BLOG/NOVEMBER 2021

Reactive pressure relief – is your plant protected?

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Reactive relief is one of more obscure aspects of pressure relief engineering – it is difficult to quantify, it requires a special set of skills and knowledge, and in our experience is often wrongly calculated or (even worse) ignored completely.

Operating companies should be aware of the consequences of failing to design an adequate protection system for overpressure events caused by reactions, which are often catastrophic. It's easy to see why this is often not the case - operating companies don't do these types of calculation very often, so engineers can struggle to build up and retain this competency. Also, in our experience a lack of available information on the reaction is common. It is very rare that companies have documentation for the whole suite of tests needed for a complete design.

The most common example of relief leading to overpressure is runaway reaction. If you have an exothermic reaction, it is necessary to remove the heat from the system. If you don't effectively remove the heat, this can lead to a runaway reaction. Runaway reactions, also called thermal runaway, are uncontrolled conditions in reactors that can cause a potentially dangerous situation. The end result is often an explosion, or a large release of gas to the atmosphere.

Other causes of reactive relief include insufficient stirring of reactants leading to runaway reaction (localised hot spots in reactor), inadvertent addition of the wrong reactants, and addition of the incorrect ratio of reactants.

So how do you minimise risk of failure? Correct scale-up of the heat removal system from lab scale is important when considering runaway reaction. The surface area to volume ratio decreases as the volume of a vessel increases, therefore a higher rate of heat removal is required.

Typically, reactor vessels are installed with heat removal systems, e.g. jackets, coils etc. Assuming the cooling system is adequately sized, preventing the loss of cooling medium supply to the reactor (e.g. water or refrigerant) becomes the next issue. Control valve failure, inadvertent valve closure and pump failure are some of the reasons why a cooling supply is lost. This can be mitigated against by system redundancy (e.g. duty/standby equipment or instruments) or procedural controls (e.g. locked open valves). Note that these are not measures to replace a pressure relief device, they are designed to lower the likelihood of activation of the relief device.

In other causes of reactive relief, safeguards such as robust procedural controls and clearly defined operating instructions may also reduce the likelihood of operator error, such as inadvertently adding the wrong reactants, or in the wrong ratio.

The protective relief device, e.g. bursting disc or relief valve, should have been designed correctly prior to installation. However, circumstances often change – different service from the original design intent, or plant yield increase. When changes are made to a reactor (e.g. rerating of design pressure or change in design intent) it is vital that the protective relief system is also reassessed, and that the worst case runaway reaction (or other type) is considered if multiple reactions occur.

When designing a pressure protection system, the need for knowledge of the reaction process sounds obvious, but it is imperative. It's generally a given that an operating company will know the composition and mass of reactants charged to their reactor vessel(s), and the resulting reaction products. What may not be as well defined are any intermediate products that are produced as side reactions. It is important to know what materials you are dealing with, so you can clearly define what a potential overpressure scenario looks like, and also how you will dispose of the resulting relief stream (discussed in the 2nd part of this blog).

It is also important to know how the reaction proceeds – is it an exothermic reaction, is it a vapour generating reaction, or is it both? Information on the system type should be obtained through calorimetry testing on a lab scale. If this information is not available for the system in question, then it cannot be fully defined, and the parameters necessary to calculate the reactive relief rate (discussed in the 2nd part of this blog) are not available.

Designing a reactive relief system is not a simple process and requires a good understanding of the reaction mechanism. In particular, the availability of detailed calorimetry data for the exothermic or vapour-generating reaction is vital in making sure your relief system is sized correctly, as well as the use of the correct sizing methods, also to be discussed in the 2nd part of this blog.

For further information please email me at robert.a.barrett@gb.abb.com or see ABB pressure relief