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Rupture discs: Reliable safety device for protection of systems against excessive pressure in the Oil & Gas Industry

Rupture disc is a non-reclosing pressure relief device activated by static differential pressure between the inlet and outlet of the device[1].

The history of rupture discs goes back to the early days of the oil industry in the late 1800's where the level of control in pressure systems was very unreliable and the potential for excess pressures occurred leading to accidents regularly, injury or death of the workers as the pressure burst tanks, vessels and other pressure containment units.

The first discs were very simple flat pieces of metal, weakened to open, sometimes with very little accuracy or predictability. Over the years the technology employed in controlling pressures has improved and developed to high levels of safety to maintain a safe working pressure regime.

In addition, the development of safety valves has also moved forward, raising the safety level to one where many design and plant personnel have lost sight of the most important safety device in the plant: the rupture disc.

Today operators have been lulled into a false sense of security that the design engineers and system process designers have covered all possibilities with sophisticated control and monitoring systems. Nothing can go wrong so why do we need a rupture disc?

Fig. 1: Reverse acting rupture disc for absolute leak tightness.

- Fast opening times, typically < 3ms, rupture discs react to sudden pressure rises far faster than any valve
- Full bore opening, unlike safety valves where the orifice restricts the flow

Rupture discs are engineered and manufactured to meet the needs for the specific application. As many as 53 different points are needed to ensure that the disc is engineered to the full specification so it will operate correctly.

Protection of pressure relief valves by rupture discs: Combination Device

Safety valves are widely used for overpressure protection. However, pressure relief valves can quickly reach their limits, particularly where there are major requirements in terms of tightness or if the medium used is viscous, sticky or freezing. In addition, each pressure relief valves has a certain level of leakage. Seat tightness requirements are defined in the API 527[2] of which the acceptance criteria allows a certain number of bubbles per minute, meaning some level of leakage during normal operation. It has to be considered that these leakage rates are established on a brand new valve in a controlled factory environment. The plant operator need to take into account that a minimum of these bubble leakage rate or more will be released through the valve.

A solution involving an upstream rupture disc unites the benefits of both devices. This arrangement is called a Combination Device as per EN ISO 4126-3[3]. When combined, pressure relief valves and rupture discs are a reasonable and, above all, economic solution for a wide range of applications.

- 100% isolation of process fluids, no leaks until the disc opens
- no product loss during normal operation, rupture disc is leak tight
- prevents rogue emissions
- Isolate pressure relief valves from corrosive process media, with the benefits of substantial costs savings on pressure relief valve materials and reduction of regular maintenance costs on pressure relief valves to a minimum
- prevents blockage of the pressure relief valve
- it can be used to pop test the pressure relief valve in-situ, no need for removal of pressure relief valve for testing of it in a maintenances workshop, pressure relief valve can be kept in place.

Fig. 2: Combination Device with a V-Series rupture disc for In-Situ Testing of Pressure Relief Valve.

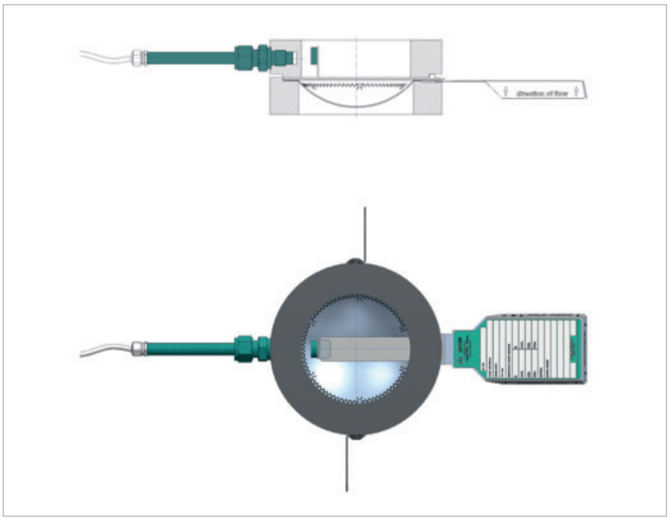
Based on these technical and economic benefits use of combination devices are recommended by the current codes and standard and finding more applications in the modern plants.
Monitoring can additionally be used to report when the disc has ruptured. Conventional signalling devices require cables to be mounted on the rupture disc, which must then be routed out through the rupture disc holder. This is not the case with REMBE®'s NIMU. Here, a signal indicator is attached to the rupture disc during the manufacturing process. The actual sensor is screwed into a blind tapping in the rupture disc holder, where it monitors the position of the signal indicator on the rupture disc. This means that the wiring only starts outside the rupture disc holder.

The system is leak-proof, and back in operation quicker

After an overpressure event, the outlet part of the rupture disc holder must be removed, the rupture disc replaced, and afterwards the system can be put back into operation. The days when the signalling cables also had to be routed again to the respective switching box are finally over.
The process is absolutely leak-tight. The blind tapping in the holder replaces the tapping which is usually required. The absence of cable glands means that they cannot become porous, thus preventing an escape of the process media.

Heat Exchanger Protection

In heat exchangers tube rupture is the major risk. The LP side is typically not designed to handle the pressure of the HP side. API 521 allows the avoidance of relief device, if certain conditions are met[4]. However, the pressure difference between LP and HP sides is in most cases extremely larger such that the conditions mentioned in the API 521 cannot be met. Use of relief devices to protect the LP side becomes inevitable.



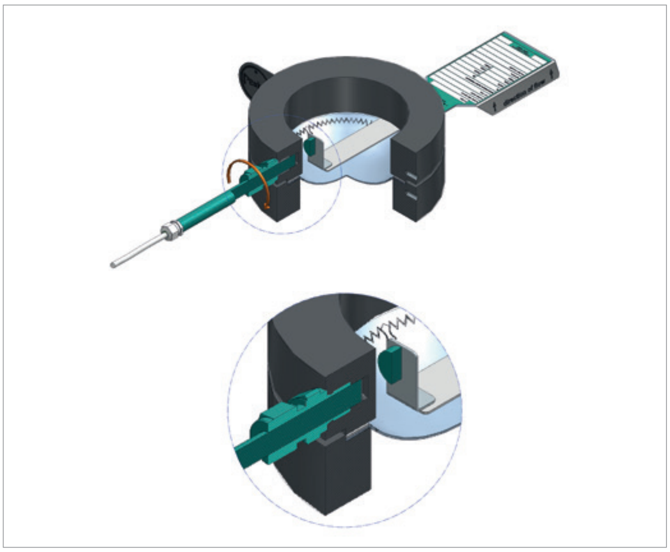


Fig. 1+2: NIMU, the non-invasive signalling: Sensor in a blind tapping in the rupture disc holder, and signal indicator on the rupture disc.

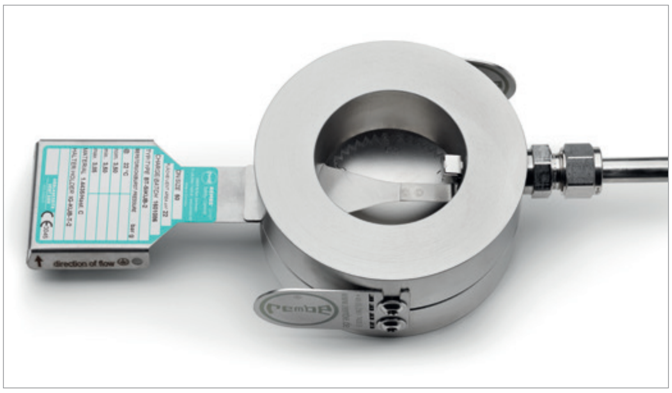


Fig. 4: When the KUB rupture disc opens, the NIMU sensor will output information to the process control unit of the system.

In heat exchangers where the LP/HP side pressure difference is high, a very high dp/dt on the shell side will happen in case of tube rupture.
Typical opening times are in the range of 50 to 100 milliseconds for a spring loaded PSV and 3 ms to 10 ms for rupture discs (depending on the design). Due to the very rapid pressure increase (dp/dt) following a tube rupture fast acting relief devices for protection against excessive pressure are recommended by API 520[1] and ASME Code Sec. VII Div. 1[5].

Reliable pressure relief on flare systems

Over the last decade the use of flares to burn off hydrocarbons has been significantly reduced and in some countries all but eliminated.
To achieve a safe system to recover the hydrocarbons end users have modified their processes and used recovery systems to channel the once waste gas back into the plant or use it directly for secondary purposes such as injection or utility fuel.

The application is mostly with back pressure which may vary over the time since several relief devices are connected to the same header. A pressure relief device cannot handle the amount of back pressure, which may be almost in the same magnitude of its setting. The use of double disc assemblies is the appropriate solution in a such an application. The process disc does not see the back pressure conditions and can be set at the required pressure for the emergency condition. The second disc is designed to handle the max. back pressure from the flare header. This arrangement ensures that the burst pressure of the process side disc is not affected and changed by the variable back pressure conditions on the downstream side.

A rupture disc is failsafe, whatever else goes wrong a properly designed and engineered disc opens at its burst ressure. Electronics, pneumatic and mechanical devices can fail, human error can cause operational errors in the pressure system, the rupture disc still opens for a fast and reliable relief of overpressure.

Case Study

An oil & gas processing facility had the requirement to protect their heat exchangers against the unexpected and sudden pressure rises that could occur with sudden internal tube failures. Normal working pressure of the vessel cooling system was approx. 12 barg, a Maximum Allowable Working Pressure (MAWP) for the vessel of 16 barg and the internal working pressure of the hydrocarbon inside the tubes of 160 to 170 barg. Calculations showed that the secondary relief device was required to handle the flow rate and pressures expected during a tube failure.
The initial technical solution by the process design engineers was to install a fast opening valve on the vessels; in this case using an offset butterfly valve of the quick opening design as opposed to a bursting disc, this choice was made on the primary basis of being able to reset the valve quickly. On the capex side the average increase in cost of this type of valve versus a bursting disc and holder was in the region of at least plus 10x per valve and there would be the need for addition supports and braces for the weight of the valve further adding to the capex costs.

During the technical reviews the operation and response times of the valve were noted to be >50ms for the valve to reach fully open. Initially this was considered acceptable, until computer simulations revealed that by the time the butterfly valve had even responded and then reached the fully open position to allow the high pressure and excess flow to exit the vessel they would have exceeded the MAWP by over a minimum of +50 to +80barg. This simulation assumed a new valve in perfect working condition and met its opening target, a partially opening valve made the results worse.
Repeated simulations confirmed that even with the best case and response time of the valve the MAWP was exceeded each time and this could not be accepted as meeting the safe working conditions for the vessel or the installation. It was also noted that an increase in the reaction time of the valve might occur during the valve in-service time due to seal ageing, control linkage wear and possible build up on the butterfly disc/seal that would add to the valve opening times and therefore increase the overpressure risk of the vessel even more.

The response time for the considered disc was in the range of 2 to 4ms and the flow capacity of the rupture disc exceeded the maximum required by the design engineers on the same piping size, this was done so as to avoid altering any of the planned piping sizes so as to reduce any possible design changes to piping sizes.
The computer simulations repeatedly proved that the use of a fast acting rupture disc allowed the end user to meet the safe operational requirements with none of the worst case simulations meeting or exceeded the MAWP of the vessel.
There are several things to consider:

- A rupture disc solution that provides for a precise engineered safety device to protect the equipment and personnel on the installation
- Substantially reduced CAPEX costs by not using the valve and not having to strengthen the vessel and piping supports for the valve
- Reduced weight consideration by using the disc and holder vs the valve and additional steel work required for the valve (several heat exchangers involved) aids installation work and handling requirements.
- The use of a resettable valve against replacing a disc was the wrong choice as a tube failure would take the heat exchanger out of service for a substantial time so being able to reset the valve was of no real value to the end user in these circumstances

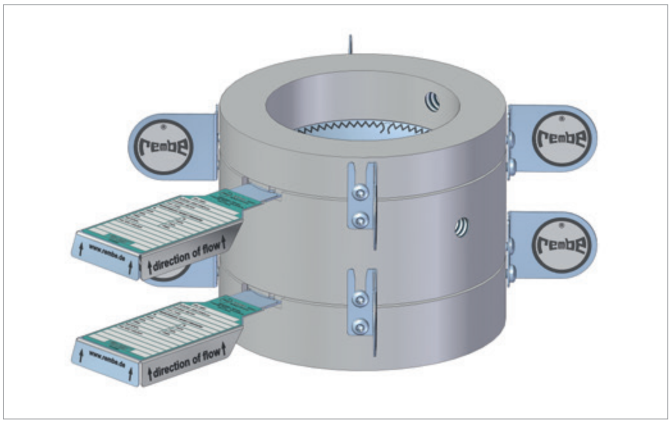


Fig. 3: Double disc installation suitable for flare lines and heat exchanger applications with variable back pressure.

A double disc installation was selected with the second disc to handle the max. back pressure of 10 barg. The second disc is set at the differential value of MAWP less the max. value of back pressure , which is by design and calculation 6 barg.

In conclusion, the end user had a correct engineered solution to give maximum vessel and personnel protection. The choice of correct disc design and material leads to increased service life with elimination of requirements for frequent shut downs for periodic maintenance. The user can profit from substantially reduced CAPEX and associated installation costs using the rupture discs compared to using any other valve, as well as reducing the overall emission balance of the plant.

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Active Member of:
ISO TC185 Pressure Relief Devices
CEN TC 69 WG10 SG2 / SG 3 Bursting Disc Devices
Bursting Disc Devices in Combination with Safety Relief Valves
DIERS The Design Institute for Emergency Relief Systems (AICHE)

References:
[1] *API 520 – Part 1 Sizing, Selection and Installation of Pressure relieving Devices, 9th Edition, July 2014*
[2] *API 527 Seat Tightness of Pressure Relief Valves, 4th Edition, November 2014*
[3] *EN ISO 4126 -3:2006 Safety devices for protection against excessive pressure - Part 3: Safety valves and bursting disc safety devices in combination*
[4] *API Standard 521 Pressure-relieving and Depressuring Systems, 6th Edition, January 2014*
[5] *ASME Boiler and Pressure Vessel Code, Sec. VIII Div. 1 (2015)*