Process Safety Engineering:

Introduction & Overview

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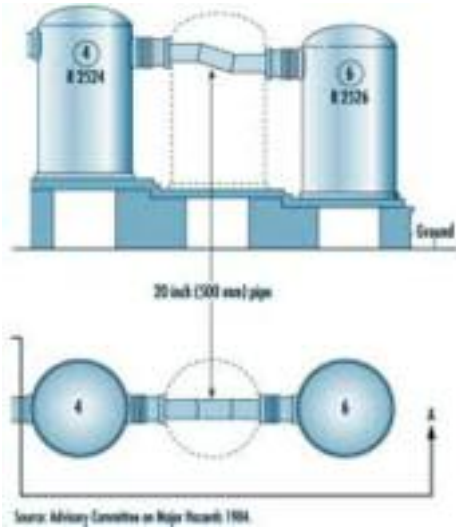
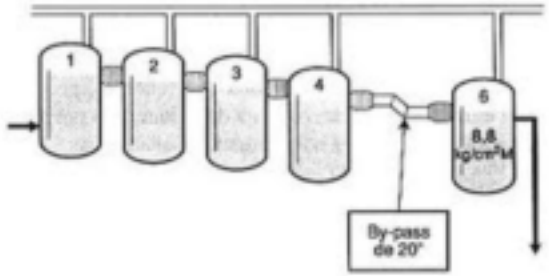
The Rising Case for Change

- Flixborough, England (1974)





- Cyclohexane explosion
- 29 Fatalities and offsite effects

The Rising Case for Change

- 1984 – Bhopal, India – Toxic Material Released

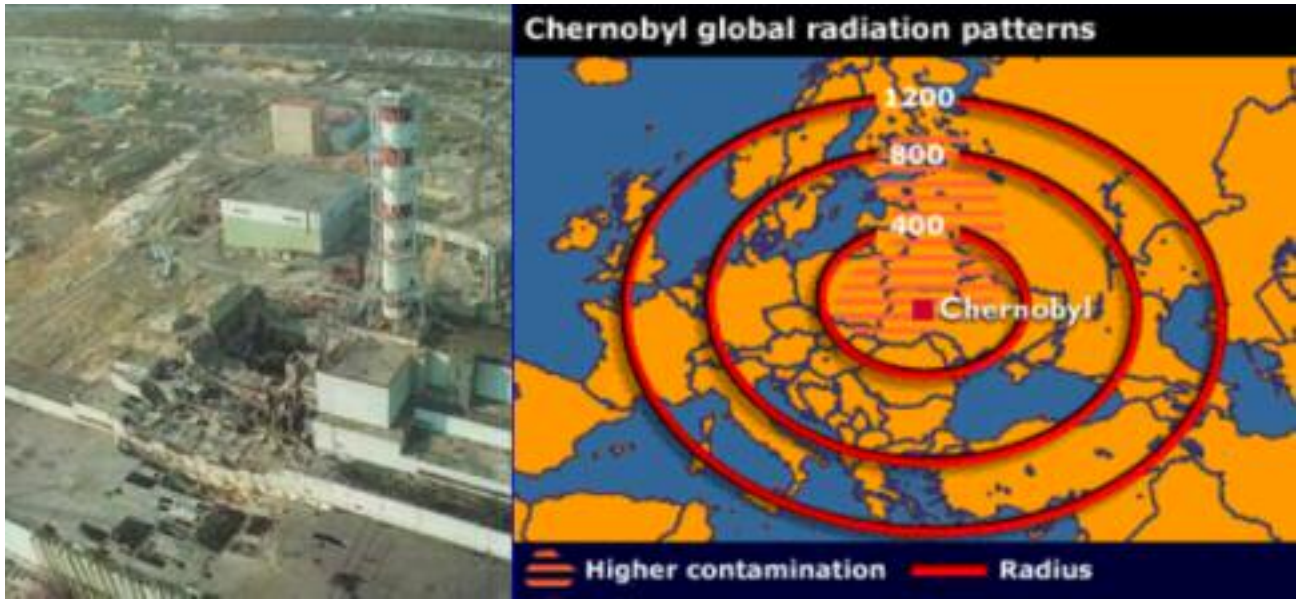
  - 2,500 immediate fatalities; 20,000+ total
  - Many other offsite injuries

- 1984 – Mexico City, Mexico –Explosion

- 300 -650 fatalities (mostly offsite)
- $20M damages

LPG explosion caused by a leak at a marketing terminal pipeline that ignited and started a fire at the terminal.

- 1986 – Chernobyl



- Large area of Russia, Ukraine and Belarus evacuated, 336,000 people resettled.
- Fewer than 50 direct death but, thousands of cancer related cases
- Severe damage to the environment

- 1988 – Norco, LA – Explosion
  - 7 onsite fatalities, 42 injured
  - $400M+ damages

- Henderson, Nevada, (1988)

- 1989 – Pasadena, TX – Explosion and Fire
  - 23 fatalities, 130 injured; damage $800M+

A seal blew out on an ethylene loop reactor, releasing ethylene-isobutane vapor cloud, a compound used in making plastics

Some Recent Incidents

T2 Laboratories Inc –Jacksonville, FL, 2007

4 Killed and 13 Wounded in reactor explosion in manufacture of gasoline additive.

BP America Refinery –Texas City, TX, 2005

15 Killed and 180 Wounded in isomerization unit explosion and fire.

West Pharmaceutical Services –Kinston, NC, 2003

6 Killed and Dozens Wounded in dust cloud explosion and fire from release of fine plastic powder.

Safety & Loss Prevention

"To know is to survive and to ignore fundamentals is to court disaster."

H. H. Fawcett

- The word **"safety"** : the older strategy of accident prevention through the use of hard hats, safety shoes, and a variety of rules and regulations.

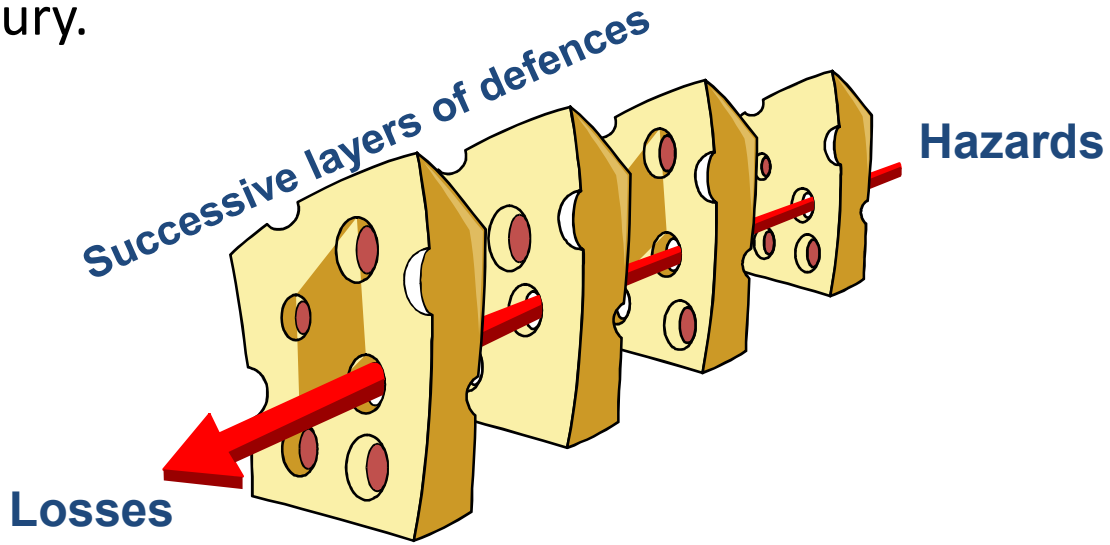
- Recently, **"safety"** has been replaced by **"loss prevention"**. This term includes hazard identification, technical evaluation, and the design of new engineering features to prevent loss.

Safety, hazard, and risk

- ***Safety* or *loss prevention:*** the prevention of accidents through the use of appropriate technologies to identify the hazards of a chemical plant and eliminate them before an accident occurs.

- ***Hazard:*** a chemical or physical condition that has the potential to cause damage to people, property, or the environment.

- ***Risk:*** a measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood and the magnitude of the loss or injury.



Hazards in Chemical plants

- Mechanical hazards that cause worker injuries from tripping, falling, or moving equipment.

- Chemical hazards. These include fire and explosion hazards, reactivity hazards, and toxic hazards.

➢ Active hazard
  - Immediately adverse effect
  - Similar to “unsafe act”

➢ Latent hazard
  - Effect may not be noticeable for some time.
  - Unforeseen trigger conditions could activate the risk.

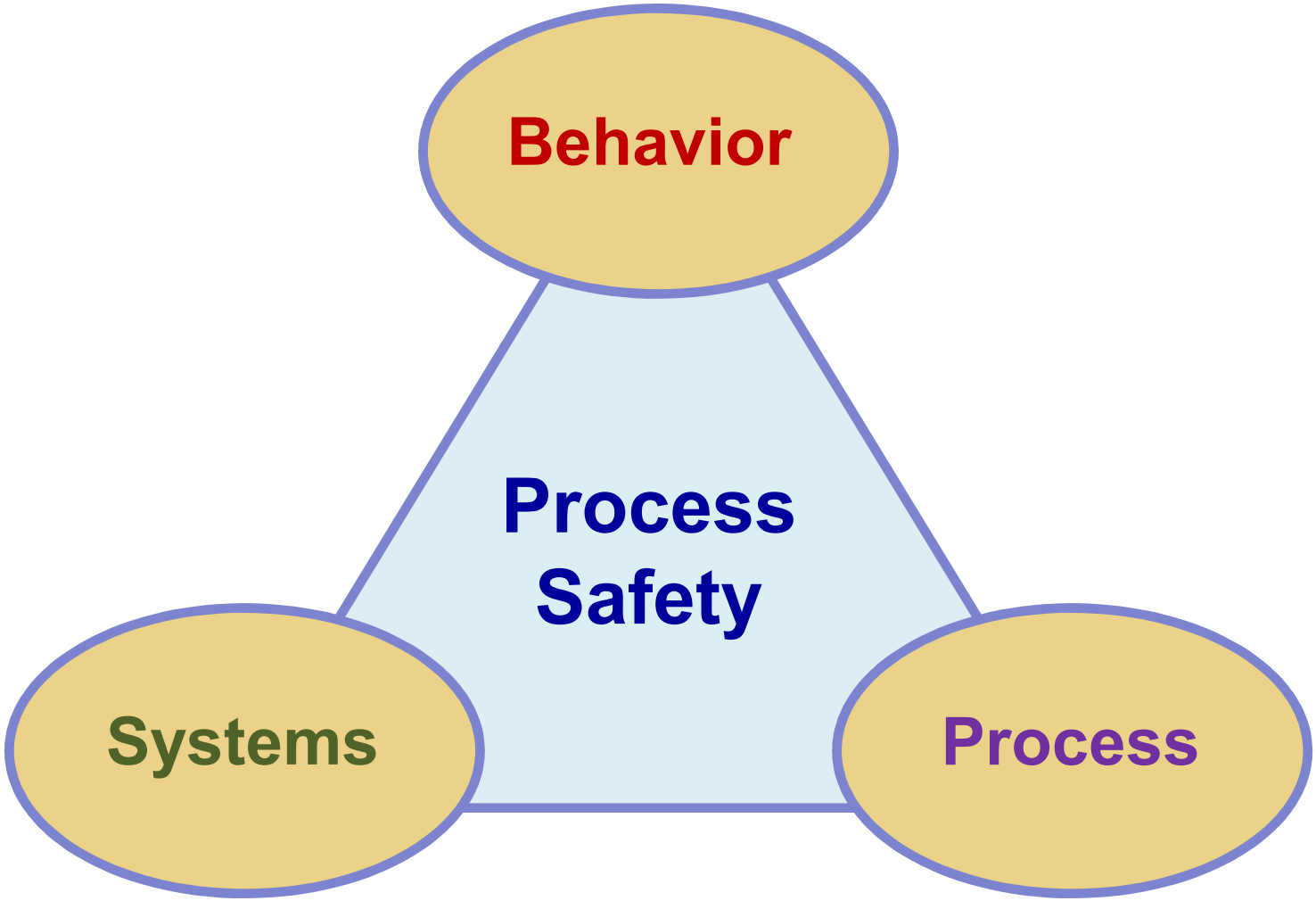
S-A-F-E-T-Y

- **S** – **Management Systems**
- **A** – **Proper Attitude**
- **F** – **Understand Fundamentals**
- **E** – **Experience**
- **T** – **Time to do things safely**
- **Y** – **Your Participation**

✓ **Safety Program:** identifies and eliminates existing safety hazards.

✓ **Safety Management Systems:** prevent the existence of safety hazards.

Three Elements of Process Safety

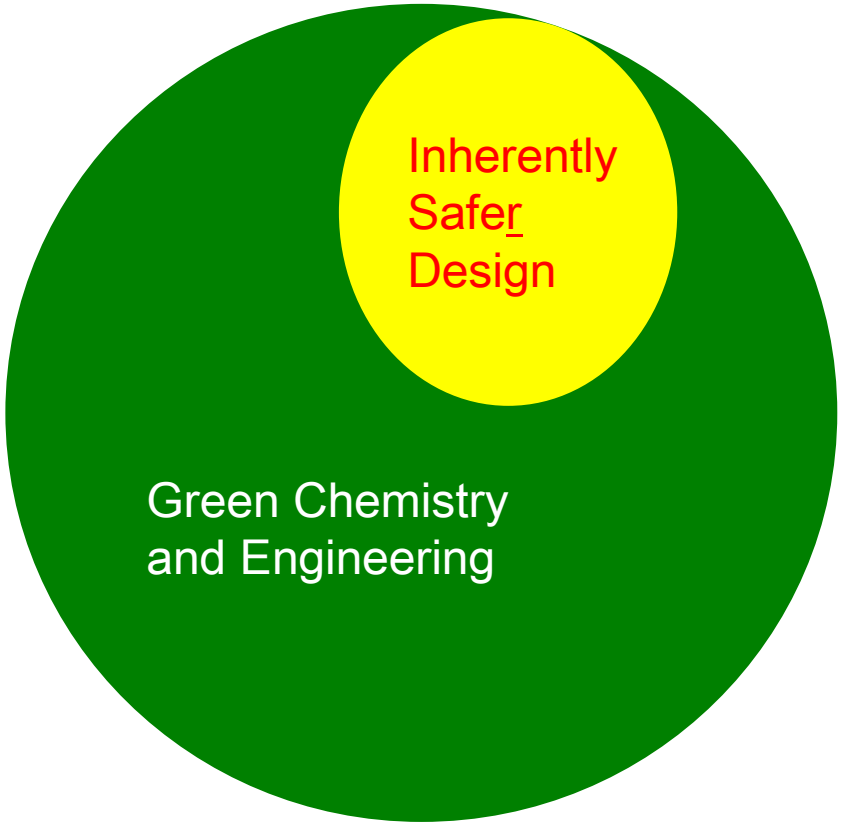


Process Safety Milestone Practices

Pre-1930's	**Identify who caused the loss and punish the guilty**	**Behavior**
Pre-1970's	**Find breakdown in, and fix man-machine interface**	**Process**
1970's, 80's	**Development of risk assessment techniques and systematic approaches**	**Mgmt Systems**
1980's +	**Performance-, risk-based standards, regulations; 'green' and 'inherent' designs**	**Comprehensive**

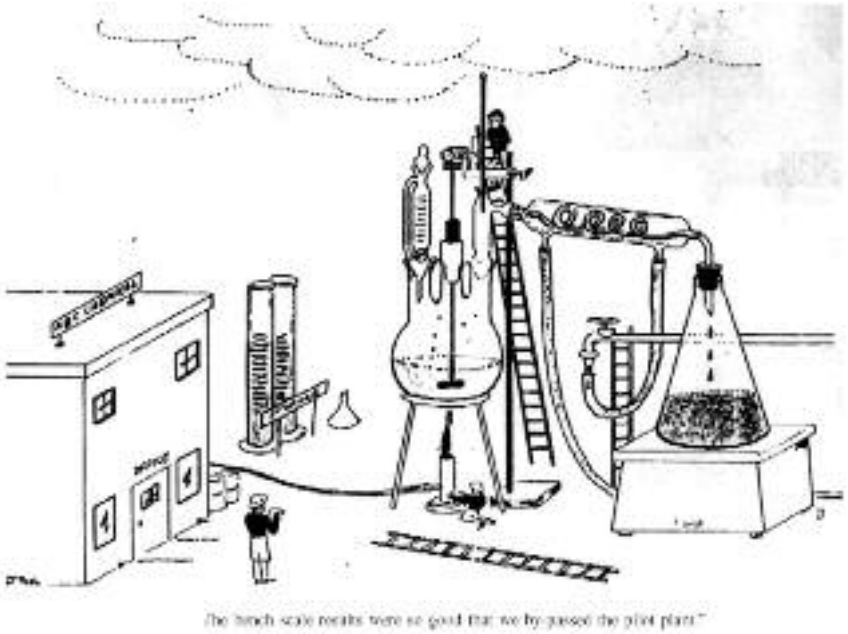
Inherently Safer Design

- **Definition:** *The design of chemical processes and products with specific attention to eliminating hazards from the manufacturing process rather than relying on the control of these hazards.*



Inherently Safer Design Strategies

- ✓ Minimize
- ✓ Moderate
- ✓ Substitute
- ✓ Simplify



Strategy	Examples
Substitute	Replace material with a less hazardous substance.
Minimize	Use smaller quantities; eliminate unnecessary equipment; reduce size of equipment or volumes processed.
Moderate	Use less hazardous conditions, a less hazardous form of material or facilities which minimize the impact of a release.
Simplify	Design facilities which eliminate unnecessary complexity and make operating errors less likely.

Accidents and Loss Statistics

Statistical methods:

- OSHA incidence rate,
- fatal accident rate (FAR), and
- fatality rate, or deaths per person per year.

OSHA incidence rate

- **OSHA** stands for the **Occupational Safety and Health Administration** of the US govt.

OSHA incidence rate based on Injury & Illness :

OSHA Injury & Illness Rate = (# of Injuries & Illness*200,000)/(Total hrs all employees)

Based on 100 worker-years

$$WorkYear = \left(\frac{40hrs}{wk}\right)\left(\frac{50wk}{yr}\right) = 2000\,{}^{hr}\!/_{yr}$$

OSHA incidence rate based on lost workdays:

- **Lost Workdays** are those days which the employee would have worked but could not because of occupational injury or illness. Also need to account for diminished long term performance.

- Same bases, but use lost workdays

OSHA Incidence Rate (lost WD) = (# lost workdays * 200,000)/ (Total hrs worked)

Fatal accident rate (FAR)

FAR= (# of Fatalities X 10^8)/(Total hrs worked by all employees)

- Based on 1000 workers' career

$$WCareer = \left(\frac{40hr}{wk}\right)\left(\frac{50wk}{yr}\right)\left(\frac{50yr}{career}\right) = 10^5\ hr/career$$

Remark: refer to Table 1.3 & 1.4 lists several FARs

Fatality Rate

$$FatalityRate = \left(\frac{\#\,Fatalities\,/\,yr}{Total\,\#\,PeopleExposed} \right)$$

In Class Assignment

- The FAR for travel by car is reported as 57 while that for travel by air is 240

1. If the average speed of travel is 50 mph by car and 250 mph by air, determine the deaths per million miles travel by car or air.

2. If you are required to make a round trip from Aqaba to Amman, which is the safer mode of transportation as indicated by the statistics?

Assignment Solution

1) Calculations

$$Car -> \left(\frac{57 deaths}{10^8 hr}\right)\left(\frac{1 hr}{50 miles}\right)\left(\frac{10^6}{MillionMiles}\right) = 0.0114 \, deaths/MillionMiles$$

$$Air -> \left(\frac{240 deaths}{10^8 hr}\right)\left(\frac{1 hr}{250 miles}\right)\left(\frac{10^6}{MillionMiles}\right) = 0.0096 \, deaths/MillionMiles$$

2) For a fixed distance, air travel is the safest mode

HW

1.1 1.2

1.3 1.4

1.5 1.6

1.8 1.9

1.25

1.26