSI flanges (not sanitary) and fragmentation is acceptable. Disk types FASS and PROS were eliminated as they install in sanitary ferrules.

Type	Holder Type	Nonfragmenting
FAS	Insert (ANSI)	Yes
~~FASS~~	~~Sanitary~~	~~Yes~~
PLR	Insert (ANSI)	Yes
PSR	Insert (ANSI)	Yes
PRO	Insert (ANSI)	Yes
~~PROS~~	~~Sanitary~~	~~Yes~~

We then look at the minimum/maximum burst pressure criteria. PLR, PRO, and PSR are eliminated due to the burst pressure being higher than their maximum burst pressure for a 4" disk in 316SS.

Type	Min Burst Press (psig) for 4" & 316SS	Max Burst Press (psig) for 4" & 316SS
FAS	50	1800
~~PLR~~	~~2~~	~~65~~
~~PSR~~	~~29~~	~~75~~
~~PRO~~	~~20~~	~~200~~

We then look at the minimum/maximum operating temperature criteria. No disks are eliminated.

Type	Min Oper Temp (F) for 4" & 316SS	Max Oper Temp (F) for 4" & 316SS
FAS	-100	900

The last criteria that is evaluated is whether or not the disk must withstand full vacuum. Since the FAS is listed as withstanding full vacuum without an additional support, it is acceptable.

Type	Withstands Full Vacuum Without Support	Vacuum Support Option Available?
FAS	Yes	No, see column #1

In this case, only one disk type was left due to the stringent requirements of the application. In other less stringent applications you may end up with several disk types acceptable after the elimination. "Soft" criteria would then be used to decide upon one final disk type.

Conclusion

There are several key benefits of using the top-down approach as defined in Figure 1. The user can quickly eliminate rupture disks that are not well suited for the application, especially those that pose a threat due to safety (i.e. gas-only disks being used in liquid service). A more in-depth review can be conducted on the remaining rupture disks to make the best selection possible. The user is not forced into making "one size fits all" rupture disk selections that unnecessarily increase cost without direct benefit to the application. All of these benefits will result in lower cost of ownership with an increase in ammonia plant safety.

GLOSSARY OF TERMS

TENSION LOADED RUPTURE DISK: A tension loaded disk is installed into a system such that the burst pressure is on the concave or cupped side of the formed crown. The disk opens by yielding at the set point.

COMPRESSION LOADED DISK: A compression loaded rupture disk is installed into a system such that the burst pressure is on the convex or raised side of the formed crown. An example of a compression loaded rupture disk would be a reverse buckling style. Most compression loaded disks are capable of 90% recommended maximum operating ratio.

OPERATING RATIO: The ratio between the operating pressure and the stamped burst pressure on the rupture disk.

NONFRAGMENTING: A rupture disk that is designed to open without releasing portions of the disk downstream.

VACUUM SUPPORT: A component added to a rupture disk to make it withstand full vacuum condition.

REFERENCES

1. API (March 1993), "Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries", API Recommended Practice 520 Sixth Edition, The American Petroleum Institute, Washington, D.C.
2. Berwanger, Kreder, and Wai-Shan Lee, "Non-conformance Of Existing Pressure Relief Systems With Recommended Practices: A Statistical Analysis", American Institute of Chemical Engineers 1999 Spring National Meeting, Houston, TX.