Solution Exercise 05-01: Criticality classes and measures

Solution exercise 1 : Condensation

Thermal potential :

Reaction : $\Delta T_{ad} = \dfrac{Q'_{rx}}{c'_p} = \dfrac{230 kJkg^{-1}}{1,7 kJkg^{-1}K^{-1}} = 135K$

Decomposition : $\Delta T_{ad} = \dfrac{Q'_{rx}}{c'_p} = \dfrac{150 kJkg^{-1}}{1,7 kJkg^{-1}K^{-1}} = 89K$

Assuming 100 % accumulation, the la decomposition would be triggered and the overall potential was rated « critical ».

Taking the accumulation into account :

$$MTSR = T_p + X_{ac} \cdot \Delta T_{ad} = 40 + 0,3 \times 135 = 81°C$$

MTSR<T_{D24}=130°C, hence the decomposition will not be triggered after a cooling failure, as long as the feed is immediately stopped.

The thermal potential is rated « negligible », but the boiling point can be reached (MTT=56°C=329K)

The criticality class is 3.

The amount of vapour released is :

$$Mv = \frac{(MTSR - MTT) \cdot c'_p \cdot M_r}{\Delta H'_v} = \frac{(81°C - 56°C) \times 1,7\ kJ\ kg^{-1}K^{-1} \times 2500\ kg}{523\ kJ\ kg^{-1}} = 203 kg_{vap}$$

$$\rho_v = \frac{PM_w}{RT} = \frac{1 bar \times 58\ kg\ kmol^{-1}}{0,08315\ m^3 bar\ kmol^{-1}K^{-1} \times 329K} = 2,12\ kg\ m^{-3}$$

The volume of flammable mixture is :

$$V_{ex} = \frac{M_v}{\rho_v \cdot LIE} = \frac{203\ kg}{2,12\ kg\ m^{-3} \times 0 \cdot 016} \cong 5885\ m^3$$

Extension : $r = \sqrt[3]{\dfrac{3V_{ex}}{2\pi}} = \sqrt[3]{\dfrac{3 \times 5985}{2 \times 3,14}} \cong 14\ m$

The flammable cloud may reach the site fences : severity rated « critical ».

Thermal activity at MTT :

$$q_{(MTT)} = q_{rx} \cdot \exp\left[\frac{E}{R}\left(\frac{1}{T_p} - \frac{1}{MTT}\right)\right] \cdot \frac{MTSR - MTT}{MTSR - T_p}$$

$$q_{(MTT)} = 20\, W\ kg^{-1} \cdot \exp\left[\frac{100000}{8,314}\left(\frac{1}{313} - \frac{1}{329}\right)\right] \cdot \frac{81-56}{81-40} = 20 \times 6,5 \times 0,6 \approx 80\, W\ kg^{-1}$$

The total heat release is 200kW for the charge of 2500 kg. Hence the condenser power of 250 kW is sufficient.

Vapour velocity :

- Mass flow rate : $\dot{m}_v = \dfrac{80\, W\ kg^{-1} \times 2500 kg}{523000\ J\ kg^{-1}} = 0,382 kg\ s^{-1}$
- Volume flow rate : $\dot{v}_v = \dfrac{0,382\ kg\ s^{-1}}{2,12\ kg\ m^{-3}} = 0,18\ m^3 s^{-1}$
- Pipe section : $S = \pi \dfrac{0,25^2}{4} = 0,049 m^2$
- Vapour velocity : $u = \dfrac{0,18 m^3 s^{-1}}{0,049 m^2} = 3,7 m\ s^{-1}$

Thus, the probabiliy of loss of control is low. The situation can be mastered as far as the condenser remains in operation in case of cooling failure on the reactor.