consilab
Gesellschaft für Anlagensicherheit
Höchst zuverlässig.

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Thermal hazards: identify, assess, control...

Part III: Help! I have a runaway reaction!

In our last two consiLetters, we showed how to determine safety-relevant parameters for safe thermal handling of substances. In combination with additional data about the actual reaction, such as reaction enthalpy or heat flux, whose measurement we will cover in a later consiLetter, measures for normal operation can now be developed based on the TRAS 410 technical rules for plant safety, which ensure safe operation of the plant.

But what about when the operation deviates from normal operation, such as due to a loss of cooling or incorrect dosing, and an unwanted rise in temperature results that could possibly initiate additional thermal process (e. g. decomposition reactions). In these cases it is important to assess the possible impacts and safely control them. First, realistic malfunction scenarios (worst case) scenarios should be defined. These deviations from normal operation should then be examined in an adiabatic reaction calorimeter (e.g. VSP2) in order to assess possible impacts. The adiabatic conditions in the laboratory test are essential for scale-up, since a laboratory reactor generally has a much larger surface-to-volume ratio than a production reactor. The relative heat loss in a non-adiabatic laboratory reactor would therefore be too great and would lead to a non-conservative result.

With the adiabatic VSP reaction calorimeter (Fig. 1) reactions that deviate from normal operation (e.g. higher heating temperature, cooling failure, improper charging, etc.) can be tested under safe conditions at a 100 ml scale. In the process, reactants are placed in what are usually a closed, very thin-walled test cell with a volume of 120 ml, and this well-insulated cell is installed in a pressure vessel with a permissible operating pressure of 120 bar. The reaction mixture is then warmed with the test cell heater to the desired starting temperature, from which the further increase in temperature results solely from the energy released by the reaction. To minimize the heat exchange with the environment, the temperature in the pressure vessel is continuously held at the temperature in the test cell with the use of a heating system, which creates a “quasi” adiabatic system that very closely replicates the conditions in a real boiler.

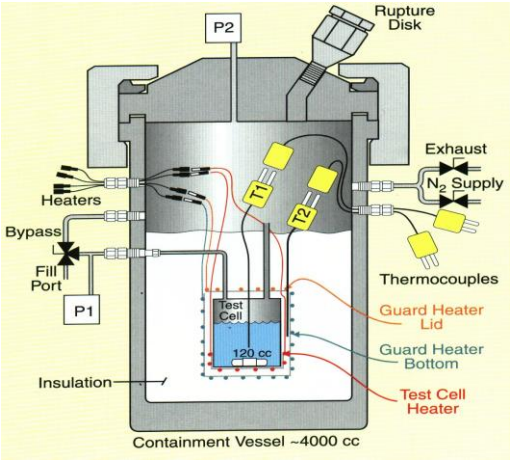

Figure 1: Vent sizing package (VSP) experimental setup

In a VSP experiment, not only can the maximum (adiabatic) temperature and pressure rise of a reaction be specified for the tested deviation from normal operation (Fig. 2) but also the respective speeds of temperature and pressure rise independent of the temperature. Additionally, a prediction regarding the formation of permanent gases can be made via the cooling curves. Based on this data, for one thing, a suitable countermeasure can now be developed to minimize the impacts of the deviation (e. g. emergency cooling), and for another, the data can be used to size the pressure relief equipment (safety valve or rupture disk) so that the plant is protected from an impermissible pressure rise in the case of a runaway reaction.

If we can assist you with a similar issue, please contact us. Our experts will be happy to advise you in specifying the test conditions and can also support you early on at the safety briefing stage.

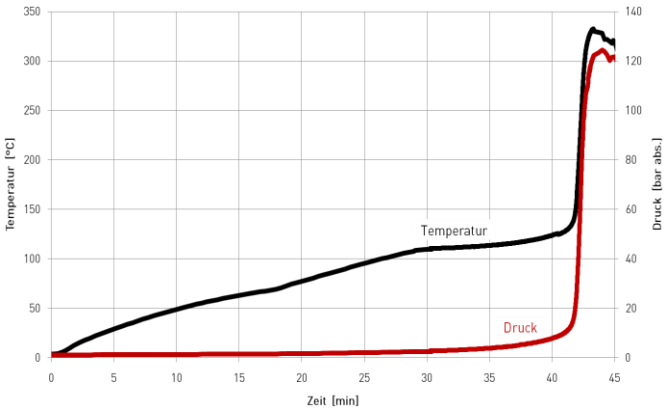

Figure 2: Test sequence for a “runaway” reaction

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