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PREVENTING PHENOLIC RESIN REACTOR ACCIDENTS

"EASY TO USE" PROCEDURE FOR CHECKING ADEQUACY OF EMERGENCY RELIEF VENT SIZES

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

$$D = 0.26\,(V)^{1/2} \qquad (1)$$

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 $P_s \approx 1.5$ psig (0.103 bar g) and corresponding self heat rate $\dot{T}_s \approx 6.5°\mathrm{C\,min^{-1}}$. Formula (1) can be restated as

$$A/V = 9.0 \cdot 10^{-3}\ \mathrm{m^{-1}} \qquad (2)$$

where A (m^2) is the vent area and V (m^3) is the volume of reactants. Following Fauske methodology (Fauske, 2006) Eq. 2 can be generalized as follows

$$A/V = 1.7 \cdot 10^{-3}\,\frac{\dot{T}_s}{P_s^{1/2}} \qquad (3)$$

Setting $\dot{T}_s = 6.5°\mathrm{C\,min^{-1}}$ and $P_s = 1.5$ psig Eq. 3 results in A/V $= 9.0 \cdot 10^{-3}\,\mathrm{m^{-1}}$.

Vent sizing formula (3) is also consistent with dedicated phenolic runaway reaction tests performed by Fauske & Associates, LLC (FAI) with A/V ≈ $2.8 \cdot 10^{-2}$ (Leung et al., 1998). Considering the most severe tests with $P_s = 13$ psig and corresponding $\dot{T}_s = 62°\mathrm{C\,min^{-1}}$, results in

$$A/V = 1.7 \cdot 10^{-3}\,\frac{62}{13^{1/2}}$$
$$= 2.9 \cdot 10^{-2}\ \mathrm{m^{-1}} \qquad (4)$$

The above observations are consistent with Fauske's generalized vent sizing formula (Fauske, 2006)

$$A/V = \frac{8 \cdot 10^{-4}}{P_s^{1/2}}\,\frac{\dot{T}_s}{C_D} \qquad (5)$$

Where C_D is the discharge coefficient determined from $C_D = [1 + 4f\,L/D]^{-0.39}$ where f = 0.005. Setting $C_D = 0.5$, $P_s = 13$ psig and $\dot{T}_s = 62°\mathrm{C\,min^{-1}}$ results in A/V $= 2.75 \cdot 10^{-2}\,\mathrm{m^{-1}}$, and $P_s = 1.5$ psig and $\dot{T}_s = 6.5°\mathrm{C\,min^{-1}}$ results in A/V $= 8.5 \cdot 10^{-3}\,\mathrm{m^{-1}}$.

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

$$\dot{T}_s = \frac{1}{1.7 \cdot 10^{-3}}\,(A/V)\,P_s^{1/2}$$
$$= \frac{1}{1.7 \cdot 10^{-3}}\,6.9 \cdot 10^{-3} \cdot 4^{1/2}$$
$$= \underline{8.1°\mathrm{C\,min^{-1}}} \qquad (6)$$

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

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Using Fauske's generalized formula results in

$$\dot{T}_s = \frac{1}{8 \cdot 10^{-4}} (A/V) P_s^{1/2} C_D$$

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

$$= \underline{8.6°C\ min^{-1}} \quad (7)$$

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 $\dot{T}_s$ at relief set pressures P_s (as low as practical < 5 psig).

References

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