BLOG/DECEMBER 2021

Reactive pressure relief – is your plant protected? (Part 2)

Blog by Robert Barrett

Robert Barrett, Senior Process Engineer, ABB

The first part of this blog discussed the need for greater awareness of the hazards of reactive relief and the protective systems required to prevent a catastrophic overpressure event. Part 2 of the blog will focus on the tools you need to design an adequate reactive relief pressure protection system, and how you would begin to tackle this seemingly daunting task.

To begin with, it should be noted that designing an adequate protection system is not simply a 'nice-to-have' situation, it is a legal requirement – assessment by employers of the risks to employees and others who may be affected by the work activities is one of the requirements of the Management of Health and Safety at Work Regulations (MHSW), and is also a requirement of various other regulations, such as the Pressure Systems Safety Regulations (PSSR), Control of Substances Hazardous to Health (COSHH) and the Control of Major Accident Hazards (COMAH).

In order to design the system correctly, firstly we need to know what type of relief system we are dealing with. Broadly, reaction relief systems fall into three categories:

1. **Vapour Pressure System**

A vapour pressure system is where the pressure rise in the reactor is due entirely to the vapour pressure of the reactants, products or solvents.

2. Gassy System

A gassy system is where the pressure rise in the reactor is due entirely to permanent gas evolution from the reaction.

3. Hybrid System

A hybrid system is where the pressure rise in the reactor is due to a combination of vapour pressure of reactants/products/solvents and the partial pressure of a permanent gas evolution.

In order to choose the correct relief system sizing method it is necessary to select the most suitable system classification. Where it is not obvious, indicators such as an Antoine plot (i.e. vapour pressure-temperature relationship) can help, which would show a linear relationship in a vapour pressure system.

As stated in Part 1 of the blog, accurate calorimetry data must be available in order to size the relief system correctly and depending on the system type (and the subsequent sizing equations), different data is required.

For example, a common method of relief system sizing for a vapour pressure system is Leung's method. A variation on Leung's method is also a common method for hybrid system sizing. Leung's method requires the following parameters to be available for the system in question:

- Average heat release rate per unit mass of reacting mixture
- Mass in reactor
- Volume in reactor
- Physical properties of reactants e.g. specific volume, latent heat of vaporisation

These parameters should be easily obtainable from lab-based testing and system documentation. For gassy systems, the following parameters should be available:

- Rate of pressure rise in system
- Adiabatic rate of temperature rise in system
- Volume, mass and temperature of test cell

There are various types of calorimeter that can calculate these parameters, such as Vent Size Package (VSP) calorimeters, Reactive System Screening Tool (RSST) calorimeters, or Accelerating Rate Calorimeters (ARC).

Once the required relieving rate has been determined, the relief system sizing can be carried out. The starting point for this process is usually to determine whether two-phase flow occurs at relieving conditions. Some systems are inherently foamy and will always produce two-phase relief, but in systems that are non-foaming (or where there is uncertainty), a level swell calculation is carried out to determine if the relieving fluid is single phase or two-phase. In order to carry out a level swell calculation the following information is required:

- Physical properties of reactants e.g. density, latent heat of vaporisation
- Vessel void fraction (derived from normal working volume)

From this point the vent size requirements are calculated in the same way as a non-reactive relief calculation. However, an additional but nevertheless important consideration in reactive relief system sizing is choosing a suitable relief device set pressure. For an exothermic (runaway) reaction it is beneficial to choose as low a set pressure as is reasonably practicable, as temperature and pressure rise rapidly once temperature control is lost, e.g. cooling system failure. Choosing a set pressure lower than the system design pressure could result in a significantly smaller vent requirement.

In summary, reactive relief system sizing is a complex, but necessary part of ensuring that your reaction processes adhere to industry codes, as well as safeguarding plant personnel and the public. The output of a reactive relief system design calculation will only be as good as the input information, therefore it is essential that accurate and relevant test data is available when designing the system, or verifying an existing system.

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