

## DISCIPLINE INFORMATION NOTE

### Chemical Reaction Hazards

<b>DIN No</b>	CD5/050	<b>Issue Date</b>	5 November 2003
<b>Open Government Status</b>	Fully Open	<b>Review Date</b>	5 November 2005

To: Process Safety Specialist Inspectors, Mechanical Engineering Specialists

## EMERGENCY PRESSURE RELIEF OF LIQUIDS CONTAINING SUSPENDED SOLIDS

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#### INTRODUCTION

The field of two-phase liquid/vapour venting has been the subject of considerable research in recent years<sup>1</sup> and, for chemical reactors, HSE has published advice in the form of a Workbook<sup>2</sup>. In some cases, however, the situation will arise, where there are also solids present in the system. The solid phase might be a heterogeneous catalyst, a partially dissolved reactant or a solid product that is crystallizing as a process proceeds. The Workbook summarised the available advice on how to allow for the presence of such solids when sizing a chemical reactor pressure relief system. However there was a need for further experimental work and guidance.

The Process Safety Topic Group (HID CTG5), in collaboration with a consortium of companies and including HSL sponsored a project to further investigate the problems on the laboratory scale, and to identify the main issues involved. The work was carried out by Hazard Evaluation Laboratory Ltd. Although the project was principally aimed at chemical reactions, where particular problems apply, it is also relevant to non-reacting systems. This DIN describes the main findings that have been published at a Technical Conference<sup>3</sup> and in an HSE Research Report<sup>4</sup>.

#### EXPERIMENTAL PROGRAM

An experimental programme was devised to examine the effects of the addition of suspended solids on a two-phase vented system. In order to do this, the depressurisation profiles during venting (pressure and temperature versus time) from tests with the addition of solids were compared to those without.

Initially non-reacting systems were examined. The depressurisation profiles of superheated water and water-glycerol mixtures were studied on their own and with added glass particles. The particles were both solid and hollow and had specific gravities both greater than and less than 1.

Similar venting experiments were then made during the runaway reaction of acetic anhydride and water, both with and without solids. In this case, the experiments were

also concerned with whether the presence of solids changed the overpressure during venting (rather than a simple depressurisation). Experimentation was carried out on both the 1 litre and 10 litre scales, in purpose-built vented pressure vessels to a catch tank (for the reaction system this was sealed and contained a quench fluid). The relief set pressures were between 3 and 5 bara, and solids concentrations were up to 30% v/v.

There were a considerable number of potential variables that could be studied in this project, including solid concentration, solid diameter, solid density, nozzle diameter, fill level, stir rate, relief pressure etc. In order to study this wide range of factors efficiently, factorial experimental design techniques were used.

## **MAIN FINDINGS**

The main findings were:

Some factors, e.g. fill level and nozzle diameter are already known to affect the depressurisation without solids. This was confirmed by the tests. However the prime interest here was to identify those experiments in which solid diameter, or solid concentration, combined with the other factors affected the depressurisation profile.

1. For the ranges of variables studied, the solids had little influence on the rates of depressurisation achieved. There is limited evidence that the less dense solids could increase depressurisation rates slightly.
2. During venting, liquid was discharged preferentially to the solids. This was observed for both naturally floating and sedimenting particles, i.e. both less and more dense than the fluid in which they are suspended. This may have important implications for the design and sizing of pressure relief vents, particularly if the solid is taking part in a runaway reaction.
3. Tests with runaway reactions highlighted some difficulties in comparing systems with and without solids present. This was because the addition of inert particles affects the heat capacity of the system.
4. A potential problem on the 1 litre scale was that the repeatability of the tests was poor, particularly when comparing many identical tests carried out over an extended time period. Tests on the 10-litre scale were more reproducible. For this reason, experimental work on the reactive system concentrated on the 10-litre scale.
5. There was no effect on any of the response variables due to the amount of glycerol added. This suggests that the viscosity and density difference between the water and water/glycerol mixtures had no effect on depressurisation for the range of variables studied.

## **ADVICE TO INSPECTORS**

The range of reaction types and conditions that may be encountered in industry is so wide that it would be impossible for the results of this series of tests to be conclusive. However, the results do confirm advice previously given by HSE in reference 2. In particular:

1. Before calculating the required vent areas in the case of liquids containing suspended solids, any effects of concentration of the solids during venting must be considered in the selection of the calorimetric test methods used for relief line sizing.
2. If inert particles are present in a reaction, these can affect the required vent size if the temperature is changing rapidly (such as during a runaway). Small particles will absorb heat more quickly than larger ones, so the larger inert particles appear to accelerate the reaction more. It is recommended that, where practicable, small scale calorimetry should be carried out with a representative fraction of the solids present, otherwise their presence will have to be accounted for in some other way.
3. The **mixture** viscosity and density should be used in vent sizing calculations, not those of the liquid with no solids.
4. Solid deposition and downstream fouling may also be issues, which will have to be accounted for by the company concerned.

Further advice is given in reference 2, Chapter 10.

## REFERENCES

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2. Etchells, J and Wilday, J: "Workbook for chemical reactor relief system sizing," 1998, HSE Books. ISBN 0-71761389-5
3. McIntosh, R.D., Waldram, S.P and Etchells, J.C., "Pressure relief of fluids containing suspended solids", IChemE **Series No. 149 (Hazards XVII)**, march 2003, **ISBN 0-85295-459-X**
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