ODH in Lab E & F from the 3000 Gallon External LN_2 Tank

W. Craddock
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A 3000 gallon (11360 liter) liquid nitrogen tank has been installed outside of Lab F to keep the Tohoku Bubble Chamber Magnet LN_2 shields cold. All vaporized LN_2 is vented outside through the 6" vent pipe. In the event of a rupture or mistaken disconnection of the incoming LN_2 line, a possible ODH situation might be present.

Lab E & F have a combined volume of 450,000 SCF. Fresh air enters at the rate of 1455 SCFM = 87300 SCFH. Approximately 13 liter per hr of LN_2 is required to keep each nitrogen shield cold.

$$1 \text{ liter } LN_2 = 22.8 \text{ ft}^3 \quad 0^\circ C$$

$$= 24.6 \text{ ft}^3 \quad 70^\circ F$$

The 3000 gallon tank has a warm gas equivalent of 2.79×10^5 SCF (70°F).

$$\frac{\text{Fresh air into Lab F}}{\text{Normal } LN_2 \text{ vaporization rate}} = \frac{87300}{26 \times 24.6} = 137$$

The normal circulation rate is two orders of magnitude greater than the average LN_2 boiloff rate.

However, the actual LN_2 transfer rate into Lab F is much greater. The Tohoku Bubble Chamber Magnet LN_2 dewars each hold about 70 liters providing a gravity feed to the shields and are periodically refilled.

The LN_2 flow into Lab F will be limited to 300 liter/hr with an orifice outside the building. Air being exhausted from Lab F can be allowed to contain as little as 135 mm/159 mm = 85% of the normal O_2 partial pressure. If the O_2 level is reduced to 85% of standard PO_2 concentrations, then the original N_2 must also be reduced by this amount with the remaining 15% coming from LN_2 entering the building. Thus, we can safely exhaust 1455 x 0.15 = 220 SCFM of LN_2 equivalent.

$$220 \text{ SCFM } N_2 = 530 \ LN_2 \text{ liter/hr}$$

A maximum allowable rate of 300 liter/hr will fill both dewars in 28 minutes which is a reasonable time.

The external 3000 gallon tank is set to ~ 25 psig. A copper 5/8" O.D. with Armaflex insulation line is run ~ 75 feet into the building. The magnet storage dewars are set to a normal relief pressure of approximate 3 psig. In addition, a 3 psi pressure drop between tanks occur due to the gravity head.

The pressure drop in the line is given by the Darcy formula

$$\Delta P = \frac{8}{\pi^2} \frac{\dot{m}^2}{\rho} f \frac{L}{D^5}$$

where

ΔP = dyne/cm^2

$\dot{m}$ = 300 liter/hr = 67.5 gm/sec

ρ = 0.81 gm/cm^3

L = 75 feet = 2290 cm

D = 0.555" = 1.41 cm

f = friction factor from the Moody diagram

μ = 0.0015 poise (gm/cm-sec)

1 dyne/cm^2 = 1.45×10^{-5} psi

$$R_e = \frac{4 \dot{m}}{\pi D \mu} = \frac{4 \times 67.5}{\pi \times 1.41 \times 0.0015 \text{ poise}}$$

$$R_e = 4.06 \times 10^4$$

Then

$$f = 0.029$$

and the pressure drop in the pipe from fluid flow is

$$\Delta P = 5.43 \times 10^4 \text{ dyne/cm}^2 = 0.79 \text{ psi}$$

To limit flow to 300 liter/hr the pressure drop across the orifice must be

25 - 3 - 0.79 = 21 psi

The formula for pressure drop across an orifice is taken from Crane's publication #410.

$$q = 0.525 \, d_1^{\,2} \, C \sqrt{\frac{\Delta P}{\rho}}$$

where d_1 is the orifice size in inches

ΔP = 21 psi

ρ = 50.4 lbs/ft^3

q = 300 liter/hr = 2.95 x 10^{-3} ft^3/sec

C = orifice flow coefficient found on page A-20 where the required Reynolds number is based on the upstream diameter.

Assume the upstream diameter to be the same of the rest of the piping (0.555" I.D.). Then R_e = 4.06 x 10^4 as before.

$$q = 0.525\, d_1^2\, C \sqrt{\frac{21}{50.4}} = 0.339\, d_1^2\, C$$

For d_1 = 0.12"

C = 0.6

and

q = 2.93 x 10^{-3} ft^3/sec = 300 liter/hr

as required.

Note also that the flow rate is relatively insensitive to changes in pressure and C is very insensitive to upstream diameter and flow rates (R_e).

Conclusion:

With a 0.12" diameter flow restriction Lab F should be classified as ODH = 0 as far as the LN_2 is concerned.

Further protection also exists because a 300 liter/hr spill would create a huge cloud immediately attacting the operators attention.