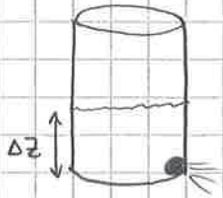
RIS520: MANDATORY EXERCISE

[redacted]

TASK

n-pentane C_5H_{12}



$V = 2\ m^3$ $\quad$ $T = 20\ °C$

$d = 2\ cm$ $\quad$ $P_g = 0{,}57$ bar g (assume constant)

$\Delta z = 1{,}2\ m$ $\quad$ $\rho_f = 600\ kg/m^3$

$g = 9{,}81\ m/s^2$

(a) INITIAL LEAK RATE

$$m_L = C_D \cdot A \cdot \rho_f \sqrt{2\left[\left(\frac{P_1 - P_2}{\rho_f}\right) + \Delta z \cdot g\right]} \qquad (4.9\ \text{FCH})$$

$$m_L = 0{,}62 \cdot (\pi \cdot 0{,}01^2\ m^2) \cdot 600\ \frac{kg}{m^3} \sqrt{2\left[\left(\frac{0{,}57 \cdot 10^5\ Pa}{600\ kg/m^3}\right) + 1{,}2\ m \cdot 9{,}81\ m/s^2\right]}$$

$$= 0{,}116867\ kg/m \cdot \sqrt{2\left[95\ m^2/s^2 + 11{,}772\ m^2/s^2\right]}$$

$$\underline{= 1{,}708\ kg/s.}$$

In correct units:

$$V_L = \frac{m_L}{\rho_f} = \frac{1{,}708\ kg/s}{600\ kg/m^3} = \underline{\underline{2{,}85 \cdot 10^{-3}\ m^3/s}}$$

(b) REGRESSION RATE

for infinitely large pools.

Heat of combustion $\Delta H_c = 49\ MJ/kg = 49 \cdot 10^3\ kJ/kg$

Heat of evaporation $\Delta H_v = 366\ kJ/kg$.

n-pentane assumed at boiling point: $T_b = T_0$.

$$V_{f\infty} = 1{,}27 \cdot 10^{-6} \left[\frac{\Delta H_c}{\Delta H_v + C_p(T_b - T_0)}\right] \qquad (7.19\ \text{FCH})$$

$$= 1{,}27 \cdot 10^{-6} \left[\frac{49 \cdot 10^3\ kJ/kg}{366\ kJ/kg + 0}\right]$$

$$\underline{\underline{V_f = 1{,}700 \cdot 10^{-4}\ m/s}}$$

ⓒ EQUILIBRIUM DIAMETER OF POOL

Assume continuous leak.

$$D_{eq} = 2\left[\frac{V_L}{\pi v_f}\right]^{1/2} \qquad (7.6 \text{ FCH})$$

$V_L = 2.85 \cdot 10^{-3}\ m^3/s$
$v_f = 1{,}700 \cdot 10^{-4}\ m/s$

$$D_{eq} = 2\left[\frac{2.85 \cdot 10^{-3}\ m^3/s}{\pi \cdot 1{,}7 \cdot 10^{-4}\ m/s}\right]^{1/2} = \underline{\underline{4{,}62\ m}}$$

We conclude that the pool is large enough to use formula for infinitely large pools.

TIME TO REACH EQUILIBRIUM DIAMETER:

$$t_{eq} = 0{,}564 \frac{D_{eq}}{[g v_f D_{eq}]^{1/3}} \qquad (7.7 \text{ FCH})$$

$$= 0{,}564 \cdot \frac{4{,}62\ m}{[9{,}81\ m/s^2 \cdot 1{,}7 \cdot 10^{-4}\ m/s \cdot 4.62\ m]^{1/3}}$$

$$= \frac{4{,}62\ m}{[7{,}7047\ m^3/s^3]^{1/3}} = \underline{\underline{13{,}192\ s}}.$$

The equilibrium diameter is 4,62 m and the time to reach this diameter is 13,192 s.

ⓓ VISIBLE FLAME HEIGHT

We assume quiscent (no wind) conditions.

$$L = 42 D\left[\frac{m_f''}{\rho_0 \sqrt{gD}}\right]^{0{,}61} \qquad (7.9 \text{ FCH}).$$

m_f'': Burning rate per unit pool area $= \rho_f v_f$ $[kg/m^2 s]$.

ρ_0: Air density $\sim 1{,}2\ kg/m^3$

$$L = 42 \cdot 4{,}62\ m\left[\frac{600\ kg/m^3 \cdot 1{,}700 \cdot 10^{-4}\ m/s}{1{,}2\ kg/m^3 \sqrt{9{,}81\ m/s^2 \cdot 4.62\ m}}\right]^{0{,}61}$$

$$\underline{\underline{L = 13{,}48\ m}}$$

The visible flame height is 13,48 m.

(e) SOOT PRODUCTION HEIGHT

Smoke generation starts at $H_L = e^{-0,12D} L$ (7.23 FCH)

$H_L = e^{-0,12 \cdot 4,62} \cdot 13,48\ m$

$H_L = 7,74\ m$

(f) MAXIMUM POOL DIAMETER IF RUPTURED TANK

Assume instantaneous release with no barriers.

$$D_m = 2 \left[\frac{V_L^3 g}{v_f^2} \right]^{1/8} \quad (7.3\ FCH)$$

$$D_m = 2 \left[\frac{(2\ m^3)^3 \cdot 9,81\ m/s^2}{(1,700 \cdot 10^{-4}\ m/s)^2} \right]^{1/8} = 30,22\ m$$

If the leak is caused by a catastrophic rupture of the tank, the maximum pool diameter is 30,22 m.

(g) AVERAGE DIAMETER OF POOL AND FLAME HEIGHT

Average pool diameter:

$$D_a = \frac{1}{2} \left[\frac{\sqrt{3}}{2} + 1 \right]^{1/2} D_m \approx 0,683\ D_m \quad (7.5\ FCH)$$

$D_a = 0,683 \cdot 30,22 m = 20,64\ m$

Flame height:

$$L = 42\ D \left[\frac{m_f''}{\rho_0 \sqrt{gD}} \right]^{0,61} \quad (7,9\ FCH)$$

$$L = 42 \cdot 20,64\ m \left[\frac{600\ kg/m^3 \cdot 1,700 \cdot 10^{-4}\ m/s}{1,2\ kg/m^3 \sqrt{9,81\ m/s^2 \cdot 20,64\ m}} \right]^{0,61}$$

$L = 38,15\ m$

The average diameter of pool is 20,64 m and the corresponding flame height is 38,15 m.

(h) CHARACTERIZATION OF THE FIRE HAZARD

By using the maximum pool diameter, we will overestimate the fire hazard as it only exists for a very short time. The average pool diameter will give a more realistic result for the thermal radiation hazards.