## **Chemical Process Safety**

Chapter 7: Prevention of Fires & Explosions



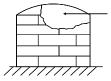
## **Design Criteria**

- 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**

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.

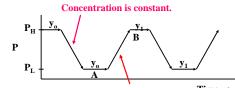


Reduce oxygen concentration to a safe level.

## **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.
- ${\bf 4. \ Siphon \ Purge fill \ with \ liquid, then \ drain \ and \ replace \ liquid \ with \ inert.}$
- ${\bf 5.\ Combined:\ pressure\ and\ vacuum\ purge,\ others.}$

# Vacuum Purge - 1



Moles oxygen constant

At A: 
$$n_{OXY} = y_o \left( \frac{P_t V}{R_g T} \right)$$
  $y_1 = \frac{n_{OXY}}{n_{TOT}} = \frac{y_o}{N_{TOT}}$ 

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

## Vacuum Purge - 2

At end of 2nd cycle:

$$y_2 = y_1 \left(\frac{P_L}{P_H}\right) = y_o \left(\frac{P_L}{P_H}\right) \left(\frac{P_L}{P_H}\right) = y_o \left(\frac{P_L}{P_H}\right)^2$$

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

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

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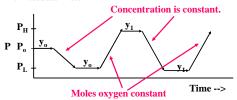
## **Purge Assumptioms**

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

# **Pressure Purge** Concentration is constant. Moles oxygen constant Faster than vacuum purge, but uses more nitrogen.

## **Combined Pressure / Vacuum - 1**

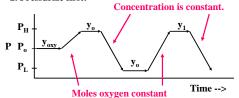
1. Evacuate first:



Best to evacuate first - uses less nitrogen.

## **Combined Pressure / Vacuum - 2**

2. Pressurize first:



$$y_o = y_{oxy} \left( \frac{P_O}{P_H} \right)$$

$$y_{j} = y_{o} \left( \frac{P_{L}}{P_{H}} \right)^{j}$$

## **Inerting with Impure Nitrogen**

Let  $y_{oxy} = concentration of oxygen in nitrogen.$ 

Then, the following equation applies:

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

Eqn. 7-12

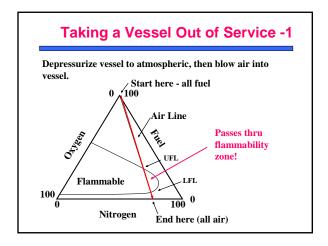
## **Sweep Purging**

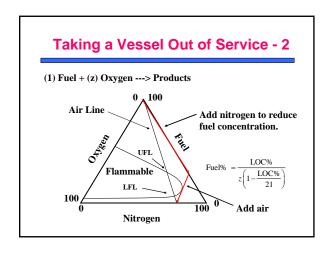
 $Q_{\rm v}$ C =oxygen conc. Well Stirred-Tank

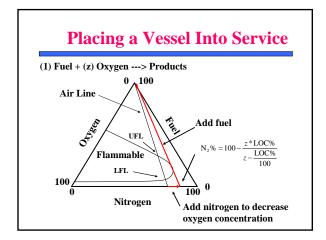
Mass Balance on Oxygen:  $V \frac{dC}{dt} = C_o Q_v - C Q_v$ 

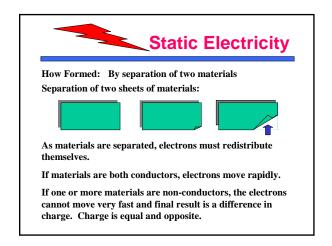
**Solution is:**  $Q_v t = V \ln \left[ \frac{C_1 - C_o}{C_2 - C_o} \right] = \text{Total Nitrogen Volume}$ 

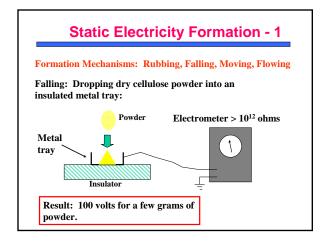
If  $C_0 = 0$ :  $Q_0 t = V \ln \left[ \frac{C_1}{C_2} \right]$  Uses lots if inert!!

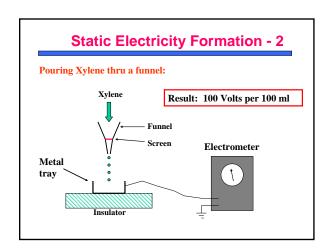


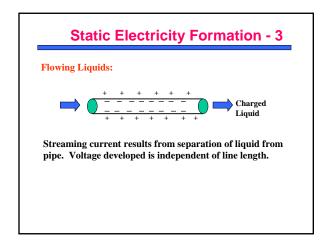


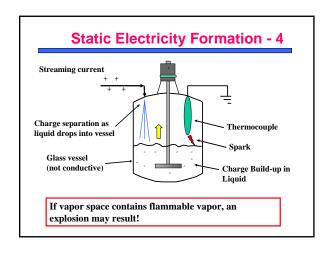


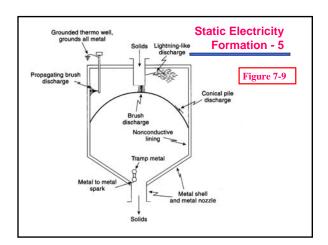


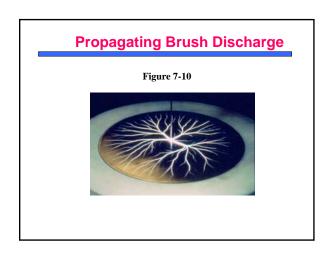


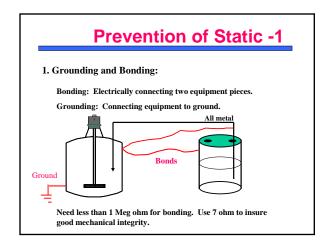


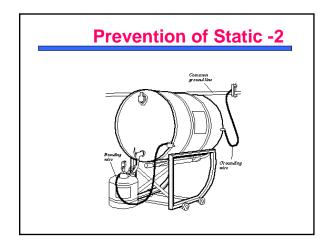












#### **Prevention of Static -3**



#### 7

#### Prevention of Static - 4

- 2. Be careful of:
  - Glass containers / vessels / pipes.
  - Plastic containers / vessels / pipes / pumps.
  - Low conductive liquids: benzene, toluene, xylene, heptane, hexane.
- 3. Avoid: Free fall of liquids into vessels.

#### **Static Electrical Hazards**

**Question:** Which item below represents the greatest static electricity hazard?

- 1. An ungrounded plastic container?
- 2. An ungrounded metal container?

#### **Static Electrical Hazards**

Answer: The ungrounded metal container represents the greatest hazard.

The charge can readily move around on the metal container and can easily cause a spark.

The static charge on the non-conductive plastic container is distributed on the surface – it is unlikely that the charge can move to a single point to create a spark.

## **Static Electrical Hazards**

Question: Which item below represents the least static electricity hazard:

- 1. A grounded plastic container?
- 2. A grounded metal container?

## **Static Electrical Hazards**

Answer: The grounded metal container. The charge can readily move around on the metal container and can be dissipated to ground. The plastic container is non-conductive and the charge cannot be easily removed.

Conclusion: Metal containers are preferred to eliminate static but, if used, must be grounded!

#### Fire Protection: Electrical Area Classification

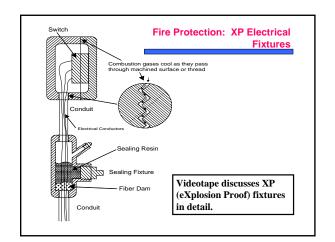
Group 1: Locations with flammable gases or vapors.

**Group 2:** Locations with flammable dusts.

**Group 3:** Locations with flammable fibers.

**Division 1:** Flammable concentrations are normally present

**Division 2:** Flammable concentrations present only under abnormal situations. Flammable materials normally contained in the closed systems.



#### Fire Protection: Ventilation

For flammable materials within buildings, use 1  $ft^3/ft^2$  of floor area.

See Table 7-6 for qualifying details.

#### Fire Protection: Sprinkler Systems

Closed Head: Typically found in occupied buildings;

Open Head: Activated from a central location.

Monitor nozzles: Fixed location, but can be directed.

Water requirements:  $0.25 - 0.5 \text{ gpm/ft}^2$  protected



See Table 7-7

Closed Head Sprinkler

#### Fire Protection: Sprinklers





Open Head Nozzle

Deluge System

# Fire Protection: Monitor Nozzle





