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Standardize Rupture Disc Installations

Evaluating a plant's pressure relief devices and updating to newer technology can lead to improved efficiency, performance and mechanical integrity.

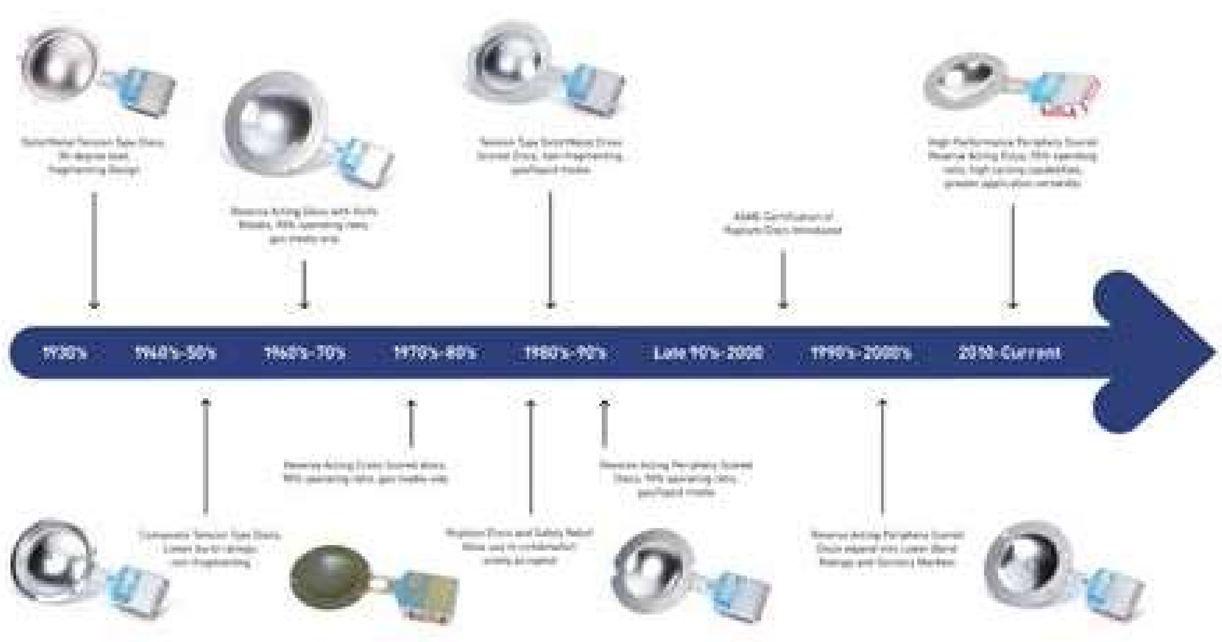
By Richard Neale, Continental Disc Corporation

Many processing plants currently operating originated in the 1920's and have evolved by adding new units or lines as demand for new products increased and the technology to manufacture those products was developed. As a result, many of these plants have a wide variety of rupture discs based on the prevailing disc technology at the time each plant addition or modification was completed.

Pressure relieving devices remain products that are individually analyzed and specified for each installation in processing plants. As pressure safety relief products, they are critical components that are the final level of protection from catastrophic failure of a pressure vessel or piping system.

When specifying rupture discs, two functions must be satisfied. The first is properly sizing and specifying the rupture disc to relieve all overpressure scenarios in a safe manner. Secondly, rupture discs must be specified carefully to ensure an acceptable service life as the process operates normally.

Functioning as the sacrificial element in a pressurized system, rupture discs are considered delicate instruments yet must be capable of withstanding corrosive media, pressure and temperature fluctuations, pressure



Design Evolution

Figure 1. Rupture disc designs have evolved greatly in the past 80 years to satisfy increasing regulatory, environmental and industry demands.

to vacuum cycles and other operating conditions that may impact the mechanical integrity of the rupture disc.

Recent rupture disc designs improve performance in all functions. New technology focuses on high performance reverse acting rupture discs that provide a means of improving flow characteristics and accuracy in overpressure relieving events in addition to improving durability under normal operating conditions. Durability is particularly important in plants that are extending turnaround frequency, putting greater demand on the rupture discs to withstand pressure/vacuum cycles or corrosive media for longer periods of time without compromising reliability.

Most chemical processing plants have processing units originally designed and built prior to the availability of current reverse acting disc designs thus have a combination of older technology tension type rupture discs and reverse acting discs in newer processing plants. As illustrated in Figure 1, rupture disc designs have evolved greatly in the past 80 years to satisfy the greater demands of OSHA for improved safety devices, the EPA to minimize potential fugitive emissions, and the needs of process industries to improve efficiency and mechanical integrity. This evolution process includes products with less flow restriction, that are designed to provide tighter tolerances, are available in a wider variety of materials and comply with current process safety, environmental and quality system codes, standards and directives.

With the growing emphasis on plant health and safety and protection of the environment, higher performance capabilities and improved durability inherent in the latest high-performance scored reverse acting disc designs make them well-suited for new construction or plant upgrades.

RUPTURE DISC

Figure 2. Modern rupture disc technology supports a range of application requirements and offers improved performance and a higher level of mechanical integrity.

WHY STANDARDIZE NOW?

New high-performance scored reverse acting discs are extremely versatile in the way they can be configured to provide the optimum level of performance and economy to each rupture disc application. In nearly all installations, reverse acting discs can replace older disc designs with significant improvement in flow capacity, accuracy and resistance to operating conditions that challenge the mechanical integrity of the rupture disc.

This greater versatility within one design of rupture disc offers greater opportunity to standardize the type of rupture disc used throughout all units within a plant site.

The standardization and optimization process can be beneficial in many ways:

- Elimination of inventory items due to standardizing similar rupture discs.

- Higher volume of one specification drives down cost.
- Greater utilization of newer rupture disc technology improves performance and reliability.
- Familiarity with the standard product improves installation and maintenance practices.
- Reorganizing and upgrading inventory control is an integral part of the process.
- Provides an opportunity to update compliance with industry codes; health, safety and environmental standards and company directives to current revisions.

Plant sites with more than 100 rupture disc applications are going to have multiple discs in ½- through 12-in. sizes in a variety of types and materials of construction. Frequently, the size and material of construction remain as originally specified. Other criteria such as: the disc type, nominal burst pressure and temperature rating, manufacturing range, maximum operating pressure capability, ability to withstand vacuum or backpressure, ability to relieve liquid as well as vapor overpressure conditions can all be standardized

A physical plant audit of all installations can reveal several important criteria needed to complete the consolidation and upgrade analysis.

without compromising safety or performance if done properly. In a single product type, later technology reverse acting rupture discs (Figure 2) provide the versatility to support a range of application requirements and will have improved performance characteristics and a higher level of mechanical integrity compared to existing discs.

WHAT IS THE PROCESS?

Analyzing the current state to determine if significant benefits can be gained from standardization is the first step. The benefits must justify the management of change process, or engineering analysis, and paper trail revisions required when upgrading or otherwise modifying process safety systems.

Storeroom inventory audits and plant audits, or walk-arounds, are two common services available. Plant audits provide details required to accurately determine what improvements are needed to resolve deficiencies in performance or compliance issues. Storeroom inventory lists and audits reveal the degree to which standardization to later technology rupture discs may be possible while eliminating obsolete or duplicate items.

Prior to making any changes in the type of rupture disc, it is prudent to verify the type of disc proposed as a replacement for the application. This step includes a physical plant audit as well as a review of the instrument data sheet (IDS).

A physical plant audit of all installations can reveal several important criteria needed to complete the consolidation and upgrade analysis. The most useful criteria to record include:

Vent system configuration. Does the rupture disc vent to atmosphere or into a containment system? In some instances, the vent piping will not accommodate a rupture disc assembly of a different height without having to cut and reweld piping. This issue usually can be avoided by verifying and duplicating the height of the existing rupture disc assembly.

Accessibility to the rupture disc location. Hard to reach locations or installations with limited space to properly torque the mating flange fasteners benefit by using pre-torque rupture disc holders to assure adequate force is applied to the rupture disc to provide a good seal and prevent disc slippage. This would also apply to installations having flanges that are non-metallic or are lined with glass or a fluoropolymer.

Rupture discs installed at the inlet of a pressure relief valve. For these installations there are ASME code requirements that must be satisfied. All installations must have a tell-tale indicator between the two relief devices, this is frequently included as a rupture disc holder accessory. Extended height holders may be used to prevent the disc petal from extending into the valve nozzle; this eliminates the need for a spool piece that would add to the difficulty in meeting the 3% pressure loss rule.

Maximal allowable working pressure (MAWP) and temperature (MAWT) of the pressure vessel or equipment. When verifying the MAWP and MAWT, include the type and class flange the rupture disc assembly will mate with and determine an equipment description or equipment number to ensure each disc is identified and tagged for use on the appropriate pressure vessel.

With the storeroom inventory data, IDSs, and audit findings of the current equipment, an analysis can be completed to determine the level of standardization possible.

Recent evaluations resulted in additional ways to improve reliability, efficiency and lower maintenance costs, such as:

- Eliminate obsolete designs such as reverse acting discs with knife blades or those that may pass unacceptable fragments of metal or graphite into downstream systems or equipment.
- Install solid metal rupture discs that are easier to seal and less sensitive to piping stress or installation issues.
- Use noble materials such as Monel, Inconel, Hastelloy C or Tantalum in place of less reliable coatings or linings for corrosion prevention.
- Remove inventory that is no longer required due to specification changes or removal or replacement of the host pressure vessel or equipment.
- Add automated alarm and control functions in critical applications such as those in lethal service gasses, environmentally sensitive media or high value or regulated process media requiring a controlled and contained environment.

MOVING FORWARD

Following a full analysis of existing conditions, the ideal method of consolidating or upgrading rupture discs varies by plant type and preference but typically aligns new product installation with planned turnarounds or as existing inventory of rupture discs is nearly depleted.

Most processing plants have significant improvement potential. With a well-executed analysis; a well-documented justification and commitment to support the changes required; eliminating inefficiency, improving performance and mechanical integrity can all be realized in one standardization and optimization process. ☐

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Properly Protect Against Overpressure

Understand the appropriate use of different pressure relief devices

By Amin Almasi, rotating equipment consultant

Many processes require a device to control or limit the pressure that can build up due to an upset, instrument or equipment failure, or fire. Pressure relief valves (PRV) most commonly provide this protection against overpressure but backflow preventers (such as check valves and others) and rupture disks also play useful roles in many applications. In addition, special classes of relief valves, usually known as vacuum relief valves, safeguard against excessive vacuum. Such devices actuate when pressure (or vacuum) exceeds a specified design value.

A conventional PRV is a self-actuated spring-loaded valve that opens at a designated pressure to allow the pressurized fluid to exit. (Some small valves commonly handle thermal relief valve applications.) The basic elements of a spring-loaded PRV include an inlet nozzle connected to the vessel or system to be protected, a movable disk that regulates flow through the nozzle, and a spring that controls the position of the disk.

Under normal system operating conditions, the pressure at the inlet is below the set pressure — so, the disk is seated on the nozzle, preventing flow through it.

However, when the set pressure is exceeded, the relief valve opens and becomes the "path of least resistance" for flow. A portion of the fluid exits the PRV, usually going through a piping system known as a flare header or relief header to a central, elevated gas flare (or similar) for combustion. The loss of fluid lowers the pressure inside the machinery or system being protected. When the pressure declines enough, the PRV will close. How much the pressure must drop before the valve reseats is termed blow-down and often is stated as a percentage of set pressure. Roughly, this can range from 3% to 20%; some valves have adjustable blow-downs.

PRESSURE RELIEF VALVE

Figure 1. When open, this valve vents fluid to atmosphere.

In systems where the outlet is connected to piping, the PRV's opening will prompt a pressure build up in the downstream piping. Other PRVs connected to the outlet pipe system may open and the pressure in the exhaust pipe system may increase. This may cause undesired operation. So, such systems frequently need an alternative solution. They often require "differential" relief valves — in these, the pressure works on an area much smaller than the opening area of the valve.

The pressure must decrease enormously before the valve closes; also the outlet pressure of the valve can easily keep the valve open.

In some cases, a bypass valve protects a pump or gas compressor and any associated equipment from excessive pressure. It acts as a relief valve by returning all or part of the fluid discharged by the pump or compressor back to either a storage reservoir or the inlet of the machine. The bypass valve and bypass path can be internal (an integral part of the pump or compressor) or external (installed as a component in the fluid path).

CONVENTIONAL SPRING-LOADED PRV

The operation of this device is based on a force balance. The spring load is preset to equal the force exerted on the closed disk by the inlet fluid when the system pressure is at the PRV's set pressure. When the inlet pressure is below the set pressure, as it should be for normal operations, the disk remains seated on the nozzle in the closed position. As the system pressure approaches the set pressure of the valve, the seating force between the disk and the nozzle approaches zero.

When the inlet pressure exceeds set pressure, the pressure force on the disk overcomes the spring force and the valve opens. Then when the inlet pressure falls to the closing pressure, the valve recloses.

Historically, many liquid applications used PRVs (or pressure safety valves) designed for compressible (or vapor) service. Many of these valves when used in liquid service required high overpressure (say, 20%) to achieve full lift and stable operation because liquids don't provide the expansive forces that vapors do. Where liquid PRVs had to operate with a 10% overpressure limit, a conservative factor (say, 0.6) usually was applied to the valve capacity during sizing. Consequently, many installations were oversized and instability sometimes resulted.

Codes now incorporate rules that address performance of liquid service valves at 10% overpressure and that require a capacity certification. Vendors have developed PRVs for liquid services that achieve full lift, stable operation and rated capacity at 10% overpressure in compliance with the requirements; some designs feature adjustable blow-down. Valves that can operate on liquid and gas are available. However, such valves may exhibit different operational characteristics depending upon whether the flow stream is liquid, gas or a combination of the two. Many PRVs designed for liquid service, for example, will have a much longer blow-down (typically 20%) on gas than on liquid service. Additionally, some variation in set pressure may occur if the valve is set on liquid and required to operate on gas or vice versa.

Pressure existing at the outlet of a PRV is defined as backpressure. This backpressure may cause variations in opening pressure, reduction in flow capacity, instability or a combination of all three. A balanced spring-loaded PRV minimizes the effects of backpressure on the performance characteristics of the valve; it incorporates a bellows, a sealed piston or other means of balancing the valve disk. Consider a balanced PRV wherever the backpressure created by flow through the downstream piping after the relief valve lifts is too high for a conventional PRV. Balanced PRVs also can serve to isolate the guide, spring, bonnet and other top works parts within the valve from the relieving fluid. This may be important if corrosive damage to these parts from the fluids (such as dirty ones from downstream) is a concern.

Two-phase systems in which the fluid being relieved may be liquid or gas call for spring-loaded PRVs designed for liquid (or liquid-and-gas) service and balanced to minimize the effects of backpressure. Many manufacturers recommend use of valves designed for liquid or liquid-and-gas service if the mass percentage of vapor in the two-phase mixture at the valve inlet is 50% or less. If you're not certain of the ratio of liquid to gas in the flow stream, selecting a valve specifically designed for liquid or liquid-and-gas service is prudent.

Conventional PRVs perform unsatisfactorily when excessive backpressure develops during a relief incident, due to the flow through the valve and outlet piping. The built-up backpressure opposes the lifting force that's holding the valve open. Excessive built-up backpressure can make the valve operate in an unstable manner. This instability may occur as chatter or flutter. Chatter refers to an abnormally rapid reciprocating motion of the valve disk where it contacts the seat during cycling. This type of operation may cause damage to the valve and interconnecting piping. Flutter is similar to chatter except the disk doesn't contact the seat during cycling.

As a rough guide, in a conventional PRV application, built-up backpressure shouldn't exceed 10% of the set pressure at 10% allowable overpressure. You may use a higher maximum built-up backpressure for allowable overpressures greater than 10% — provided the built-up backpressure doesn't surpass the allowable overpressure. When the superimposed backpressure is constant, you can reduce the spring load to compensate for the superimposed backpressure. When the backpressure is expected to exceed these specified limits, specify a balanced or pilot-operated PRV.

PILOT-OPERATED PRV

This device consists of the main relief valve, which normally encloses a floating unbalanced piston assembly, and an external pilot (usually a conventional PRV). The piston is designed to have a larger area on the top than on the bottom. Up to the set pressure, the top and bottom areas are exposed to the same inlet operating pressure. Because of the larger area on the top of the piston, the net force holds the piston tightly against the main valve nozzle. As the operating pressure increases, the net seating force rises and tends to make the valve tighter. This feature allows most pilot-operated valves to be used where the maximum expected operating pressure is higher than the percentage acceptable for conventional relief valves. At the set pressure, the pilot vents the pressure from the top of the piston; the resulting net force is now upward, causing the piston to lift and thus permitting fluid flow through the main valve. After the overpressure incident, the pilot will close the vent from the top of the piston, thereby reestablishing pressure; the net force will cause the piston to reseat.

The main valve of the pilot-operated PRV can use a diaphragm system in place of a piston to provide the unbalanced moving component. A disk, which normally closes the main valve inlet, is integral with a flexible diaphragm. The external pilot serves the same function to sense fluid pressure, vent the top of the diaphragm at set pressure, and reload the diaphragm once the fluid pressure is reduced. As with the piston valve, the seating force increases proportionally with the operating pressure because of the differential exposed area of the diaphragm. Built-up backpressure doesn't affect the lift of the main valve piston or diaphragm. This allows for higher pressures in the relief discharge manifolds than prudent with conventional and balanced spring-loaded PRVs.

The modulating pilot can handle gas, liquid or two-phase flow applications. In contrast to a pop-action PRV, a modulating pilot-operated valve limits the amount of relieving fluid to just the amount necessary to prevent the pressure from exceeding the allowable level. Because a modulating pilot only releases the required relieving rate, you can calculate the built-up backpressure based on that rate instead of the rated relieving capacity of the valve. The modulating pilot valve also can reduce interaction with other pressure control equipment in the system during an upset condition, decrease unwanted atmospheric emissions, and lower the noise level associated with discharge to the flare piping or atmosphere.

BACKFLOW PREVENTER

You need a backflow preventer when there's a possibility of developing a pressure on the discharge side of the valve that exceeds its inlet pressure. The higher discharge pressure can create sufficient upward force on the diaphragm, piston or other element to open the valve and cause flow reversal. Reverse flow can occur with any standard type or design of pilot-operated PRV when sufficient reverse differential pressure exists.

A backflow preventer permits the introduction of outlet pressure into the dome of the main valve, thereby holding the piston firmly on the nozzle and overcoming the effect of a reverse differential pressure. The backflow preventer allows the discharge pressure to provide a net downward force on the diaphragm or piston to keep the valve closed. Proper operation of the backflow preventer is critical to further ensuring no flow reversal occurs in the valve. The material and seals in the backflow preventer should match those of the pilot-operated PRV.

RUPTURE DISKS

These are non-reclosing devices for protecting against excessive pressure (or sometimes vacuum). A single or multiple rupture disks may be used in an installation. They also can serve as redundant pressure relief devices.

With no moving parts, rupture disks are simple and reliable — and faster acting than other pressure relief devices. Rupture disks react quickly enough to relieve some types of pressure spikes. Because of their light weight, rupture disks can be made from high-alloy and other corrosion-resistant materials that aren't practical for relief valves.

A rupture disk is also a temperature-sensitive device. Burst pressures can vary significantly with its temperature, which may differ from the normal fluid operating temperature. As the temperature at the disk increases, the burst pressure usually decreases. Because the effect of temperature depends upon the rupture disk design and material, consult the manufacturer for specific applications. Specify the pressure and temperature at which the disk is expected to burst.

SIZING AND RELIEF PRESSURE

Carefully evaluate the contingencies that can cause overpressure in terms of the pressures generated and the rates at which fluids must be relieved. You need the package's process and instrumentation drawings, equipment specification sheets, and design basis for the facility to calculate the individual relieving rates for each pressure relief device. An important parameter is the set pressure of a PRV installed in the machinery, package or facility. As a rough guide, this set pressure could be 110% of the maximum allowable working pressure (MAWP) in the package or system protected by a single pressure relief device sized for operating (non-fire) contingencies.

A multiple-device installation requires the combined capacity of two or more pressure relief devices to alleviate a given overpressure contingency. In this way, you might increase the set pressure, for instance, to 118% of the MAWP in a package protected by multiple pressure relief devices sized for operating (non-fire) contingencies. For fire cases, the relief pressure (set pressure) usually is higher — e.g., it could be around 120% or 125% of the MAWP in a package protected by devices sized for fire contingencies.

OVERPRESSURE CAUSES

An unbalance or disruption of the normal flows of fluid and energy in a machinery system or package can prompt the energy or fluid, or both, to build up in some part of the package (such as its discharge). Analysis of the causes and magnitudes of this overpressure, therefore, is a special and complex study of energy and fluid balances in different machinery operating scenarios.

Double-jeopardy scenarios usually aren't credible ones for sizing a PRV. Such scenarios generally involve two independent failures or malfunctions at the same time — e.g., simultaneous failures of two completely independent machines or controls, or operator error leading to a blocked outlet coincident with an overall plant power failure. On the other hand, treat instrument-air failure during fire exposure as a single jeopardy if the fire exposure causes local airline failures.

Excessive speed and other machinery malfunctions can result in overpressure. Sometimes, the inadvertent opening of a valve from a source of higher pressure, such as a high-pressure process fluid, can lead to overpressure. For instance, in many packages there's always a possibility of the suction system becoming pressurized by the discharge (high-pressure) fluid; in many cases, some portion of the suction system actually is designed based on discharge pressure or other means of protection (such as a PRV) is considered.

A single check valve isn't always an effective means for preventing overpressure by reverse flow from a high-pressure source such as a high-pressure discharge. For example, if a fluid is pumped or compressed into a system that contains fluid at significantly higher pressure than the design rating of the equipment upstream (suction) of the pump or compressor, loss of pumped flow with leakage or latent failure of a check valve in the discharge line results in a reversal of the fluid's flow. When high-pressure fluid enters the low-pressure system, overpressure can result. In most cases, you should focus on prevention of reverse flow. It's important to note that, in addition to overpressure of the upstream system (or suction system), reverse flow through machinery might destroy mechanical equipment, causing loss of containment. In many cases, this hazard is of concern, so provide additional means of backflow prevention.

Even proper inspection and maintenance might not completely eliminate check-valve seat leakage and leakage will occur. Consequently, even without total failure of the check valve, the low-pressure system upstream of a check valve still could be over-pressurized. A detailed analysis and study on a case-by-case basis then can show whether automatic isolation, a pressure-relief device sized for leakage, or an alternative means of protection is needed. You must define the appropriate leakage rate for each specific machinery system. Experience has shown that when inspected and maintained to ensure reliability and capability to limit reverse flow, two back-flow-prevention devices in series suffice to eliminate significant reverse flow.

In addition, carefully evaluate the possibility of overpressure developing from the loss of any utility service (such as cooling water, electricity, etc.), whether plant-wide or local. □

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