Introducing PrEVent - Practical Emergency Vent Sizing Software

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Vent Sizing for Reactive Systems

Runaway chemical reactions can generally be classified as tempered or non-tempered types. A tempered system is one in which the reaction heat can be removed by the latent heat of vaporization, preventing further increase in temperature and thereby controlling the reaction. This is accomplished by pressure relief venting, and the latent heat can be provided by either the reactant(s) or the solvent(s). On the other hand, a non-tempered system exhibits little or no latent heat of cooling; this is typical of a low vapor-pressure system (or high boiling point compound). Quite often the reaction product(s) are noncondensable gasses - these are so-called "gassy" systems. For non-tempered systems, the heat release is largely retained in the runaway reaction mass. If left unattended may lead to very large temperature and pressure excursions. As might be expected, emergency vent sizing methods differ depending on the system type.

The key parameters in relief vent sizing are the reaction rates at relief conditions, specifically, the rate of temperature rise (dT/dt) and the rate of pressure rise (dP/dt). Safe process design requires knowledge of these adiabatic chemical reaction rates, and also an understanding of the system character (gassy or vapor pressure driven, foamy or not-foamy).

DIERS Methodology

The AIChE Design Institute for Emergency Relief Systems (DIERS) provided the necessary laboratory tools to gather such data (Fauske & Leung, 1985). A primary purpose of DIERS was evaluation of emergency relief vent requirements, including energy and gas release rates for systems under actual upset conditions, and the effects of two-phase flow on the discharge process. DIERS methodology suggested a vent sizing approach utilizing two-phase flow whether the material being vented behaves as a vapor pressure (tempered), gassy, or hybrid (combined gas/vapor pressure) system. Given the difficulty of predicting two-phase flow regimes, the original DIERS technology recommended the use of the classical homogeneous equilibrium model (HEM) for calculating the two-phase discharge through relief devices. The widely recognized omega method of Leung (1986a,b) was introduced to quickly calculate critical and subcritical discharge of such two-phase fluids.

Later DIERS developments by Leung (1987) considered alternate level swell models (churn-turbulent or bubbly flow) to better represent the vessel discharge flow regime for vapor pressure systems. However, in order to take full advantage of the Leung omega techniques it is necessary to evaluate vapor/liquid disengagement characteristics for the reacting chemical system. Leung's methods are well suited for use with adiabatic calorimetry data derived from the VSP2, or Vent Sizing Package (Askonas et. al, 2000). The VSP2 (originally called the DIERS Bench Scale Apparatus) measures the pressure/temperature (P/T) relationship and reaction rates dT/dt and dP/dt in an adiabatic runaway system (directly scalable to process conditions due to the low thermal inertia i.e. low Φ-factor design); it can also be used to characterize vessel flow regime by experimental simulation of "blowdown" venting. Note that for gassy and hybrid systems the Leung approach remains consistent with the traditional DIERS assumption of homogeneous vessel conditions.

Practical DIERS Extensions

The assumption of homogeneous vessel venting has since continued on page 7

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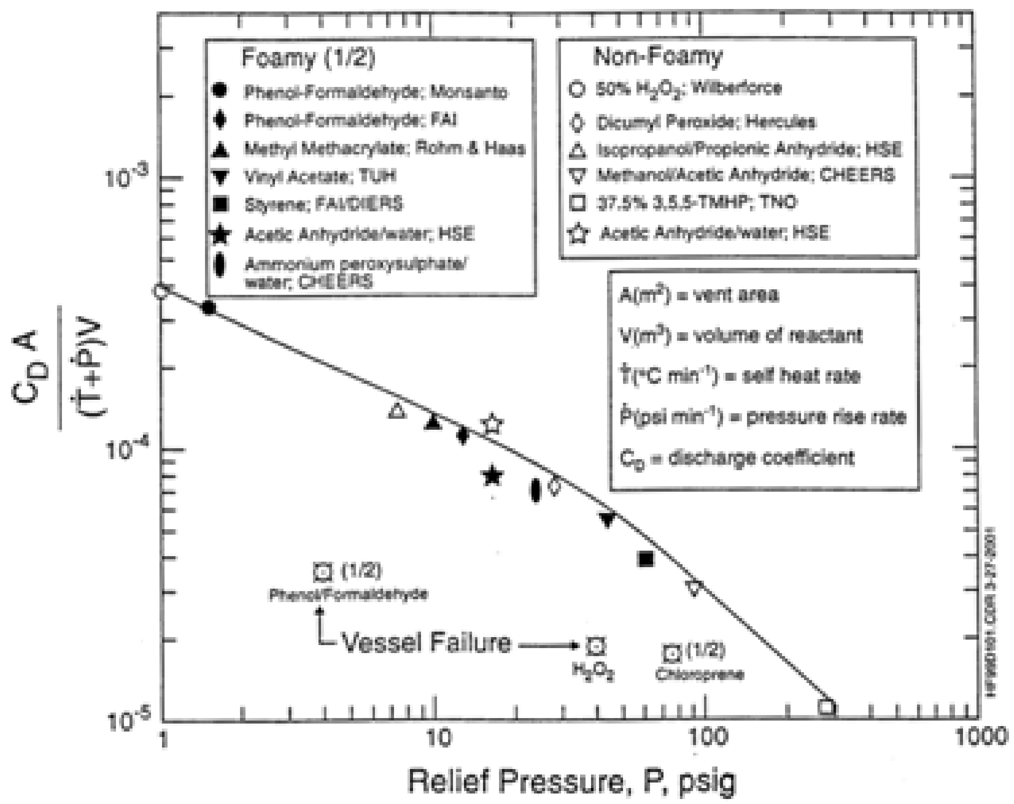
been criticized as overly conservative in some cases, particularly for gassy systems, and later articles by Fauske (1998, 2000) cite large-scale experimental data for several reactive systems that support a gas/vapor venting approach. Fauske has gone on to develop a practical emergency vent sizing method, based on vapor/gas venting, which makes direct use of relevant low Φ-factor adiabatic data. Such data are readily obtained with the VSP2 or the easy-to-use ARSST, or Advanced Reactive System Screening Tool (Burelbach, 2000).

Note also that in Fauske's recent vapor/gas venting methods it is not necessary to resolve uncertainties in the two-phase flow regime; rather it is sufficient to distinguish between "foamy" and "non-foamy" systems. For vapor pressure systems that exhibit foamy behavior (detectable in the ARSST) an adequate vent size may be obtained using twice the vapor venting relief area and allowing for modest overpressure above the relief set pressure (about 40% on an absolute basis). This does not mean that two-phase flow does not occur, but just that in many cases a practical emergency vent size can be determined without taking a two-phase flow penalty.

Fauske (2006) has further simplified the vapor/gas venting equations to eliminate the need for any physical properties whatsoever. The result is the Fauske General Screening Equation which compares favorably with the available large scale data (Fig. 1). Kinetic modeling and detailed thermophysical properties - information that is expensive to generate and often not available - are not required.



$$\frac{C_D}{\dot{T}+\dot{P}}\frac{A}{V} = \frac{3.5 \cdot 10^{-3}}{P\left[1+\dfrac{1.98 \cdot 10^{3}}{P^{1.75}}\right]^{0.286}}$$

Fig. 1. Fauske (2006) General Screening Equation and comparison with benchmark data.

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PrEVent Software

The above practical emergency vent sizing methods are easily implemented using Fauske's new PrEVent. Sizing Software. The main Calculation window for PrEVent is illustrated in Fig. 2. This new application retains the most popular features of previous Fauske vent sizing software programs (VSSP, VSSPH, and RMS) including the Leung omega method, Fauske Gas/Vapor method, and Fauske General Screening method. The modern user interface features clear navigation, logical tabs, and intuitive drop down menus that take advantage of cutting edge Windows programming techniques for a crisp seamless user experience. The streamlined interface allows users to make changes to input values "on the fly" and see the results updated immediately. This is convenient for parametric studies, such as varying the batch size to see how much reactant will "fit" within a particular vessel/relief installation. Input parameters, including vessel geometry, reactant properties and adiabatic reaction rates at venting, are conveniently entered using simple drop down windows and saved for later use.

PrEVent will be offered as a stand alone Windows application, or as a Silverlight 4 based web application-supporting a wide-range of platforms including all major browsers on both Mac OS X and Windows – Internet Explorer 6, 7 8, Firefox2 and 3, Safari 3 and 4, and Google Chrome.

The release date of PrEVent 1.0 is December 1, 2010. For technical information on PrEVent please contact Jim Burelbach at burelbach@fauske.com. For sales, contact Russ Lee at rlee@fauske.com or (630) 887-5285. Call now for special pre-release pricing!

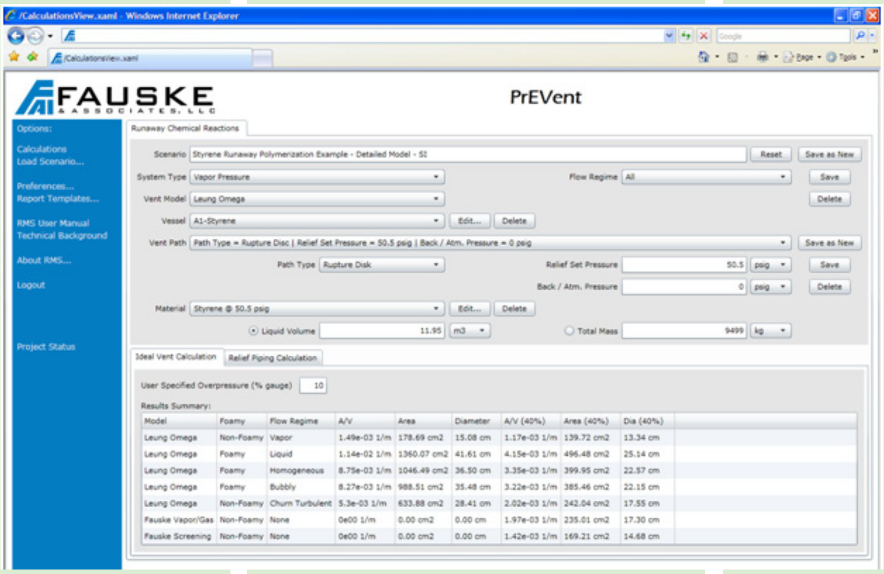

Fig. 2. Calculations page of PrEVent software showing styrene runaway reaction case. (For this illustration results are shown for all flow regime options including both Leung and Fauske methods.)

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