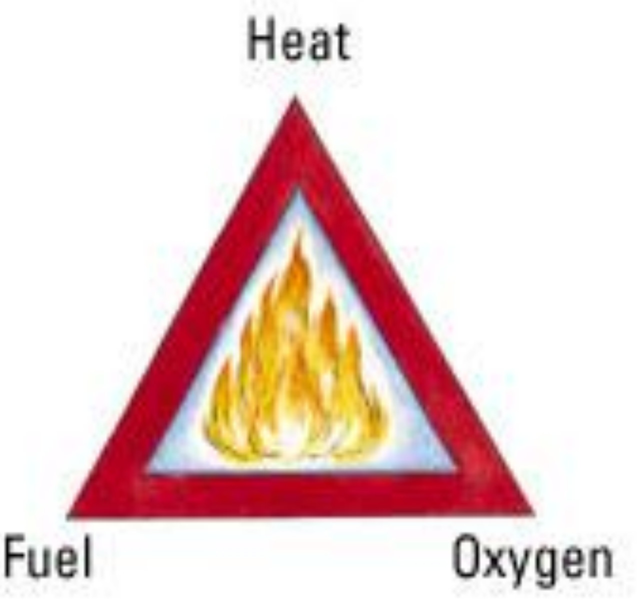
Designs to Prevent Fires and Explosions

Objective

Prevent the initiation of the fire or explosion and minimize the damage produced after it.

- **How can it be prevented?**
  - **Inerting**
  - **Control static electricity**
  - **Ventilation**
  - **Explosion–proof equipment**



Inerting

Process of adding an inert gas to a combustible mixture to reduce the concentration of O_2 below the LOC

Ex. N_2, CO_2

<u>Process</u>

Purge vessel with inert gas → **Flammable material is charged**

Purging Methods

- **Vacuum purging**
- **Pressure purging**
- **Combined pressure – vacuum purging**
- **Sweep through purging**
- **Siphon purging**

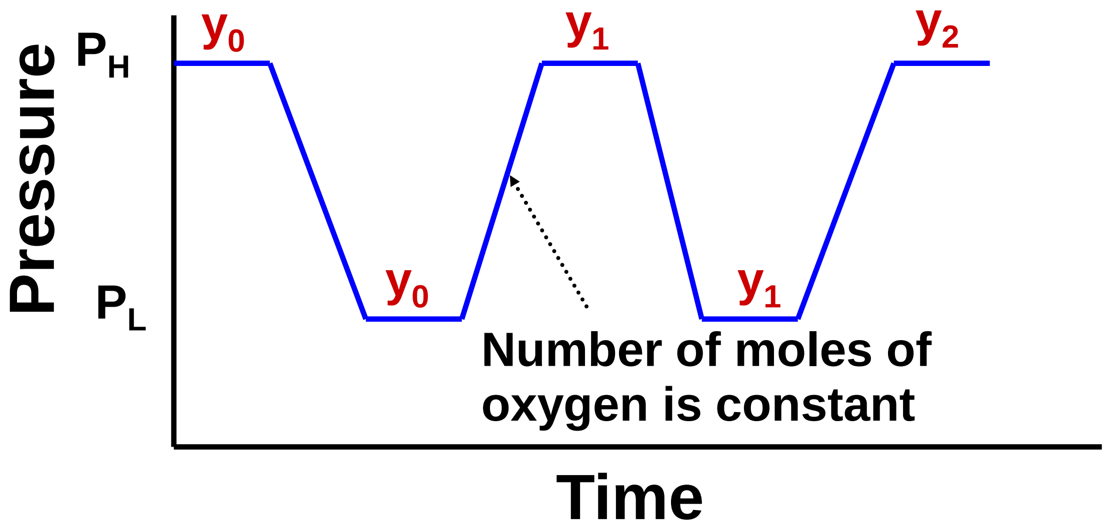
Vacuum Purging

- **Most common procedure**
- **Not design for large storage tanks**

Steps

1. **Vacuum the vessel**
2. **Relieve the vacuum with an inert gas to P_{atm}**
3. **Repeat steps 1&2 until the desired oxidant concentration is reached**

Vacuum Purging 2



$$y_j = y_0 \left(\frac{n_L}{n_H} \right)^j = y_0 \left(\frac{P_L}{P_H} \right)^j$$

$$\Delta n_{N2} = j \left(P_H - P_L \right) \frac{V}{R_g T}$$

Example 7-1

- Reduce O_2 conc. to 1ppm
- 1000 gal vessel
- T = 75 ºF
- Vacuum pump reaches 20 mm Hg

Determine the number of purges required and the total nitrogen used.

Pressure Purging

1. **Add inert under pressure**
2. **Vent to the atmosphere**

$$y_j = y_0 \left(\frac{n_L}{n_H} \right)^j = y_0 \left(\frac{P_L}{P_H} \right)^j$$

Advantage: **Potential for cycle time reductions. However, more inert gas is needed.**

Compare the result of Vacuum!!

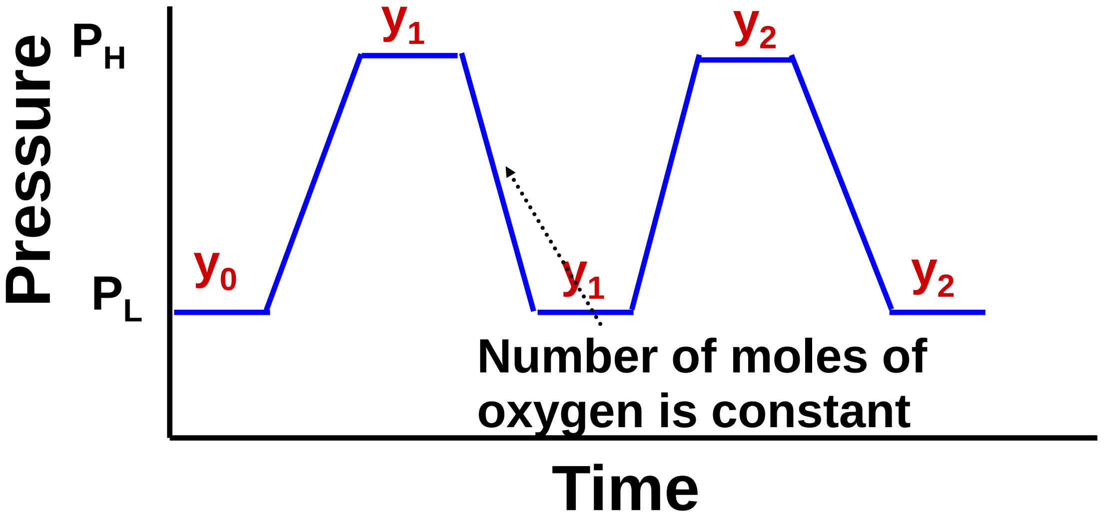
Vacuum vs. Pressure

	Vacuum	Pressure
Pressure purge cycles	4	6
Total moles of nitrogen	1.33	11.1

Ex 7-1(p. 294) vs.
Ex 7-2(p. 296)

- Pressure purging
  - Faster, uses more inert gas than vacuum purging
- Vacuum purging
  - Uses less inert gas

Pressure Purging 2



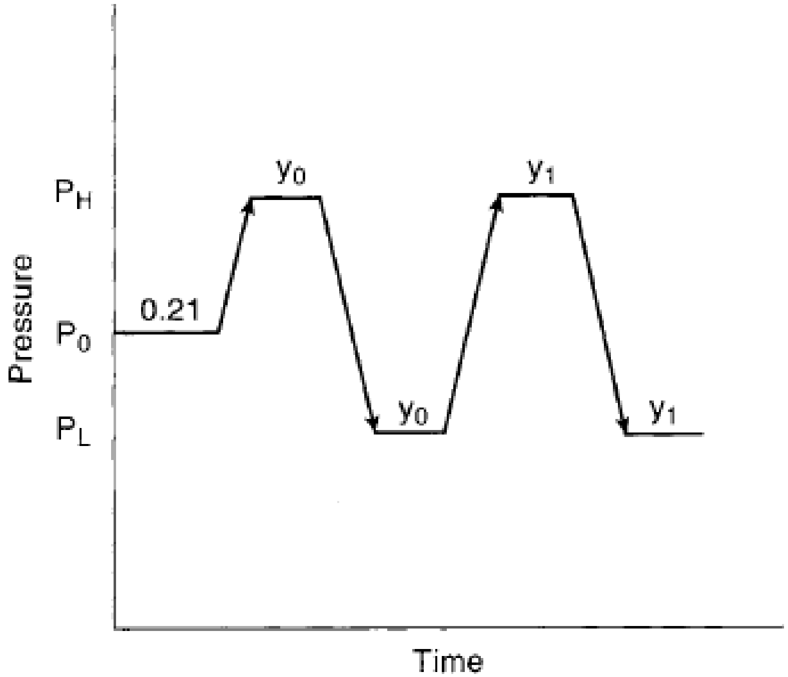
Combined Pressure – Vacuum Purging

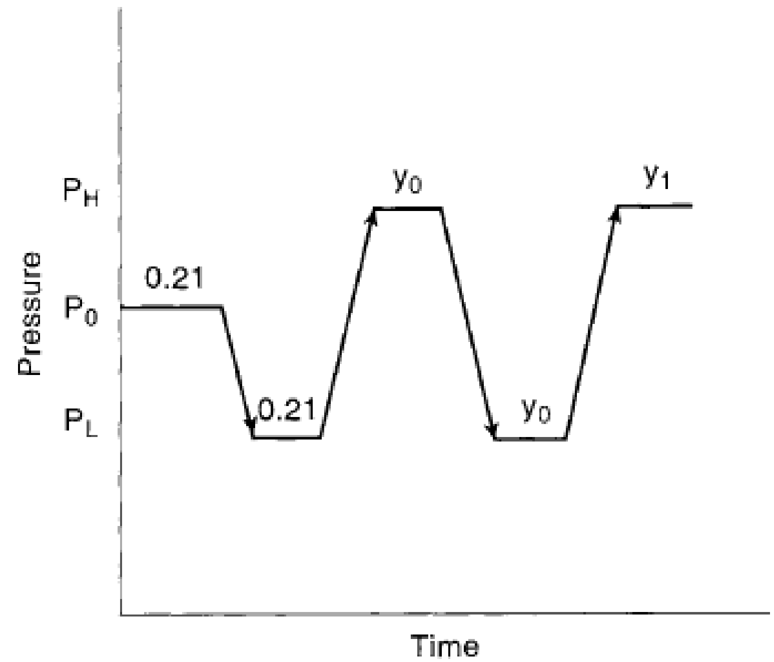
Which one should be performed first?

- **Pressure → Vacuum**

$$y_0 = 0.21\left(\frac{P_0}{P_H}\right)$$

- **Vacuum → Pressure**





Vacuum-pressure purging with initial pressurization

Vacuum-pressure purging with initial evacuation

Purging with Impure Nitrogen

$$y_j = y_{j-1}\left(\frac{P_L}{P_H}\right) + y_{oxy}\left(1 - \frac{P_L}{P_H}\right)$$

$$\left(y_j - y_{oxy}\right) = \left(\frac{P_L}{P_H}\right)\left(y_0 - y_{oxy}\right)$$

$$y_j = y_0\left(\frac{n_L}{n_H}\right)^j = y_0\left(\frac{P_L}{P_H}\right)^j$$

For pure N_2 purging

Sweep through

- **Sweep through purging**
  - **Process where the purge gas is added into a vessel at one opening and withdraws**
  - **The mixed gas from the vessel to the atmosphere from another opening.**
  - **Requires large quantities of nitrogen**

$$Q_v t = V \ln\left(\frac{C_1 - C_0}{C_2 - C_0}\right)$$

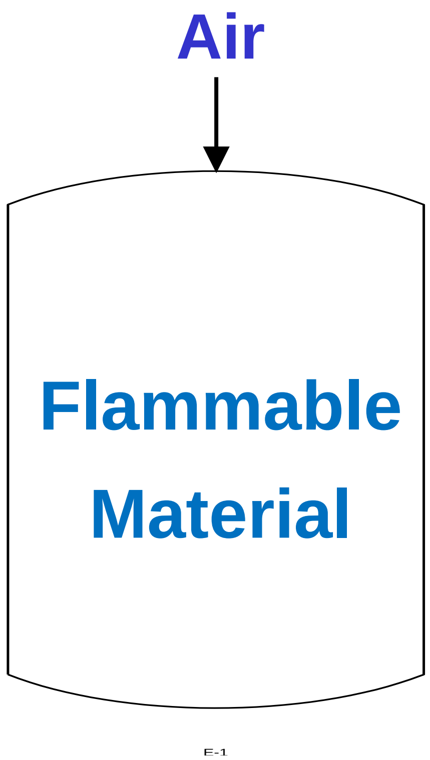
Siphon Purging

- **Fill the vessel with liquid-water or any liquid compatible with the product.**
- **The purge gas is added to the vapor space as the liquid is drained from the vessel.**

Vol. purge gas = Vol. vessel

Rate of purging = Vol. rate of liquid discharge

Out of Service Fuel Concentration



$$\mathrm{OSFC} = \frac{\mathrm{LFL}}{1 - z\left(\frac{\mathrm{LFL}}{21}\right)}$$

out-of-service fuel concentration

$$= \frac{\mathrm{LOC}}{z\left(1 - \frac{\mathrm{LOC}}{21}\right)}$$

Estimate Flammability Limits

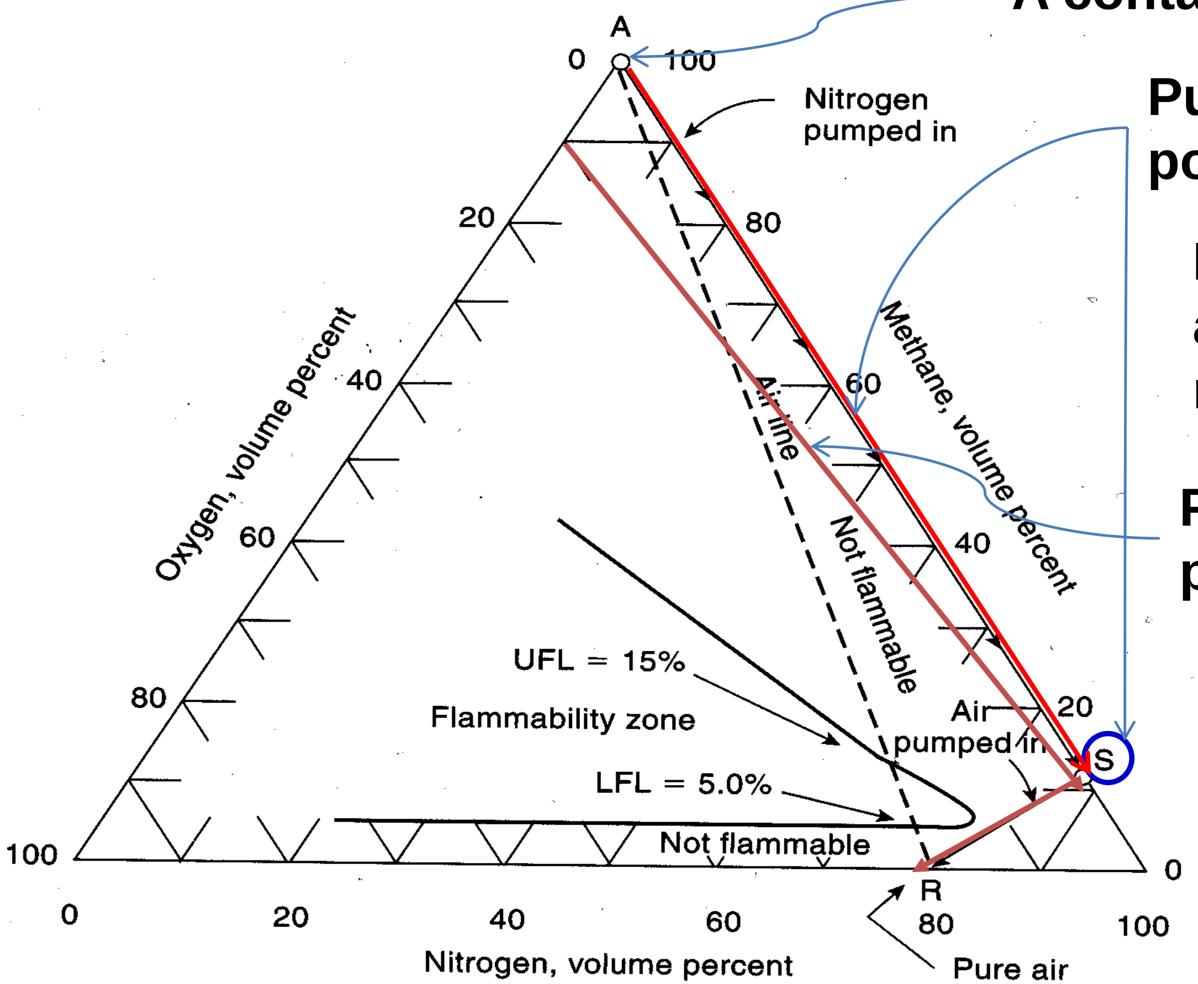
Combustion: $C_m H_x O_y + zO_2 \rightarrow mCO_2 + (x/2)H_2O$

$$z, \frac{moles\ O_2}{moles\ \ fuel}, \ = m + x/4 - y/2$$

C_{st} = vol. % fuel in air = $\dfrac{moles\ \ fuel}{moles\ \ fuel + moles\ air}$

= $\dfrac{100}{1 + z/0.21}$ **for 21 % O_2 in air**

Flammability Diagram - OSFC



A contains pure fuel

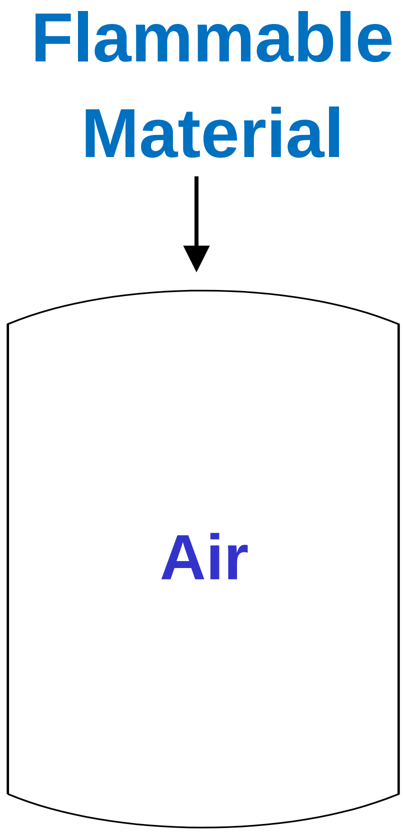
Pure N_2 added till point S, OSFC

Requires a large amount of nitrogen ⇒ costly

Pure N_2 added till point S, OSFC

the air forms a flammable mixture at the entry point

In Service Oxygen Concentration

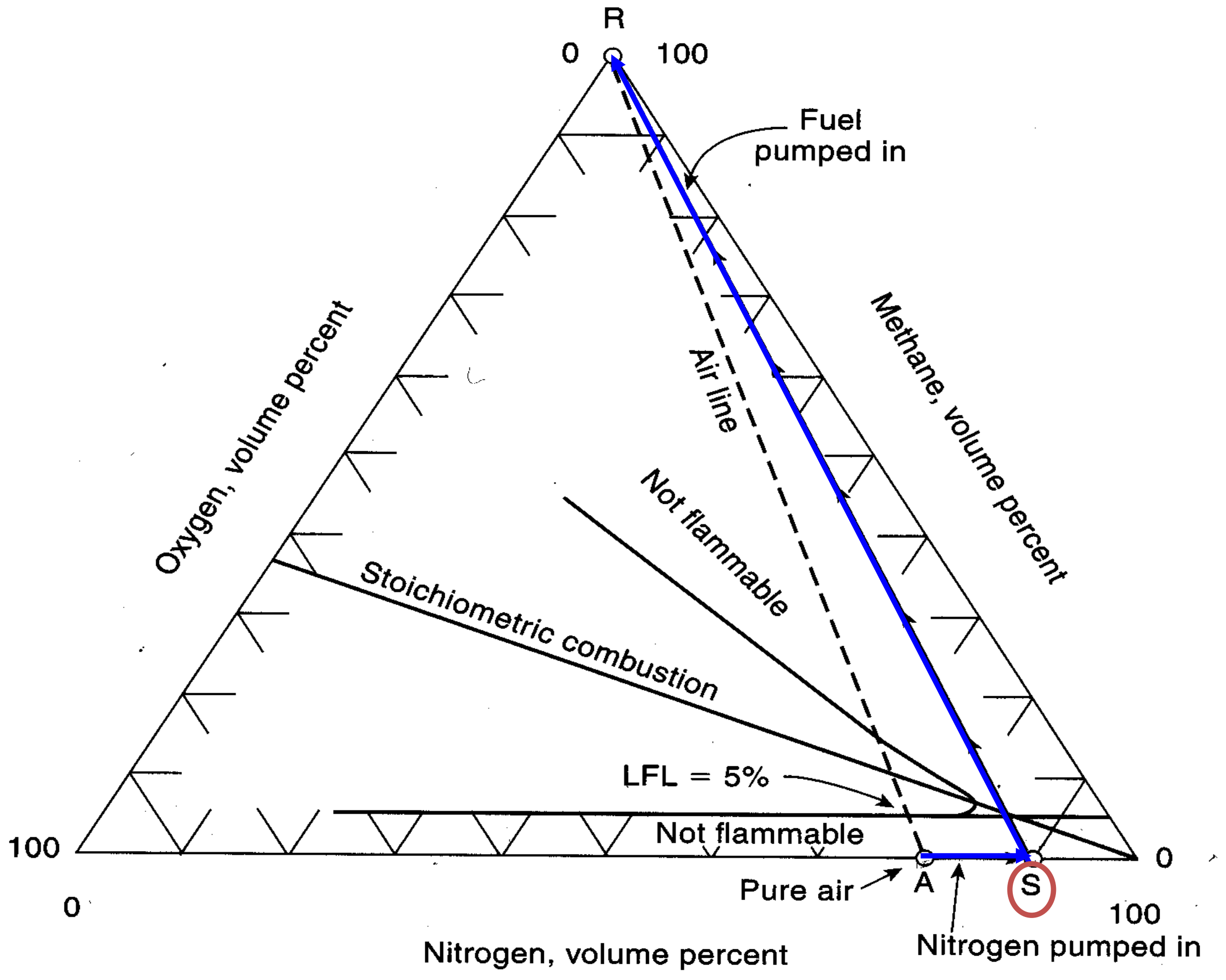


$$\mathrm{ISOC} = \frac{z\,\mathrm{LFL}}{1 - \left(\dfrac{\mathrm{LFL}}{100}\right)}$$

in-service oxygen concentration

$$\mathrm{ISOC} = \frac{z\,\mathrm{LOC}}{z - \dfrac{\mathrm{LOC}}{100}}$$

Flammability Diagram - ISOC

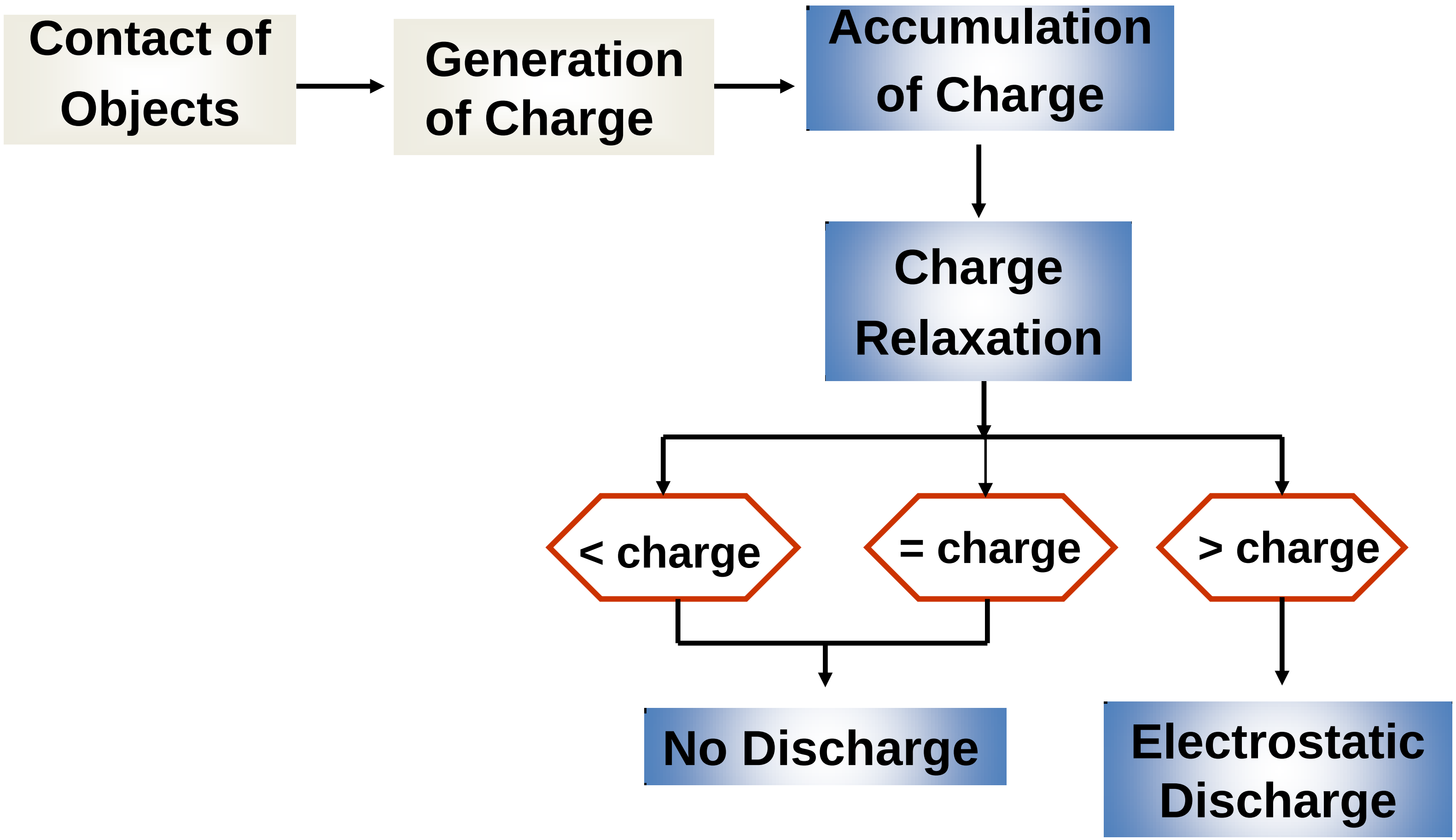


Static Electricity

- Ignition source of many fires & explosions
- Difficult to eliminate

Static electricity hazards or nuisances arise when charge separation occurs leading to an accumulation of one sign charge within some defined boundary.

Electrostatic Process



Household Examples

- Walking across a rug ~ 20mJ
- Placing different materials in a tumble dryer
- Removing a sweater
- Combing hair
- Clinging fabrics, audible sparks

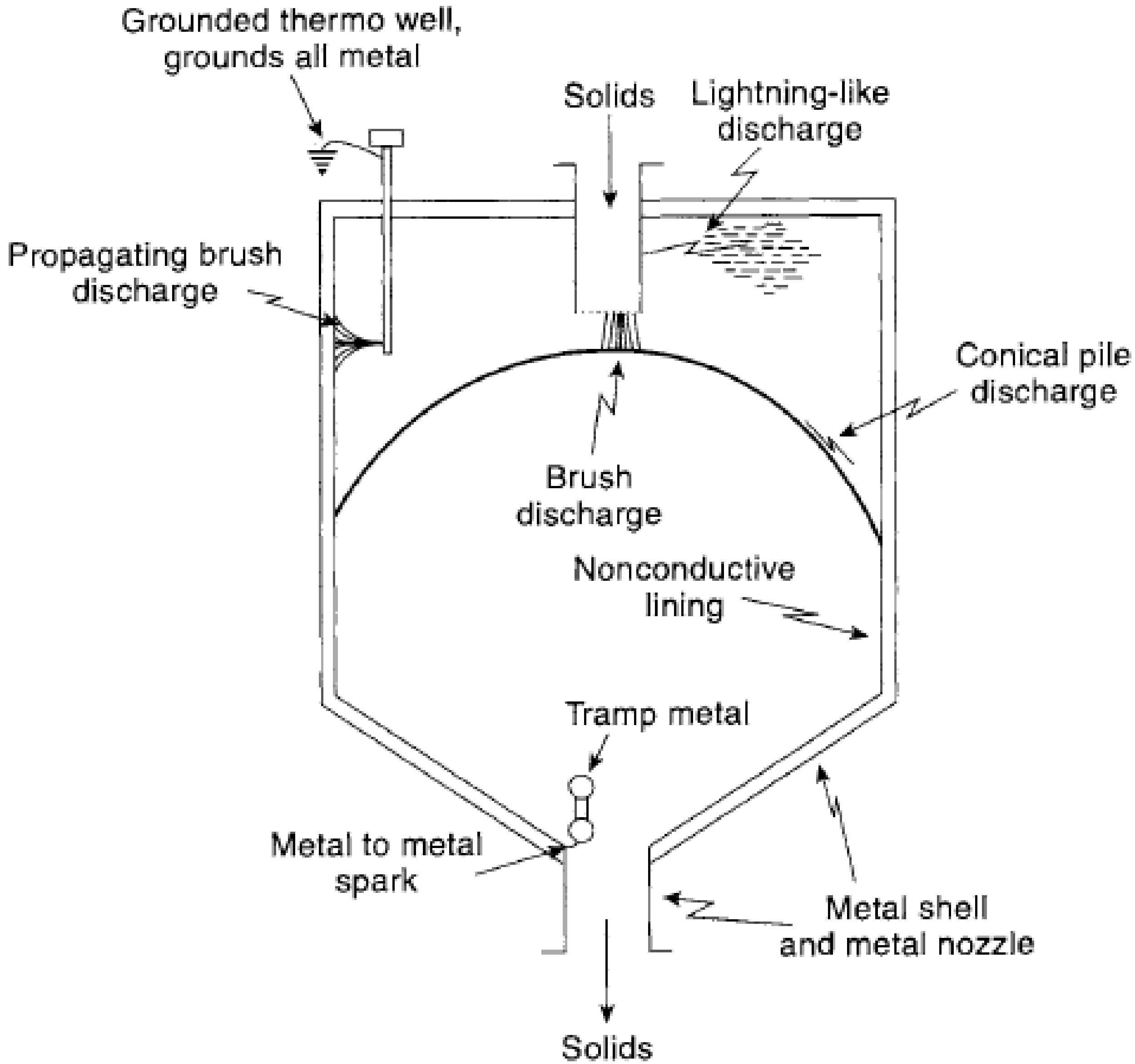
Industrial Examples

- Flow of liquids through pipes and filters
- Settling of solid or an immiscible liquid through another liquid
- Ejection of droplets, mist particles, or aerosols from a nozzle as a liquid is pumped through a hose or pipe
- Splashing or agitation of a liquid against a solid surface

► ~ 0.1mJ is considered dangerous

Charge Accumulation

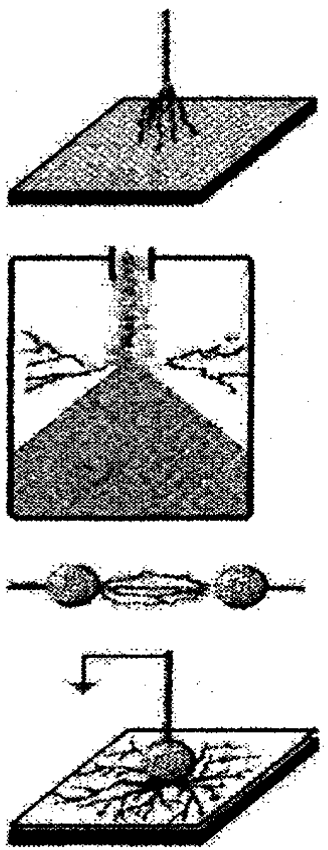
- Contact and frictional
  - dissimilar material
  - s-s interfaces
- Double layer charging
  - separation on microscopic scale at liquid interfaces (l-l, l-g, l-s)
- Induction
  - a conductor is placed in an electric field created by an electrostatic charge being held in a nonconductor
- Charge transfer
  - when charged objects contacts an uncharged object and the charge is shared between them



Common electrostatic discharges

Electrostatic Discharges

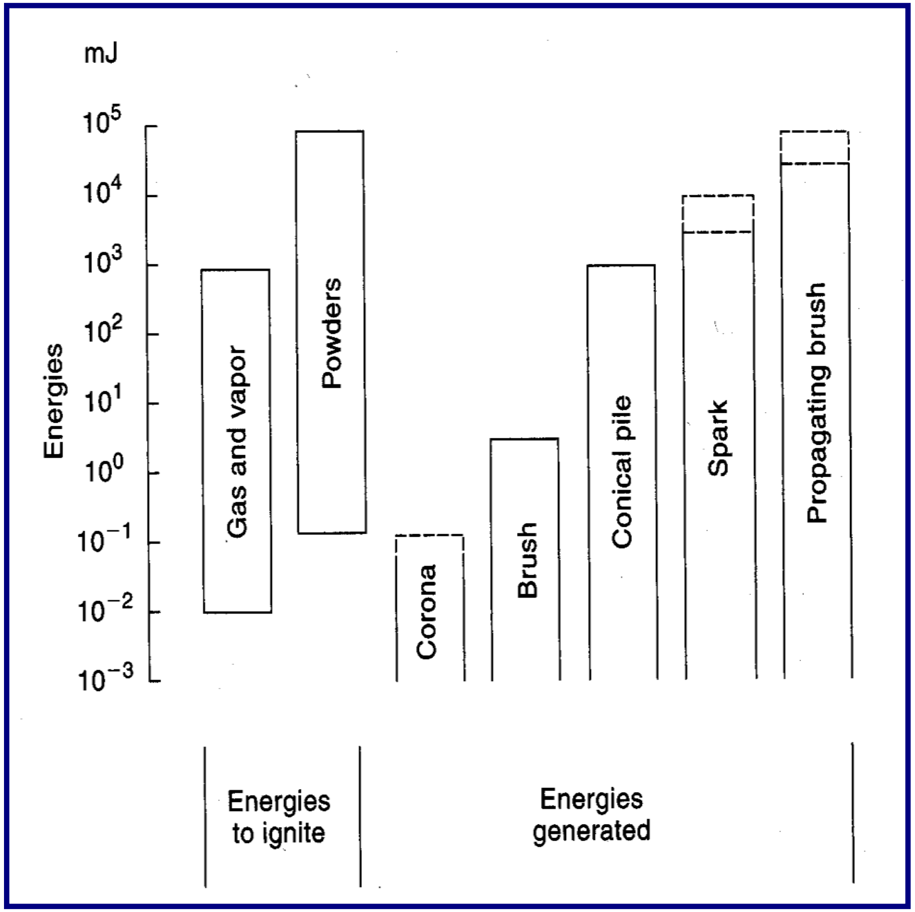
Ignition sources:	Incendivity for
Brush discharge	MIE<3 mJ[1]
Conical pile discharge	MIE<1 J[2]
Spark discharge	MIE<1 J
Propagating brush discharge	MIE<10 J



- Field Intensity>3MV/m (Breakdown voltage of air)
- Surface charge> 2.7×10^{-5} C/m^2

- Powder with a high resistivity>10^{10} ohm
- Coarse particles>1mm
- High charge of mass ratio
- Filling rate≥0.5kg/s

Energy from Electrostatic Discharge



- **The energy depends on:**
  - **Q, the accumulated charge**
  - **C, the capacitance of the object**
  - **V, potential of the object**

$$C = Q/V$$

$$J = \frac{Q^2}{2C}$$

Although this expression is only for capacitance discharges in conducting systems, it is used qualitatively for the other discharges.