Based upon large scale experience, Monsanto Company used the following simple vent sizing formula for the phenolic resin reactors (Howard, 1973)

\[ D = 0.26 \sqrt[1/2]{V} \]  

(1)

where \( D \) is the vent diameter in inches and \( V \) is the volume of reactants in gallons. It is noted that formula (1) is only applicable for a relief set pressure \( P_s \approx 1.5 \text{ psig} \) (0.103 bar) and corresponding self heat rate \( \dot{T}_s = 6.5^\circ \text{C min}^{-1} \). Formula (1) can be restated as

\[ \frac{A}{V} = 9.0 \cdot 10^{-3} \text{ m}^{-1} \]  

(2)

where \( A \) (m²) is the vent area and \( V \) (m³) is the volume of reactants. Following Fauske methodology (Fauske, 2006) Eq. 2 can be generalized as follows

\[ \frac{A}{V} = 1.7 \cdot 10^{-3} \frac{\dot{T}_s}{P_s^{1/2}} \]  

(3)

Setting \( \dot{T}_s = 6.5^\circ \text{C min}^{-1} \) and \( P_s = 1.5 \text{ psig} \) Eq. 3 results in \( A/V = 9.0 \cdot 10^{-3} \text{ m}^{-1} \).

The generalized Monsanto formula (Eq. 3) also clearly explains the 1999 catastrophic vessel failure of a phenol-formaldehyde reactor with \( A/V = 6.9 \cdot 10^{-3} \text{ m}^{-1} \) and a relief set pressure \( P_s = 4 \text{ psig} \) (0.276 bar g). The allowable self heat rate \( \dot{T}_s \) for safe relief venting is given by

\[ \dot{T}_s = \frac{1}{1.7 \cdot 10^{-3}} \left( \frac{A}{V} \right) P_s^{1/2} \]

\[ = \frac{1}{1.7 \cdot 10^{-3}} 6.9 \cdot 10^{-3} \cdot 4^{1/2} \]

\[ = 8.1^\circ \text{C min}^{-1} \]  

(6)

which compares to the actual self heat rate of \( \dot{T}_s = 50^\circ \text{C min}^{-1} \) at 4 psig obtained by VSP2 calorimetry simulation of the accident.

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Using Fauske’s generalized formula results in

\[ T_s = \frac{1}{8 \cdot 10^{-4}} (A / V) P_s^{1/2} C_D \]

\[ = \frac{1}{8 \cdot 10^{-4}} \cdot 6.9 \cdot 10^{-3} \cdot 4^{1/2} \cdot 0.5 \]

\[ = 8.6 \text{°C min}^{-1} \]  

Therefore, formula (5) is recommended as an "easy to use" procedure to check the adequacy of existing reactor relief systems together with appropriate calorimetry testing of credible worst case scenarios providing the correct values of \( T_s \) at relief set pressures \( P_s \) (as low as practical < 5 psig).

References


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To support our growing Nuclear & Non-Nuclear businesses, FAI is looking for qualified individuals to fill the following positions in both permanent and consulting roles:

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  Successful candidate will have a demonstrated ability to setup and run various bench top laboratory equipment including: VSP2, ARSST, ARC, TAM, DSC and other thermal hazards testing equipment.

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  Successful candidate will work with other engineers on projects related to nuclear power plants. Projects include small scale setups of plant systems along with analyzing and working on nuclear plant electrical systems. Will work hands on with data acquisition systems and equipment including data collection, troubleshooting and post-test analysis.

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