Prevention of Fires & Explosions

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Design Criteria

1. Prevent flammable mixtures.

2. Reduce ignition sources.

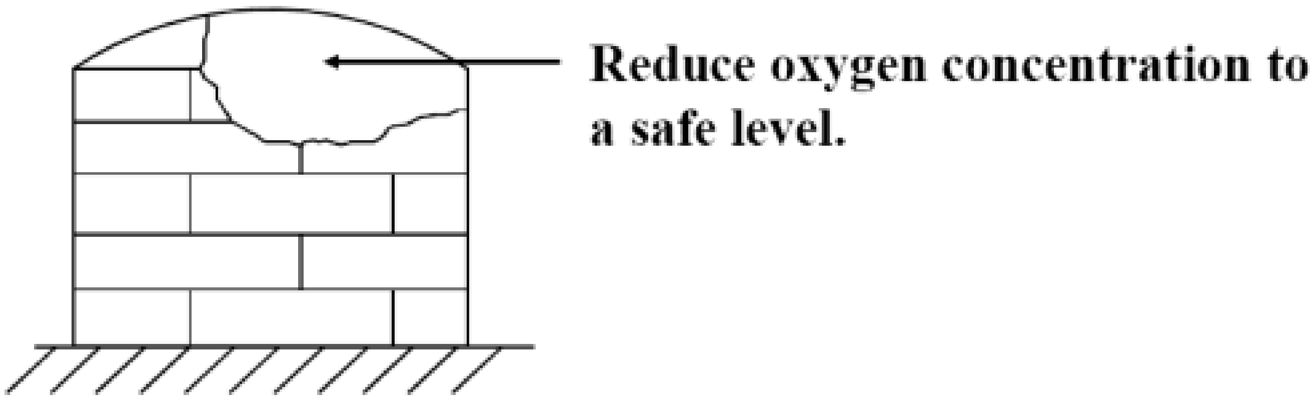
- Need to remember inherently safer design, that is, to reduce inventories, substitute with less dangerous materials, and reduce operating T and P.

Inerting and Purging

- Inerting is the process of adding an inert gas to a combustible mixture to reduce the concentration of oxygen below the limiting oxygen concentration (LOC).

Purpose:

To reduce the oxygen or fuel concentration to below a target value using an inert gas. Can use nitrogen, carbon dioxide, others. Nitrogen is the most common.



Inerting Procedures

1. Vacuum Purge - evacuate and replace with inert.
2. Pressure Purge - pressurize with inert, then relieve pressure.
3. Sweep Purge - continuous flow of inert.
4. Siphon Purge - fill with liquid, then drain and replace liquid with inert.
5. Combined: pressure and vacuum purge, others.

Vacuum Purge

Inerting – Vacuum Purging

Most common procedure for inerting reactors Steps

1. Draw a vacuum
2. Relieve the vacuum with an inert gas
3. Repeat Steps 1 and 2 until the desired oxidant level is

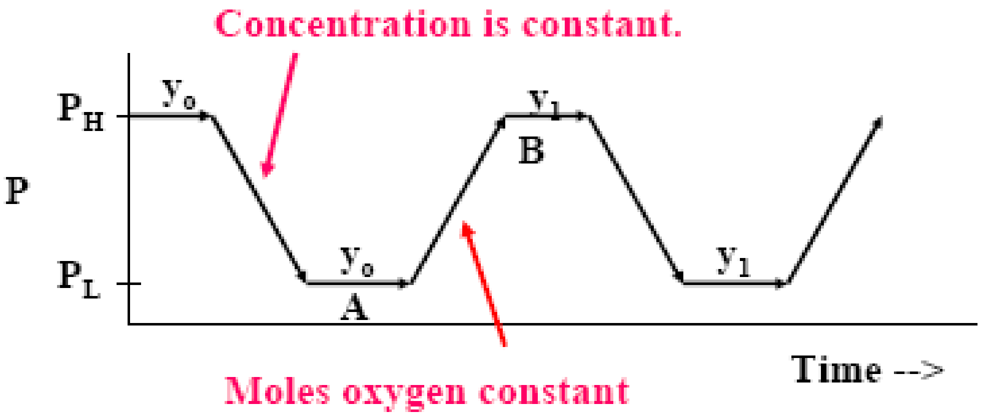
At A: $n_{oxy} = y_o\left(\frac{P_L V}{R_g T}\right)$

At B: $n_{TOT} = \frac{P_H V}{R_g T}$

$$y_1 = \frac{n_{oxy}}{n_{TOT}} = \frac{y_o\left(\frac{P_L V}{R_g T}\right)}{\frac{P_H V}{R_g T}} = y_o\left(\frac{P_L}{P_H}\right)$$

At end of jth cycle: $y_j = y_o\left(\frac{P_L}{P_H}\right)^j$ Eq. (7-6)

Total nitrogen used: $\Delta n_{N_2} = j(P_H - P_L)\frac{V}{R_g T}$ Eq. (7-7)



1. Pure nitrogen used.
2. Vessel is well mixed (not a bad assumption for gases).
3. Ideal gas law.

Example 7-1

Use a vacuum purging technique to reduce the oxygen concentration within a 1000-gal vessel to 1 ppm. Determine the number of purges required and the total nitrogen used. The temperature is 75°F, and the vessel is originally charged with air under ambient conditions. A vacuum pump is used that reaches 20 mm Hg absolute, and the vacuum is subsequently relieved with pure nitrogen until the pressure returns to 1 atm absolute.

Solution

The concentration of oxygen at the initial and final states is

$$y_o = 0.21 \text{ lb-mol } O_2/\text{total mol},$$

$$y_f = 1 \text{ ppm} = 1 \times 10^{-6} \text{ lb-mol } O_2/\text{total mol}.$$

The required number of cycles is computed using Equation 7-6:

$$y_j = y_o\left(\frac{P_L}{P_H}\right)^j,$$

$$\ln\left(\frac{y_j}{y_o}\right) = j \ln\left(\frac{P_L}{P_H}\right),$$

$$j = \frac{\ln(10^{-6}/0.21)}{\ln(20 \text{ mm Hg}/760 \text{ mm Hg})} = 3.37.$$

The total nitrogen used is determined from Equation 7-7. The low pressure P_L is

$$P_L = \left(\frac{20 \text{ mm Hg}}{760 \text{ mm Hg}}\right)(14.7 \text{ psia}) = 0.387 \text{ psia},$$

$$\Delta n_{N_2} = j(P_H - P_L)\frac{V}{R_g T}$$

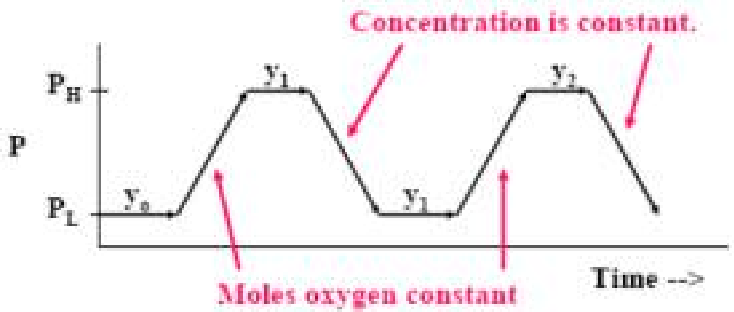
$$= 4(14.7 - 0.387) \text{ psia} \frac{(1000 \text{ gal})(1 \text{ ft}^3/7.48 \text{ gal})}{(10.73 \text{ psia ft}^3/\text{lb-mol}°\text{R})(75 + 460)°\text{R}}$$

$$= 1.33 \text{ lb-mol} = 37.2 \text{ lb of nitrogen}.$$

Inerting – Pressure Purging

Most common procedure for inerting reactors Steps

1. Add inert gas under pressure
2. Vent down to atmospheric pressure
3. Repeat Steps 1 and 2 until the desired oxidant level is reached

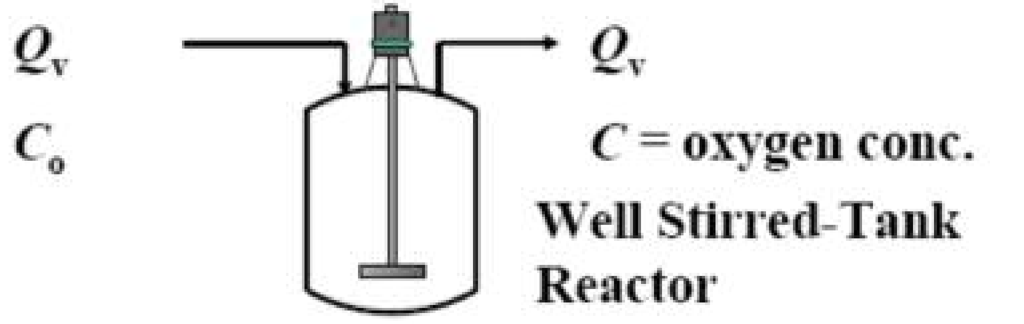


$$y_j = y_o\left(\frac{P_L}{P_H}\right)^j$$

✓ **Faster than vacuum purge, but uses more nitrogen.**

Sweep Purging

- 'In one end, and out the other'
- For equipment not rated for pressure, vacuum
- Requires large quantities of inert gas



Mass Balance on Oxygen: $V\dfrac{dC}{dt} = C_o Q_v - CQ_v$

Solution is: $Q_v t = V \ln\left[\dfrac{C_1 - C_o}{C_2 - C_o}\right]$ = Total Nitrogen Volume

If $C_o = 0$: $Q_v t = V \ln\left[\dfrac{C_1}{C_2}\right]$

Uses lots if inert!!

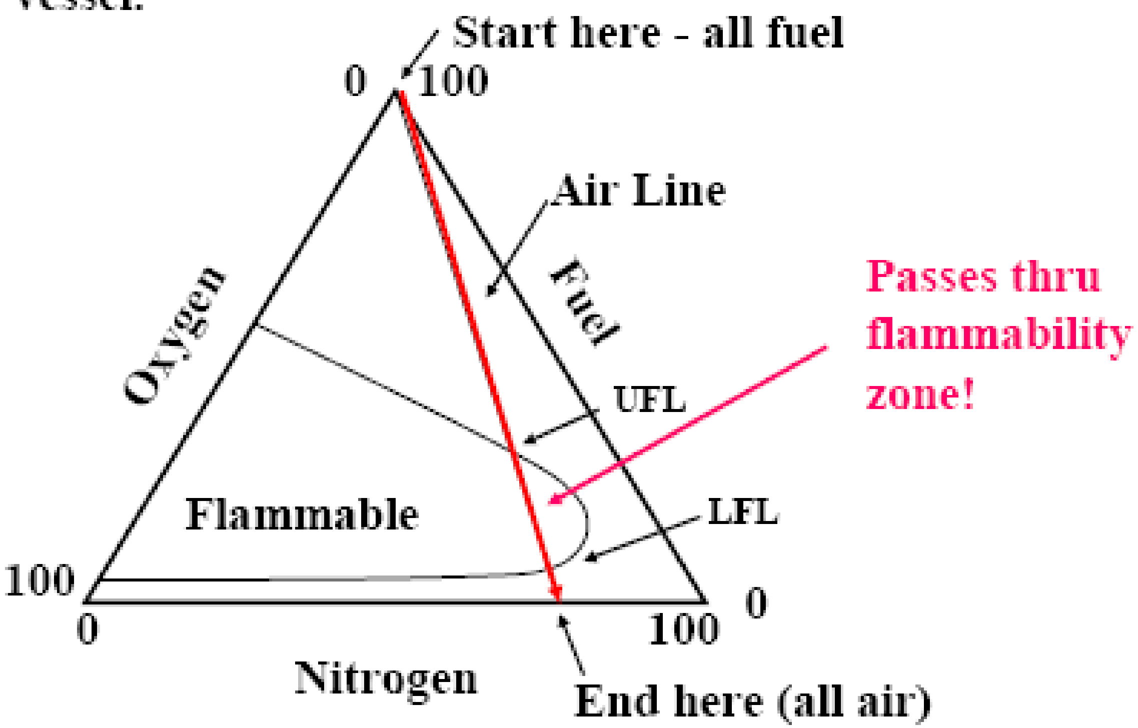
Assumes well-stirred

Using the Flammability Diagram

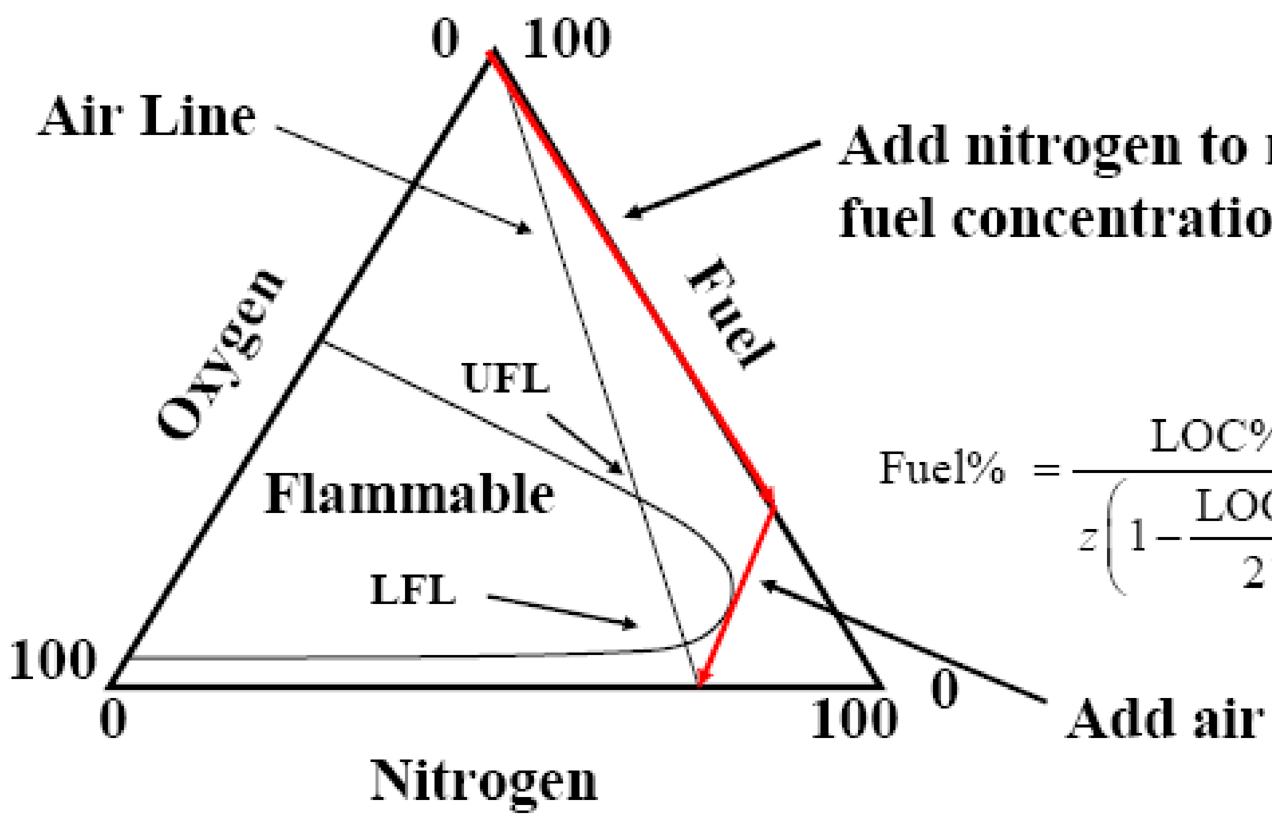
Taking a Vessel Out of Service

- Out-Of-Service Fuel Concentrations (OSFCs)

Depressurize vessel to atmospheric, then blow air into vessel.



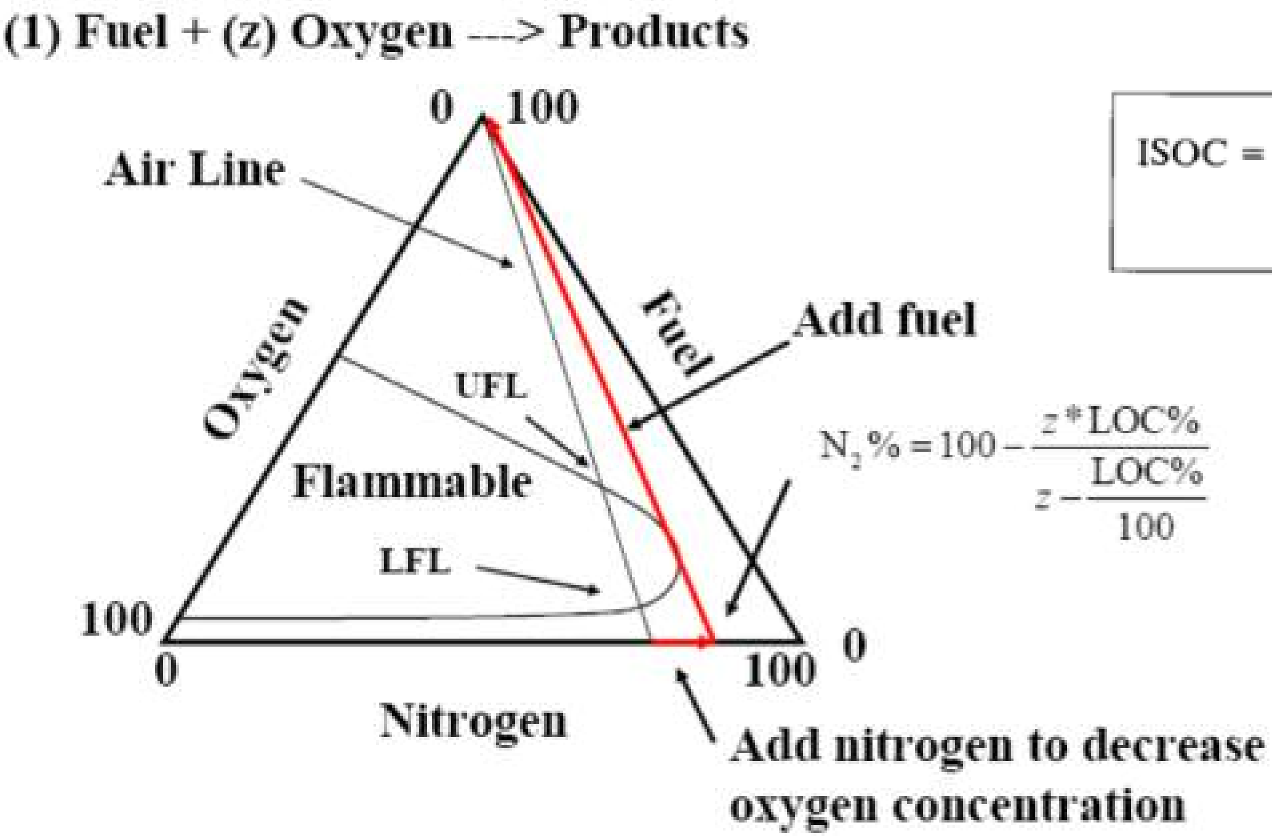
(1) Fuel + (z) Oxygen ---> Products



$$\text{Fuel\%} = \frac{\text{LOC\%}}{z\left(1 - \frac{\text{LOC\%}}{21}\right)}$$

Placing a vessel into service

The in-service oxygen concentration (ISOC) represents the maximum oxygen concentration that just avoids the flammability zone, with a small margin of safety.



$$ISOC = \frac{zLFL}{1 - \left(\frac{LFL}{100}\right)},$$

$$N_2\% = 100 - \frac{z * LOC\%}{z - \frac{LOC\%}{100}}$$

HW

7.5

7.7